Decision Support Suite for use in Airport Planning

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Image source: The Japan Times (2013)

Investigating the further development of a Decision Support Suite for use in Airport Planning

By

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Preface

"In preparing for battle I have always found that plans are useless, but planning is indispensable"

– Dwight D. Eisenhower

The future of aviation is one that is closely tied to worldwide economic, political, and social conditions, which makes it a very dynamic, complex, and unpredictable industry. Traditional approaches to Airport Strategic Planning have long been proven ineffective, underscoring the need for airports to adopt new approaches.

The broad nature of this thesis project was the main reason I chose it, as I knew that it would provide me with the kind of development I was looking for. It would not only require developing knowledge in the field of airport operations, but would include other fields such as finance, economics, and policy analysis, to name a few. My interest in aviation has been a long-term affair. I was exposed at an early age to aviation, being made to travel frequently due to having lived in seven different countries over the course of my life. This interest grew, and when asked what I wanted to study when I grew up, I would always say I wanted to design airplanes, which led me to enrol in a bachelors program at the TU Delft in 2008. After a minor in project management during my Bachelors, I discovered that I was also interested in the business and commercial aspects of aviation, which motivated me to take the Entrepreneurship Annotation during my Masters. This involved taking a few extra courses, as well as having an entrepreneurial element in my Thesis report, in the form of a business plan for the creation of a company to commercialise the Airport Business Suite, the software which is the main focus of this Thesis project. Furthermore, my internship project was to carry out a benchmark study on 17 regional airports in Europe, with the aim of providing suggestions for the three Flemish Airports, which was then presented to the Flemish parliament with the aim of shaping government policy towards these airports.

After receiving this topic in November 2013, I carried out a literature study, and familiarised myself with the Airport Business Suite, in order to determine the most pressing areas of improvements, and the state-of-the-art in Airport Strategic Planning. In collaboration with my Thesis supervisors, we decided that I should focus on implementing a financial analysis for the ABS, as this was not possible with the ABS at the time. In order to achieve this, I had to research the various aspects of an airport's operations, in order to be able to model their impacts on an airport's finances, as well as the current practices and regulations surrounding them. In doing so, I utilised a lot of the research that had been carried out by my supervisors in this area, and was able to leverage their invaluable experience and advice.

After completing my literature study in March 2014, I turned my attention to learning the Visual Basic .NET programming language, since Visual Basic 6, which the original ABS was written in, is currently an unsupported and stagnant programming language. This proved to be the most challenging aspect of my Thesis project, as I also needed to understand how the original ABS worked. Since Visual Basic .NET is not taught at the TU Delft, there were very few places of help to turn to, which were mostly in the form of programming manuals and online resources such as programming forums. For example, I followed an approach presented in a programming textbook, before realising that it would not be suited to the original ABS, which required a more flexible approach in database connection and interaction, due to the nature of the ABS whereby a separate database was created for each project created.

But perhaps the most hard-earned lesson learnt was in time management, and the importance of not taking on more than I could handle. The summer of 2014 saw me start a part-time job.

In addition to this, I decided to found a startup with four other founders, as we believed the business and regulatory climate was just right for the civilian unmanned aerial systems industry. Two grant applications, one student competition, and countless meetings and networking events later, I made an important decision to devote myself full-time to finishing my Thesis project in December 2014, and to stop thinking that I could manage to do both simultaneously. I was tired of the procrastination, and was eager to conclude this chapter of my life, so that I could start to write the next chapter of my life. With the help of my Thesis project, I have come to learn about the importance and nuances of strategic planning, financial planning, and policy analysis, and hope to apply all I have learnt to the startup. If there is one major takeaway I have gained from this thesis project, it is that although plans in and of themselves are useless, the process of planning is invaluable, not just to running an airport, but in all aspects of life.

I would like to say thanks to the following people who supported me on my journey. My parents, Annie and Femi, who always supported me regardless of my (sometimes wrong) decisions. In the end, they always knew best, and although they gently advised me otherwise, they allowed me to make my own mistakes. My sister Tomini, and my brother Tosin, who would always ask me how I was doing, without needing to discuss my thesis delays. My supervisors, Professor Warren and Professor Roling, who were always available with advice whenever I needed it, and who helped guide me, especially in the beginning stages of my Thesis. My former colleagues in the Air Transport Operations department at the TU Delft, with whom I could swap stories about our Thesis progress. And lastly, thanks to you, the reader, for reading this line, after all the others. You have at least read one and a half pages of my thesis. I hope the remaining 150 or so pages will prove to be an interesting, informative, and useful read.

Tunmise Odediran

Delft, January 2015

Abstract

The overall aim of this thesis project was to investigate the further development of a Decision Support Suite (DSS), the Airport Business Suite (ABS), for use in Airport Strategic Planning (ASP). As a result, a financial model was developed and implemented by incorporating state-of-the-art approaches and methodologies in Airport Strategic Planning, with various financial guidelines and practices suggested by aviation authorities, and internationally accepted financial accounting methods.

The ABS was created to address the shortcomings associated with the current dominant approach to Airport Strategic Planning, which include: a rigid and inflexible nature; a narrow focus; the inability to deal with uncertainty effectively; and an ineffective and inefficient problem solving process or framework. Although it was initially created to be used by airports, it is currently only being used in university-level learning environments. This can be attributed to a number of factors, the most important being its inability to model an airport's financial performance, since the financial model was removed since it was not able to produce reasonable results.

The resulting Financial Model allows for financial modelling of standalone years by a user, while the more advanced functionality of being able to model an airport's financial performance over a number of years was limited to a Spreadsheet Model. The inputs were gotten from the operational information calculated by the original ABS, and the use of so-called editors (cost, revenue, and balance sheet editors) for the input of financial parameters. A financial case could then be created from a combination of these schemes, and would cover the span of one year, while a financial plan would be composed of a combination of financial cases, and would cover a period of up to 20 years. The relationships used to predict the financial performance of an airport were integrated from various sources, such as airport planning manuals, and international accounting standards, to name a few. The aim was to develop a generic and flexible model which could be applied to any airport situation.

The developed Financial Model was found to produce only satisfactory results, using the test case of Atlanta International Airport (ATL). This could be attributed to the fact that detailed information was not available (only aggregate information were presented in the financial reports), and many simplifying assumptions and approximations were made. Nevertheless, the proof-of-concept Financial Model developed in this Thesis Project has the potential to dramatically increase the usefulness of the ABS program, and allow it to be truly used as a complete Airport Strategic Planning tool. The successes and shortcomings of traditional approaches to airport planning, and previous attempts at similar projects, were critically evaluated, which guided the design of the model. The proposed solution does not just combine a modelling approach, but also attempts to tackle the problem from the planning and policy analysis side, and so a lot of attention was paid to improving the user interface, and user experience. It will serve as a good starting point, upon which future projects can be developed.

The aim was not for the model to produce results with a high degree of accuracy (since the forecast is always wrong), but rather to model a number of generic relationships which could be applied to any airport or situation, which would allow the user to have a better understanding of how the airport system functions, and quickly visualise and explore the financial effects of various policy options and assumptions. It was found that in order for effective airport planning to take place, the computer-based tool should not just focus on analytical process and forecasting, but should also focus on the entire process surrounding good practices of airport strategic planning. The entire problem-solving process (formulation, analysis, and interpretation) should be acknowledged, and the tool should be designed accordingly. The tool should not just be used as a planning tool, but should also be used an ongoing financial control tool, to introduce a dynamic element to airport planning. Thus, the control was put in the hands of the user, requiring them to properly formulate the airport's vision and objectives, as well as possible policy options, and different assumptions and uncertainties, and test these using the Financial Model. This is in contrast to the previous ABS Financial Model, or other similar projects, which attempted to

develop a single optimisation model, and use advanced techniques for forecasting an airport's future performance.

Although an initial proof-of-concept was carried out in this project, the next step will be to develop and implement a more detailed level of analysis using real-world detailed financial data. The ABS and Financial Model should be integrated into one single program, and share the same user interface. Lastly, potential users such as students, professors, and users in the airport business sector should be invited to use this new ABS, and offer their reactions and opinions.

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List of Acronyms

AASP	Adaptive Airport Strategic Planning
ABC	Airport Benefit-Cost
ABP	Assumption-Based Planning
ABS	Airport Business Suite
A/C	Aircraft
ACC	Airports Consultants Council
ACI	Airports Council International
ACRP	Airport Cooperative Research Program
ADG	Airplane Design Group
AE	Aerospace Engineering
AIP	Airport Improvement Program
AMP	Airport Master Planning
AP	Accounts payable
APM	Adaptive Policymaking
AR	Accounts receivable
ARC	Airport Research Centre
ASP	Airport Strategic Planning
ATC	Air Traffic Control
ATM	Air Traffic Management
CAA	Civil Aviation Authority
CAP	Critical Assumption Planning
DBMS	Database Management System
DLL	Dynamic Link Library
DSP	Dynamic Strategic Planning
DSS	Decision Support System
EASA	European Aviation Safety Agency
EDMS	Emissions and Dispersion Modelling System
EOS	Entrepreneurial Operating System
FAA	Federal Aviation Administration
FF&E	Furniture, Fixtures and Equipment
FSG	Flight Schedule Generator
FSP	Flexible Strategic Planning
GUI	Graphical User Interface
HARMOS	Holistic Airport Resource Management and Optimisation System
IAS	International Accounting Standards
IATA	International Air Transport Association
ICAO	International Civil Aviation Organisation
IDE	Integrated Development Environment
IFRS	International Financial Reporting Standards
IMC	Instrument Meteorological Conditions
INM	Integrated Noise Module

IPO	Initial Public Offering
IT	Information Technology
KPA	Key Performance Area
LOS	Level of Service
MBMS	Model Base Management System
MIT	Massachusetts Institute of Technology
MS	Microsoft
MVP	Minimum Viable Product
NATS	National Air Traffic Services
NLR	Nationaal Lucht- en Ruimtevaartlaboratorium
O&D	Origin and Destination
OOP	Object-Oriented Programming
OPAL	Optimisation Platform for Airports, including Landside
OPTAS	Optimization of Airport Systems
Pax	Passenger
PDF	Portable Document Format
PFC	Passenger Facility Charge
PMAD	Peak Month Average Day
PMBOK	Project Management Body of Knowledge
PRM	Persons with Reduced Mobility
RDL	Report Definition Language
RWTH	Rheinisch-Westfälische Technische Hochschule
SEO	Search Engine Optimization
SFA	Stochastic Frontier Analysis
SID	Standard Instrument Departure
SPADE	Supporting Platform for Airport Decision-Making and Efficiency Analysis
SQL	Structured Query Language
STAR	Standard Arrival Route
TAAM	Total Airspace and Airport Modeller
TAPE	Total Airport Performance Evaluation
TAT	Turn-Around Time
TCM	Terminal Capacity Model
TFP	Total Factor Productivity
TPM	Technology, Policy, and Management
TRB	Transportation Research Board
TU	Technische Universiteit
TUD-ADC	Technische Universiteit Delft Airport Business Suite
USA	United States of America
VB	Visual Basic
VB.NET	Visual Basic.NET
VMC	Visual Meteorological Conditions
VS	Visual Studio
VS.NET	Visual Studio.NET

1. Introduction

The origins of aviation can be traced back to 400 BC, with the advent of kite flying by the Chinese. Humankind has always been fascinated by the idea of flying like birds, and have made various ill-fated attempts over the centuries to turn this dream into a reality. In 1783, this was finally made possible when Joseph and Jacques Montgolfier invented the first manned flight, using a hot air balloon. It was only in 1903 that the first sustained, controlled, and powered, heavier-than-air flight was accomplished by Wilbur and Orville Wright (Shaw, 2010). However, commercial aviation was slow to catch on, and it was only with the aid of a constant stream of technological developments, brought about to a large degree by the World Wars and the Cold War, as well as new legislation, that commercial aviation was able to grow at an unprecedented rate to 6.3 billion passengers and 96 million metric tons of cargo in 2013 (ACI, 2014). Air travel is now widely regarded as a fundamental pillar of our global life, influencing politics, business, and culture all over the world. Technological innovation, record economic growth, and regulatory reform transformed what was once a luxury for the privileged few, into a critical part of the infrastructure supporting global economic activity (Evans & Hawrylko, 1997). It provides numerous vital economic benefits by contributing to 3.5% of global GDP, and social benefits, by way of bringing together families and friends, bridging cultures, and spreading ideas. Airports play a crucial role in providing the ground infrastructure that enables air travel. Although airports function as a gateway to a city or region, many large airports are becoming cities in their own right. This phenomenon, called an 'Aerotropolis', is a new urban form where the layout, infrastructure, and economy is centred on an airport, in order to facilitate global trade, and take advantage of undervalued and underused land found in the vicinity of airports (The Economist Newspaper Limited, 2013).

Despite a series of shocks in recent decades: the deregulation of airlines in 1978; the September 11 terrorist attacks on the World Trade Centre in 2001; and the global financial crisis in 2008, air travel has rebounded each time. According to Airbus, air travel is forecast to more than double in the next 15 years. This amounts to an increase from 16,094 passenger aircraft in 2013 to 33,651 aircraft in 2032, and an increase from 2.9 billion passengers in 2012 to 6.7 billion passengers in 2032. Airbus also predicts that airlines will increasingly favour larger aircraft in order to reduce fuel burn and cost per seat (Airbus, 2013, pp. 9-10, 14). These trends, combined with the increasing popularity of low-cost airlines and airline mergers, means that airports will need to develop new infrastructure to satisfy the changing needs of airlines, along with the forecasted increase in passenger numbers. This comes with a number of inherent concerns, as decision makers will need to have access to all the pertinent information, in order to make feasible plans that are as cost efficient as possible. The high complexity of airport systems, and a very uncertain future, compounds the need for a decision support tool which will allow airport planners to not just keep pace with increasing passenger demand, but to anticipate changes, and where necessary, mitigate any adverse effects on the airport, or exploit opportunities. The main challenge faced by airport management is to find a match between capacity and demand, given a number of constraints, for both the short- and long-term, while managing the economic, environmental, and land-use effects of airport operation. Forecasting is an integral resource at the disposal of airport management, which helps them decide between various strategies. Forecasts can be either qualitative in nature (based on the judgement of forecasters), or quantitative (based on numerical data or mathematical models), in order to model an airport and its operations (Young & Wells, 2011).

Airport modelling and simulation became prevalent in the 1990s as air transport researchers and airport engineers explored practical aspects of airport simulation and their utilisation, to improve airport planning and design practices, and capacity evaluation. No major airport development is now conducted without the use of airport modelling and simulation at some level, particularly in airport master plans, airport-airspace capacity studies, and environmental studies. The Airport Business Suite (ABS) is one such tool that was designed by the Delft University of Technology Airport Development Centre (TUD-ADC) for this very purpose. '[It] is a computer-based system for decision support that enables users to obtain, through a graphical user interface, consistent information about all facets of the airport's business (for current and future situations)' (Roling & Wijnen, 2004, p. 73). Although it was initially envisioned to be used in the airport business sector, it has mainly been used for educational purposes by students at the Technische Universiteit (TU) Delft (Roling & Wijnen, 2004, p. 75). Therefore, the main aim of this Master's thesis is to investigate various ways in which the ABS can be further developed in order to make it more applicable to real-world airport planning, in order to transform it into a commercial product.

The layout of this introduction chapter is as follows: the current approach to airport planning will be explored in Section 1.1, while Section 1.2 will present the main shortcomings with this approach. Section 1.3 and 1.4 will present an introduction to the TUD-ADC and the ABS decision support tool, respectively. Section 1.5 will elaborate on the various problems with the current version of the ABS. After an examination of the various areas of improvement needed for the ABS, the research objective and scope and limitations of this project will be presented in Section 1.6 and 1.7, respectively. Section 1.8 will conclude this introduction chapter with an outline of the thesis.

1.1 Current approach to airport planning

Since the aviation industry is dynamic, complex, and unpredictable, it is crucial for an airport to balance its business realities, expansion requirements, and societal requirements, when contemplating its development and growth. Privatization and liberalization have made these characteristics even more pronounced in recent years, and have forced airports to adopt ways with which to deal with airport planning.

According to Ashford et al. (2011, p. 106) and Walker et al. (2003, p. 4) there are various levels at which planning is conducted:

- *Strategic level*: procedures, timelines, and interaction modalities are set out that will lead to an optimum long-term plan with an ideal structure for the aviation system and its future performance.
- *Tactical level*: short- and medium-term tasks, procedures, timelines, entities involved, and courses of action are examined in order to arrive at a plan that would best fit the overall strategic goals.
- *Project level*: identifies details of executing a tactical plan to carry out a project of a specific nature and clear objectives, such as the timeline, budget, management procedures, and specific outcome.
- *Operational/Logistics Level*: usually includes the planning for individual short-term processes and operations.

An airport is a small entity in a large and complicated system. When conducting airport planning, it is essential to consider its role, function, and interaction within this entire system. Aviation System Planning is a process carried out by a governmental agency, aimed at translating goals and policies into programs that would guide the evolution of the entire aviation system. This results in strategic aviation system plans that guide the overall vision and development of air travel at various levels (nation-wide, regional, and state-wide). These plans are designed to optimize and harmonize the role of individual airports in order to achieve the best, and most efficient system performance. It also serves as a mechanism to determine an airport's development needs, to grant approval and funding for infrastructure development projects, and as a base template for reporting airport condition and performance (Ashford, Mumayiz, & Wright, Airport Engineering - Planning, Design, and Development of 21st Century Airports, 2011, pp. 105-106). This means that the objectives of individual airports will be set in accordance with the needs of the community, and so airports will only be able to operate and develop within these constraints laid out by the aviation system plans.

At the individual airport level, Airport Strategic Planning (ASP) is defined as the 'activity that encompasses all other planning activities [facility, economic, financial, organisational, and environmental planning] into a coordinated effort to maximise the future potential of the airport to the community' (Wells & Young, 2004, p. 368). ASP consists of four main phases: preplanning, analysis/evaluation, implementation/execution, and monitoring, and is meant to guide all other airport planning analyses (Figure 1-1).

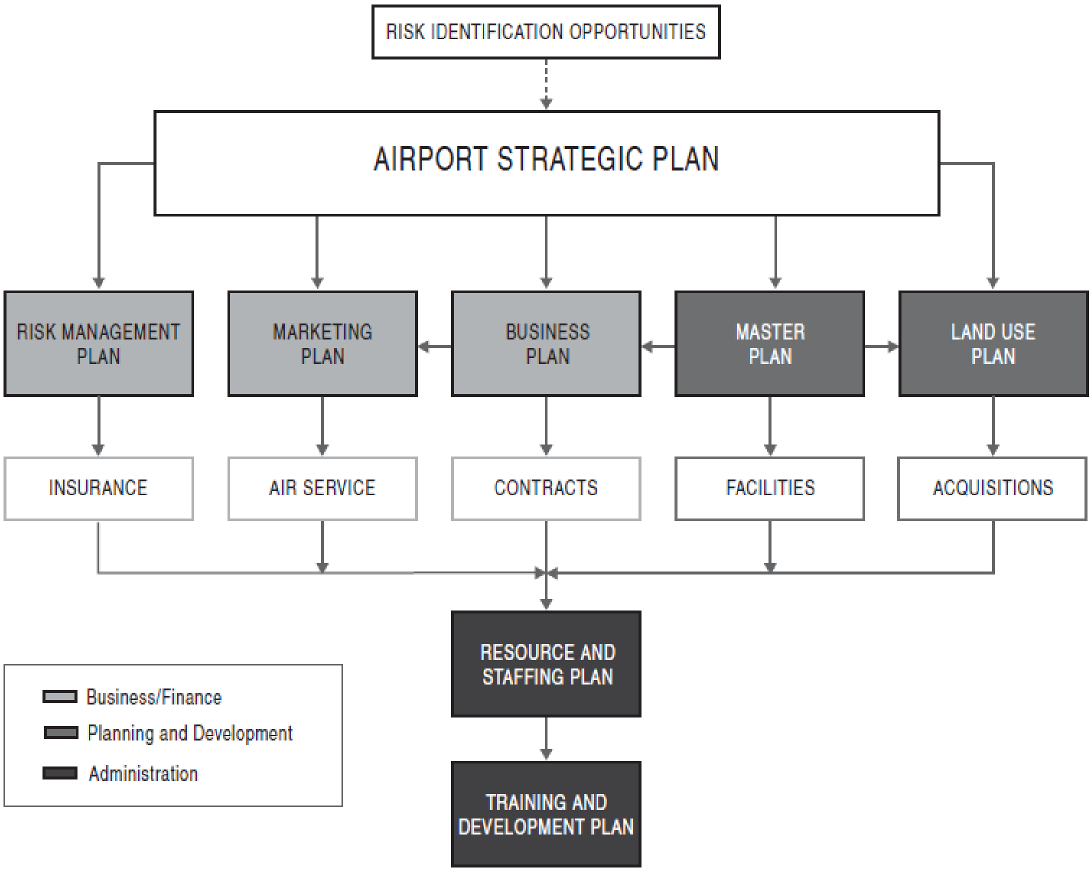


Figure 1-1: Interrelationship between airport planning processes
Source: TRB (2009, p. 17)

Airport Master Planning (AMP) is currently the dominant approach for ASP. An airport's Master Plan is currently the core artefact of airport planning that details the specific long-range plans of the individual airport within the framework of the national system plans, identifying the development needs at individual airports on the basis of forecasts of aviation activity, the potential environmental effects, community compatibility, and financial feasibility. It usually covers a period of 20 years, with updates often being necessary to factor in actual conditions and trends, as they become apparent. An aviation demand forecast may aim to predict the number of passengers, the amount of freight, the number of aircraft movements, or a combination of the three. In order to develop an aviation demand forecast, past trends based on time series data and/or theories about underlying mechanisms, are identified and extrapolated in order to obtain a forecast for the year of interest (Kwakkel J. , The treatment of uncertainty in Airport Strategic Planning, 2010). The objectives of an Airport Master Plan are (AAAE, 2004/2005, p. 15):

- Gathering and presenting all the information and data necessary to formulate the plan.
- Establishing a framework for a continuing planning process at the local, regional, state, and national level.
- Describing the concepts and alternatives for development, both technically and procedurally.
- Establishing realistic priorities, and a schedule for implementation of the development proposed in the plan.
- Proposing an achievable financial plan to support the implementation schedule.
- Providing an effective graphic presentation of the ultimate development of the airport, and anticipated land uses in the vicinity of the airport.
- Providing a concise and descriptive report for the general public, and for public policymakers.

In order to achieve these objectives, an Airport Master Plan will at the very least, usually contain the following elements: existing conditions and issues; aviation demand forecasts; requirements analysis and concepts development; airport site selection; environmental procedures and analysis; simulation; airport layout plans; and a plan implementation. The AMP process begins with a local initiative brought on by pressures for development and expansion from various sources, such as: an airport's demand exceeding its capacity; the introduction of more demanding aircraft; a critical environmental problem; community actions; or actions taken by airport users (AAAE, 2004/2005, pp. 18-19).

1.2 Problems with the current approach to airport planning

AMP has proven to be ineffective when used as the main way to shape and determine the long-term development of an airport. In recent years, the opportunities to accommodate the market-driven growth in air traffic demand have become increasingly more restricted due to environmental and safety constraints, affecting the ability of the air transport system to accommodate this growth (Visser, et al., 2003). This phenomenon has been witnessed in numerous examples of airport planning failures. Amsterdam Airport Schiphol, for example, put forward a Master Plan in 1995 which had a time horizon of 20 years, but this Master Plan was made obsolete in 1999 due to the rapid growth in aviation demand at an unanticipated rate (Kwakkel, Walker, & Marchau, 2007). Four main weaknesses of AMP have been identified: i) rigid and inflexible nature; ii) narrow focus; iii) inability to deal with uncertainty effectively; and iv) an ineffective and inefficient problem solving process or framework. These are elaborated in further detail below in Subsections 1.2.1 to 1.2.4.

1.2.1 Rigid and inflexible nature

The Federal Aviation Administration (FAA) in the US has strict guidelines for an AMP study (FAA, 2005), while internationally, IATA manuals (IATA, 2004) and books by leading scholars heavily influence AMP practices. The AMP method, as laid out by the aforementioned organisations, follow a strict linear process. In addition to this, Airport Master Plans are by nature are static, are usually based on a single scenario, and any changes are handled in an *ad hoc* manner, leading to the consistency of the Master Plan being gradually lost over time. In some instances, it is even impossible to integrate mew business models and results into former AMP studies. These inconsistencies and time consuming adjustments and costs can no longer be tolerated (Walker, et al., 2003, p. 2), especially given the dynamic nature of the aviation industry.

1.2.2 Narrow focus

Another problem faced by the AMP process is that it usually focuses on the development of a plan, and not on the decision making process of this plan. Furthermore, AMP is predominantly characterised by object-oriented activities focused on the airport system, and its measurable inputs and outputs (Mayer, van Daalen, & Bots, 2004). It also assumes that airport authorities are able to implement an Airport Master Plan without opposition from other stakeholders, which can cause serious problems and conflicts when an airport tries to implement their plan, through actions, legal and otherwise, undertaken by the excluded stakeholders. It should be noted that the problem of a lack of involvement of stakeholders is becoming less of an issue, and is now being integrated into the AMP process of most airports.

1.2.3 Inability to deal with uncertainty effectively

Uncertainty can be defined as 'any departure from the unachievable ideal of complete determinism' (Walker, et al., 2003) and can manifest itself in various areas: aviation demand; regulatory context; technological breakthroughs; and demographic developments. AMP only focuses on reducing demand uncertainties through aviation demand forecasting, although it is generally accepted that 'forecasts are always wrong'. Because the other types of uncertainties are ignored, and most Airport Master Plans are only based on one forecast of future traffic, demand forecasts are practically always wrong, making them almost impossible to implement. This causes severe capacity constraints due to unanticipated regulations, inability to meet actual demand, and unnecessary investments in facilities (Kwakkel J. , The treatment of uncertainty in Airport Strategic Planning, 2010). According to Flyvbjerg, Bruzelius, and Rothengatter (2003), reasons for demand prediction failures that can be allocated to uncertainty include discontinuous behaviour and the influence of complementary factors, unexpected changes of exogenous factors, and unexpected political activities or missing realisation of complementary policies.

1.2.4 Ineffective and inefficient problem solving process or framework

When using AMP, inconsistencies and contradictions are commonplace in large airport organisations which are made up of different departments, which use different models, tools, assumptions, and data, that have different priorities. This can only be solved by manually collecting, combining and post-processing this data, which is very time- and resource-consuming, and may still lead to inconsistencies. According to Flyvbjerget al. (2003), reasons for demand prediction failures that can be allocated to an ineffective problem solving process include the methodology applied, poor database, implicit appraisal bias of the consultant or forecaster, and appraisal bias of the project promoter.

The very nature of airport strategic planning problems compounds the ineffectiveness of the AMP problem solving process. They can be classified as ill-structured problems since they seldom have a linear, pre-determined path for problem solution or plan evaluation (Simon, 1973). This means that simplification and structuring procedures are required, along with a strong degree of human judgment. The effects on various airport performance aspects due to changes in the airport system and operation need to be quickly evaluated, which are much better performed by computer-based systems. Thus, various projects have attempted to design and build integrated computer-based systems for airport performance analysis, which allows the benefits of a computer's analytical capabilities, while preserving human judgment (Wijnen R. , 2013). These projects are summarised in Section 2.4, with the ABS (Section 1.4) being one such project undertaken by the TUD-ADC (Section 1.3).

1.3 The TUD-ADC

The TUD-ADC is a joint initiative of the faculties Technology, Policy, and Management (TPM) and Aerospace Engineering (AE) of the Delft University of Technology. It was created to be a multi-disciplinary research centre for airport development and planning, in cooperation with the Airport Research Centre (ARC) of the Rheinisch-Westfälische Technische Hochschule (RWTH) Aachen University in Germany, The Massachusetts Institute of Technology (MIT) in the USA, Schiphol Airport, and KLM. Its aim is:

> *To provide a platform for conducting and applying research to help organisations in the air transport sector meet their strategic and operational challenges through the development and use of tools and solutions enabled by innovative concepts and advanced technologies'* (TU Delft, 2014).

These organisations include local, regional, national, and international governments; airliners and other transport companies; airports and air traffic control (ATC) organisations; handlers and air transport related companies; organisations that have a business interest in the air transport system; residents in the local area; and members of public interest groups

The TUD-ADC links science and technology to business and policy issues by using a problem-and market-oriented approach based on multi-disciplinary knowledge from various branches of science, while applying a systems analysis framework, and considering the full range of stakeholders, and any environmental, spatial, economic, and societal impacts. It provides advanced tools for decision support in the aviation industry which are comprehensive, problem-oriented and customizable. These tools are flexible, adaptable, consistent, and time-saving in nature, allowing an organisation to identify solutions with better quality and lower cost than currently possible, and to provide information at various levels of aggregation. The two projects the TUD-ADC is currently working on are the Holistic Airport Resource Management and Optimisation System (HARMOS), and the ABS (Roling & Wijnen, 2004), which will be the focus of this thesis project, and is presented in more detail in Section 1.4.

1.4 The ABS

A research theme being carried out in the framework of the TUD-ADC relates to the development of models that address airport strategic planning. More specifically, it was envisioned to develop a Decision Support System (DSS), the ABS, which would be able to address the entire range of problems associated with strategic airport planning. This implies that models should be created which would have the ability to describe all the aspects of an airport system, at both the operational and strategic level. Using this DSS, a decision advisor would be able to provide airport decision makers with all the information and advice needed to assess the effects of policy decisions on airport performance, in a wide variety of circumstances, and in situations of high uncertainty (TU Delft, 2014).

The ABS was designed to counter many of the shortcomings of AMP, as outlined in Section 1.2. This was done by developing an integrated toolbox of tools which were designed to be user-initiated, user-controlled, and easy to use interactively. The ABS provides information at various levels of aggregation, and integrates models, databases, and displays in order to help users to identify good solutions. These generic tools are able to be customized to better reflect the needs and circumstances found at individual airports (Zawadzki, 2003). The ABS was envisioned to be a continuously updated research and development project, carried out in close cooperation and communication with air transport organisations and other stakeholders. Thus, a second version of the ABS was developed, as detailed in Subsection 1.4.3. It is important to get a good understanding of what has been previously attempted with the ABS, in order to deduce what has been proven to work, and what has been attempted, but later discarded. This will also help to reveal any current areas of improvement for the ABS (Section 1.5).

1.4.1 ABS design principles

The ABS was designed to be a computer-based decision support tool that enables the end user, envisioned to be advisors to an airport's strategic decision-makers, to obtain, through a single graphical user interface, consistent information about all facets of the airport's business for current and future situations at the desired level of aggregation. The ABS is designed to have one or more users linked to the system at the same time. The dialogue management subsystem allows the user to interact with the database through a database management subsystem, and with an interlinked system of models through a model management system. In order to improve the efficiency and effectiveness of AMP in ASP, the ABS should function in the following ways (Walker, et al., 2003):

- Provide models for rapid estimate calculation of the various aspects of performance of the airport system under a range of (user-defined) situations.
- Provide different levels of aggregation, in order to be able to do both quick initial scans and more detailed analyses when required.
- Maintain consistency among all of the models.
- Presenting information on the full range of decision-relevant criteria in an integrated, easy to understand format.
- Presenting information on the main factors driving decision-relevant criteria, in order to identify bottle-necks.
- Preserving decision-making memory of results for cases already run.
- Enabling fast and thorough comparisons of any number of 'what-if' cases.

According to Walker et al. (2003), three main principles guided the design of the ABS:

1. **Coordinate and integrate the decision-making tools**

The models in question were either developed in-house by the TUD-ADC, or built by others. Interfaces between these models should be created which are convenient and adaptable to changes in other models. In order to aid consistency and integration, a common, centralised database is used which contains all relevant information for reports, inquiries, and input to models, while a common high-level programming language is used in the models to facilitate updating and maintenance.

2. **Place the user in control**

The ABS focuses on the decision-making processes, rather than computer models, and is designed to be responsive to the user's needs. It combines the analytic power and capabilities of the computer with the judgments, needs, and problem-solving processes of the user, but does not replace their judgment. The system provides online access to the modules and the database, large numbers of policy variables that can be manipulated to perform 'what-if' analyses, and graphical displays. Default values are supplied by the system when the user does not wish to adjust parameter values or specify new data input.

3. **Make the system flexible, adaptable, and easy to maintain**

The ABS has been designed to be easy to modify based on changing needs, knowledge, and situations. The models will need to be easy to change and revise, permit the use of new variables, and be amenable to revision in response to changes in the data on which they are based. The database will also need to be able to allow continual updating. Flexibility and adaptability is helped by the use of several small, simple models, which are well documented and easily updated. The data required by the modules are easy to obtain, and do not require extensive preparation or previous analysis, and is usually routinely collected by most airports. Additionally, the toolbox approach means that it is possible to make all these changes without incurring large amounts of time, skill, and confusion in reprogramming.

1.4.2 ABS version 1

As stated before, the ABS was designed using the toolbox approach, whereby a number of models, each designed for a specific purpose, are linked using a common user interface and data layer to model the business processes. The advantages of this approach are that it mitigates the problems inherent in building a single large model, makes it easier for users to understand (and accept), and makes it relatively easy to adapt the ABS to a variety of circumstances, availability of data, and types of analyses. (Wijnen, Roling, & Heblij, 2006).

The five models that made up the original version of the ABS resulted from a division of the airport business process into five parts (Figure 1-2), and are elaborated in more detail.

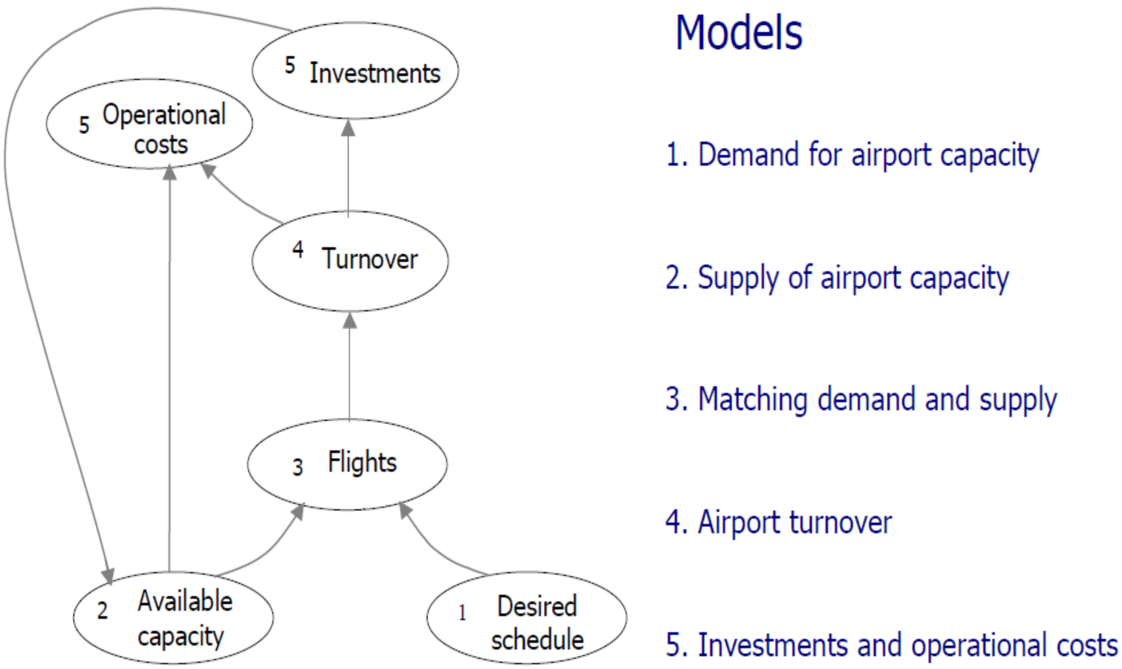


Figure 1-2: The five sets of models of the ABS V1
Source: Wijnen, Roling, and Heblij (2006)

Model 1: Demand for airport capacity

This model develops a forecast of the unconstrained primary demand for air transport by linking future economic factors to current (base year) annual passenger flows on the flight routes served by the airlines. These passenger flows are then transformed into annual aircraft movements, considering aircraft size, after which the total set of flights is translated into a desired schedule, distributed over the desired number of daily flight banks. Since yearly flights are not distributed evenly across the year, airport planning only focuses on peak hours as these determine the airport capacity requirements. The user is able to choose which peak days to use in the planning process (Visser, et al., 2003, p. 4).

Model 2: Supply of airport capacity

Capacity and delay are two of the most important measures of an airport's performance, and the ABS airside capacity and delay model integration scheme is shown in Figure 1-3. The key factors affecting capacity are: the runway system and operational use; aprons and gates configuration; passenger terminals; and environmental constraints. In order to enable many cases to be explored in a short amount of time, the tools implemented in this model are fairly aggregate in nature, while remaining sensitive to the parameters that have a significant influence on capacity and delay. These parameters include: the number, orientation, and usage of runways; the characteristics of the ATC system; and operational characteristics such as the mix of aircraft types and arrival/departure operations, and weather conditions.

Model 2 is made up of a number of different modules. The FAA airfield capacity module was included in this model, with the possibility to replace it with a more advanced alternative model in the future. The terminal capacity module is designed to allow a rapid and easy assessment of a specified terminal building given the peak hour values of a schedule, and identifies the capacity constraining factors. The Integrated Noise Module (INM), developed by the FAA, is included in this model to enable the calculation of noise contours based on total flight movements and runway use. Model 2 also includes a network of queuing modules that are used to predict delays due to congestion in the various airport elements. These are linked to a gate module, which estimates turn-around times and gate occupancy statistics (Visser, et al., 2003, pp. 4-6).

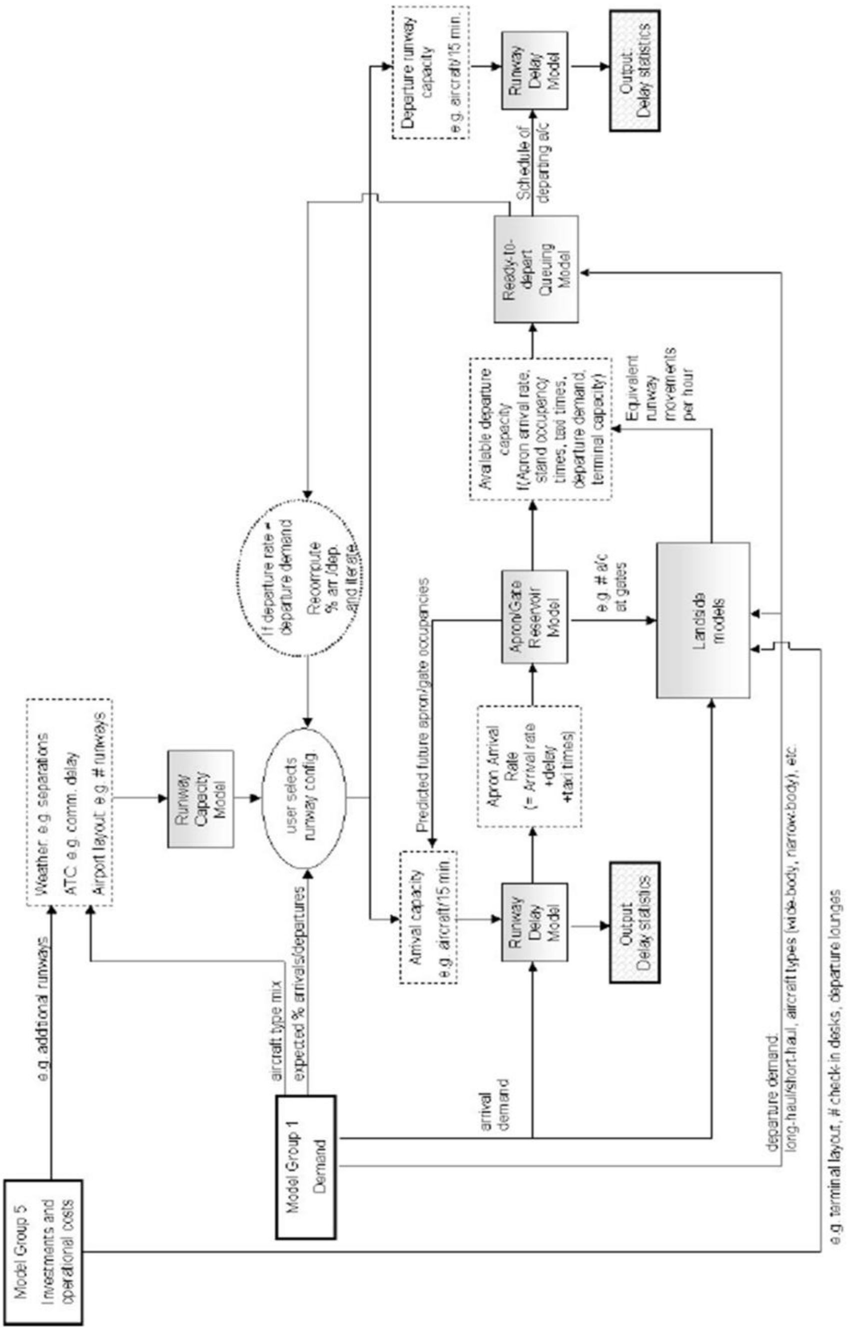


Figure 1-3: ABS airside capacity & delay model
Source: Visser, et al. (2003, p. 7)

Model 3: Flight schedule

This model is concerned with matching demand and supply at the airport by allowing the user to make choices about how to adjust the desired airline schedule to meet the capacity and quality limitations. The initial output from Model 2 will most likely not show satisfactory performance, as capacity or quality limitations may be exceeded. Through the Graphical User Interface (GUI) provided by Model 3, the user is able to test a wide range of alternative approaches, in order to arrive at a promising demand with a satisfactory level of capacity or quality which can then be examined for its financial consequences (Visser, et al., 2003, p. 8). This can be done using various combinations of terminal, runway, schedule, and weather schemes.

It should be noted that the analysis of the capacity and delay occurs on a 'peak day' basis. A peak day case relates to a specific runway configuration for a specific peak day. Based on user discretion, these can then be combined with other peak days, in order to obtain a yearly case, which will be the basis for the proceeding models in the program. However, this process currently requires a lot of user input, and so automation is clearly required in order to produce yearly cases. This will be done by implementing data from various real world airports, and determining which combination of peak day cases consistently leads to a satisfactory approximation of yearly cases.

Model 4: Airport revenues

This model estimates airport revenues and costs, and the difference between the two (profits or losses). Airport revenues are generated from the airport activities that have been defined in Models 1, 2, and 3. And can generally be divided into aviation and non-aviation revenues. Most aviation revenues are directly related to the volumes determined in the previous models, and can be determined by multiplying these volumes by predetermined fees which can be modified by the user. Non-aviation revenues are less directly linked to these volumes, and are either offered by the airport, or as a concession, in which case concession revenues are generated. Important categories of airport costs include employee costs, depreciation, and interest costs (Visser, et al., 2003, p. 10).

Model 5: Airport investments and balance sheet items

Investments play an important role in airports, and so Model 5 deals with this aspect. This model offers two alternative approaches to deal with investments. In the first, the investment level is determined within the model, whereby the investment levels for maintenance and expansion depends on airport activity. The second approach allows the user to determine these investments. Investments, and the way they are financed, change the balance sheet structure, on both the active and passive side. The active side is affected by changes in fixed assets and cash position, while the passive side is affected by changes in the structure of liabilities. There are predefined conditions in the structure of the balance sheets which include minimum cash levels, as well as limits to debts as percentage of all liabilities. These conditions determine the extent to which there is scope for new investments. The other main contributor to changes in the balance sheets are the profits and losses incurred annually. Profits may be added to the cash reserves, or used to reduce the airport's debt position, thereby decreasing interest costs (Visser, et al., 2003, p. 10).

1.4.3 ABS version 2

According to Walker et al. (2003), the first version of the ABS proved to be too constraining. By basing much of the design on the requirements of a 'typical' user session, an interface was developed that proved very hard to change or extend afterwards, violating the key design principle of 'putting the user in control'. The user was granted greater freedom to change decision parameters, conduct model runs in any desired order, and visualize results as desired. The second version of the ABS was developed around a spreadsheet-based interface, for which all the major user interface elements are predefined, but remain fully adjustable by the user. In this way, users are invited to quickly and easily pursue their favourite ideas and scenarios. Certain standard displays have been pre-programmed, but Excel offers them the opportunity to design any table or graph they desire. Added support for tracking and managing user decisions ('case management') further improves user control (Walker, et al., 2003).

Model 1 in version 1 of the ABS was replaced as it proved to be very inflexible. Models 4 and 5 were also removed, as they turned out to be too rigid and produced inconsistent results. They were replaced with some data output for manual calculations. The new models are outlined below (Roling & Wijnen, 2004):

Model: Flight schedule generator

A Flight Schedule Generator (FSG) replaced the earlier demand-forecasting model. The earlier model was removed as it proved inflexible for use with different airports, due to fixed city pairs and aircraft. It was passenger-based, whereas the FSG is aircraft-based, more versatile, and easier to use. Distribution of traffic over the day was too concentrated, and growth numbers were difficult to adapt. The FSG takes an existing set of data which can be imported from a present-day flight schedule, and extrapolates these data to create a future flight schedule. One of the major inputs required is the traffic growth rate per year, which can be separately assigned for each connecting city, or all cities can be assigned the same growth rate. Policy options include the distribution of flights over the day, with manual adjustment of the fleet mix and ratio of transfer to O&D passengers a possibility (Roling & Wijnen, 2004).

Model: Capacity and delay model

An upgraded FAA airfield capacity model was integrated into the ABS to calculate runway capacity and subsequent delays, as well as gate usage. Runways, runway configurations, and runway use schemes can be imported or defined by the user. A Terminal Capacity Model (TCM) consists of a set of IATA-based algorithms for the calculation of the required and used capacity for the different terminal facilities. In addition to setting the size and parameters of the facilities, the level of service can be changed by the user (Roling & Wijnen, 2004).

Model: Integrated Noise Model

This was used to create input for the INM, in order to calculate noise contours around the airport.

1.5 Areas of improvement for the ABS

Roling and Wijnen (2004) concluded that the current version of the ABS is able to compute the airport performance indicators that are important for runway expansion alternatives to a satisfactory degree of accuracy, based on a hypothetical study carried out for Amsterdam Airport Schiphol. Likewise, Visser et al. (2003) is confident that although work remains to be done to realise the ABS' full potential, they are confident of the model system's usefulness and importance for airport strategic exploration. Walker et al. (2003, p. 452) Visser et al. (2003, pp. 10-11), and Roling and Wijnen (2004) provided suggestions for possible areas of improvements to the ABS, and these suggestions were used as a basis for determining the key improvements that can be made to the ABS, for the purposes of this Graduate Thesis Project.

1.5.1 Place the user in more control and increase flexibility

- *Understanding:* Provide the user more insight into how the structure of the model system determines its behaviour. This can be done by preparing a more in-depth, technical manual for the ABS.
- *Multi-user:* Implement the ABS as a multi-user system which can be achieved using a web-based implementation of the ABS.

- *Different depths of analysis:* Develop models featuring different levels of aggregation, allowing the user to conduct both quick initial scans and more detailed analyses, as required.
- *Automation:* Reduce the amount of manual input required by the user, in order to make it easier for the user, and reduce the amount of time spent creating the peak day cases. This can be done by automated scenario generation, making it easier for users to run alternative scenarios. Make the evaluation and comparison process easier for the user by implementing some form of automation. This can be done using output parsing, and offering graphical comparison between cases.

1.5.2 Improvements to current models and modules

- *Real-world application:* Change the hypothetical airport into one or more actual airports for use in real policy studies.
- *Yearly case:* Improve the translation of a peak day case into a yearly case. This can be improved by estimating seasonal effects or introducing random 'black swan' events.
- *Terminals:* Allow modelling of multiple terminals, based on their individual characteristics, rather than aggregating all the terminals into one terminal, as is the practice in the current ABS. Terminal queuing can also be integrated into the terminal capacity model.
- *Runways:* The ABS is currently limited to two-runway sets, rather than the four-runway set capability of the FAA model. This can be upgraded, in order to have the ability to represent the more complex runway systems found at larger airports more accurately.
- *INM module:* Automate the creation of Standard Instrument Departure (SID) routes and Standard Arrival Routes (STARs) in the INM module.
- *Weather module:* Expand the weather module to include other factors such as wind strength and direction. The current module only takes visibility and cloud base into account.
- *Database:* Update the database entries for aircraft types and airports to include any new entrants since the last ABS update. This will remove the need for users to manually replace unknown aircraft types or airports.

1.5.3 Additional models and modules

- *Financial Model:* Integrate the financial analysis of airports into the ABS system, rather than the current practice of having data output, which would be used for manual or spreadsheet-based calculations of the airport's financial situation.
- *Economic model:* Enable an analysis of the effects that the airport will have on the local economy, with regards to job creation, revenue generation, and multiplier effects, among others.
- *Other types of operations:* Develop modules related to demand forecasting in order to be able to capture cargo and general aviation operations.
- *Constraining elements:* Integrate modules with additional capacity constraining elements, such as airspace, taxi-ways, air cargo facilities, and landside access.
- *Safety:* Develop model related to external safety risk. In the Netherlands, this is required for an Environmental Impact Statement.
- *Risk:* Implement the TRIPAC external risk assessment module created by the NLR.
- *Pollution:* Develop an air pollution analysis module. This can be done by integrating the Emissions and Dispersion Modelling System (EDMS) developed by the FAA for the modelling of emissions.

1.6 Research objective and questions

After a consideration of the possible areas of improvement to the ABS (Section 1.5), and a consultation with the supervisors of the thesis project, the development of a Financial Model was deemed to be the most pressing area of development for the ABS. While the ABS currently provides the user with the ability to determine the best levels of performance possible, without a financial analysis, these results are not very useful. An integral aspect of strategic planning is the trade-off between cost and performance. Developing a Financial Model was also deemed to be of sufficient scope for a Master's Thesis, and would be the most tangible result, rather than making a number of smaller improvements to the current ABS models, which already produce satisfactory results. Initially, the development of an economic model for the ABS was envisioned, in addition to a Financial Model. After some initial exploration of this research area, it was discovered that modelling the effects that an airport has on the local and national economy is too large of a task. Most methods are very primitive, and require a lot of significant approximations and simplifications, which do not produce accurate results. The uniqueness of each airport, and the economy it operates in, further compounds this problem, and makes it harder to create a generic model which can be applied to different airports.

Thus, the research objective was defined as follows.

> *Develop a generic Financial Model for the ABS that gives the user a high degree of control and flexibility, in order to explore various scenarios and plans, by producing a good estimation of an airport's future financial situation.*

In order to achieve this research objective, several research questions were formulated:

1. What lessons can be learnt from past and current efforts to build computer-based systems to tackle airport strategic planning?
2. What are the main features of an effective framework to utilise the ABS Financial Model, and implement its results?
3. What is the importance of a financial analysis or forecast in an airport's decision-making and strategic planning?
4. What are the most important elements in an airport's financial planning, and how can an airport's operations be translated into financial results?

1.7 Scope and limitations

It is always crucial to know exactly what a project will encompass, as well as its limitations. In the case of this project, the end-product will be a Financial Model for the ABS program, which allows the user to carry out a financial analysis on the various cases produced by the other models of the ABS. For this reason, the current ABS program will naturally impose restrictions on this new model, in terms of its capabilities, data input, and user GUI. More importantly, the design principles envisioned for the original ABS program will be incorporated into the design of this Financial Model.

The model will only consider single airports, and will not consider external effects, such as a multi-airport system, or macroeconomic effects. It will be limited in terms of the types of strategies it will be used to explore. These will mostly include infrastructure-, and operation-related strategies. It will also allow for analysis of simple generic strategies such as determination of airport charges, debt financing, and balance sheet structuring, but not more complicated generic strategies such as privatisation, although the user may be able to explore these at a basic level.

The model will be made up of three layers: the GUI, computational models, and common data models. The GUI will be designed in an intuitive manner that makes it easy for the user to learn how to use the model quickly. Revenues, costs, and balance sheet items will be considered separately, both in the GUI and computational models. This will allow the user to explore various combinations of revenues, costs, and balance sheet schemes. It will also allow the user more insight into how the model works, although this will be supplemented by the information found in this report. Finally, the Financial Model will utilise the database for data retrieval and storage that the ABS currently uses, in order to ensure consistency of data within the ABS program. State-of-the-art airport planning methodologies will be used to guide the design of the Financial Model, and to provide some suggestions on the framework with which to use the ABS, and apply its results.

The model will allow for two depths of analysis. For a quick analysis, user input will be kept to a minimum, and simple calculations will be utilised. This level of analysis will be implemented. A more in-depth analysis will be explored, which will require more user input, but will be able to provide the user with a more detailed overview of the airport's financial performance. However, this detailed analysis will not be implemented. In order to reduce user input, certain data will be automatically imported from the other models in the ABS, while those data requiring user input will be provided with default values, which the user can manually change if required. These default values will be based on average values gotten from various studies, or averaged from the data of airports.

The three main outputs of the model will be an income statement, a balance sheet statement, and a statement of cash flow. In addition to these, the user will also have the ability to create various graphs and (productivity) ratios, in order to allow for comparison between different cases.

The relevance of this project is that it will enable the ABS to reach its envisioned potential. By allowing a more complete assessment of an airport's performance, it will become a much more relevant and useful tool for an airport's decision-maker. It will provide airports with a more efficient and attractive computer-based DSS, as most current alternatives are very time- and resource-intensive. It should be noted that this project will not result in a finished product ready to be marketed to airport businesses, as there are still a number of improvements that need to be made to the ABS, as presented in Section 1.5. A business plan to create a startup company, the Airport360, whose main goal is to commercialise the ABS, is shown in Appendix G.

1.8 Outline of the thesis

This introduction chapter presented the current dominant approach to ASP, and the various problems associated with it. After laying out the reasons for the need for an alternative to AMP, it then went on to introduce the TUD-ADC and the ABS program. Various areas of improvement for the ABS were identified, after which the research objective and questions were formulated. Finally, the scope and limitations of this project were discussed.

Chapter 2 will present a review of the literature consulted, in order to be able to answer the research questions. These were broken up into eight distinct areas. Section 2.1 presents a broad perspective on the airport system, while Section 2.2 presents an overview of an airport's effects on the economy, environment, and society. Section 2.3 presents new methodologies in airport planning, and Section 2.4 discusses the past and current initiatives for computer-based systems used in airport planning. Section 2.5 then explores various ways for dealing with forecasting and uncertainty. Various aspects of the Financial Modelling of airports are presented in Section 2.6, after which the different ways of the measuring an airport's performance are discussed in Section 2.7. Section 2.8 presents the various approaches to business development, and ultimately creating a business plan.

Chapter 2 answers research questions 1 to 4, as stated below:

1. What lessons can be learnt from past and current efforts to build computer-based systems to tackle airport strategic planning?
2. What are the main features of an effective framework to utilise the ABS Financial Model, and implement its results?
3. What is the importance of a financial analysis or forecast in an airport's decision-making and strategic planning?
4. What are the most important elements in an airport's financial planning, and how can an airport's operations be translated into financial results?

Chapter 3 presents the architecture of the ABS Financial Model, by integrating the knowledge in Chapter 2. Section 3.1 begins with the design principles of the model, while Section 3.2 discusses the development process. Section 3.1 gives an overview of the software architecture, such as its logical view, functional view, and use cases.

Chapter 4 describes the implementation of the architecture of the Financial Model. Section 4.1 presents the overall implementation of the model, such as the layout of the GUI, data input, data processing, and database interaction. Sections 4.2 to 4.4 present the project selection, editors, and yearly case modules, respectively. Sections 4.5 to 4.9 present the modules used in calculating the forecasts for the financial cases and financial plans, while Sections 4.10 to 4.14 presents the modules used for the outputs of the model: the income statement, balance sheet statement, statement of cash flow, performance ratios, and graphs, respectively.

Chapter 5 presents the results of the Financial Model. Section 5.1 explains the way in which the input data was obtained, or prepared. Section 5.2 presents the verification of the program and its results, while Section 5.3 presents a validation of the model, by ultimately comparing it with real-world data.

Chapter 6 is the epilogue of this thesis. Section 6.1 summarizes the answers to the research questions, after which Section 6.2 discusses the conclusions. The recommendations are presented in Section 6.3.

Finally, Appendix G presents a business plan for creating a business entity that will commercialise the ABS program, to satisfy the requirements for obtaining an Entrepreneurship Annotation.

2. Literature Review

This chapter presents a summary of the literature review carried out, as a first step in answering the research questions formulated in Section 1.6. It will also be the basis for the architecture of the model, as detailed in Chapter 3. Section 2.1 will present the airport system, in order to emphasize the complex nature of airports, and the inherent challenges with respect to making plans for airports. Section 2.2 explores the various effects an airport may have on the economy, environment, and society. Section 2.3 presents alternative approaches that have been developed to attempt to address the shortcomings of AMP, while Section 2.4 provides an overview of the past and current initiatives for computer-based systems that can be used in the airport planning process to assist decision making. Section 2.5 briefly presents different ways of dealing with uncertainty in forecasting. A summary of the various aspects of an airport's finances is presented in Section 2.6, and Section 2.7 presents literature used to determine the current practices of airport benchmarking, in order to allow ease of comparison between different plans generated by the ABS. Finally, Section 2.8 presents the literature consulted in order to be able to write a business plan for a startup company that would commercialise the ABS.

2.1 Airport system

The airport system is very complex, and is made up of various systems which all need to be considered when carrying out strategic planning for an airport. These systems are shown in Figure 2-1 on the next page.

An airport is divided into an *airside*, which refers to the part of the airport that facilitates the movement of aircraft around the airport, and a *landside*, which includes everything else, and accommodates the movements of passengers and cargo. The airside consists of the airspace (en-route system and terminal system) and the airfield (runway system and taxiway system), while the landside consists of the terminal system (apron-gate system and the passenger and baggage handling system) and the ground access system (Wells & Young, 2004). It is crucial to avoid any bottlenecks in order to maximise airport performance, and so the capacity of each of these systems needs to be carefully planned, while considering the interactions between them, which leads to one of the biggest challenges in airport strategic planning.

Since an airport is a very large and complex system, it has a number of impacts (e.g. economic impacts and environmental impacts) on society at large, and many specific stakeholders in particular. These stakeholders include passengers, air carriers, general aviation users, investors and bond-holders, concessionaries, service providers, employees, government at the national and local level, communities affected by airport operations, environmental bodies, local businesses affected by airport activity, parking operators and ground transportation providers, and airport suppliers (Schaar & Sherry, 2010). These stakeholders need to be involved in an airport's strategic planning, in order to allow the airport to balance its economic and societal performance, which is essential for its sustainability (Wijnen R. , 2013).

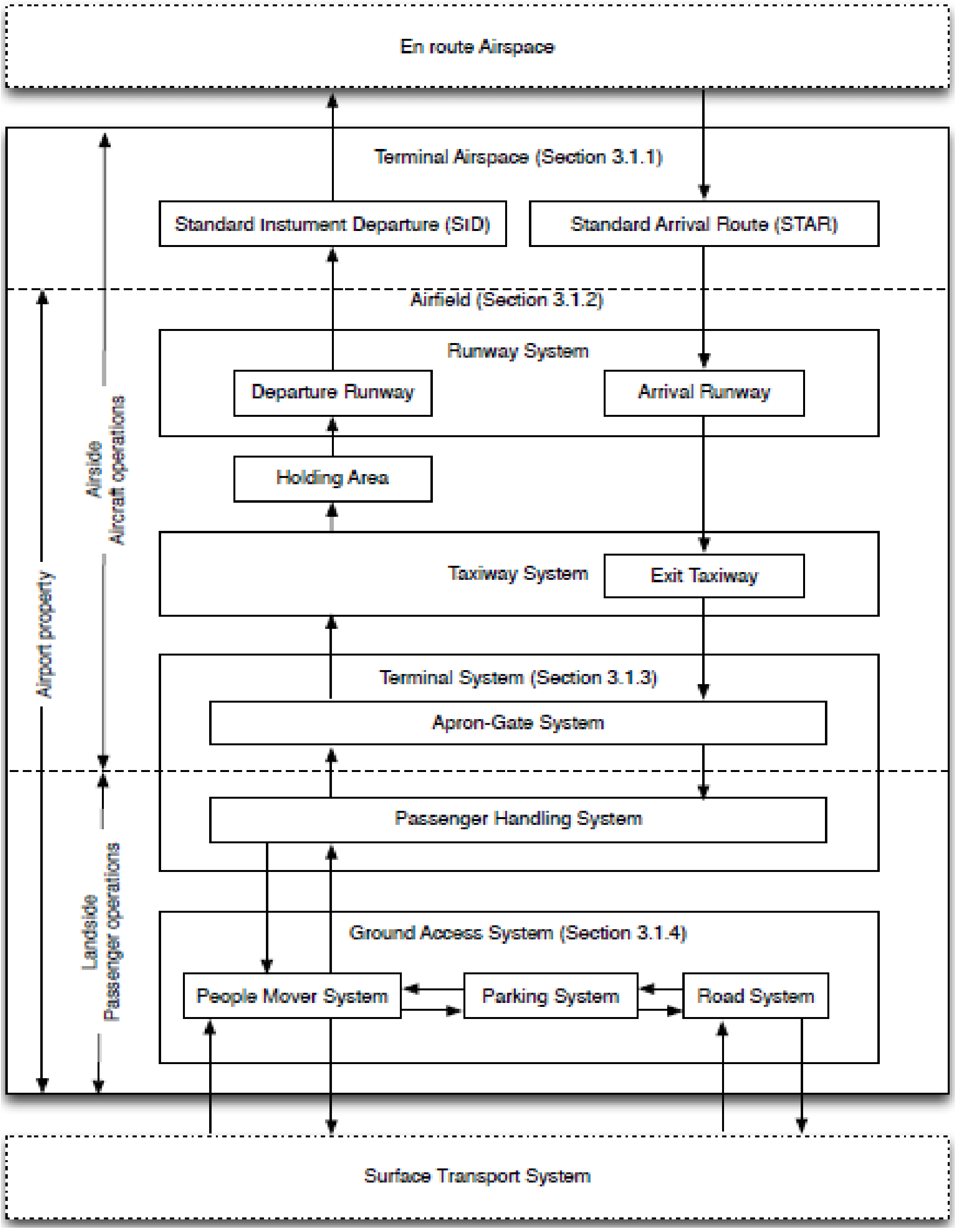


Figure 2-1: Airport system
Source: Wells & Young (2004)

2.2 Airport effects on the economy, environment, and society

Although the aim of this project does not include developing an economic model for the ABS, this still remains an important research area, as it provides an understanding into the importance of airports in the local economy. It is dangerous to underestimate the importance of the economy in airport strategic planning, as it can influence an airport in numerous ways, the largest being its effect on aviation demand, as witnessed in the 2008 global financial crisis.

Airports provide critical connections in the operation of the transportation system and have significant multiplier effects on national and regional economies' (TRB, 2009, p. v). This makes it of paramount importance that airport management assumes the responsibility of leading the airport in positively contributing to the local economy, maintaining good working relations with the airport's users and surrounding community, and minimizing the adverse effects airports have on the surrounding environment.

The largest role an airport has is that of transportation. But, an airport is also vital to the growth of business and economy, by providing access to new sources of supply and expanding market areas. It is also important for tourism and convention businesses. Airports and related businesses located at or near the airport provide a major source of employment, which has a direct effect on the economy by providing the means to purchase goods and services, and generating tax revenues, while the indirect effects are less tangible, and thus harder to quantify. However, this needs to be balanced against the detrimental effects an airport may have on its surroundings, which includes noise emissions, effects on air and water quality and endangered species, and hazardous waste emissions. The large number of stakeholders means that an airport should consider the implications of a decision on its stakeholders, before any decisions can be made about airport policy or expansion.

The TRB (2008) explores the way in which airports impact the community, and this will provide some insight when developing the framework to use in implementing decisions from the ABS. For instance, when carrying out a cost-benefit analysis for building a new runway, the intangible costs and benefits to the community should also be considered.

The Airport Benefit-Cost (ABC) software was developed by the Economic Development Research Group for the Wisconsin Department of Transportation (Economic Development Research Group, 2000). It combined three different functions: i) it implemented the FAA guidebook for individual project benefit-cost evaluation; ii) it served as a state-wide database for ranking and evaluating projects in the State Airport System Plan; and iii) it calculated the economic impacts of airports (Transportation Economics, 2014). It was applied to various airport projects over the years. Poorthuis (2008) used this software as a basis for developing a Microsoft (MS) Excel program with which to analyse the impact of the airport activity on the economy, and the impact of an expansion project at the airport. This work will provide some useful insights for this project.

2.3 Alternative approaches to airport planning

In practice, airport planners are now increasingly trying to deal with the inefficacy of AMP in various ways, which are usually reactive in nature, and still restricted by the static approach of AMP. These include defining formal procedures for updating the Master Plan, which often consists of semi-independent capital investment projects that allow for the postponement or speeding up of individual projects. It is also possible to solve problems that emerge when the real world deviates significantly from the anticipated world underlying the Master Plan, by making operational adjustments (Kwakkel J. , 2010). De Neufville and Barber (1991) recommend planning for shorter term horizons and designing facilities in a more flexible manner to serve a range of future needs to minimize the risk of obsolescence (Ashford, Coutu, & Beasley, 2012).

2.3.1 Assumption-Based Planning

Assumption-Based Planning (ABP) was developed at the RAND Corporation to aid the U.S. Army with its long- and mid-range planning in uncertain times, but it has also been applied to various situations outside of the military world. The most important elements in this approach include identifying important assumptions about the future on which the plan is based, as well as identifying the vulnerabilities, or elements that would cause these assumptions to be violated. Then, 'signposts' (events/thresholds) that indicate the changing vulnerability of an assumption should be defined, as they will be used to monitor the uncertainties in an organisation's future. 'Hedging actions', i.e. actions the organisation should take in the case that an assumption has failed, should be also defined. It should be noted that this approach provides a systematic way of thinking about an organisation's future, and a framework for dealing explicitly with these uncertainties over time (Dewar, Builder, Hix, & Levin, 1993, pp. xii-xiv).

2.3.2 Critical Assumption Planning

Critical Assumption Planning (CAP) goes a step further by constructing a model to calculate the impact of assumptions on each other, and to assign uncertainty ranges to the primary assumption values, in order to allow managers to focus on learning, and a flexible approach to planning, in order to develop cost-effective plans (Sykes & Dunham, 1995). The main methodologies from this approach and ABP will be incorporated into the user manual, to allow the user to be mindful of any assumptions they make, and any resulting vulnerabilities.

2.3.3 Dynamic Strategic Planning

De Neufville and Odoni (2003) proposed Dynamic Strategic Planning (DSP) as an alternative approach to AMP that emphasises flexibility. Airport operators are instructed to dynamically adjust their plans and designs over time to accommodate the variety of futures that may occur. The resulting plan defines a flexible development over several stages. It commits to the first stage, and suggests various developments for the subsequent phases. However, it is still based on traditional systems analysis, which is also present in AMP. Flexibility of the DSP is achieved through the use of 'real options'. According to de Neufville (2003), an option is a right, but not an obligation, to take an action for a certain cost at some time in the future, thus allowing the ability to not take this option if future conditions do not turn out to warrant it. de Neufville (2000) defines the categories of methods and activities which will result in a dynamic strategic plan as:

- *Modelling:* should result in one or more models of the technical system and its performance.
- *Optimisation:* to present an overview of different cost-effective means for achieved specified levels of results.
- *Estimation of probabilities:* it is necessary to estimate the range of values for key system parameters and the likely probability distributions for these parameters, since the future performance of a system cannot be forecast.
- *Decision analysis:* can be carried out for the set of choices, based on the previous three activities.
- *Sensitivity analysis:* makes sure that the outcome of the decision analysis is robust with regards to changes in parameter values.
- *Evaluation of real options:* should focus on identifying cost-effective real options to increase the flexibility of the plan.
- *Analysis of implicit negotiation:* aims at analysing the relevant stakeholders and their possible behaviour, since implementation is largely dependent on their support.

2.3.4 Adaptive Policymaking

Walker (2000) presents Adaptive Policymaking (APM) as a generic approach for the treatment of uncertainty. In order to plan effectively in a rapidly changing world where fixed static policies are likely to fail, he suggests adaptive planning and allowing for learning over time. This approach seems to share some similarities with the ABP approach, although this is applied to policy making. APM is comprised of two main phases:

- *Thinking phase:* the basic policy is designed and analysed for vulnerabilities, i.e. plausible events of developments that would impact the plan's performance. These vulnerabilities are screened based on their level of uncertainty, whereby relatively certain vulnerabilities are taken into account by including mitigating actions that should be taken during implementation. Uncertain vulnerabilities are addressed through the use of hedging actions to make the policy more robust, and a monitoring system is created to determine when these uncertain vulnerabilities manifest themselves.

- *Implementation phase:* The policy is implemented, its performance is monitored through the use of signposts, and it is adapted if necessary through defensive or corrective actions. The policy remains active as long as the signposts signify that the policy remains valid and can achieve its intended outcomes, otherwise, a reassessment of the policy is carried out.

2.3.5 Flexible Strategic Planning

Burghouwt (2007) suggests Flexible Strategic Planning (FSP) as an alternative to traditional AMP. FSP seems to draw some elements from ABP and DSP, with the main added element being the addition of the notion of proactive planning, whereby an airport should try and shape its future through its own actions. In order to achieve this, FSP depends on real options, scenario style robustness, back casting, contingency planning, monitoring, experimentation, and diversification. However, concrete guidelines for how FSP should be implemented are missing, and Burghouwt (2007) acknowledges that the creation of flexibility and adaptability is important due to the presence of stakeholders affected by the airport, but that there is an absence of the sophisticated tools needed to support airport planners in using FSP.

2.3.6 Adaptive Airport Strategic Planning

Adaptive approaches which take actions that are needed right away and create a framework for future actions that allow for adaptations over time, as knowledge about the future becomes known and critical events for implementation takes place. Kwakkel (2010) created an integrated adaptive approach called Adaptive Airport Strategic Planning (AASP), which combined elements from DSP, APM and FSP. The major steps in AASP are:

1. *Stage setting:* analysing the existing conditions of an airport by specifying the objectives, constraints, and available policy options. Results in a definition of success in terms of the specification of desirable outcomes.
2. *Assembling the basic policy:* involves specifying a promising policy and the identification of conditions needed for it to succeed.
3. *Robustness:* identify the vulnerabilities and opportunities for the policy, along with the relevant mitigating and hedging actions for the vulnerabilities, and seizing and shaping actions for the opportunities. This step draws inspiration from ABP and CAP.
4. *Contingency planning:* this involves defining signposts to specify information that should be tracked, and identifying critical values for the signposts (triggers), beyond which actions should be implemented to ensure a policy that keeps the system moving in the right direction. These actions include defensive, corrective, capitalizing, and reassessment actions.
5. *Implementation:* involves implementing the entire plan. The adaptive policymaking process is suspended until a trigger event occurs, at which point previously decided upon actions are carried out.

2.4 Past and current initiatives for computer-based systems

It is important to get an orientation of the software currently used in airport planning, to see what strengths can be drawn from these, and what is currently lacking, in order to determine any possible contributions to the Financial Model being developed. Airport planners are familiar with static calculators based on spreadsheets, but these lack the strength of advanced simulation tools to calculate traffic, and make better forecasts. Various tools have been developed for the analysis of an airport's performance, and can be categorised into three main types. On one end of the spectrum, *macroscopic tools* typically use analytical expressions to model and study airport operations at a fairly high level of aggregation, providing a global picture of the system with a crude level of detail. *Microscopic tools* lie on the other end of the spectrum, and use simulation methods to investigate individual aircraft or passenger movements. *Mesoscopic tools* for capacity and delay, use traffic flow models, and lie somewhere between microscopic and macroscopic tools in terms of their level of detail and aggregation. Microscopic tools do not necessarily provide more accuracy, but rather provide a higher level of detail for investigation an airport's performance (Wijnen R. , 2013).

There are numerous tools which have been developed to deal with certain aspects of airports. Tools dealing with capacity and delay include: the FAA Capacity Model which calculates the capacity of a runway system given continuous demand, using logic based on the fundamental concepts of the classical Blumstein model and its extensions (Swedish, 1981); SIMMOD and its commercial variants that model dynamic airfield and airspace routing, taxiing operations, and departure queuing, among others (ATAC, 2010); Pathplanner by Simtra, which models airside planning, design and operations (Airport Suppliers, 2009b); Total Airspace and Airport Modeller (TAAM), which is a large-scale detailed fast-time simulation system used to model entire air traffic systems (Ashford, Mumayiz, & Wright, Airport Engineering - Planning, Design, and Development of 21st Century Airports, 2011, p. 623); and many others. Some of the more comprehensive software packages like CAST Airport Simulation Software (Airport Suppliers, 2009a) come with a team of expert consultants, and are very expensive. For the purpose of noise analysis, the INM model is the most widely used tool, and is also used in the current version of the ABS. The Emissions and Dispersion Modelling System (EDMS) is used in the United States to conduct air quality analyses of aviation emission sources at an airport, and includes both an emissions inventory and dispersion analyses. Tools used to evaluate third-party risk at an airport include TRIPAC, which is used in the Netherlands (Nationaal Lucht- en Ruimtevaartlaboratorium, 2005, p. 23), and a model developed by the National Air Traffic Services (NATS) which is used in the UK (Foot, 1997). However, these tools are of limited use in airport strategic planning studies since they are usually related to a single airport performance aspect, configuration, or operation; they usually require a lot of work on the part of the user; and each tool uses different data and assumptions.

The problem with airport strategic planning is not a lack of tools, but rather, the appropriate use of computer-based tools (Odoni, et al., 1997). There is a need to find the right balance between ease of use, validity of forecasts, and price of software, and so a number of projects have been carried out to provide an integral view of an airport's performance, with the ABS being one such project. Other similar projects include (Wijnen R. , 2013):

- *Total Airport Performance Evaluation (TAPE):* Its objective was to develop a computer aided capability for evaluating the impact of the entire airport alternatives for increasing airport capacity and efficiency, both in the air and on the ground. Implementation was done via a multi-layered toolkit consisting primarily of analytical models, and a few simulation models, managed through a set of utility programs.
- *Optimization of Airport Systems (OPTAS):* Its objective was to use and evaluate a suite of airside and landside simulation tools, in order to create a high-level modelling tool using System Dynamics (SD) techniques, and achieve a comprehensive overview of the current state-of-the-art research into airport capacity. Three separate models of the same airport were implemented in parallel. The SD approach was found to be valid for a limited scope of problems.
- *Optimisation Platform for Airports, including Landside (OPAL):* Its objective was to provide a unified and integrated facility for modelling and evaluating total airports. Implementation involved the use of a central communication infrastructure that interfaces with the various tools and databases, with each tool module having its own local database, and a central database used for sharing data. It was the follow-up to the TAPE project.
- *Supporting Platform for Airport Decision-Making and Efficiency Analysis (SPADE):* Its objective was to develop a seamlessly integrated computational platform that will support policy and political decisions relating to airport development, planning, and

operations. Based on a pre-defined set of planning problems, it provides a user interface for specifying the required set of input data, controls to execute a pre-defined workflow of tools, and displays for reviewing the integrated results of the tools. Its data model is supported by a Relational DBMS.

- *Holistic Airport Resource Management and Optimization System (HARMOS):* Its objective is to enable airport operators to deploy their resources more efficiently, resulting in an improved understanding of the airport system. It also explicitly facilitates the involvement of stakeholders in the planning process. The key design principles were identified as being policy analysis and integration.

None of the systems developed in the aforementioned projects have been deployed and used in their entirety in actual airport operations. Possible explanations are that: their decision environment and context were not defined; they focused largely on capacity and delay analysis; there was a strong focus on tools and models, rather than the problem itself; and the usability, robustness, and user interfaces of these systems were severely deficient.

2.5 Forecasting and uncertainty

The purpose of using aviation forecast is to indicate the relative timing for airport investments in a manner that minimizes forecast errors. The idea is to forecast the different elements of aviation demand, compare that demand over time with airport facility capacity, and identify the time when new or expanded facilities may be necessary. When this basic approach is integrated into a continuous master planning process, the future year forecasts can be updated to reflect the appropriate time for phasing in capital investments or other measures (AAAE, 2004/2005, p. 21)

According to Young & Wells (2011, pp. 394-395), there are two main types of forecasting methods available to assist planners in the decision making process: Qualitative forecasting methods, which rely on the judgment of forecasters based on their expertise and experience, and can include management, administration, employees, consumers, and aviation experts; and quantitative methods, which use numerical data and mathematical models to derive numerical forecasts, and are more objective in nature. The two most common methods of quantitative methods are: trend analysis models; and causal models. Trend analysis models interpret the historical sequence and apply this to the immediate future. They are used where time and data are limited, and only one variable is being examined. Causal models use sophisticated statistical and other mathematical methods that are developed and tested using historical data to determine the value of a dependent variable based on one or more independent variables.

In order to make a forecast based on past performance, certain probabilistic methods can be used. Hunter (2010) explores modelling the impact of weather on airport capacity, which is currently not implemented in the ABS, and will serve to make the forecasted flights schedules more realistic. Probabilistic forecasts aim to provide calibrated and sharp predictive distributions for future quantities or events of interest (Gneiting & Ranjan, 2011). Another option is to use values given in the Global Market Forecasts (Airbus, 2013) as a basis for estimating future growth in air travel. This can be done by setting a default value for the current edition of the Global Markets Forecasts, and enabling an option for the user to input this manually to reflect the values of newer editions.

As previously mentioned in Section 1.5, the models used to predict flight schedules in the current version of the ABS have been shown to have an acceptable degree of accuracy, according to studies carried out using the analysis gleaned from these models (Roling & Wijnen, 2004). However, there is always a possibility to improve these models in the future, using recently developed methods for forecasting. In order to estimate values for the costs and revenues, simple relationships and rules of thumb will be used, which the user will be able to manipulate if needed, to create more accurate and detailed breakdowns of the costs and revenues.

2.6 Airport financial modelling

Financial Modelling is the process by which a firm constructs an abstract financial representation of some, or all aspects of the firm. This is usually characterized by performing calculations, in order to make recommendations based on that information (Investopedia US, 2014). Although Financial Models lack the technical complexity and high profile nature of operations models, they have nonetheless proved indispensable to provide critical, timely, and relevant information on a number of fiscal concerns. The increased need for capital requirements, coupled with decreasing public sector financial commitment, due to limited tax revenue and spending priorities in other areas, means that airport planners increasingly need to understand the full potential of Financial Modelling techniques, and their relevant applications for use in airport strategic planning. The main focus of this project will be *financial feasibility models*, which determine the potential of a given project against its anticipated cash flow streams, through the ability to attract project financing, cover expenditures, or produce a positive net present value. (Evans & Hawrylko, 1997).

The most important task is to understand what has already been attempted with the previous Financial Model of the ABS, in order to determine what improvements need to be made to it. The first, and perhaps most important source used, was the Master's Thesis on the design of the previous Financial Model of the ABS (Zawadzki, 2003). It was insightful, as it showed what had been attempted in the past for the economic model of the ABS. In particular, it presented the approach used to arrive at the model, and the design principles. It then went on to present the equations and relationships used to calculate the various values of interest in airport finance.

As the main focus of this project is to develop the economic model of the ABS, this research area was explored. *Airport Economics Manual* (ICAO, 2013) presents the latest ICAO policies on charges for airports. Although this is not directly useful for this project, since it does not include any quantitative guidelines, it still proved useful in getting a general idea of the rules concerning airport charges and taxes. It then details all the revenues and costs associated with running an airport, as well as the depreciation periods for various assets, which will prove useful when calculating the depreciation costs incurred by these assets. In order to get an understanding of the general elements of corporate finance, the work of Berk (Berk & Demarzo, 2011) will be used to gain the required knowledge. The works of Ashford, Mumayiz, and Wright (2011, pp. 9-15), and Young and Wells (2011) present the various airport revenues, costs, and investment types, and will serve as a starting point to determine which variables are important to creating the Financial Model of an airport.

According to (Zawadzki, 2003, pp. 25-54), sources of an airport's revenues include passenger fees, landing fees, aircraft parking fees, handling fees, retail revenues, car parking, real estate revenues, utilities revenues, and other revenues. Passenger fees, landing fees and aircraft parking fees were determined by multiplying the volumes gotten from airport activities defined in the ABS by fees which had a default value, but could be changed by the user to better reflect the situation in a particular airport. Handling fees could either be outsourced or performed by the airport. Non-aviation revenues like retail and car parking revenues were determined using passenger volumes and, like handling fees, could either be outsourced or performed by the airport. For outsourcing, the airport received only a certain percentage of the revenues, but did not have any costs. Costs included employee costs, depreciation, maintenance costs, utility service costs, retail costs, administration costs, interest costs, and other operational costs. It should be noted that for some of these values, in particular the investments, approximations were used, which should be improved. This can be done by allowing more possibility for user input to be customizable to a particular airport or scenario. Examining the latest articles on airport finance, and the annual reports of airports, will most likely yield better approximations. Another avenue that will be explored will be collecting and analysing the financial performance of various airports, in order to find more accurate trends which can be used for these approximations. Thus, the annual accounts and airport charges of various airports were found, in order to carry out this analysis.

Graham (2009, p. 108) investigates the importance of commercial revenues in today's airports, and includes a breakdown of the components of commercial revenues of airports, which will prove useful when making estimations about the proportions of revenues generated by an airport. In addition to the area of non-aeronautical revenues, Tovar and Martin-Cejas (2009, p. 220) explore outsourcing, and the effects it has on the efficiency of Spanish airports, and conclude that outsourcing activities, and having well-developed commercial activities contribute to a higher efficiency level. According to Fuerst, Gross, and Klose (2011), commercial revenues per passenger are mainly determined by the number of passengers passing through the airport, the ratio of commercial to total revenues, national income, the share of domestic and leisure travellers, and the number of flights. Volkova (2009, pp. 16-17) analyses the importance of various factors affecting the retail revenue of selected airports between 2001 and 2003, and concludes that the number of short stay parking spaces, check-in facilities, and the number of employees contribute to retail revenue, more so than the types of passengers. Also, it was found that once a certain level of retail area is reached, retail revenue per square meter starts to grow, due to the benefits of specialisation. The location of bars and restaurants, financial and car rental services, and the habits and mentality of different nationalities, were seen to have an important impact on retail revenues. Although it may be hard to quantify these aspects, the user will be made aware of these factors, so that they can change the retail growth rates accordingly.

In order to get an understanding for the elements that have to be included in an airport's financial statements, as well as other aspects of corporate finance, textbooks by Young & Wells (2011) and Berk (2011) were used. The International Financial Reporting Standards (IFRS) are adhered to where relevant (Deloitte Global Services Limited, 2014a).

2.7 Airport performance measures

Perhaps the best source of information about airport performance measures is the area of airport benchmarking. Airport benchmarking aims to provide objective data of capacity utilization or financial performance of an airport, to allow a comparison between airports, and identify best practice standards (Kamp, Niemeier, & Muller, 2005). According to the Civil Aviation Authority (CAA) (2000), the methods commonly used to benchmark airports can be categorised as:

- *Quantitative methods* derived from econometrics and mathematical programming, e.g. Total Factor Productivity (TFP) and Stochastic Frontier Analysis (SFA).
- *(Statistical) performance measures* and comparisons, e.g. comparison of passengers per employee, comparisons of revenue per aircraft movement.
- *Qualitative measures* and comparisons, e.g. questionnaires and surveys.
- *Expert assessments* utilising a case study.

The category of airport benchmarking methods most relevant to this project are the statistical performance measures and comparisons. Rather than compare the performance of an airport to other airports via 'external benchmarking', these measures will be used to compare the performance of an airport over time and across various 'plans' via 'internal benchmarking (Wyman, 2012, p. 2). However, performance measures have a few drawbacks: (i) while they can act as indicators of performance in specific areas, they may not adequately reflect the complex processes that characterize airport performance, and so must be handled with caution since good performance on one partial measure (e.g. a low number of security costs per passenger) may reflect under performance in another (e.g. the time taken for security processing of passengers); (ii) these ratios are unable to take account of different operational conditions faced, for example, differences in the level of outsourcing; (iii) each indicator can only examine one input and one output at a time, so using only two variables means that each indicator will be highly sensitive to data errors (Dodgson, et al., 2001).

Airports Council International (ACI) (Wyman, 2012) put forward a guide designed to help airports around the world in their performance management efforts by: defining a useful set of performance measures across a number of Key Performance Areas (KPAs); discussing the factors that drive particular results; identifying the types of airports where each measure is applicable; and discussing the strengths and weaknesses of each measure as a benchmarking tool. These six KPAs are defined as: core; safety and security; service quality; productivity/efficiency; financial/commercial; and environmental. For the purposes of the ABS, the safety and security, and environmental KPAs will not be explored, since the ABS cannot produce the required data for these performance measures. Granberg and Munoz (2013) developed a set of eleven airport key performance indicators (KPIs) that were manageable, easy to interpret, and useful for analysing the entire airport, through carrying out a questionnaire-based survey on airport managers in Sweden and Spain. These key performance measures will be presented to the user for a quick overview of the results.

2.8 Business plans

It is generally accepted that creating a startup is a very risky endeavour, with only 37% of startups in the IT industry still operating after four years (Statistic Brain, 2014). For this reason, numerous methodologies regarding business development have been proposed in order to increase the chances of success of startups. These include Traction Entrepreneurial Operating System (EOS) (Wickman, 2011), Business Model Zen (Business Model Zen, 2014), and Effectuation (Society for Effectual Action, 2014), among others. Currently, the most well-known methodology is The Lean Startup (Ries, The Lean Startup: How Today's Entrepreneurs Use Continuous Innovation to Create Radically Successful Businesses, 2011). Although it was only proposed in 2011, many of the techniques it proposes have been used in some form or the other by successful startups in the past few decades. The lean startup is a new way of looking at the development of innovative new products that emphasizes fast iteration and customer insight, a huge vision, and great ambition, all at the same time. Before creating a business plan, a lean canvas (a lean startup adaptation of the Business Model Canvas), can be used to develop a visual chart of the business model. The lean startup introduces various concepts which will be introduced and explained in more detail in the business plan (Appendix G). These include: validated learning (or Build-Measure-Learn); Minimum Viable Product (MVP); Continuous deployment; split testing; actionable metrics; pivot; and innovation accounting. The generic business plan in the Business Plans Handbook (Gale, 2012) was used as a template for the business plan in Appendix G.

3. Architecture of the model

A Financial Model encompasses the formality of economics and the empiricism of accounting, through the imposition of structure, incorporation of knowledge, and inclusion of technology. However, its drawbacks (garbage in, garbage out, and being time- and cost-intensive) should be acknowledged and mitigated as much as possible (Field, n.d.).

The architecture of the Financial Model will be presented in this chapter. Section 3.1, will present the key design principles for the Financial Model. Section 3.2 will provide a summary of the development process, while Section 3.1 will present an overview of the software architecture of the model, covering both the logical and functional views.

3.1 Key design principles

The relevance of this project is that it will provide a Financial Model to the ABS program that is accessible, easy-to-understand, time-saving, and cost-saving. The ABS is envisioned to be used as a strategic decision support tool by airport decision makers in order to get the overall picture of the performance of an airport, especially when cost and time are a factor. It is also envisioned to be used by university students to enable them to get a better understanding of airport operations and airport strategic planning. This Financial Model is designed to complement the current ABS program, and is intended to address the most pressing weakness of the ABS: its inability to carry out a financial analysis of the cases generated by the ABS. The following design principles will guide the design and development of the Financial Model:

Coordinate and integrate the decision-making tools

In order to improve ease-of-use for the user, and reduce the time needed to become proficient with the ABS and the Financial Model, it is essential that the Financial Model be fully integrated into the ABS, and share the same GUI and platform. Interfaces between the Financial Model, and the existing ABS models should be created to be convenient and adaptable to changes in other models. In order to aid consistency and integration, the same database used to store data for the ABS will be utilised by the Financial Model. This database contains all relevant information for reports, inquiries, and input to models.

Place the user in control

The ABS focuses on the decision-making processes, rather than computer models, and is designed to be responsive to the user’s needs. It combines the analytic power and capabilities of the computer with the judgments, needs, and problem-solving processes of the user, but does not replace their judgment. In order to place the user in control, the user will be provided more insight into how the structure of the Financial Model determines its behaviour, through information presented in the user manual. The GUI will be designed to be intuitive, and easy to learn. The user should comfortably be able to request information from the database; change data in the database; specify parameters and input data for a module; run a model or sequence of models; and tailor output reports in terms of scope, level of aggregation, time period covered, and format, making the evaluation and comparison process easier.

The Financial Model will contain two levels of aggregation, allowing the user to conduct both quick initial scans and more detailed analyses, as required. The detailed analyses will contain large numbers of policy variables in order to more accurately represent the situation found at the airport. The amount of manual input required by the user will be reduced, in order to reduce the amount of time spent using the model. Default values will be supplied by the system for the quick initial scan level of analysis, when the user does not wish to adjust parameter values, or specify new data input.

Make the system flexible, adaptable, and easy to maintain

The ABS has been designed to be easy to modify based on changing needs, knowledge, and situations. It is able to deal with unanticipated problems, test new strategies, and adapt to changing circumstances. The Financial Model will be easy to change and revise, permit the use of new variables, and be amenable to revision in response to changes in the data on which they are based. The data stored in the database will also allow continual updating. This will be done by ensuring that the code is well documented. Flexibility and adaptability is achieved by using several small, simple modules, rather than a few large, complex ones. Thus, the Financial Model will be divided into various modules, which each deal with a certain aspect of the model. For example, there will be separate modules for the calculation of revenues, costs, and balance sheet items.

The data required by the modules should be easy to obtain, not require extensive preparation or previous analysis, and should be routinely collected by most airports. Additionally, the toolbox approach means that it is possible to make all these changes without incurring large amounts of time, skill, and confusion in reprogramming.

3.2 Development process

In this section, the development process for the Financial Model to be implemented in the ABS program will be presented. This process was carried out, whilst keeping the key design principles (Section 3.1) in mind. In order to build the Financial Model, use was made of the literature identified in Chapter 2, which represent current and state-of-the-art practices developed for airport planning. The literature on the ABS (Section 1.4) also served as good starting point, as it enabled a good understanding of the ABS system, its current strengths and weaknesses, as well as what had been previously attempted with the Financial Model of the ABS. The major steps taken in this project are outlined as follows (the project schedule can be found in Appendix A):

1. *Determine which issues need to addressed with the ABS:* This was done by conducting research about the ABS, becoming familiar with the ABS program, and getting input from professors familiar with the project.
2. *Carry out research in the chosen area:* In this case, the chosen area was the Financial Modelling of airports. However, research was also conducted in related areas, such as airport systems in general, new approaches to airport planning, computer-based initiatives for use in airport planning, and approaches to deal with uncertainty in forecasting.
3. *Design the various modules:* Due to the toolbox approach being employed, the Financial Model was broken up into smaller, manageable components. The layout and algorithms to be used were determined with the help of the information gleaned from the literature review. An exploration was carried out into the various methods available for performing the tasks required by the model, for example, accessing and inserting data into the common database. The GUI was designed in a way that would be logical and intuitive for the user. Various modules were created, according to data input, processing, and output. Data input refers to the GUI through which the user would be able to enter and manipulate information, as well as update the database. Processing refers to the calculations carried out to obtain the various elements required for airport Financial

Modelling. These were divided along the lines of revenues, costs, assets, and liabilities. Data output refers to the reports and graphs generated to allow for a financial analysis or comparison of the various cases.

4. *Implement these modules in stages:* Using staged implementation, some modules were developed in parallel with others, while some were developed sequentially, in order of their priority. Testing of a module began whenever it reached a point that the programmer felt comfortable trying and debugging it. There was a lot of iteration and feedback among the steps. For example, testing of the data input module for revenues revealed shortcomings in the approach used, and required a reiteration of the design of the module. This approach ensured that problems in the modules could be identified and corrected early in the process.
5. *Test using real-world airport data:* When the entire model was completed, it was tested using real-world airport data to verify that the model produced satisfactory results. Airport annual reports could be used in the testing of the 'quick' analysis, as these usually contained sufficient information. However, for the testing of the 'detailed' analysis, data would need to be gotten from an airport.
6. *Feedback from airport decision advisors, professors and students:* Verification and validation of the project will be performed through the use of real-world airport data to see whether the output of the ABS is consistent with these data. A possibility would be to contact an airport to obtain more detailed information which is not readily available online in an airport's annual report. Potential users such as students, professors, and users in the airport business sector will be invited to use the ABS, and offer their reactions and opinions regarding its ease-of-use and intuitiveness; the validity of the results produced; the added value of the Financial Model to the ABS; and any important elements which are missing, or which might enhance the usefulness of the ABS.
7. *Make modifications:* make modifications to the model based on feedback from the ABS' potential users.
8. *Develop a framework:* This will be done to support the user in using the ABS and the Financial Model. A framework will be provided in the user manual, in order to enable the user to use the ABS in the right way, for example, by reminding the user to give attention and thought to the decision making process; instructing them to use the scenario approach and ensure that the plan chosen is robust across a range of scenarios, to name a few.
9. *Document the development process and code:* The development process and code will be well documented in order to allow for another programmer to easily understand the code, and its various functions. This will allow for easy maintenance or updating of the model.

The iterative and incremental nature of the development process is shown in Figure 3-1 on the following page.

3.1 Software architecture

A software system's architecture is the set of principal design decisions about the system. These design decisions encompass every aspect of the system under development such as: the system structure; behavioural or functional requirements; interaction among system elements; non-functional requirements; the system's development itself; and the system's business position (Medvidovic, Dashofy, & Taylor, 2007). Early software engineering research and software mainly focused on the technological aspects of architecture, which can explain why the development of computer-based systems to support airport strategic planning has not been very successful (Wijnen R. , 2013).

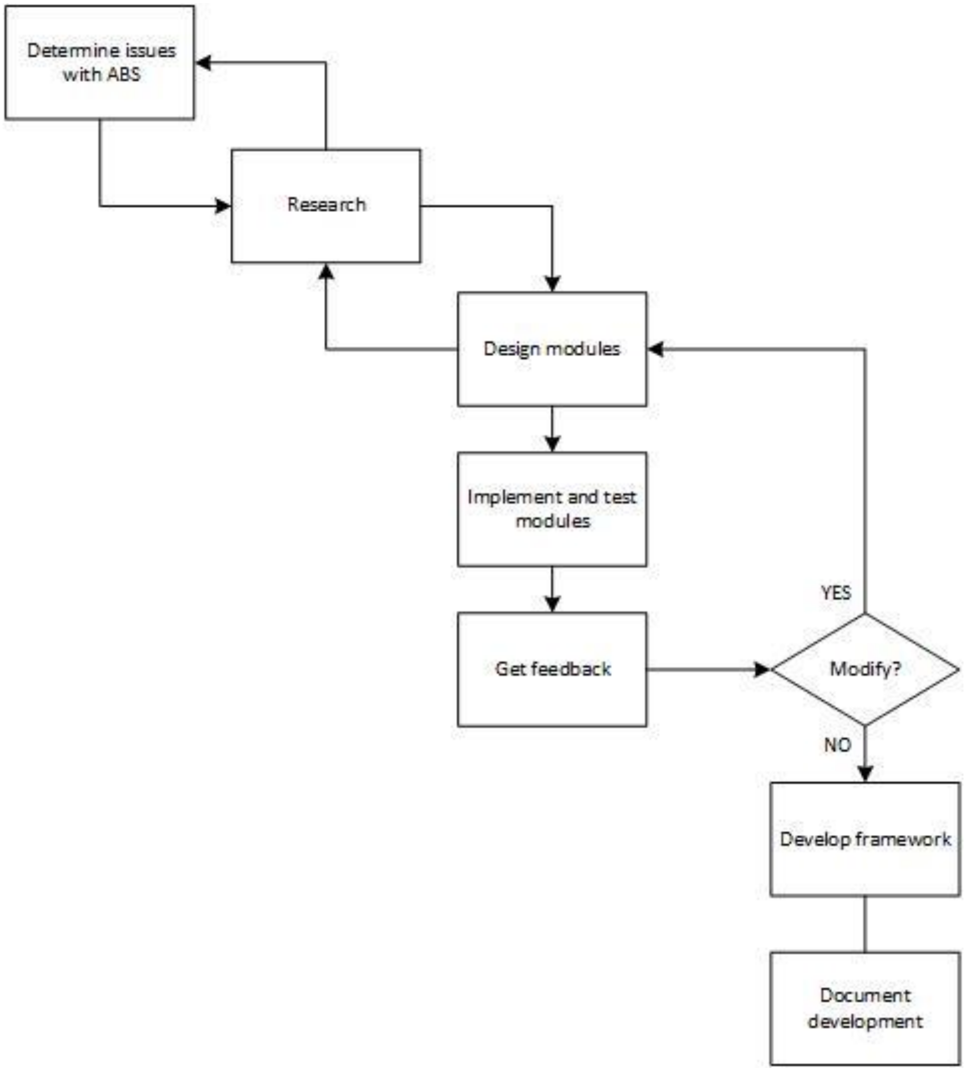


Figure 3-1: Development process for the Financial Model

It should be noted that the original ABS program was written using Visual Basic (VB) 6.0, an object-oriented programming language, which is suited to the toolbox approach. However, VB 6.0 is currently a stagnant language, since Microsoft has chosen to stop providing support for it. They have instead replaced it with the newer Visual Basic.NET (VB.NET) language (Microsoft, 2014a). Although there is a possibility to upgrade the code to the new language, a project as big as the ABS means that there will inevitably be some complexities, especially in the case of the user interface. This upgrade is a huge task in and of itself, which is why it has not yet been attempted. Since it is mostly a programming endeavour, rather than a research one, it was deemed irrelevant for a Master's Thesis project. Thus, there are two alternative courses of action to take with regards to writing the code for the new Financial Model:

- *Write the new modules for the Financial Model in VB 6.0:* However, at some point in time, an upgrade of the entire ABS system would have to be made, in order to exploit the functionality and features of the newer VB.NET language, and to make it easier to carry out upgrades to the ABS in the future.
- *Write the new model using the VB.NET language:* VB.NET is a multi-paradigm, high-level programming language, implemented on the .NET Framework, and was launched as the successor to its original VB language. The biggest changes are the semantics, which is now a fully object oriented language, and a far larger class library. This would introduce some integration issues, as the user will have to run two separate programs. It will be possible to call the data from the existing ABS models using Dynamic Link Library (DLL) files which are executable files that allow programs to share code and other resources

necessary to perform particular tasks (Microsoft, 2014b). The same MS Access Database can be used by both programs, in order to ensure consistency of data. The main advantage of this method is that the Financial Model will be able to take advantage of the new features of the VB.NET language. It is also assumed that the ABS program will be upgraded to the newer VB.NET language. If this is the case, then only the original models will need to be upgraded. After a careful consideration of the pros and cons of both approaches, the approach of writing the Financial Model using VB.NET was chosen.

VB.NET utilises Object-Oriented Programming (OOP), a method of software design and construction which improves code reusability and maintainability. Individual software components (classes) are designed, each with its own set of associated behaviours (methods) and data limitations (properties), allowing the programmer to piece these components together to create a complete application. It allows data to be grouped into discrete variables contained within a class in an application, and a specific interface has to be used before a class can interfere with the data in another class (Microsoft, 2014e).

After an analysis of the various types of simulation approaches possible, a discrete-event simulation was chosen to be implemented, whereby the system is described using logical relationships (presented in Chapter 4) that describe the change in variables over time. Simulation moves from one scheduled event to the next, where simulation events are executed based on a pre-set schedule of activities, and entities are routinely assigned to resources (Ashford, Mumayiz, & Wright, Airport Engineering - Planning, Design, and Development of 21st Century Airports, 2011, p. 607). It is commonly used to monitor and predict the behaviour of investments, and to predict how a system performs under extraordinary conditions. An effective discrete-event simulation process includes predetermined starting and ending points which can be: instances in time; a method of keeping track of the time that has elapsed since the process began; a list of discrete events that has occurred since the process began; a list of pending or expected discrete events until the process is expected to end; or a record of the function for which the simulation is currently engaged.

In order to describe the software architecture of the Financial Model, the logical view and the functional view will be presented. The logical view describes the structure of the systems, while the functional view provides the central view that drives the design, implementation, and testing of the architecture.

3.1.1 Logical view

The ABS was designed as an organisational DSS. According to Zachary (1998), a DSS has the following characteristics:

- It projects into the future despite uncertainty.
- It makes trade-offs among competing goals.
- It manages large amounts of information simultaneously.
- It analyses complex situations within constraints on time and resources.
- It visualises and manipulates those visualisations.
- It makes heuristic judgments, even if they are only qualitative.

The ABS in its current state does not possess all of these characteristics. It should be noted that although this is very hard to achieve in practice, these characteristics should drive the design process for the Financial Model as much as possible. The general architecture of the ABS system is presented in Figure 3-2. It has one or more users linked to the system. The dialogue management subsystem allows the user to interact with both the database, through a Database Management System (DBMS), and an interlinked system of models, through a Model Base Management System (MBMS). A case management subsystem keeps track of the models and data that are used (Walker, et al., 2003). The ABS employs a layered design, whereby the three layers are the GUI, computational models, and the common data model. Thus, the Financial Model will be designed using these same principles, in order to allow for better integration.

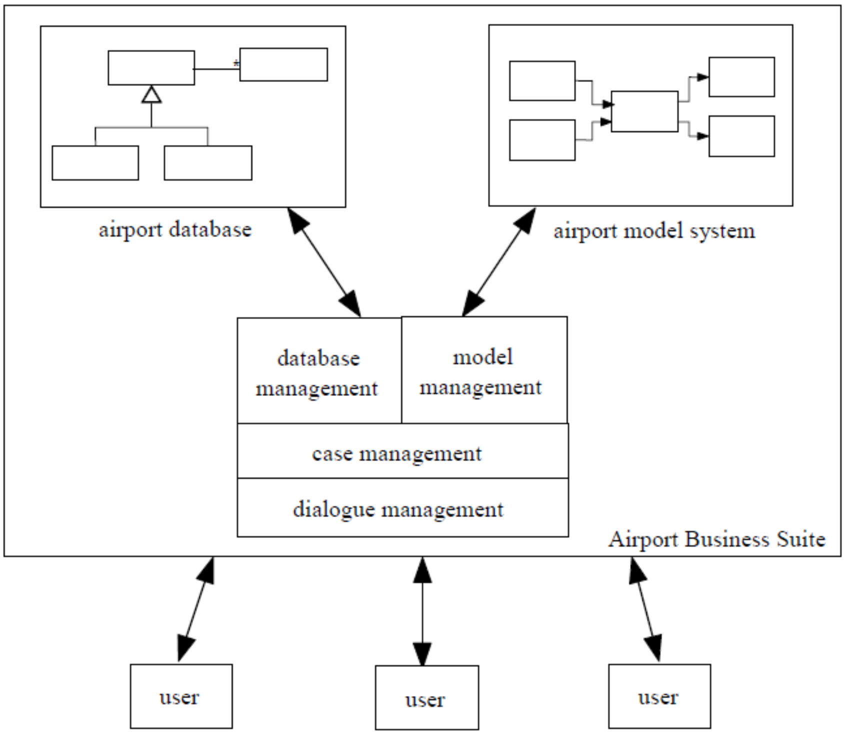


Figure 3-2: The ABS architecture

Source: Walker, et al. (2003)

The GUI implementation for the Financial Model will be developed using the .NET Framework, with the Integrated Development Environment (IDE) used being Visual Studio (VS) 2010. Most of the GUI code is generated by the IDE, which provides a 'what you see is what you get' editor for laying out the different GUI controls and elements. Through the GUI, the user is able to manipulate database entries about the airport's revenues, costs, and balance sheet items. The user is also able to create and run cases and plans, choose the level of aggregation (quick or detailed) and the time-analysis required, and choose the types of output to enable ease of comparison.

An overview of the model structure of the ABS, along with the Financial Model, is shown in Figure 3-3 on the next page. The ABS computational model system was designed using a toolbox approach, whereby many small models, each with a specific purpose, are interlinked. This was done to mitigate the problems inherent in building a large model, to make it easier for users to understand the models, and to adapt it to a wide variety of circumstances, availability of data, and types of analysis. It also allows the information needed for strategic decision-making to be synthesized in an efficient, effective, and consistent manner. The models were defined according to the classification of input types (i.e. revenues, costs, plan details, etc.) required by the user, as well as for ease of calculation purposes. According to ICAO (2013, p. 3.5), a budget is composed of two elements: 1) a budget that forecasts revenues and expenses (including depreciation and interest); and 2) a capital budget that forecasts capital expenditure used to upgrade existing assets, or acquiring new ones.

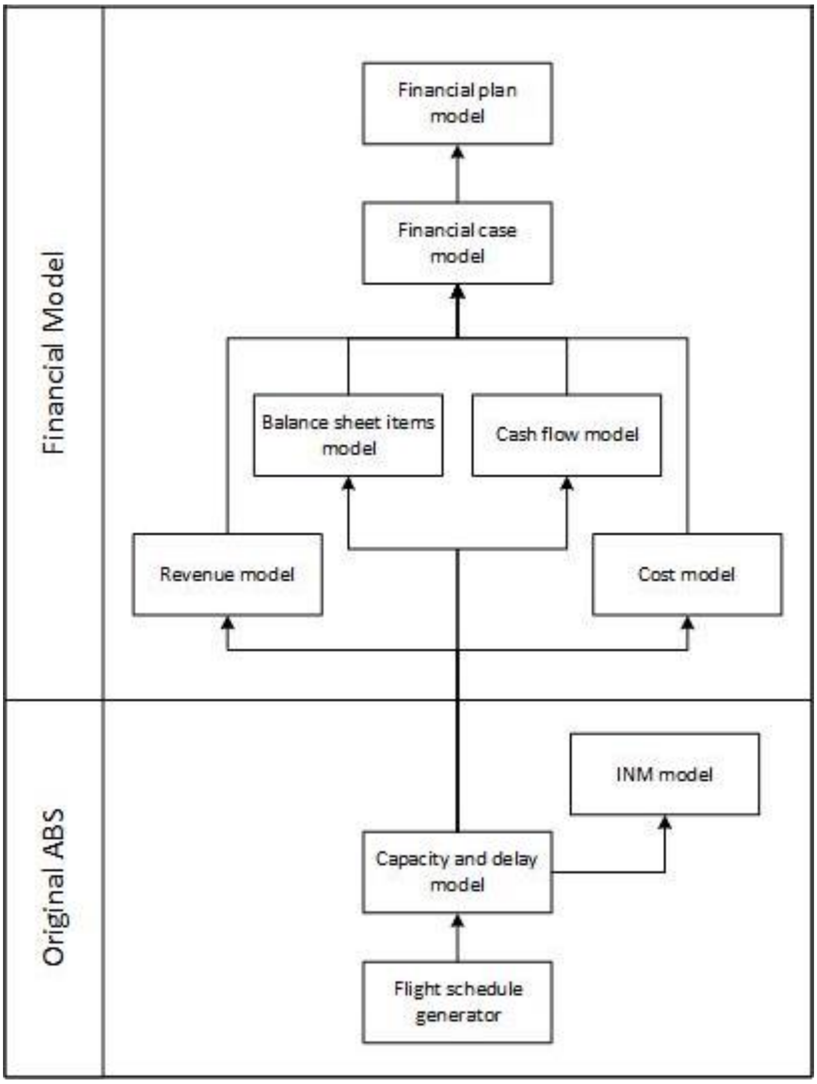


Figure 3-3: ABS models

3.1.2 Functional view of the architecture

In order to define the functional uses of the ABS, it is crucial to identify its primary actors, i.e. actors that have their goals fulfilled through using the services of the system. By identifying the primary user, the user goals can be identified, which will serve as a basis for the functional requirements of the Financial Model. The ABS is envisioned to be mainly used by decision advisors, who define strategies, develop scenarios, and evaluate strategies. They then provide this information to the decision-makers in a condensed and easily understandable format. A decision-maker defines the decision-making context and compares strategies, in order to choose the best one, and could be a primary actor, depending on the organisational structure of the airport (Wijnen R. , 2013, pp. 148-150). The ABS can initially be tested by students in the course 'Strategic Planning for Airport Systems', whereby the students take the role of an airport decision advisor (exploring various strategies, and providing a recommendation on the best course of action), and the professors take the role of the decision advisor (defining the decision-making context by providing the guidelines of the assignment, and reviewing the results) Thus, the two main primary actors remain the decision-makers and decision advisors.

Figure 3-4 on the next page shows the functional view of the Financial Model itself, and the functions to be carried out by both primary actors. The decision advisor's use of the ABS will likely be the most comprehensive, as they will have access to detailed airport data, and create a large number of scenarios and plans. The airport decision-maker will likely use the ABS in a more holistic manner, and will likely use the ABS to review the most promising plans identified by the decision advisor. Students, on the other hand, may explore a number of scenarios and plans in a similar way to decision advisors, but will most likely only have access to airport data which is made available to the public in the form of annual reports, and information displayed on the airports' websites.

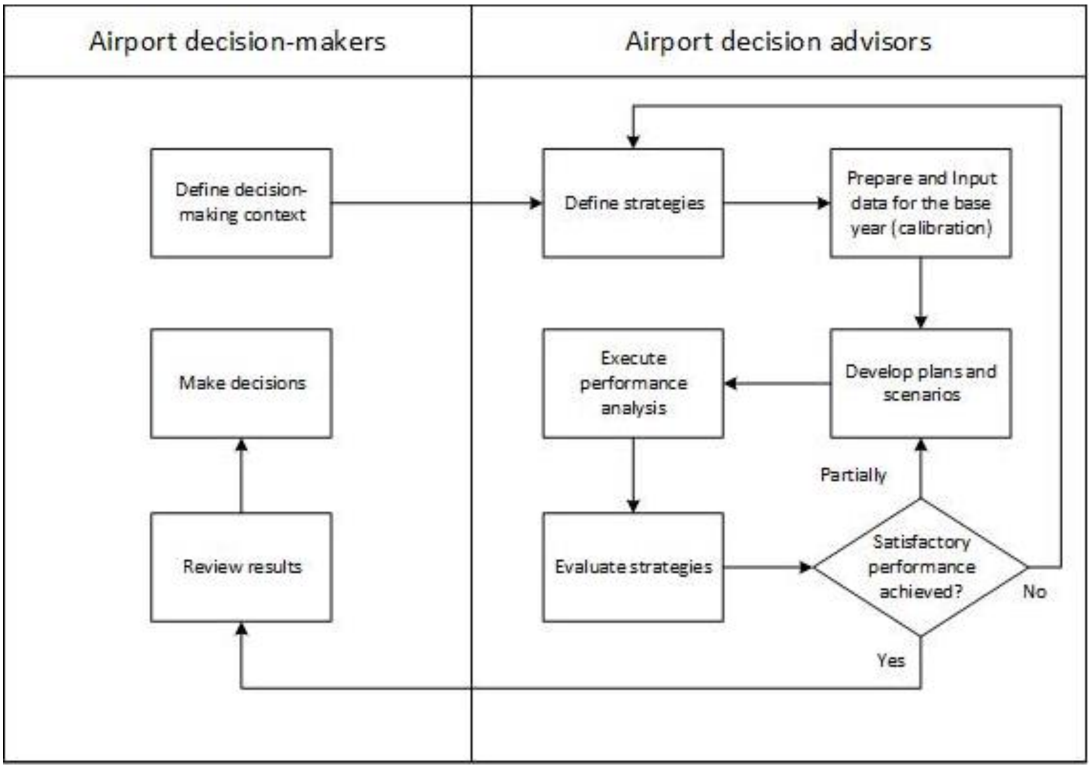


Figure 3-4: Functional view of the ABS system

The decision-making context is defined by identifying the problem or opportunity, choosing the planning period, and selecting critical performance indicators. Strategies to mitigate the problem, or exploit the opportunity will then be defined. A reference case which represents the current situation at the airport is then defined, in order to serve as a calibration to ensure that reasonable results are produced. If this is not the case, the equations used to define the relationships between various variables in the models need to be examined, and changed to reflect the situation at the airport. After the reference case shows satisfactory results, plans are then developed, to enable the user to explore the various strategies defined. These cases are then entered into the Financial Model using the various editors, and a financial analysis is carried out. The strategies are then evaluated, and if satisfactory performance is achieved, the decision-maker is presented with the relevant information required to make a decision. If unsatisfactory results are achieved, the strategies to be explored are either refined, or new plans and scenarios are generated to explore other future possibilities.

Strategies that may be explored include the addition of a new runway to satisfy increasing aviation demand. More flights will be served by the airport, leading to increased revenues. However, these revenues, and the various forms of airport financing employed, will need to be balanced against the expansion project's investment costs, and the increased operational costs, to ensure that the airport sponsor can afford to proceed with the planned investment. Other strategies involve investigating which combination of financing sources yields the most desirable outcome, whether it is low interest rates, or a longer payback period. The Financial Model will assist in designing budgets, to determine the financial feasibility of expansion plans, and it will be possible to explore various planning options, e.g. delaying or speeding up construction. Another aspect whereby these models will prove useful is in determining the break-even need of the airport to aid in setting airport fees and charges. Finally, the intangible costs and benefits to the airport's stakeholders will be able to be explored in a quantitative way, either through a Cost-Benefit Analysis or the Value Operations Methodology, and a framework will be available to the user to make consistent decisions by guiding them to consider all the important aspects.

It should be noted that the main trade-off when using the ABS will be between ease-of-use and accuracy. The user will be able to determine the level of accuracy of the forecast/analysis by deciding how much time to spend on data input. Most variables will be assigned default values, which can be changed by the user to better reflect the situation found at the airport. For example, when determining the revenues gotten from landing charges, the user can either choose to use the default values provided, change these default values to the average revenue gotten from each aircraft for a quick analysis, or carry out a more detailed analysis.

Since this program is intended for strategic planning, and not for detailed operational planning, it is not expected to have a high degree of accuracy. Thus, complex algorithms are not necessary, as it defeats the purpose of the ABS. This is because it is widely accepted that forecasting is more of an art than a science, due to the large degree of uncertainty which can make a certain scenario and its accompanying plan obsolete. However, the ABS should still be able to give a good indication of the levels of revenues and costs to expect from a certain scenario, in order to determine the operational and financial feasibility of a plan. The biggest challenge will be in defining relationships for the data that are general enough to apply to various types and sizes of airports, while still retaining a satisfactory degree of accuracy. The literature suggests that instead of creating a highly detailed forecast which will very likely turn out to be wrong, it is better to focus on the decision making process surrounding these plans. This includes considering many types of uncertainties and futures, and making a final plan which is robust across all futures, while still remaining flexible through the use of contingency planning. Thus, the added value of the ABS is that it allows decision makers to quickly explore various scenarios, without the need for excessive data input, in order to determine which plan to adopt. It will also be useful in the implementation phase of an investment project, in order to update the plan to keep abreast of unexpected changes which have occurred since the inception of the plan, and to use as a financial control. Any deviations in actual airport financial performance will need to be explained, and the planning can then be adjusted accordingly.

3.1.3 Use cases for the ABS

A use case refers to the decision-making context that the ABS may be used for, i.e. the real-world problems that the ABS and the Financial Model will help the decision-adviser and decision-maker to solve. The envisioned use-cases for the ABS include:

- *Creation of the development plan for a new airport*
  To provide the strongest potential revenue streams.
- *Determination of the value of the airport as an on-going concern*
  By calculating the discounted future cash flows.
- *Determination of airport charges*
  The ABS will be used to determine what levels of charges will be required to break-even, with regards to operational costs and capital projects. This is especially important for airports that follow a residual cost approach, whereby airlines agree to cover all costs incurred by the airport through the airport fees and charges (Young & Wells, 2011, p. 551).
- *Evaluation of a capital (investment) project*
  This includes determining whether it is possible to carry out a financial project, and which types and structure (equity-debt mix) of financing produces the desired results. It also determines the levels of enplanements, operations and/or revenue required to finance a specific capital project.
- *Determination of the break-even requirements*
  For either a capital project or for regular operations. The user will be able to determine the cash flow requirements needed to make the project feasible, and look for additional sources of funding if needed.

- *Balance sheet structure*
  - Sale and lease-back: change assets into liabilities, to reduce equity.
  - Cost expenditure vs. investment expenditure: list certain items as liabilities instead of assets.
- *Financial control*
  Refers to the system of monitoring financial performance to ensure that expenses comport with plan, and income flows correspond to budget. It consists of: i) comparing actual income and expenses with the plan; ii) determining whether income or expense variations from plan are a problem of the budget, management of the airport, or external factors; and iii) determining what corrective action should be, and can be, taken (Dempsey, 2008).

4. Implementation of the model

Before any work could be commenced, the general sequence of processes to be carried out by users of the ABS Financial Model was defined, as shown in Figure 4-1. It is assumed that when a user runs the ABS Financial Model, the original ABS program has already been used to create a yearly case based on a combination of peak day cases, which are in turn comprised of a certain combination of flight schedule, runway scheme, weather, terminal data, and FAA Dataset policy options.

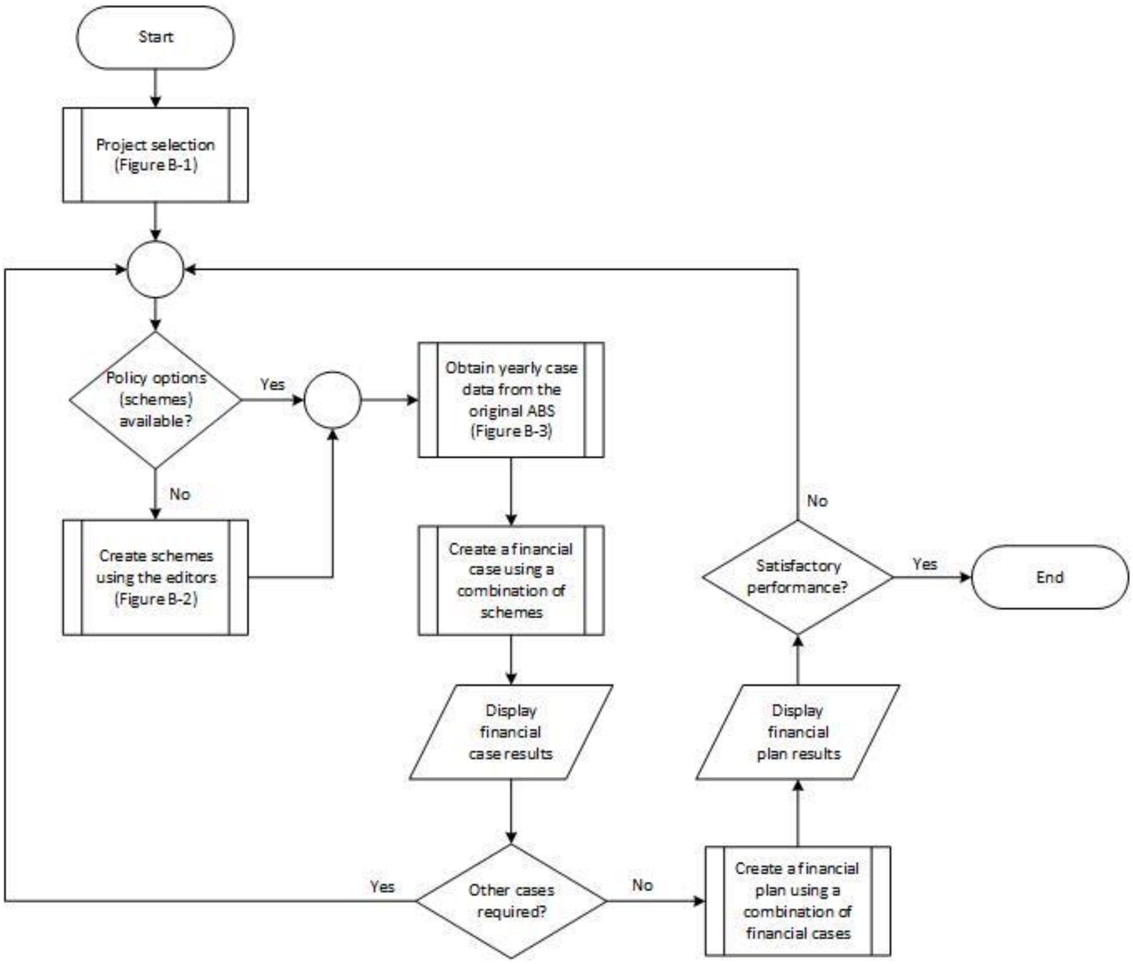


Figure 4-1: ABS Financial Model

The Financial Model was divided into various classes (modules) which would each handle a separate part of data input, data processing, or data output. This was done to compartmentalise the program, and make it easier to carry out changes in the future (Microsoft, 2014e). Chapter 4 will present the implementation of these various classes, and the various design decisions made, as well the rationale behind them.

The first task to be carried out by the user is to choose the folder in which the project to be financially evaluated is saved (Section 4.2), since each project is saved in its own separate folder. This will give the Financial Model access to the database for that particular project, which will include information on the performance of the airport produced by the original ABS. All the relevant project data defined in the original ABS will be displayed. If is the first time that a financial analysis is being carried out, database tables needed to store the information required for the financial analysis will be created in the common database.

The user will need to create a financial case by using a combination of 'options'. This will include the analysis level, revenues, costs, balance sheet, and yearly case. The revenues, costs, and balance sheet items will be created or edited using their respective editors (Section 4.3), where user input parameters will be displayed according to the analysis level selected by the user. Once a financial case has been created, calculations will be carried out for the revenues, costs, and balance sheet items (Sections 4.5 to 4.7). In order to create a financial plan (Section 4.9), the user will be able to define the planning horizon, and the financial cases (Section 4.8) which pertain to each year in the planning horizon. Output will be in the form of reports in the form of an income statement (Section 4.10), a balance sheet (Section 4.11), a statement of cash flows (Section 4.12) performance indicators (Section 4.13), and graphs (Section 4.14). Since the ABS is envisioned to support an iterative decision process, if analysis is required of more cases, the process will repeat itself, until a sufficient number of cases and plans have been explored, and a plan is proven to be robust across all of the possible scenarios.

4.1 Overall implementation

The various decisions made during the implementation phase that apply to the overall ABS Financial Model are described in this section.

4.1.1 Layout of the GUI

The layout of the original ABS program was adhered to as much as possible, to give the user a sense of familiarity between the two programs. Thus, the layout of the menus, buttons, and forms were adhered to as much as possible, and where relevant. Likewise, the approach of using various combinations of 'schemes' to create a case was adhered to, and these schemes were divided into the categories of operational revenues, operational costs, and balance sheet items, with each category having its own editor. More information on the editors are given in Section 4.3. More information on the layout of the GUI, in the form of screenshots, can be found in 0.

4.1.2 Data input

A lot of thought was given to data input and validation, in order to make it easy and intuitive for the user to enter information, while ensuring that the correct type of data was being entered.

The *numeric-up-down control* was chosen for numerical input. It was chosen because it would only allow numbers, and only within a certain range, which provides an inherent level of data validation to a certain extent. This range was usually a non-negative restriction, and a reasonable maximum constraint. It also allows the user two ways to input information, either through the scroll buttons, or by manually entering the numbers, and allows the easy formatting of values it displays: values are right-aligned for improved readability; the thousands separator was used for large numbers; and the number of decimal places allowed were specified. The *decimal* data-type was initially chosen since it provides a higher degree of precision than the single or double data types, which is very important for financial calculations. However, this comes at a performance cost, as the decimal data type contains 16 bytes and has a range of 1.0e-28 to 7.9e28, while the *single* data-type is only 4 bytes, and has a range of 1.5E-45 to 3.4E38 (Microsoft, 2014c).

The *text-box control* was chosen for regular text input. The *combo-box control* was used for situations where a choice had to be made for a data input, scheme, or yearly case. If the user did not need to create a new entry, scheme, or case, the edit function was disabled, so that the combo-box only functioned as a drop-down list. The text-length for both of these control types were limited, as a form of data validation. The *string* data-type was chosen, as it allows for all kinds of symbols to be used in the text, and will provide the user with the utmost flexibility when creating names for schemes and cases.

Further data validation is carried out by performing a check before a save operation, to ensure that none of the fields for data entry are left empty. In the case of numbers, the user will be advised to enter a zero for numbers, where applicable, rather than leave the field empty.

Option Strict checking was enabled in order to prevent narrowing conversions, late binding, and implicit typing that results in an Object type, by causing a compile-time error. Its other benefits are that (Microsoft, 2014d):

- It enables Intellisense support for variables and parameters, showing their properties and other members as code is typed.
- It enables the compiler to perform type checking to find statements which can fail at run-time due to type conversion errors, and identifies calls to methods on objects that do not support those methods.
- It speeds up the execution of code since the compiled code does not have to convert back and forth between Object and other data types.

The user is provided with a set of default values for the 'quick' analysis level, to reduce the amount of user input required, and to allow for less time required for input. These default values (as well as the allowable ranges) for each input variable were gotten from literature in the form of research papers and benchmark studies, and by examining airport data found on the airports' websites and annual reports. Units were chosen which would be universal in nature, as shown in Table 4-1.

Table 4-1: Units of measurement

Value	Unit
Length	Meter [m]
Area	Square meter [m^2]
Weight	Metric ton (tonne) [t]
Currency	Universal currency [¤]

4.1.3 Database interaction

According to Bai (2012), there are currently two main ways to connect to a MS Access database from a VB.NET application. The first involves using design tools and wizards provided by the Visual Studio.NET (VS.NET), while the second involves the use of runtime objects.

Design tools and wizards

These allow you to quickly and easily build simple database applications without experiencing complicated coding issues. It allows the user to develop binding relationships between the data source and controls on the VB windows form object to navigate, scan, retrieve, and manipulate data stored in the data source with a few lines of code. The shortcomings of this method are that: the auto-generated codes related to tools and wizards are embedded into the programs; and these connection codes are machine-dependent, and are not able to be applied to other instances of the database. Also, once the piece of connection information is compiled, it cannot be modified, meaning that the program cannot be distributed to, and run in other platforms (Bai, 2012, pp. 241, 312). This makes it a very rigid approach, and impractical for the purposes of this project, where a folder is created and specified by the user for each new project.

Runtime objects

Runtime objects can be described as objects or instances used for data connections and operations in a data-driven application, which are created and implemented during the period when the project runs. In order words, these objects are created and utilised dynamically. It provides programmers more flexibility in creating and implementing connection objects and data operation objects related to ADO.NET by allowing them to use different methods to access and manipulate data from the data source and the database. However, it brings with it some complexity, as the different data providers and commands have to be created to access the different databases. This means that it can be linked to different databases which can be specified during runtime by the user.

Thus, the runtime objects method was chosen for interacting with the MS Access database, as it was able to meet the functional requirements of the ABS. The ADO.NET architecture was chosen for implementation of the database interaction. The ADO.NET architecture can be divided into three components: Data Provider (includes the Data Connection, Data Command, DataReader, and TableAdapter), DataSet and a DataTable. The Ole-DB namespace, is compatible with MS Access databases.

When using runtime objects, there are two approaches that allow users to develop a professional data-driven application: the DataSet-DataAdapter method; and the DataReader method. According to Bai (2012, p. 314), the DataReader method allows you more flexibility by allowing the programmer to use each object individually. The DataReader method is more applicable to a read-only, forward-only stream of data from a database, thus increasing performance and reducing system overhead since there is only one row at a time in memory (Microsoft, 2014d). Thus, the DataReader approach was used for reading the input of the user, and saving the data processing and calculations of the various classes in the Financial Model. The DataSet-DataAdapter method is used to navigate between multiple discrete tables of results, and data can be gotten from various sources, such as the various database tables used to store the calculations. Thus, the DataSet-DataAdapter method will be used in data reporting (creation of the various financial reports), whereby the calculated data will need to be presented to the user.

For database queries, use was made of parameterised query in order to let the code interact with the database engine in a more secure and robust way.

4.1.4 Data processing

Data processing was divided into various classes (modules), depending on the main functions, while data calculations were performed using functions. This was implemented with the aim of improving readability, maintainability, and upgradeability of the model, to be carried out in the future by a different programmer.

4.1.5 Data output

Three methods of data output were identified, as ways with which to create reports:

- *Crystal Reports Viewer*: third-party business intelligence application that can be used to create and view powerful, richly formatted, dynamic reports in various formats in VB.NET. However, it has issues with portability since the crystal runtime will need to be packaged with the application (SAP, 2015).
- *Microsoft Reports*: a freely redistributable control that enables embedding reports in applications developed using the .NET Framework (Microsoft, 2015a). It is based on an open Report Definition Language (RDL) and can be used without requiring a Structured Query Language (SQL) Server License, or a connection to an SQL server, with the ability to export the reports to various common formats such as Microsoft Word, Microsoft Excel, and Portable Document Format (PDF). However, for creating more complex reports at run-time, depending on a user's selection, a developer's license is required.

The free version requires the use of a strongly typed dataset, which would not be practical.

- *Rich-text Document*: This was determined to be the simplest method, which could be implemented easily. It was chosen for now, with the intention that a more complex method of reporting, with increased functionality, could be added at a later date.

4.1.6 Model assumptions

In this subsection, the general assumptions used in the Financial Model are presented:

Time

For ease of accounting, all actions are made at the end of the fiscal period, which coincides with the calendar year. Thus, all receipts or payments will be made at the end of the reporting period.

4.1.7 Documentation practice and debugging

In order to allow for easy maintenance or upgrading of the code by a different developer, various conventions were followed. The naming convention put forward by McKweon (2010, pp. 679-680) in the naming of controls and variables was used. A three letter identifier is assigned to variables to denote their data type, while a prefix denotes their scope. A three letter identifier is also assigned to controls to identify their control type. Names will be chosen for modules, classes, forms, and variables which are intuitive and self-explanatory.

Commenting will be used to describe the functions of a certain module, procedure, function or class. According to McKweon (2010, p. 71), commenting does not affect the program by slowing it down or making it larger, and so there are no downsides to using extensive commenting. To make debugging easier, use was made of Try-Catch blocks, in order to allow code to continue running, and allow the easy identification of errors.

4.2 Project selection

The user is allowed to choose the folder location of the project to be loaded by the ABS Financial Model, and a check is carried out to ensure that this folder contains a valid ABS project. The program then carries out a check to determine whether the database tables (Figure B-1, Appendix B) required for the Financial Model have been created, and will create them if necessary. The project information is then displayed. If financial cases and plans have already been created in a previous run, these will be available to the user through the drop-down boxes. Figure B-1 (Appendix B) shows the flow chart for the project selection procedure.

4.3 Editors

The editors were given their own separate forms for user input. These were further divided into tab pages based on the sub-type: aeronautical and non-aeronautical revenues in the operational revenues editor; operating, depreciation, and capital costs in the operational costs editor; and assets, and liabilities in the balance sheet items editor. Table 4-2 shows the information that each editor contains, while Figure B-2 (0) shows a flowchart depicting the general logic and processes of the editors. Figure D-2, Figure D-3, and Figure D-4 (Appendix D) show the GUI of the revenue, cost, and balance sheet editors, respectively.

When the editors are opened, the user will first need to select a level of analysis detail, which will then display the corresponding set of inputs. The input method takes two forms:

- *Numeric up-down controls*: Information for the aeronautical revenues, non-aeronautical revenues, and operating costs, are displayed according to further sub-divisions. In some situations, the user has the option of entering the revenues and costs in unit terms (e.g. per pax), percentage terms (e.g. percentage of total operating revenues), or absolute terms. An example can be found in Figure D-2 (Appendix D).
- *Data-grid-view tables*: In the case of the input forms for depreciation costs, capital costs, assets, and liabilities, use was made of data-grid-view tables. This was done to allow the user to get an overview of all the items associated with the chosen scheme, and would give the user the opportunity to sort the data according to different criteria (e.g. asset name in alphabetical order, or asset types), in order to find something the item they are looking for quicker. This was combined with the use of numeric up-down controls for data input, which was found to be more user-friendly, as direct input into the data-grid-view table was susceptible to user entry error e.g. entering information on the wrong line. An example can be found in Figure D-4 (Appendix D).

The user is able to make changes to the items saved, through adding, updating or deleting items. At the bottom of the form, controls are provided to allow the user to save, re-save, or delete a scheme, as well as reset all values to zero or default values.

Table 4-2: User inputs for the editors

Revenue editor	Aeronautical revenues	Non-aeronautical revenues	
	Passenger service charges Passenger handling Passenger catering Aircraft landing and parking Aircraft handling Fuel Other aeronautical revenues	Passenger service charges Passenger handling Passenger catering Aircraft landing and parking Other non-aeronautical revenues	
Cost editor	**Operating costs**	**Depreciation costs**	**Capital costs**
	Personnel Services Rates Utilities Maintenance Administrative costs Passenger service charges Passenger handling Passenger catering Aircraft landing and parking	Airside infrastructure Landside infrastructure Ground transportation Equipment/machinery Intangible assets Others	Airside infrastructure Landside infrastructure Ground transportation Equipment/machinery Others
Balance sheet editor	**Assets**	**Liabilities**	**Equity**
	Cash Accounts receivable Bonds/Notes Stocks Land	Accounts payable Grants Loans Leases Bonds/Notes Leases/mortgages	Owners'/shareholders' equity Issue of stocks Accumulated retained earnings

4.3.1 Default values

Some default values were derived from information made available to the public (airport websites, financial statements, etc.) for various airports, and the average of these were gotten. It should be noted that not all the required information could be found, given the time constraints, and this is something that can be tackled in a future project. This could be done by preparing a benchmark study whereby airports share the required detailed information. A general average should not be found, as it will prove useless. Rather, averages should be gotten for various categories defined according to an airport's characteristics, such as number of passengers served, regional area of airport, etc. This is a long and exhaustive project in and of itself, and deemed to be outside the scope of this project.

4.4 Yearly case

The yearly case class (Figure B-3 in 0) is used to obtain the yearly numbers of passengers and aircraft movements from the original ABS. The approach to creating a yearly case in the original ABS program is to use a combination of peakday cases to define the yearly case, by assigning a percentage to each of the peakday cases that make up the yearly case. It is generally accepted that it is impractical to design an airport to deal with the highest flow volume, as this would be uneconomical and wasteful. Thus, most airports are designed such that for a certain amount of time each year, there is an acceptable amount of capacity overload. Various methods can be used to determine this acceptable level of delay.

4.4.1 Peak hour

One approach to determining the peaking characteristics of an airport is to define the design peak hour, i.e. the traffic flow upon which an airport is designed (Ashford, Coutu, & Beasley, 2012). The various methodologies in most common use worldwide are:

- *Standard busy rate:* defined as the thirteenth highest hour of passenger flow, or that rate of flow which is surpassed by only 29 hours of operation at higher flows. This approach is well rooted in civil engineering practice to design highways.
- *Busy-hour rate (or five percent busy hour):* The hourly rate above which five percent of the traffic at the airport is handled. Operational volumes are ranked in order of magnitude and the cumulative sum of volumes that amount to 5 percent of the annual volume. The next ranked volume is the busy-hour rate.
- *Typical peak-hour pax:* The FAA uses a measure defined as the peak hour of the average peak day of the peak month, which approximates very closely to the SBR. It then gives the TPHP as a percentage of annual flows.
- *Busiest timetable hour:* This method uses average load factors and existing or projected timetables, and is applicable to small airports.
- *Peak profile hour (or average daily peak, or peak-profile hour):* the peak month is selected, after which the average hourly volume for each hour is computed across the month using the actual length of the month, which gives an average hourly volume for an 'average peakday'. The PPH is the largest hourly value in the average peak day. Practice has shown this is close to the standard busy rate.
- *30th highest hour:* Currently used by most airport authorities in Germany and the UK. Studies in Paris have shown that this tends to occur on the fifteenth busiest day.
- *3 percent overload standard:* This approach is used in France by Aéroports de Paris.
- *Sixth busiest hour:* This is approximated by the average of the 20 highest hours, and is used by airports in the Netherlands.

4.4.2 Design day

The design day is used by airport planners to size facilities, and usually represents the level of activity that can be accommodated with an acceptable level of service (LOS). The intent is to strike a balance between under- and over-designing the size of the airport facilities. Since the output of the ABS is not in peak-hours, but in peak-days, the design peak day can be determined by according to the following methods proposed by the Transportation Research Board (TRB, 2013):

- *Peak Month Average Day (PMAD*): identifying the peak month (with the highest operations and passengers), and dividing the operations or passengers in that month by the number of days in that month. This approach is the most common practice in the USA.
- *15th busiest day of the year*
- *30th busiest day of the year*
- *90th percentile:* corresponds to the 36th busiest day of the year.
- *User defined threshold:* percentage of days in the year in which passengers or operations will exceed those of the design day.

The PMAD definition has found favour because it requires less data and effort to calculate. However, it can generate very different design day thresholds depending on an airport's unique situation. Thus, it seems that a more concrete approach would be to choose a user-defined threshold, depending on requirements set by stakeholders.

4.4.3 Converting to the yearly case

The ABS allows the user the flexibility to apply any of the methodologies in Subsection 4.4.2 to define the design day of a peakday case. However, these peakdays are not accurate representations of the average days, and so a method is required to perform this transformation. It should be noted that there are a lot of factors which affect the peaking experienced at an airport (e.g. domestic/international ratio, charter/scheduled flights ratio, and long-haul/short haul ratio), which makes it very hard to create a generic relationship for all airports. Regardless of the difference in peaks caused by these factors, in some aspects, there is great overall similarity between airports, which makes it possible to deduce relationships between peak and annual flows at airports. The information provided by Ashford et al. (Table E-1 in Appendix E) shows the relationship between the peak day and the average annual day, and this data will be used to determine the yearly case activity levels.

Although the numbers of arriving and departing passengers produced could be different (as is the case in the real world), the number of arriving and departing aircraft were set as equal over the entire year, although this was not the case in the peakday case. This is because it is simply not physically possible to have different aggregate numbers of arrivals and departures, as an aircraft that lands at the airport will have to depart from the same airport at some point in time.

4.5 Revenue model

The flowchart of the revenue class is shown in Figure B-4 (0). A distinction will be made between aeronautical, non-aeronautical, and non-operating revenues, in order to allow airports that utilise the double-till or hybrid-till approach to use the results of the ABS to determine their future pricing policies, and estimate their revenues. These approaches require a categorization of the revenues between aeronautical and non-aeronautical sources. Aeronautical revenues are generated by services or facilities directly related to the processing of aircraft and their passengers and cargo in connection with facilitating travel, while non-aeronautical revenues are related to the ancillary commercial services, facilities and amenities available at an airport. With regards to the revenues acquired from charges and fees collected from aircraft operators for the use of facilities and services provided by the airport for the handling of aircraft, these are classified as aeronautical revenues if the airport does not outsource these activities, but carries them out themselves. In the case that the airport outsources these activities, a concession or rental fee will be charged, which will be classified as non-aeronautical activities. Non-operating revenues refer to all income that accrues from sources not directly related to airport functions. These include revenues from bank and cash management such as interest on bank accounts, treasury bills, short-term debentures and bonds, and trading in discounted notes (Ashford, Mumayiz, & Wright, 2011).

Aeronautical and non-aeronautical sources of revenues will be defined using the revenue editor, while non-operational revenue will be defined using the balance sheet editor. Revenues from airport fees and charges are directly linked to the airport traffic, but for those forms of revenue that are not so closely linked to airport performance, rough rules-of-thumb will be used to estimate their values. However, the user will be able to further refine these values to reflect the actual situation found at the airport, or a situation representing a particular scenario. It should be noted that most of the equations presented in Section 4.5 are based on the work of Zawadzki (2003), Young and Wells (2011), and Ashford, Mumayiz, and Wright (2011). It is important to note that various airports have their own systems for defining airport charges, which means the user will have to perform some data preparation to accurately reflect the conditions found at the airport. Using the detailed level of analysis will allow the user to define more categories for input (e.g. in the determination of airport landing charges, where different charges apply to different weight classes of aircraft).

The relevant revenue data is gotten from the database, based on the information entered in the revenue and balance sheet options chosen by the user. The revenues are then calculated according to the equations presented in Subsections 4.5.1, 4.5.2, and 4.5.3.

4.5.1 Aeronautical revenues

The various sources of aeronautical revenues, and the equations used to calculate them are presented below. Revenues from airport fees and charges are directly linked to the airport traffic, but for those forms of revenue that are not so closely linked to airport performance, other ways were developed to estimate them.

Passenger service charges

These charges are collected for the use of passenger facilities, with different fees (sometimes) charged for Origin & Destination (O&D) passengers and transfer passengers. Most airports also charge a security service charge, for the provision of security services at the airport such as screening of passengers and their baggage, and a Persons with Reduced Mobility (PRM) charge. The numbers of annual O&D and transfer passengers will be gotten from the yearly case of the yearly case. Depending on the airport, passenger service charges may apply to either departing passengers or arriving passengers. Some airports charge both arriving and departing passengers, for example, in Australia. In the quick analysis, the user will be able to specify which segments of passengers are charged: arriving, departing, or both. The detailed analysis will allow the user to specify charges for additional passenger segments, such as domestic and international passengers, or in the case of European airports, EU and non-EU flights. The general relationship used to calculate the revenues gotten from passenger service charges is shown in equation (1) below.

$$AR_{ps} = \sum_{i=1}^{n} (Pax_i \cdot PC_i) \tag{1}$$

With:

AR_{ps} = revenues from passenger service charges [¤]
Pax_i = number of passengers in category i [-]
PC_i = passenger service charge per passenger in category i [¤]
Quick analysis: n = 2, i = [AOP, ATP] or [DOP, DTP] or [SOP, STP] [-]
Detailed analysis: n = 4, i = [IAOP, IATP, NAOP, NATP], or [IDOP, IDTP, NDOP, NDTP], or [ISOP, ISTP, NSOP, NSTP], A = Arrival, D = Departing, O = O&D, T = Transfer, S = Sum, P = Pax, I = International/non-EU, N = National/EU [-]

Passenger handling charges

This refers to charges not included above which are charged on a per passenger basis, such as baggage handling, which will apply to all passengers, and is shown in equation (2) below.

$$AR_{ph} = \left(1 - \mathrm{r}_{\mathrm{ph\_out}}\right) \cdot \sum_{i=1}^{n} (Pax_i \cdot PHC_i) \tag{2}$$

With:

AR_{ph} = revenues from passenger handling charges [¤]
r_{ph_out} = ratio of passenger handling activities outsourced [-]
Pax_i = number of passengers in category i [-]
PHC_i = Passenger handling charge per passenger in category i [¤]
Quick analysis: n = 2, i = O&D pax, transfer pax [-]
Detailed analysis: n = 4, i = IOP, ITP, NOP, NTP, I = International/non-EU, N = National/EU, O = O&D, T = Transfer, P = Pax [-]

Catering charges

This refers to catering charges, and only applies to departing passengers. It should be noted that very few airports provide this service, as it is usually outsourced. However, since the user is given the option of specifying whether this service is outsourced, this equation is included here in the event that an airport does not outsource catering. The equation used to determine the revenues gotten from catering charges is shown in equation (3) below.

$$AR_{cater} = \left(1 - \mathrm{r}_{\mathrm{cater\_out}}\right) \cdot (\mathrm{Pax}_{dep} \cdot \mathrm{CC}) \tag{3}$$

With:

AR_{cater} = revenues from catering charges [¤]
r_{cater_out} = ratio of catering activities outsourced [-]
Pax_{dep} = number of departing passengers [-]
CC = catering charge per departing passenger [¤]

Passenger based revenues

This refers to the sum of revenues gotten from passenger service charges, passenger handling charges, and catering charges, as shown in equation (4) below.

$$AR_{pb} = AR_{ps} + AR_{ph} + AR_{cater} \tag{4}$$

With:

AR_{pb} = passenger based revenues [¤]
AR_{ps} = revenues from passenger service charges [¤]
AR_{ph} = revenues from passenger handling charges [¤]
AR_{cater} = revenues from catering charges [¤]

Aircraft landing charges

These charges are collected for the use of runways, taxiways and apron areas, as well as lighting, and can be charged to landing aircraft, departing aircraft, or all aircraft, which the user will be able to specify. The charges are usually based on the maximum takeoff weight (MTOW) of an aircraft, which will be gotten from the database table in the ABS that contains aircraft data. It should be noted that various airports have their own schemes for implementing landing charges e.g. based on the time of day, and noise levels of aircraft, to name a few, and so it is a challenge to make an input method that can be used to accurately reflect the situation at different airports. The amount of total aircraft MTOW is calculated by the Yearly Case class (Section 4.4), and is used in equation (5) below to calculate the revenues gotten from landing charges.

$$AR_{lc\_quick} = \mathrm{LC}_i \cdot \mathrm{W}_i \tag{5}$$

With:

AR_{lc_quick} = quick calculation for revenues from landing charges [¤]
LC_i = (average) landing charge for aircraft in category i per tonne [¤/tonne]
W_i = total MTOW of aircraft in category i [tonne]
i = landing aircraft, or departing aircraft, or total aircraft [-]

In the detailed analysis level, the user will be allowed to specify various categories of aircraft based on aircraft weight, by specifying a flat fee, and a variable fee based on the aircrafts' weight. Individual calculations will then be performed for each of the aircraft in the specific category that is charged (landing, takeoff, or both), according to equation (6).

$$AR_{lc\_detailed} = \sum_{i=1}^{n} [C_{fixed} + C_{variable} \cdot (W_{AC} - W_i)] \tag{6}$$

With:

$AR_{lc\_detailed}$ = detailed calculation for revenues from landing charges [¤]
C_{fixed} = fixed charge for aircraft in category i [¤]
$C_{variable}$ = variable charge for aircraft in category i per tonne above lower limit [¤/tonne]
W_{AC} = MTOW of aircraft [tonne]
W_i = lower limit of MTOW for specified aircraft in category I [tonne]
n = specified by user, maximum of 5 categories [-]
i = category of aircraft according to MTOW, and whether it is landing, taking off, or both [-]

Aircraft parking (and hangar) charges

These charges are collected for the parking of aircraft, and their housing in airport-owned hangars, when this is not included in the landing charge. Like landing charges, these are based on the MTOW of aircraft, but the actual pricing scheme varies from airport to airport, with some airports giving free parking for short turn-around times (TAT), further compounding these dissimilarities. Parking charges only apply to half of the total annual movements (arriving and departing movements). It remains to be investigated whether turnaround time of aircraft can be determined from the ABS program. If this is the case, then the parking costs of each aircraft movement will need to be calculated, which will produce more accurate results. Equation (7) shows the expression used to calculate revenues gotten from parking and hangar charges.

$$AR_{phc} = \sum_{1}^{\mathrm{n}} (\mathrm{PF}_n \cdot \mathrm{TAT_n} \cdot \mathrm{W_n}) \tag{7}$$

With:

AR_{phc} = revenues from parking and hangar charges [¤]
PF_n = parking fee for aircraft in category n [¤/hour/tonne]
TAT_n = average turnaround time for aircraft in category n [hours]
W_n = total MTOW of aircraft in category n [tonne]
Quick analysis: n = landing aircraft
Detailed analysis: n = specified by user

Aircraft-based handling charges:

It should be noted that aircraft handling fees are no longer as closely dependent on the number of passengers or aircraft movements as the previous revenue sources presented above. For example, the amount of revenues from de-icing activities depends on the weather experienced that year, and not all aircraft landing at an airport will require fuelling. Finally, airports are increasingly choosing to outsource these activities, and so only receive concession fees. These charges include those charged per aircraft, regardless of the number of passengers, such as aircraft fuelling, de-icing, towing, and cleaning. As these charges vary based on aircraft size, categories will have to be defined by the user, and the average fees assigned for each category in the detailed analysis, and will apply to half of the annual aircraft movements. Equation (8) gives the expression used to calculate aircraft handling charges.

$$AR_{ah} = \left(1 - \mathrm{r}_{\mathrm{ah\_out}}\right) \sum_{1}^{\mathrm{n}} (\mathrm{AHF}_n \cdot \mathrm{W}_n) \tag{8}$$

With:

AR_{ah} = revenues from aircraft handling [¤]
r_{ah_out} = ratio of aircraft handling activities outsourced [-]
AHF_n = average aircraft handling fees for aircraft in category n [¤]
W_n = total MTOW of aircraft in category n [tonne]
Quick analysis: n = landing aircraft
Detailed analysis: n = specified by user

Aircraft-based revenues

This will include the sum of revenues gotten from aircraft landing charges, aircraft parking charges, and aircraft handling charges, as shown in equation (9) below.

$$AR_{ab} = AR_{lc} + AR_{phc} + AR_{ah} \tag{9}$$

With:

AR_{ab} = aircraft based revenues [¤]
AR_{lc} = revenues from landing charges [¤]
AR_{phc} = revenues from parking and hangar charges [¤]
AR_{ah} = revenues from aircraft handling [¤]

Other aeronautical revenues

This category is used to enable the user to include any aeronautical revenues not currently covered in the above categories. These may include night surplus charges, peak charges, etc. This input will require the user to input the overall revenues estimated to be gotten from these charges, so that crude approximations can be made on future revenues gotten from these sources. A separate input is given for revenues gotten from sales of fuel. The user is given the option of entering the absolute value, or the value expressed as a percentage of another value, as shown in Table 4-3. Fuel revenues are linked to the level of aircraft-based revenues, while other aeronautical revenues (taken to mean any revenues not covered by any other category) is indicated as a percentage of all aeronautical revenues.

Table 4-3: Other aeronautical revenues

Category of other aeronautical revenue (i)	Value it is expressed as a percentage of (S_i)
Fuel revenues	Sum of aircraft-based revenues
Other aeronautical revenues	Sum of aeronautical revenues

In the case that the user specifies the absolute value of fuel revenues, equation (10) can be used to find the corresponding percentage value, while equation (11) can be used to find the absolute value if the percentage value is given by the user.

$$AR_{fuel\_perc} = \frac{NAR_{fuel}}{S_{fuel}} \cdot 100 \quad (10)$$

$$AR_{fuel} = \frac{NAR_{fuel\_perc}}{100} \cdot S_{fuel} \quad (11)$$

With:
AR_{fuel_perc} = percentage of other aeronautical revenues of category i [%]
AR_{fuel} = absolute value of aeronautical revenues of category i [¤]
i = equip, services, advert, other (see Table 4-5) [-]
S_{fuel} = value that AR_{fuel_perc} is expressed as a percentage of (see Table 4-5) [¤]
Detailed analysis: For the detailed analysis, use will be made of the GPS coordinates of the airports, the fuel efficiency of aircraft, and a safety margin factor, in order to make an estimation of the amount of fuel required by each departing aircraft.

In order to determine the percentage value of the second category (other sources of aeronautical revenue), since the percentage is defined as a percentage of the total amount of aeronautical revenues, equation (12) is used, while equation (13) is used to determine the absolute level of this revenue category.

$$AR_{o\_perc} = \frac{AR_o}{AR_{sum} + AR_o} \cdot 100 \quad (12)$$

$$AR_o = \frac{AR_{sum}}{1 - AR_{o\_perc}/100} - AR_{sum} \quad (13)$$

With:

AR_{o_perc} = percentage of other aeronautical revenues of the others category [%]
AR_o = absolute value of aeronautical revenues of the others category [¤]
AR_{sum} = sum of aeronautical revenue except AR_o [¤]

The equation to obtain the sum the other aeronautical revenues is shown in equation (14) below.

$$AR_{others} = AR_{fuel} + AR_o \quad (14)$$

With:

AR_{other} = other aeronautical revenues [¤]
AR_{fuel} = revenues gotten from sales of fuel [¤]
AR_o = aeronautical revenues gotten from other sources [¤]

Total aeronautical revenues

The sum of all the aeronautical revenues can be found according to equation (15).

$$\mathrm{AR}_{total} = \mathrm{AR}_{pb} + \mathrm{AR}_{ab} + \mathrm{AR}_{other} \quad (15)$$

With:

AR_{total} = total aeronautical revenues [¤]
AR_{pb} = passenger based revenues [¤]
AR_{ab} = aircraft based revenues [¤]
AR_{other} = other aeronautical revenues [¤]

4.5.2 Non-aeronautical revenues

The various sources of non-aeronautical revenues, as well as the expressions used to estimate them, are presented in this Subsection.

Retail revenues

These are classified as non-aeronautical revenues, and include revenues generated from direct sales of shops, restaurants, bars, and catering services on airport premises, when these activities are carried out by the airport. It also includes revenues from services such as hotels, banking, and exchange bureaus. The user will be able to specify the amount of retail activities contracted out, and in the case that some activities are contracted out, the concession fees as a percentage of revenues. The user will be able to specify various passenger segments, and the current amount of average spending for each of these segments. The user will be able to specify the amount or division of passengers in each of these segments, although the numbers of domestic versus international passengers, and O&D versus transfer passengers can be gotten from the original ABS program. The user will be required to specify the average spending for each of these passenger segments. Equation (16) shows the calculation of retail revenues in the quick level of analysis.

$$NAR_{r\_quick} = \left(1 - \mathrm{r_{r\_out}}\right) \sum_{1}^{\mathrm{i=n}} (\mathrm{Pax}_i \cdot \mathrm{AS}_i) \tag{16}$$

With:

NAR_{r_quick} = quick calculation for revenues from retail activities [¤]
r_{r_out} = ratio of retail revenues contracted out [-]
CF_r = concession fees as a ratio of revenues gotten from retail activities [-]
Pax_i = number of passengers in segment i [-]
AS_i = average spending of a passenger in segment i [¤/-]
n = 2 [-]
i = departing pax, transfer pax [-]

For the detailed analysis calculations, the findings of Volkova (2009) and Fuerst (2011) will be used to define the relationship with which to forecast future retail revenues (R_{c_growth}) at an airport, as they provide the statistical impacts certain factors have on retail revenues. The factors that were determined to have a positive influence on the retail revenues at an airport are shown in Table 4-4 below, which will serve as the basis for the detailed calculation of retail revenues.

Table 4-4: Factors affecting retail revenues

Volkova (n.d.)	Fuerst et al. (2011)
number of international passengers	number of passengers
number of leisure passengers	ratio of commercial to total revenue
retail surface area	Gross Domestic Product (GDP) per capita
number of employees	percentage of international passengers
number of short stay parking places	percentage of leisure passengers
number of check-in facilities	number of traffic movements

Car parking revenues

These are the revenues gotten from operating car parking facilities at the airport, and are classified as non-aeronautical revenues. According to the ACRP Report 24 (Jacobs Consultancy, 2009), airport parking is the single largest source of revenue at US Airports, representing approximately 25% of all revenues, while car rentals represent about 12% of total revenues. Similar to retail revenues, these revenues are very difficult to estimate since they are dependent on a number of different factors, and the parking rates pricing scheme differ greatly from one airport to the next.

There will be an option for users to input how much of these activities are contracted out by the airport, how many parking spaces are available for both short-term parking and long-term parking, the respective fees per hour, and the average occupancy level throughout the year. There will also be an option to define the amount of revenues per passenger gotten from concessions of ground transportation service providers. In the case of exploring the effects of adding new parking spaces, the user will be able to specify the new number of parking spaces, and the amount of time it is expected to reach 'normal' parking occupancy, with a constant growth rate being assumed in this time period. It should be noted that for the case whereby no expansion is made to parking facilities, the user is able to manipulate the expected occupancy rate. Equation (17) shows the expression used to determine the amount of car-parking revenues.

$$NAR_{cp} = \left(1 - \mathrm{r_{cp\_out}}\right) \sum_{1}^{\mathrm{i=n}} (\mathrm{OR_i} \cdot \mathrm{PS}_i \cdot \mathrm{HF}_i) * 24 * 365.25 \tag{17}$$

With:

$\mathrm{NAR_{cp}}$ = revenues from car parking [¤]
$\mathrm{r_{ap\_out}}$ = ratio of car parking contracted out [-]
$\mathrm{CF_{ap}}$ = concession fees as a ratio of overall revenues from car parking [-]
$\mathrm{OR_i}$ = occupancy rate in segment i [-]
$\mathrm{PS_i}$ = number of parking spaces in segment i [-]
$\mathrm{HF_i}$ = hourly fee for segment i [¤/hr]
i = short-term parking, long-term parking [-]

Concession revenues

Concession revenues include revenues from activities which an airport outsources to other companies, or profit-sharing agreements with concessionaries such as restaurants, shops, and car rentals (Dempsey, 2008). It is assumed that a certain percentage of the activities carried out at an airport are outsourced, and that the concession revenues paid to the airport is based on a percentage of the revenue generated by the company performing these activities, which according to Dempsey (2008), is the most common practice for airports. Some airports impose an increasing percentage as the volume of business increases, while others divide space into different zones. The former is too complicated to implement, and so the latter will be implemented via the real estate revenues to apply to the case where concessions are determined on the basis of area rented. Concession revenues are gotten from: passenger handling using equation (18); catering using equation (19); aircraft-based handling using equation (20); retail using equation (21); and ground transportation services such as car parking, car rentals, taxis, and buses using equation (22). It is assumed that all ground transportation services, such as trains and buses, are outsourced by the airport, as is usually the case in the real world. The sum of concession revenues is calculated using equation (23).

$$CR_{ph} = \left(\mathrm{r_{ph\_out}} \cdot \mathrm{CF}_{ph}\right) \cdot \sum_{i=1}^{n} (Pax_i \cdot PHC_i) \tag{18}$$

With:

CR_{ph} = concession revenues from passenger handling charges [¤]
r_{ph_out} = ratio of passenger handling activities outsourced [-]
CF_{ph} = concession fees of passenger handling activities as a ratio of total revenues [-]
Pax_i = number of passengers in category i [-]
PHC_i = Passenger handling charge per passenger in category i [¤]
Quick analysis: n = 2, i = O&D pax, transfer pax
Detailed analysis: n = 4, i = IOP, ITP, NOP, NTP, I = International/non-EU, N = National/EU, O = O&D, T = Transfer, P = Pax

$$CR_{cater} = \left(\mathrm{r}_{\mathrm{cater\_out}} \cdot \mathrm{CF}_{cater}\right) \cdot \left(\mathrm{Pax}_{dep} \cdot \mathrm{CC}\right) \tag{19}$$

With:

CR_{cater} = concession revenues from catering charges [¤]
r_{cater_out} = ratio of catering activities outsourced [-]
CF_{cater} = concession fees from catering as a ratio of total revenues [-]
Pax_{dep} = number of departing passengers [-]
CC = catering charge per departing passenger [¤]

$$CR_{ah} = \left(\mathrm{r}_{\mathrm{ah\_out}} \cdot \mathrm{CF}_{ah}\right) \sum_{1}^{\mathrm{n}} \left(\mathrm{AHF}_{n} \cdot \mathrm{W}_{n}\right) \tag{20}$$

With:

CR_{ah} = concession revenues from aircraft handling [¤]
r_{ah_out} = ratio of aircraft handling activities outsourced [-]
CF_{ah} = concession fees from aircraft handling as a ratio of total revenues [-]
AHF_n = average aircraft handling fees for aircraft in category n [¤]
W_n = total MTOW of aircraft in category n [tonne]

$$CR_{r\_quick} = \left(\mathrm{r}_{\mathrm{r\_out}} \cdot \mathrm{CF}_{r}\right) \sum_{1}^{\mathrm{i=n}} \left(\mathrm{Pax}_{i} \cdot \mathrm{AS}_{i}\right) \tag{21}$$

With:

CR_{r_quick} = quick calculation for concession revenues from retail activities [¤]
r_{r_out} = ratio of retail revenues contracted out [-]
CF_r = concession fees as a ratio of revenues gotten from retail activities [-]
Pax_i = number of passengers in segment i [-]
AS_i = average spending of a passenger in segment i [¤/-]
n = 2 [-]
i = O&D pax, transfer pax [-]

$$CR_{gts} = \left[\left(\mathrm{r}_{\mathrm{cp_{out}}} \cdot \mathrm{CF}_{\mathrm{cp}}\right) \cdot \sum_{1}^{\mathrm{i=n}} \left(\mathrm{OR}_{\mathrm{i}} \cdot \mathrm{PS}_{i} \cdot \mathrm{HF}_{i}\right) * 24 * 360\right] + \mathrm{CR}_{pts} \tag{22}$$

With:

CR_{gts} = concession revenues from ground transportation services [¤]
r_{cp_out} = ratio of car parking contracted out [-]
CF_{cp} = concession fees as a ratio of overall revenues from car parking [-]
OR_i = occupancy rate in segment i [-]
PS_i = number of parking spaces in segment i [-]

HF_i = hourly fee for segment i [¤/hr]
CR_{pts} = concession revenues from public transportation services (e.g. bus, trains) [¤]
i = short-term parking, long-term parking [-]

$$NAR_{cr} = CR_{ph} + CR_{cater} + CR_{ah} + CR_{r\_quick} + CR_{gts} \quad (23)$$

With:

NAR_{cr} = total concession revenues [¤]
CR_{ph} = concession revenues from passenger handling charges [¤]
CR_{cater} = concession revenues from catering charges [¤]
CR_{ah} = concession revenues from aircraft handling [¤]
CR_{r_quick} = quick calculation for concession revenues from retail activities [¤]
CR_{gts} = concession revenues from ground transportation services [¤]

Real estate revenues

Real estate revenues refer to the revenues generated from renting out airport-owned building space or land to other entities, and are classified as non-aeronautical revenues. This amount includes all the associated revenues from utility charges from services such as heating, air conditioning, lighting, water, cleaning, and telephone use that the airport charges to the renters. The segments for the quick analysis calculation will be office and retail space, while the user will be able to define up to ten different segments in the detailed analysis. The rent and utility fees will be charged on a per meter square basis. It is assumed that all the available space is rented out.

$$NAR_{re} = \sum_{i=1}^{n} (Area_i \cdot Rent_i) \quad (24)$$

With:

NAR_{re} = real estate revenues [¤]
$Area_i$ = total area in segment i [m^2]
$Rent_i$ = rent charge per square meter for segment i [¤/m^2]
Quick analysis: n = 2, i = retail space, office space
Detailed analysis: n = determined by user, maximum of 10, i = determined by user

Other non-aeronautical revenues

This category includes all non-aeronautical revenues not covered in the non-aeronautical revenue categories mentioned above. It can include revenues from activities such as: rental of airport-owned equipment; services provided by the airport: advertising; and other sources of non-aeronautical revenues. It should be noted that the user has the option to enter absolute values for these revenue sources, or simply express them in terms of a percentage of another value (see Table 4-5). The former will be used in the calculation of revenues generated in the year of the financial case, while the latter will be used in the estimation of future levels of revenues. Equipment rental is assumed to be linked to the level of aeronautical revenues at the airport, while services provided is assumed to be linked to the level of aeronautical revenues and most of the non-aeronautical revenue sources. Advertising revenue is assumed to be linked to the passenger levels (since advertising is usually dependent on the target audience reached), and thus the amount of passenger-based revenues, while other non-aeronautical revenue (taken to mean any revenues not covered by any other category) is indicated as a percentage of the all non-aeronautical revenues. This last category can be used to represent the three other categories, in cases where the user does not have the available information, or wants to carry out a quick analysis.

Table 4-5: Other non-aeronautical revenues

Category of other non-aeronautical revenue (i)	Value it is expressed as a percentage of (S_i)
Equipment rental	Sum of aeronautical revenues
Services provided	Sum of aeronautical, retail, car parking, concession, and real estate revenues
Advertising	Sum of pax-based revenues
Other sources	Sum of all non-aeronautical revenues

When the user specifies the absolute values, equation (25) can be used to arrive at the corresponding percentage value. Equation (26) can be used in the reverse situation for the first three categories of equipment rental, services provided, and advertising.

$$NAR_{i\_perc} = \frac{NAR_i}{S_i} \cdot 100 \tag{25}$$

$$NAR_i = \frac{NAR_{i\_perc}}{100} \cdot S_i \tag{26}$$

With:

NAR_{i_perc} = percentage of other non-aeronautical revenues of category I [%]
NAR_i = absolute value of non-aeronautical revenues of category i [¤]
i = equip, services, advert, other (see Table 4-5) [-]
S_i = value that NAR_{i_perc} is expressed as a percentage of (see Table 4-5) [¤]

In order to determine the percentage value of the fourth category (other sources of non-aeronautical revenue), since the percentage is defined as a percentage of the total amount of non-aeronautical revenues, equation (27) is used, while equation (28) is used to determine the absolute level of this revenue category.

$$NAR_{o\_perc} = \frac{NAR_o}{NAR_{sum} + NAR_o} \cdot 100 \tag{27}$$

$$NAR_o = \frac{NAR_{sum}}{1 - NAR_{o\_perc}/100} - NAR_{sum} \tag{28}$$

With:

NAR_{o_perc} = percentage of other non-aeronautical revenues of category i [%]
NAR_o = absolute value of non-aeronautical revenues of category i [¤]
NAR_{sum} = sum of non-aeronautical revenue except NAR_o [¤]

Equation (29) shows the calculation of the sum of other non-aeronautical revenues.

$$NAR_o = NAR_{equip} + NAR_{services} + NAR_{advert} + NAR_{other} \tag{29}$$

With:

NAR_o = sum of all other non-aeronautical revenues [¤]
NAR_{equip} = revenues from rentals of airport-owned equipment [¤]
$NAR_{services}$ = revenues from services provided by the airport [¤]
NAR_{advert} = revenues from advertising [¤]
NAR_{other} = other sources non-aeronautical revenues not previously covered [¤]

Total non-aeronautical revenues

The following equation is used to find the sum of all the non-aeronautical revenues. It should be noted that discrepancies may be caused by the definition of concession revenues used in this model, whereby it does not just relate to retail revenues, but relates to any concession revenues an airport receives, regardless of the activity.

$$NAR_{total} = NAR_r + NAR_{cp} + NAR_{cr} + NAR_{re} + NAR_o \quad (30)$$

With:

NAR_{total} = total revenues from non-aeronautical activities [¤]
NAR_r = revenues from retail activities [¤]
NAR_{cp} = revenues from car parking [¤]
NAR_{cr} = total concession revenues [¤]
NAR_{re} = real estate revenues [¤]
NAR_o = sum of all other non-aeronautical revenues [¤]

4.5.3 Non-operating revenues

The sources of non-operating revenues (account receivables, cash investments, investments, and government grants and subsidies), as well as the methods and relationships used to estimate them, are presented in this subsection. The user input will be gotten from the Balance Sheet Editor, and since the user has the option of entering as many entries as they wish in each category, the calculation will account for this, and automatically find the sum of revenues earned from all these sources.

Interest revenues from accounts receivable

It is common for businesses to provide goods or services to other businesses on credit, i.e. without receiving immediate payment. Payment is then collected at a later date, sometimes with interest charged, which may generate additional revenues for the company, albeit a small amount. This will allow the user to account for the revenues to be gotten from interest on accounts receivable. Within this category, the user can define an allowance for doubtful accounts, or bad debt provision, i.e. accounts which may not be paid at all, which is common accounting practice. The user is also able to specify the average collection period, i.e. the approximate amount of time it takes a business to receive payments owed. The accounts receivable ratio will apply to all aeronautical revenues, and all non-aeronautical revenues, except revenues from car-parking (which are collected immediately, before the vehicles are allowed to exit the car parking facilities), according to equation (31). In the case that the airport does not charge interest on their lines of credits, the user can enter an interest rate of 0%, which will still allow the accounts receivable to be taken into account in the financial statements (Sections 4.10 and 4.11). It is assumed that interest on account receivables accrued in a financial period will be paid in that year, while the cash-flow on the actual accounts receivable amount will be credited to the next year in the financial statements.

$$R_{ar} = AR_{total} + NAR_{total} - NAR_{cp} \quad (31)$$

With:

R_{ar} = revenues which accounts receivable can be applied to [¤]
AR_{total} = total aeronautical revenues [¤]
NAR_{total} = total non-aeronautical revenues [¤]
NAR_{cp} = revenues from car parking [¤]

Revenues from interest charged on accounts receivable can be calculated according to equation (32). It is assumed that interest will be compounded. The user has the option to be as detailed as necessary, by entering data for each separate account receivable, or by amalgamating them into one representative category to save time, or gain a rough overall estimate of the situation when detailed information is not available.

$$NOR_{ar} = \sum_{i=1}^{n} [(ARA_n - BDP_n) \cdot R_{ar} \cdot \ (1 + r_n)^{t_n} - (ARA_n - BDP_n) \cdot R_{ar} \cdot (1 + r_n)^{t_n - 1}] \quad (32)$$

With:

NOR_{ar} = revenues from interest on accounts receivable [¤]
n = number of categories of account receivables, defined by the user [¤]
ARA_n = accounts receivable allocation as a ratio of R_{ar} [-]
BDP_n = bad debt provision expressed as a ratio of R_{ar} [-]
R_{ar} = revenues which accounts receivable can be applied to [¤]
r_n = rate of interest (as a decimal) for the accounts receivable [-]
t_n = average amount of time before accounts receivable is settled in months [-]

Interest revenues from cash investments

Cash investments earn interest when deposited in a bank account or other investment fund which gives a certain rate of return (interest rate). It should be noted that this category is intended for investment vehicles which offer a relatively safe and secure way to invest money. Compound interest can be found according to equation (33) (Pyles, 2014). In order to increase flexibility for the user, there will be an option to specify how many times interest is compounded yearly, thus negating the need to manually convert monthly interest rates into annual interest rates, and vice versa.

$$A = P\ (1 + \frac{r}{c})^{ct} \quad (33)$$

With:

A = amount of money accumulated after n years, including interest [¤]
P = principal amount (initial amount deposited) [¤]
r = annual rate of interest (decimal form) [-]
c = number of times the interest in compounded per year [-]
t = number of years the amount is deposited [-]

The interest revenues from cash investments will be calculated according to equation (34), if it is found that the deposit is still in the bank during that fiscal year, by comparing the current year of calculations to the starting year and lifetime of the deposit, as specified by the user. In order to find the amount of interest earned in that year, the difference is found between the amount of money accumulated over n years, and the amount of money accumulated up until the previous (n – 1) year. Interest is only earned after the year of purchase.

$$NOR_{cash} = \sum_{i=1}^{n} [(P_n \left(1 + \frac{r_n}{c_n}\right)^{c_n t_n}) - (P_n \left(1 + \frac{r_n}{c_n}\right)^{c_n (t_n - 1)})] \quad (34)$$

With:

NOR_{cash} = revenues from interest on bank deposits [¤]
n = number of cash deposits, defined by the user [-]
P_n = principal amount (initial amount deposited) for cash deposit n [¤]

r_n = rate of interest (in decimal form) for cash deposit n [-]
c_n = number of times the interest is compounded each year [-]
t_n = number of years of cash deposit n being in the bank, in this case, 1 [-]

Interest revenues from bonds

A bond is a financial device through which a corporation (or government) borrows money from entities, generally on a long-term basis. A (commercial) note is similar to a bond, except for the fact that its maturity is shorter: two-, three-, five-, and ten-year terms for notes, compared to more than ten years for bonds. Thus, the method of calculation is the same. In exchange for the money loaned, the lender/investor receives coupon payments (specific interest payments paid to the investor at specified intervals) and repayment of the face value (amount an investor loans a firm) is performed when the bond matures (Pyles, 2014). Bonds are used to refer to fixed-income securities which are founded on debt, and are considered to be relatively low-risk, especially when purchased from a government. This is because they have a defined series of future cash flows, According to Berk (2011, p. 218), a method to calculate the coupon payments is shown in equation (35).

$$CPN = \frac{CR \cdot FV}{n} \tag{35}$$

With:

CPN = coupon payment [¤]
CR = coupon rate in decimal form [-]
FV = face value [¤]
n = number of coupon payments per year [-]

It is assumed that any bonds bought will be held until the date of maturity (i.e. only term bonds without a call feature), and that all payments will be executed on schedule. Coupon payments only start to be received the year after the year of deposit. Finally, the annual amount of coupon (interest) payments for a bond is gotten using equation (36).

$$NOR_{bond} = \sum_{i=1}^{n} [CR_n \cdot FV_n \cdot NB_n] \tag{36}$$

With:

NOR_{bond} = revenues from coupon payments of bonds owned [¤]
n = number of categories of bonds, defined by the user [-]
CR_n = coupon rate as a decimal for bond category n [-]
FV_n = face value of bond in category n [¤]
NB_n = number of bonds owned in category n [-]

Interest revenue from stocks

Stocks are a much more volatile form of investment because they fluctuate in value on a daily basis, and so it is not as straightforward to estimate the amount of dividends that an investor may receive. An investor who purchases stocks becomes a part owner of the company, which entitles the investor to vote at shareholder meetings and receive any profits allocated to the owner in the form of dividends. According to Berk (2011), there are three approaches to valuing a firm's shares: dividend discount model; constant dividend growth model; and total pay-out model. According to Pyles (2014, pp. 168-174), there are three approaches to valuing a firm's shares over time: zero growth; constant growth; and multiple growth rates. The zero-growth rate will be used in the Financial Model. Cash dividends come in four types: regular; extra; special; or liquidating.

It should be noted that only the regular dividends will be estimated in this model, since the other types are dependent on other external factors. In order to account for the latter three types of stocks, the user will be able to specify these manually in the detailed analysis. For the quick analysis, dividend payments are only received after the year of purchase of the stocks, and there is no option to specify when a stock is sold, since the method of determination of the stock prices is too complicated and is not something that can be easily or accurately predicted. Equation (37) shows the way in which revenues from dividend payments of stocks owned are calculated.

$$NOR_{stock} = \sum_{i=1}^{n} [EPS_n \cdot DPR_n \cdot NS_n] \tag{37}$$

With:

NOR_{stock} = revenues from dividend payments of stocks owned [¤]
n = number of categories of shares, defined by the user [-]
EPS_n = earnings (before Interest and Tax) per share outstanding [¤]
DPR_n = dividend pay-out rate as a ratio [-]
NS_n = number of shares owned [-]

Interest revenues from investments

Investment vehicles are used by investors (individuals or companies) with the intention of having positive returns. The two most common vehicles for doing this are debt and equity, more colloquially known as bonds (and notes) and stocks. Alternative vehicles which represent more complicated types of securities and investing strategies include: options, futures, the Foreign Exchange, gold, real estate, etc. The bonds and stocks themselves are classified as assets (Subsection 4.7.1), so only the revenues generated (coupon payments and dividends) will be considered in this calculation. It should be noted that on average, a larger number of privately-owned airports tend to carry out financial investments, compared to publicly-owned airports. Bonds and stocks are also possible sources of financing for airports, but this will be dealt with in the section on airport’s liabilities (Subsection 4.7.2).

The total revenues from investments can be gotten by simply summing the revenues gotten from cash investments, bonds, and stocks, according to equation (38).

$$NOR_{invest} = NOR_{cash} + NOR_{bond} + NOR_{stock} \tag{38}$$

With:

NOR_{cash} = revenues from interest on cash investments [¤]
NOR_{invest} = revenues gotten from investments [¤]
NOR_{bond} = revenues gotten from coupon payments of bonds owned [¤]
NOR_{stock} = revenues from dividend payments of stocks owned [¤]

Government grants and subsidies

These are usually issued by a government body, at various levels. These do not need to be paid back by the airport, but usually come with grant assurances, for example, in ensuring a certain level of service or quality. Since grants do not need to be paid back, they do not incur any costs for the airport.

According to the International Accounting Standards (Deloitte Global Services Limited, 2014c), a government grant is only recognised when there is reasonable assurance that: 1) the entity will comply with any conditions attached to the grant; and 2) the grant will be received. However, for the purposes of this Financial Model, these two conditions will be assumed to be true. A grant is recognised as income over the period necessary to match them with the related costs. For example, if an airport receives a grant to construct a new runway, the grant will be recorded as income in the same period(s) that the costs of building the runway are recorded. Grants are not to be recorded as equity in the balance sheet. The two main types of grants are:

- *Grants related to income:* all grants other than those related to assets. These funds can be recorded as a credit in the income statement under 'non-operating income', in the period(s) that the recognition criteria are met.
- *Grants related to assets:* see Section 4.11.

In order to record the effects of grants related to income, equation (39) is used, given that the current year is in the period of payment of the grant, where it is assumed that these payments are spread evenly. If the payment period is zero years, a one-time payment will be received in the starting year, while if the payment period is one year, a payment is received in the start year, and at the end of the next fiscal year.

$$NOR_{grant} = \frac{GA}{(period + 1)} \tag{39}$$

With:

NOR_{grant} = other income from government grants and subsidies [¤]
GA = grant amount [¤]
period = period of payment of the grant [years]

Other non-operating revenues (detailed analysis)

This category is meant to allow the user to account for revenues that do not fall into the categories of cash, accounts receivable, and investments. Possible sources of non-operating revenues in this category includes gains incurred due to foreign exchange, asset write-downs, etc.

Total non-operating revenues

Total non-operating revenues can be obtained using equation (40).

$$NOR_{total} = NOR_{ar} + NOR_{invest} + NOR_{grant} \tag{40}$$

With:

NOR_{total} = total non-operating revenues [¤]
NOR_{ar} = revenues from interest on accounts receivable [¤]
NOR_{invest} = revenues gotten from investments [¤]
NOR_{grant} = other income from government grants and subsidies [¤]

4.6 Cost model

Cost gives a measure of resource consumption, as resources themselves are hard to define and measure. Cost is usually a key decision variable since it reduces the issue of resources to a common metric and can be used in establishing cash requirements for an operation/ project, estimating revenue requirements for project success, and determining strategies (make-buy decisions, choice of process, design, technology, and acquisition/selling strategies). Cost modelling aims to erode the complex problem of cost estimation by reducing them to a set of simpler analyses and explicit assumptions by incorporating technical knowledge, economic assumptions and processing practices, within a consistent framework for analysis (Field, n.d.).

An airport's costs can be broadly categorised into operating, non-operating, and capital/investment costs. It is very hard to quantify the factors that determine operational costs, as these will vary between different airports. To account for each airport's unique situation, it was decided to define costs as fixed costs linked to the airport capacity, variable costs linked to the traffic volumes experienced, or a combination of the two. Most of the equations presented in Section 4.6 are based on the work of Zawadzki (2003), Young and Wells (2011), and Ashford, Mumayiz and Wright (2011). The flowchart of this class is shown in Figure B-4 (0).

4.6.1 Operating costs

Operating costs are the expenses associated with administering a business on a day-to-day basis, and are linked to revenue-generating activities. They can be categorised as variable costs and fixed costs. Using the Cost Editor input form, the user has the option of specifying the costs for terminal and runway maintenance and utility as either an absolute value, or per area and runway length respectively.

Personnel costs

Although personnel costs are dependent on the number of passengers and aircraft movements at the airport, other factors such as productivity, and the degree of outsourcing, also play an important role. For example, an airport that does not outsource labour intensive activities such as baggage handling, will incur a higher personnel cost per passenger. Personnel costs can also be influenced by airport capacity, but it is expected that these will be accompanied by a roughly proportional increase in traffic volumes in the long run, negating the need to link personnel costs to airport capacity. Thus, employee costs will be linked to the number of passengers. In the detailed level of analysis, it is envisioned that the user will be able to specify any changes in productivity levels for future estimations of employment costs when defining the financial plan, which can be attributed to economies of scale, training of employees, or including more automation in work processes. Equation (41) is used to find the unit cost of personnel, for use in calculations of the employee costs in future years.

$$OC_{p\_u} = \frac{OC_p}{Pax} \tag{41}$$

With:

OC_{p_u} = unit personnel costs [¤/pax]
OC_p = total personnel costs [¤]
Pax = number of passengers [-]

Costs of services contracted out

This refers to costs incurred from services which the airport contracts an outside firm to perform, for example, paying contributions to the (governmental or private) agencies which carry out ATC, security, and the airport fire brigade, depending on the arrangements agreed upon. It should be noted that for services which are not contracted out, the costs will instead be reflected in the costs of personnel. In the quick analysis, the user will only be able to specify the overall costs of services, and it is assumed that these services will be linked to the passenger numbers experienced at the airport, as shown in the calculation for the unit costs of services contracted out in equation (42).

$$OC_{s\_u} = \frac{OC_s}{Pax} \tag{42}$$

With:

OC_{s_u} = unit costs of total services contracted out [¤/pax]
OC_s = total costs of services contracted out [¤]
Pax = number of passengers [-]

In the detailed analysis, the user will be able to specify various categories of services. Estimates of future ATC and the fire brigade costs will be based on the number of aircraft movements, while security costs are based on the number of passengers. All other services, for example, hiring a consulting firm to analyse work processes with an aim to making them more efficient, will be assumed to be related to the overall level of revenues that the airport generates, since these services may be related to the airport's other business areas, and not just its air traffic operations.

Costs of utilities

This refers to costs incurred by the usage of utilities such as lighting, water, and heating, and includes areas of the airport which are rented out. This cost is highly dependent on the airport capacity, and so will be defined either in absolute terms, or in terms of a (percentage of) a certain value (see Table 4-6). The quick analysis will limit the user to the three categories of runway, terminal, and other utilities, while the detailed analysis will provide the user with the ability to define various categories of airport facilities and their associated utilities costs. It is assumed that any future expansion of a certain airport facility will be accompanied by a proportional increase in utilities cost, except in extraordinary circumstances with external effects, e.g. the installation of more energy efficient devices.

Table 4-6: Cost of utilities

Category of utility (i)	Value it is expressed in terms of (S_i)
Terminal	Area of terminal buildings and the car park (from ABS)
Runway	Length of the runways (from ABS)
Other	Total utility cost

For the first two categories of runway and terminal, if the user specifies the absolute values, equation (43) can be used to arrive at the corresponding percentage value, while equation (44) can be used in the reverse situation. The terminal area is found by taking the value specified by the user in the original ABS program, while the runway length is gotten by summing the runway lengths defined in the original ABS program, and dividing by two, since each runway is recorded twice, to account for runway operations in the opposite orientation/direction.

$$UC_{i\_unit} = \frac{UC_i}{S_i} \tag{43}$$

$$UC_i = UC_{i\_unit} \cdot S_i \tag{44}$$

With:

- UC_{i_unit} = unit value of utility cost of category i [¤/m or ¤/m^2]
- UC_i = absolute value of utility cost of category i [¤]
- i = terminal (t), runway (r) [-]
- S_i = value that UC_{i_unit} is expressed as a unit of [m or m^2]

In order to determine the percentage value of the third category (other utility costs), if the absolute value is supplied by the user, equation (45) is used, while equation (46) is used to find the absolute value when the percentage value is specified.

$$UC_{o\_perc} = \frac{UC_o}{S_o + UC_o} \cdot 100 \tag{45}$$

$$UC_o = \frac{S_o}{1 - UC_{o_{perc}}/100} - S_o \tag{46}$$

With:

UC_{o_unit} = unit value of utility cost of other category [%]
UC_o = absolute value of utility cost of other category [¤]
S_o = sum of terminal and runway utility costs [¤]

In order to arrive at the total utility costs, equation (47) is used.

$$OC_u = UC_t + UC_r + UC_o \quad (47)$$

With:

OC_u = total utility costs [¤]
UC_t = terminal utility costs [¤]
UC_r = runway utility costs [¤]
UC_o = other utility costs [¤]

Cost of maintenance

This refers to any inspection and maintenance work carried out on the various airport facilities, such as the runways, taxiways, apron areas, aircraft parking and hangars, terminal building, and car parking facilities. Similar to the determination of the cost of utilities, in the quick analysis, two main categories of runway and terminal building are defined, while the third category is used to cover all other items. The first two categories are assumed to be capacity dependent, and so any expansion in these facilities would cause a corresponding increase in maintenance costs. Thus, they can be expressed either in absolute terms, or per terminal area or runway length, while the third category can be expressed as a percentage of the total maintenance costs (see Table 4-7). It should be noted that this calculation will only cover routine maintenance undertakings. For example, a runway may require minor maintenance yearly, and a major maintenance every decade. Major, unscheduled, or infrequently scheduled maintenance projects, will be handled as a capital project cost (Subsection 4.6.3). In the detailed analysis, the user will have the option to enter more detailed categories of maintenance costs.

Table 4-7: Cost of maintenance

Category of utility (i)	Value it is expressed in terms of (S_i)
Terminal	Area of terminal buildings and the car park (from ABS)
Runway	Length of the runways (from ABS)
Other	Total utility cost

For the first two categories of terminal and runway, if the user specifies the absolute values, equation (48) can be used to arrive at the corresponding percentage value while equation (49) can be used in the reverse situation.

$$MC_{i\_unit} = \frac{MC_i}{S_i} \quad (48)$$

$$MC_i = C_{i\_unit} \cdot S_i \quad (49)$$

With:

MC_{i_unit} = unit value of utility cost of category i ¤/m^2 or ¤/m]
MC_i = absolute value of utility cost of category i [¤]
i = terminal (t), runway (r) [-]
S_i = value that MC_{i_unit} is expressed as a unit of [m^2 or m]

In order to determine the percentage value of the third category (other utility costs), if the absolute value is supplied by the user, equation (50) is used, while equation (51) is used to find the absolute value when the percentage value is given.

$$MC_{o\_perc} = \frac{MC_o}{S_o + UC_o} \cdot 100 \tag{50}$$

$$MC_o = \frac{S_o}{1 - MC_{o\_perc}} - S_o \tag{51}$$

With:

MC_{o_unit} = unit value of maintenance cost of other category [%]
MC_o = absolute value of maintenance cost of other category [¤]
S_o = sum of terminal and runway maintenance costs [¤]

Once all the individual categories have been calculated, the total maintenance costs can be arrived at using equation (52).

$$OC_m = MC_t + MC_r + MC_o \tag{52}$$

With:

OC_m = total maintenance costs [¤]
MC_t = maintenance cost of the terminal buildings [¤]
MC_r = maintenance cost of runways [¤]
MC_o = value of maintenance cost of other category [¤]

Costs of leasing

The concept of leasing is very important in the business world, as it allows a business to acquire or use fixed assets and eliminate the up-front costs inherent in purchasing. Companies may also use sale-and-lease-back, to improve their financial position, and amount of cash on hand.

Leases can take one of two forms: i) a *finance (or capital) lease* if it transfers substantially all the risks and rewards incident to ownership; and ii) an *operating lease* which applies to all other leases where the lessee only pays for the use of the asset (Deloitte Global Services Limited, 2014b). A finance lease thus comprises of a depreciation and interest expense, while an operating lease is considered as an operating expense, with regular lease payments paid at certain periods in the year (e.g. monthly, quarterly). The advantage of an operating lease is that it has tax incentives, and does not result in assets or liabilities being recorded on the lessee's balance sheet, which can improve the lessee's financial ratios. In the quick analysis, only operating leases will be considered, since a financial lease can be recorded, and accounted as a regular asset. Equation (54) is used to find the annual lease payments.

$$OC_{lease} = \sum_{i=1}^{n} [LP_i \cdot c_n] \tag{53}$$

With:

OC_{lease} = total annual (operating) lease payments [¤]
n = number of leases, specified by the user [-]
LP_i = lease payments [¤]
c_n = number of lease payments per year [-]

Other operating costs

This category is intended to allow the user to specify operating costs not covered in the cost categories mentioned above. It should be noted that for those activities which the airport does not contract out, the costs of performing these services will be reflected in the costs of personnel, the costs of maintenance, the administration costs, and the costs of supplies.

The following are the various sub-categories defined in this category:

- *Administration costs:* expenses that an airport incurs through controlling and directing itself, but which are not directly related to financing, marketing, or production operations. This includes the salaries of senior executives, and costs of general services such as accounting, contracting, and industrial relations. Administrative costs can usually be specified as a percentage of total costs.
- *Cost of supplies:* include costs of supplies that are needed in the operation of the airport, and are likely to remain at the same proportion of total costs.
- *Cost of insurance:* refers to insurance of airport assets, but also includes liability insurance, in the case that an accident occurs at the airport. It is likely to remain at the same percentage of total costs.
- *Other costs within this category:* encompass every operating cost item not covered in another category, including items such as additional government charges. If the user does not wish to give detailed input, only this category can be filled in.

These categories can be given as absolute values, or as a percentage of the total operating costs. If the user specifies the absolute values, equation (54) can be used to find the corresponding percentage values, while equation (55) can be used in the reverse situation to find the corresponding absolute values.

$$OOC_{i\_perc} = \frac{OOC_i}{S_i} \cdot 100 \qquad (54)$$

$$OOC_i = \frac{OOC_{i\_perc}}{\sum OOC_{i\_perc}} \cdot [\frac{S_c}{1 - \sum OOC_{i_{perc}}/100} - S_c] \qquad (55)$$

With:

OOC_{i_perc} = percentage value of other operating cost of category i [%]
i = administration cost (a), cost of supplies (s), cost of insurance (ins), other (other) [-]
OOC_i = absolute value of other operating cost of category i [¤]
S_i = sum of all operating costs, including 'other' operating cost categories [¤]
S_c = sum of operating costs, excluding those of 'other' operating cost categories [¤]

The total operating costs in the 'others' category can be found according to equation (56).

$$OC_o = OOC_a + OOC_s + OOC_{ins} + OOC_{other} \qquad (56)$$

With:

OC_o = other operating costs [¤]
OOC_a = administration costs [¤]
OOC_s = cost of supplies [¤]

OOC_{ins} = cost of insurance [¤]
OOC_{other} = operating cost not in aforementioned categories [¤]

Total operating costs

The sum of all the operating costs can be found using equation (57).

$$OC_{total} = OC_p + OC_s + OC_u + OC_m + OC_{lease} + OC_o \tag{57}$$

With:

OC_{total} = total operating costs [¤]
OC_p = total personnel costs [¤]
OC_s = total costs of services contracted out [¤]
OC_u = total utility costs [¤]
OC_m = total maintenance costs [¤]
OC_{lease} = total annual (operating) lease payments [¤]
OC_o = other operating costs [¤]

4.6.2 Depreciation and amortisation costs

Depreciation refers to prorating a tangible asset's cost over that asset's life, while amortisation refers to spreading an intangible asset's cost over that asset's life. However, it should be noted that in some instances, these two terms are used interchangeably. Depreciation is considered an operating expense, as it is incurred as part of normal business operations. In the envisioned ABS program, the user will be able to specify the rates of depreciation, and the lifetime of the assets in question, and a suggested schedule can be shown to the user, based on the ICAO Airport Economics Manual (ICAO, 2013). There are four main methods for calculating the depreciation of an asset (AccountingStudy.com, 2014):

- *Straight-line method:* It is the most commonly used method for depreciation whereby depreciation is charged as a constant amount each year during the book life of the asset concerned (ICAO, 2013, pp. 72-73).
- *Declining balance method:* The depreciation expense decreases at a constant rate as the life of an asset progresses.
- *Sum-of-the-years'-digits method:* The depreciation charge declines by a constant amount as the life of the asset progresses.
- *Units of activity method:* The depreciation charge varies each period in proportion to the change in level of activity.

For the detailed analysis level, the user has the option of specifying which of the aforementioned methods to use. The user will also be able to specify finance (or capital) leases, i.e. those that transfer substantially all the risks and rewards incident to ownership, and so the depreciation costs of the leased asset will need to be calculated as well.

The user is encouraged to group assets into classes or groups, to reduce user input. Since the straight-line method in equation (58) is the most commonly used method, it is used in the quick analysis calculations, since it is best used in situations where the pattern of economic benefits are hard to determine (AccountingStudy.com, 2014). The depreciation costs for the various assets (including improvement assets) are calculated, with a prior check being performed to ensure that the current year of calculation is within the lifetime of the asset. In order to be able to group the airport's assets into functional categories, five categories defined are: airside infrastructure; landside infrastructure; equipment/machinery; intangible; and others. The quick analysis will only determine the intangible assets depreciation costs, and the total depreciation costs, while the detailed analysis will calculate the depreciation costs for each of the categories.

$$DC_{total} = \sum_{i=1}^{n} (\frac{PP - SV}{L}) \tag{58}$$

With:

DC_{total} = total cost of depreciation [¤]
i = individual asset [-]
n = number of assets, as defined by the user [-]
PP = purchase price of asset i [¤]
SV = salvage value, i.e. the price the asset will be sold at the end of its useful life [¤]
L = lifetime of asset, from time of acquisition to termination of use [years]

4.6.3 Non-operating costs

Non-operating costs refers to those costs that would have to be met even if the airport ceased operations. The most common type relates to interest payments on outstanding debt, which can be broadly categorised as public or private debt. Private debt is generally a one-to-one transaction (or in some cases, a syndicated loan), where one borrower enters a contract with one lender, which is usually a financial institution. This includes avenues such as accounts payable, loans, and leases. Public debt is a one-to-many transaction, with many potential lenders, whereby an open call for funds is issued by a firm to the investing public, and includes avenues such as bonds and notes (Pyles, 2014, pp. 133-134). The methods of calculation for each of these categories is given in this section. In the detailed analysis level, additional categories of non-operating costs will be considered, such as one-time or unusual costs, such as those incurred from restructuring or reorganizing, currency exchange, charges on obsolescence of inventory, and lawsuits, etc.

Interest costs from accounts payable

Accounts payable is money owed by a business to its supplier. It should be noted that the method of calculation is similar to that used to calculate interest revenues from accounts receivable (Subsection 4.5.3). The user is able to specify the average percentage of its bills which it pays late, and the amount of interest costs incurred by making these late payments. The cost sources from which an airport may defer payments are gotten according to equation (59), and the interest from these accounts payable can be found according to equation (60).

$$C_{ap} = OC_{total} \tag{59}$$

With:

C_{ap} = costs which accounts payable can be applied to [¤]
OC_{total} = total operating costs [¤]

$$IC_{ap} = \sum_{i=1}^{n} [ARA_n \cdot C_{ap} \cdot \ (1 + r_n)^{t_n} - ARA_n \cdot C_{ap}] \tag{60}$$

With:

IC_{ap} = interest costs from accounts receivable [¤]
n = number of categories of account payables, defined by the user [¤]
APA_n = accounts payable allocation as a ratio of C_{ap} [-]
C_{ap} = costs which accounts payable can be applied to [¤]
r_n = monthly rate of interest (as a decimal) for the accounts payable [-]
t_n = average amount of time before accounts receivable is settled [months]

Interest cost from bonds

If an airport uses bonds as a means of financing, it will need to pay the costs associated with it, which include coupon payments and a repayment of the face value when the bond matures. The method used to calculate the interest revenues from bonds (Subsection 4.5.3) is used to calculate these interest costs, along with the same assumptions. Coupon payments (equation (61)) are made until the year of maturity of the bond.

$$IC_{bond} = \sum_{i=1}^{n} [CR_n \cdot FV_n \cdot NB_n] \tag{61}$$

With:

IC_{bond} = interest costs from coupon payments of bonds issued [¤]
n = number of categories of bonds, defined by the user [-]
CR_n = coupon rate as a decimal for bond n [-]
FV_n = face value of bond n [¤]
NB_n = number of bonds issued in category n [-]

Interest costs from loans

A loan is one of the most common ways of borrowing money, for both businesses and individuals. However, the amount of money that can be raised using loans is limited, and loans usually need some form of security or collateral (e.g. a building is the collateral in a mortgage loan). There are four major forms that loans can take (Pyles, 2014, pp. 120-124): pure discount loan; interest-only loan; amortised loan; and hybrid loan.

For the quick level of analysis, an amortised loan will be assumed, whereby interest payments and principal payments are made at intervals during the life of the loan, since this is the most common form of loan in the real-world. The interest rate will be assumed to be fixed. It should be noted that these calculations will not include any additional costs such as closing costs, property taxes, or mortgage insurance, so these will have to be reflected elsewhere by the user. For the detailed level of analysis, the user will have the option of specifying the form of loan, and a changing interest rate over the lifetime of the loan. The annual loan repayment, for loan n, is shown in equation (62). This amount includes both the interest payments and the principal payments.

$$A_n = \frac{P_n \cdot r_n}{1 - (1 + r_n/c_n)^{-t_n c_n}} \tag{62}$$

With:

A_n = annual loan payment amount for loan n [¤]
n = number of loans, defined by the user [-]
P_n = principal amount (initial amount deposited) for cash deposit n [¤]
r_n = rate of interest (as a decimal) for cash deposit n [-]
c_n = number of times (periods) the interest is compounded each year [-]
t_n = lifetime of loan in years [-]

In order to arrive at the loan interest payments for that year, a loan amortisation schedule will be created using arrays in VB.NET, according to Table 4-8 on the next page, whereby i refers to the period, and A_n is calculated using equation (62).

Table 4-8: Loan amortisation schedule

Index (i)	Principal amount PA(i)	Interest payment IP(i)	Principal payment PP(i)
0	$PA(0) = P_n$	$IP(0) = PA(0) \cdot (r_n/c_n)$	$PP(0) = A_n - IP(0)$
1	$PA(1) = PA(0) - PP(0)$	$IP(1) = PA(1) \cdot (r_n/c_n)$	$PP(1) = A_n - IP(1)$
i	$PA(i) = PA(i-1) - PP(i-1)$	$IP(i) = PA(i) \cdot (r_n/c_n)$	$PP(i) = A_n - IP(i)$

In order to find the corresponding annual interest costs, the sum of the periods of the year in question will be found according to equation (63).

$$IC_{loan} = \sum_{i=1}^{n} [IP(i)] \tag{63}$$

With:

IC_{loan} = annual interest costs on loans [¤]
n = number of loans, specified by the use [-]
IP(i) = interest payments in the periods in the year being considered for all loans [¤]

Interest cost from leases (detailed analysis)

In the detailed analysis, the user will be able to specify finance (or capital) leases, i.e. those that transfer transfers substantially all the risks and rewards incident to ownership, and so the interest costs will be calculated as well.

Total interest costs

$$NOC_{interest} = IC_{ap} + IC_{bond} + IC_{loan} \tag{64}$$

With:

$NOC_{interest}$ = total interest costs [¤]
IC_{ap} = interest costs from accounts receivable [¤]
IC_{bond} = interest costs from coupon payments of bonds issued [¤]
IC_{loan} = annual interest costs on loans [¤]

Other non-operating costs (detailed analysis)

This category is meant to allow the user to account for costs that do not fit in the categories of cost of capital, and will only be implemented in the detailed analysis.

4.6.4 Other income statement costs

This category includes the two remaining items which need to be presented in an income statement: the taxes; and dividend payments.

Corporate income tax

Corporate income tax is applied to the taxable income of a firm, i.e. the income after operating, depreciation, and interest costs have been deducted from the total revenues a firm generates (Pyles, 2014, p. 31). This is usually administered as a percentage of this taxable income, according to the specified tax rate. In the quick analysis, the user can only specify a flat *tax rate* (ratio of total amount of taxes paid to the taxable income). Using equation (65), the taxable income is found, which is then used to arrive at the tax costs in equation (66). This situation is found in the Netherlands, for example, where the tax rate is 20% if income is less than €200,000, and 25% when income is higher than €200,000 (Government of the Netherlands, 2014). However, the detailed analysis will provide the option of specifying a *marginal tax rate* (when different tax rates are applied to each tax bracket that the company qualifies for), which is the practice in some other parts of the world.

$$TI = (AR_{total} + NAR_{total} + NOR_{total}) - (OC_{total} + DC_{total} + IC_{total}) \quad (65)$$

With:

TI = taxable income [¤]
AR_{total} = total aeronautical revenues [¤]
NAR_{total} = total revenues from non-aeronautical activities [¤]
NOR_{total} = total non-operating revenues [¤]
OC_{total} = total operating costs [¤]
DC_{total} = total depreciation costs [¤]
$NOC_{interest}$ = total interest costs [¤]

$$TC = \frac{r_t}{100} \cdot TI \quad (66)$$

With:

TC = tax costs [¤]
r_t = tax rate [%]
TI = taxable income [¤]

Shareholder dividend payments

Only in the case that the airport is a publicly traded company, will this category have a significance for the airport. The user will be able to specify the dividend pay-out ratio, which is the proportion of net income that is paid to the shareholders as dividends. A check will be performed to ensure that the current year of calculation is after the year of issue of the shares. The method used to estimate the annual shareholder dividend payments is shown in equation (67).

$$DP = r_{dp} \cdot (TI - TC) \quad (67)$$

With:

DP = dividend payments [¤]
r_{dp} = dividend pay-out ratio as a decimal [-]
TI = taxable income [¤]
TC = tax costs [¤]

4.7 Balance sheet items model

The balance sheet provides information on what a firm owns (its assets), what it owes (its liabilities), and the value of the business to its owners (equity). It is important in showing the net value of the business at a given point in time, and provides a basis for comparison with other firms, or the performance of the firm across a number of years. A firm's asset should equal the sum of its liabilities and equity (Pyles, 2014, pp. 36-37).

While the outputs of the revenue and cost models (Sections 4.5 and 4.6, respectively) are used in the annual income statement, the outputs of this model will be used in the annual balance sheet, which will give the user a better picture of an airport's overall financial situation, and will show the ability of an airport to finance future capital expenditure projects. It is assumed that the balance sheet is prepared only at the end of a financial year, and that all payments for the current year have been made (except the accounts payable allocation), and all payments have been received (except the accounts receivable allocation). This will simplify the calculations involved with the balance sheet. Most of the equations presented in Section 4.7 are adapted from Berk and Demarzo (2011), Deloitte Global Services Limited (2014a), and Poorthuis (2008).

4.7.1 Assets

Assets are economic resources that are expected to produce economic benefits for the owner. They can be classified as current assets (those which may be converted to cash, sold, or consumed within a year), and non-current assets (all other assets) (Investopedia, LLC., 2014).

Cash

This refers to the amount of cash that a company holds, and the amount of cash it holds at the beginning of a specific year can be specified manually by the user in the Balance Sheet Editor. This category can be used to reference and record cash receipts or spending, for example, extraordinary gains or losses from the sale of an asset. The cash amount will also be gotten from the 'ending cash balance' of the statement of cash flow (Section 4.12), in the financial plan.

Accounts receivable

This refers to the amount of accounts receivable that a company will receive within a year, and can be found according to the following equation (68).

$$CA_{ar} = \sum_{i=1}^{n} [(ARA_n - BDP_n) \cdot R_{ar}] \quad (68)$$

With:

CA_{ar} = total accounts receivable amount [¤]
ARA_n = accounts receivable allocation as a ratio of R_{ar} [-]
BDP_n = bad debt provision expressed as a ratio of R_{ar} [-]
R_{ar} = revenues which accounts receivable can be applied to, equation (31) [¤]

Other current assets

This category will be used to determine the present value of the salvage value of assets which are due to be sold or disposed (reaching the end of their useful life) in the next fiscal year (capital assets, bonds, stocks, and cash investments). In the case of bonds which are due to mature in the next year, the present value of the face value of the bonds to be received will be calculated. In the case of assets to be disposed in the next year, the present value of the salvage values will be found. The present value of cash investments that mature in the next year will also be calculated. The generic calculation for the present value of a future cash flow is shown in equation (69). Although calculating future value has its benefits, it is important to remember that it does not include adjustments for inflation, fluctuating interest rates or fluctuating currency values that are likely to affect the true value of money or assets in the future.

$$PV = \frac{C}{(1+r)^n} \quad (69)$$

With:

PV = present value of a cash flow [¤]
C = cash flow amount [¤]
r = discount rate as a decimal [-]
n = number of years in the future that a cash flow is received [-]

Total current assets

This will be found according to equation (70) below.

$$CA_{total} = CA_{cash} + CA_{AR} + CA_{other} \tag{70}$$

With:

CA_{total} = total current assets [¤]
CA_{cash} = total cash reserves [¤]
CA_{AR} = total accounts receivable amount [¤]
CA_{other} = other current assets [¤]

Original value of fixed assets

Non-current assets can be divided into the following categories:

- *Land:* sum value of the purchase price of land assets, as specified by the user.
- *Infrastructure:* sum of the value of the purchase price of airside infrastructure and landside infrastructure assets, as specified by the user.
- *Fixtures and Equipment:* sum of the value of the purchase price of equipment assets, as specified by the user.
- *Improvements:* capital projects which may include major improvements or overhauls to an existing asset, which will be capitalised and included in this category during its construction period, whereby its value will be spread evenly across this period. The year of start of operations of the capital expenditure project will be the point at which it is added to the balance sheet as an asset.
- *Intangible assets:* sum of the value of the purchase price of intangible assets, as specified by the user. Examples include goodwill, patents, and trademarks.
- *Other assets:* sum of the value of the purchase price of other assets, as specified by the user. This section will also include the purchase price of stocks currently held by the company, as it will be difficult to predict the future selling price of the stock. The present value of the face value of a non-current firm's bonds can be easily calculated using equation (69), which can then be used to calculate the sum of the present values of the bonds a firm owns. Cash investments will include the amount from previous cash investments in the financial plan that are still active, along with any compound interest received.

Improvements (capital projects/expenditures) are those that alter the future of a business, by acquiring fixed assets, or adding to the value of an existing fixed asset by extending its useful life beyond the taxable year, or upgrading it to improve its economic benefits. There is a clear distinction from maintenance costs (operating costs), which are costs incurred to keep the asset operational, but does not extend its lifetime. The accepted financial accounting practice for capital projects is to depreciate these costs over the lifetime of the asset in question (dealt with in Section 4.7), rather than declaring these as operating expenses on the income statement. The value of the capital expenditures (or projects) will be declared in the 'improvements' category of the balance sheet.

Accumulated depreciation

The accumulated depreciation is calculated for each of the asset items, including improvement assets, from its purchase date to the current year. It is assumed that all acquisitions are on the last day of the year specified, right before the reporting is done, while the end of the asset's lifetime is the last day of the fiscal/calendar year specified, also before the reporting is done. For this reason, depreciation starts in the year following the year of acquisition.

Total non-current assets

The total non-current assets can be found by subtracting the accumulated depreciation from the sum of the value of a firm's non-current assets, according to equation (71).

$$NCA_{total} = \sum_{i=1}^{n} (NCA_i) - ADC \tag{71}$$

With:

NCA_{total} = total non-current assets [¤]
NCA_i = total value of non-current asset of category i [¤]
i = land, infrastructure, equipment, intangible, and others [-]
ADC = total accumulated depreciation costs [¤]

4.7.2 Liabilities

Liabilities can be seen as obligations the firm has to outside parties, i.e. others' rights to the firm's money, goods, or services. Liabilities can be classified as current liabilities (those which need to be paid within a year), and long-term liabilities (all other liabilities). Long-term obligations are reported as the present value of all future cash payments (Investopedia, LLC., 2014).

Accounts payable

This refers to the amounts of accounts payable that a company is obligated to pay, and can be found according to equation (72):

$$CL_{ap} = \sum_{i=1}^{n} [APA_n \cdot C_{ap}] \tag{72}$$

With:

CL_{ap} = total accounts payable amount [¤]
APA_n = accounts payable allocation as a ratio of C_{ap} [-]
C_{ap} = costs which accounts receivable can be applied to, equation (59) [¤]

Current bonds payable

This will include the present value of the face value of any bonds that mature in the next year, as shown in equation (69).

Current portion of long-term debt

A loan's principal payment is recorded as a reduction in its liability, and can be found according to the loan's amortisation schedule (Table 4-8). Equation (69) can be used to find the present value for the principal payment of the next year.

Total current liabilities

This will include the sum of the accounts payable, the present value of bonds payables within one year, and the present value of the current portion of long-term debt, according to equation (73).

$$CL_{total} = CL_{ap} + CL_{bond} + CL_{loan} \tag{73}$$

With:

CL_{total} = total current liabilities [¤]
CL_{ap} = total accounts payable amount [¤]
CL_{bond} = present value of current bonds payables [¤]
CL_{loan} = present value of current portion of long-term debt [¤]

Bonds payable

This will include the present value of the face value of all the bonds that mature in more than a year's time, as shown in equation (69).

Loans payable

A loan's principal payment can be found according to the loan's amortisation schedule (Table 4-8), while equation (69) can be used to find the present values for the outstanding future principal payments.

Total long-term liabilities

The total long-term liabilities is found by getting the sum of the present values of the face value of a bond, and a loan's future principal payments, as shown in equation (74).

$$LL_{total} = LL_{bond} + LL_{loan} \tag{74}$$

With:

LL_{total} = total current liabilities [¤]
LL_{bond} = present value of bond's face value at time of maturity [¤]
LL_{loan} = present value of future loan principal payments [¤]

4.7.3 Equity

Owners' or shareholders' equity can be regarded as the value of a business to its owners after all its obligations have been met. It reflects the amount of capital the owners have invested, and any profits generated that were reinvested into the company (Investopedia, LLC., 2014).

Owners'/Shareholders' Equity

This can take one of two forms, depending on the form of the company: i) owners' equity (investments of the owners and/or investors) if it is a privately held company, and ii) shareholders' equity (raised through the public issuance of stocks), if the company is a publicly held company. In this Financial Model, it is assumed that all stock is *common stock*, and so *preferred stock* (have priority to receive dividend payments over common stock) are not considered. Owners' equity is found by obtaining the sum of all the equity contributions, while shareholders' equity is found using equation (75), given that the year of issue is prior to the current year of calculation.

$$E_{sh} = n_{si} \cdot P_s \tag{75}$$

With:

E_{sh} = shareholders' equity [¤]
n_{si} = number of shares issued [-]
P_s = price of one share [¤]

Retained earnings

In this case, retained earnings refers to the accumulated retained earnings over the life of the business, and is found by obtaining the sum of the retained earnings specified by the user, and that calculated in the income statement (Table 4-9).

Total equity

The total equity can be found according to the following equation (76).

$$E_{total} = E_o + E_{sh} + E_{re} \tag{76}$$

With:

E_{total} = total equity [¤]
E_o = owners' equity [¤]
E_{sh} = shareholders' equity [¤]
E_{re} = retained earnings [¤]

4.8 Financial case

A financial case is built from the main screen of the ABS Financial Model GUI, with the user specifying the year of calculation, the level of detail, and a combination of the following schemes:

- Revenues
- Costs
- Balance sheet items
- Yearly case

In order to build the financial case, the revenue model (Section 4.5), cost model (Section 4.6), and balance sheet items model (Section 4.7) will calculate all the required information. Once the information has been calculated and saved in separate database tables, the various outputs can then be used to display the relevant data, and allow the user to carry out an analysis of the financial case.

4.9 Financial plan

The financial plan will allow a user to evaluate the financial performance of an airport over a number of years. Although all the values have been already calculated, certain values need to be recalculated, to take into consideration the effects of the previous years in the financial plan. The following are the differences between the financial case and financial plan calculations:

Balance sheet module

- *Cash:* in the financial case, this will be gotten from the user input in this category. In the financial plan, this will be gotten from the ending cash of the preceding year in the financial plan, as calculated in the cash flow module.
- *Accounts receivable/payable:* The difference between the current and previous year will be found, as those accounts receivable/payable from the last fiscal year will have been paid in the current fiscal year.
- *Owner/shareholder equity:* Will include the sum of all the equity over the previous years in the financial plan.
- *Retained earnings (net position):* Retained earnings will include the accumulation of retained earnings from the income statements, over the entire lifetime of the user. Thus, it will require the user to specify the retained earnings in prior years.

Cash flow module

- *Beginning cash:* The ending cash balance of the statement of cash flow of the previous year will be added to any cash that the user specifies, to become the beginning cash balance of the current year.
- *Accounts receivable/payable:* The difference between the current and previous year will be found, as those accounts receivable/payable from the last fiscal year will have been paid in the current fiscal year.

A very simple method of implementation for the financial plan was developed, whereby the user has to create a financial case for each of the years to be considered in the financial plan, according to the following steps:

1. Creating the yearly cases using the original ABS program.
2. Creating a financial case for the base (starting) year, which would require the most input.
3. Run the financial case analysis, to ensure that satisfactory performance is achieved.
4. Use the financial schemes of the base financial case as a template for the next years in the financial plan, making the relevant adjustments e.g. to simulate the start of a new capital project, or the purchase of a new asset.
5. Create each of the financial cases, by matching the yearly case scheme with the corresponding financial schemes.
6. Run the financial plan analysis, by choosing the combination of financial cases.
7. Make adjustments to the financial cases, as necessary, e.g. higher airport passenger charges.
8. Keep iterating until an optimal plan is found that is robust across various scenarios, i.e. various yearly case.

The aforementioned implementation is of a crude nature, since it is not very user-friendly. A proper implementation of the financial plan was deemed to be beyond the scope of this thesis project, as it will require a team of programmers, who will also need to upgrade the original ABS program. However, it was implemented in an Excel Model, and compared to real-world data, as a proof of concept (Sections 5.2 and 5.3). The author's envisioned additional capabilities for the financial plan are presented in Section 6.3.

4.10 Income statement

The income statement is a financial statement that attempts to obtain a reasonable estimate of how much of the company's revenues were retained as income throughout the accounting period (Pyles, 2014, pp. 30-31). The information from an income statement can be used in the financial plan analysis, to determine trends in the financial performance of the airport. It also provides information from various performance ratios. However, it is not able to depict the firm's overall financial condition, and it does not show what the firm owns, and owes, which is why a balance sheet is also presented (Section 4.11).

In the financial case analysis, the information used will be those gotten from the calculations of the individual years, with no possibility to consider the effects of the previous and past years. This will allow the user to be able to already determine if a financial case (yearly plan) is feasible when taken on its own, and already allows for a comparison between two different cases which represent different versions of the same financial year in question. It should be noted that different airports may have different fiscal years, which may not correspond to the calendar year, and so the user should be careful when this is the case, and adjust the yearly traffic estimations in the original ABS model accordingly.

The template of the income statement is shown in Table 4-9 below, along with the method used to calculate each value (or a reference to the equation that performs this). In addition to the absolute values in the income statement, a standardised column should be created in a future improvement of the model, to allow ease of comparison between financial cases (by determining each as a percentage of the total revenues).

Table 4-9: Income statement template

	Absolute value	Percentage value
i. Aeronautical revenues	(15)	
ii. Non-aeronautical revenues	(30)	
iii. Non-operating revenues	(40)	
iv. Total Revenues	i + ii + iii	100%
v. Operating costs	(57)	(v ÷ iv) × 100%
vi. EBITDA	iv – v	(vi ÷ iv) × 100%
vii. Depreciation costs	(58)	(vii ÷ iv) × 100%
viii. EBIT	vi – vii	(viii ÷ iv) × 100%
ix. Interest costs	(64)	(ix ÷ iv) × 100%
x. Taxable income	(65)	(x ÷ iv) × 100%
xi. Tax costs	(66)	(xi ÷ iv) × 100%
xii. Net income	x – xi	(xii ÷ iv) × 100%
xiii. Earnings per share	xii ÷ shares outstanding	
xiv. Shareholder dividends	(67)	(xiii ÷ iv) × 100%
xv. Retained earnings	xii – xiii	(xiv ÷ iv) × 100%

- EBITDA: Earnings before Interest, Taxes, and Depreciation and Amortisation
- EBIT: Earnings before Interest and Taxes

4.11 Balance-sheet statement

The balance sheet is a financial statement that summarizes a company's assets, liabilities, and equity at a specific point in time, and is one of the major financial statements used by accountants and business owners. It is useful in showing the net value of the business, how much of the loan debt is current, and provides the input for various ratios which can be used to analyse a firm. It is important to note that it does not show the income or expenses, the market value of assets, the quality of assets, contingent liabilities, and any operating lease obligations.

The template of the balance sheet statement is shown in Table 4-10, along with the method used to calculate each value (or a reference to the equation that performs this, or the subsection where an explanation can be found).

Table 4-10: Balance sheet template

	Value		Value
i. Cash	4.7.1	xiv. Accounts payable	(72)
ii. Accounts receivable	(68)	xv. Bonds Payable	4.7.2
iii. Other current assets	(69)	xvi. Current portion of long-term debt	4.7.2
iv Total current assets	(70)	**xvii. Total current liabilities**	(73)
v. Land	4.7.1	xviii. Bonds payable	4.7.2
vi. Infrastructure assets	4.7.1	xix. Loans payable	4.7.2
vii. Improvements	4.7.1	**xx. Total Long-Term liabilities**	(74)

	Value		Value
viii. Fixtures & equipment assets	4.7.1	**xxi. Total liabilities**	xvii + xx
ix. Intangible assets	4.7.1	xxii. Owners'/shareholders' equity	(75)
x. Other non-current assets	4.7.1	xxiii. Accumulated retained earnings	4.7.3
xi. Accumulated depreciation	4.7.1	**xxiv. Total Equity**	(76)
xii. Total non-current assets	(71)	**xxv. Total liabilities and equity**	xxi + xxiv
xiii. Total assets	iv +xii		

4.12 Statement of cash flows

The statement of cash flows complements the income statement and balance sheet. It analyses the changes in cash and cash equivalents over a period of time. It shows if the firm has enough money to cover daily expenses, pay its debts on time, and grow the business, without incurring an unsustainable negative cash flow. It does not show balances in assets, liabilities, and net worth, and depreciation of equipment.

According to the International Accounting Standards (IAS) 7 (Deloitte Global Services Limited, 2014d), cash flows during the period of reporting are classified according to the following:

- *Operating activities:* the main revenue-producing activities of the entity that are not investing or financing activities, and includes operating revenues and costs.
- *Investing activities:* the acquisition and disposal of non-current assets that are not considered to be cash equivalents.
- *Financing activities:* activities that alter the equity capital and borrowing structure (long-term liabilities) of the entity.

In order to determine the cash flow from asset purchases in the investing activities segment, it is assumed that any assets purchased will require a full payment at the time of acquisition. It will thus need to be financed using the retained earnings, or other means of financing, such as debt or equity. The cash payments towards capital project costs will be assumed to be paid in equal instalments over the construction period of the asset, according to equation (77), with the first instalment paid in the year that the construction commences.

$$CC = \sum_{i=1}^{n} \frac{Cost}{y_o - y_c} \tag{77}$$

With:

CC = capital project annual costs [¤]
n = number of capital projects, specified by user [-]
Cost = total cost of capital project [¤]
y_o = year of operational start [-]
y_c = year of construction start [-]

The *indirect method* of presentation is chosen for the statement of cash flow, to allow an accrual basis adjustment for net profit or loss, for the effects of non-cash transactions (accounts receivable and accounts payable). The template to be used for the statement of cash flows in shown in Table 4-11.

Table 4-11: Statement of cash flow template

	Inflow	Outflow
Cash flow from operating activities		
i. Operating revenues	(15) + (30)	
ii. Net accounts receivable	(68)	
iii. Operating costs		(57)
iv. Net accounts payable		(72)
v. Interest revenues	(31) + (38)	
vi. Interest costs		(64)
vii. Income taxes paid		(66)
vii. Net cash from operating activities		(i + ii + v) – (iii + iv + vi + vii)
Cash flow from investing activities		
viii. Acquisition/purchase of assets		Sum(Purchase Price)
ix. Purchase of debt or equity securities		Sum (Face value + Stock price)
x. Disposal/sale of assets	Sum (Salvage value)	
xi. Disposal/sale of debt or equity securities	Sum(Face value + Stock price)	
xii. Capital expenditure projects		(77)
xiii. Net cash from investing activities		(x + xi) – (viii + ix + xii)
Cash flow from financing activities		
xiv. Issuance of equity securities (stocks)	Sum (stock price × shares issued)	
xv. Issuance of debt securities	Sum(face value × bonds issued)	
xvi. Owners' equity contribution	Sum(EquityAmount)	
xix. Government grants	(39)	
xvii. Shareholders' dividends		(67)
xviii. Redemption of long-term debt (loan)		Sum(LoanPrincipalPayments + FaceValue)
xix. Net cash from financing activities		(xiv + xv + xvi + xix) – (xvii + xviii)
xx. Net change in cash		vii + xiii + xix
xxi. Beginning cash balance		Specified by user
xxii. Ending cash balance		xxi + xx

4.13 Performance indicators

There are a large number of performance measures in use by the aviation industry. Furthermore, different stakeholders place importance on different areas, and thus require different measures. Ratio analysis is a way of combining and comparing multiple pieces of information, to create a comparable analysis between two entities, which in this case would be the various financial cases and plans, in order to determine a good plan which is robust over a number of scenarios and assumptions (Pyles, 2014). It also provides a benchmark to compare the airport's future performance to its current performance, or to the performance of competitor airports. The performance measures were grouped into three main categories: i) operational indicators, ii) profitability ratios, and iii) liquidity ratios. They were only implemented in the Excel Model.

4.13.1 Operational indicators

- Arriving passengers
- Departing passengers
- Origin and destination passengers
- Transfer passengers
- Total passengers
- Total aircraft movements
- Total maximum aircraft MTOW

4.13.2 Productivity/efficiency ratios

These ratios are used to evaluate the productivity and efficiency of an airport's operations, and can be seen in Table 4-12 below.

Table 4-12: Productivity/efficiency ratios

Ratio	Calculation
Cost per passenger • Total cost • Operating cost • Employee cost	Cost ÷ number of passengers
Cost per aircraft movement • Total cost • Operating cost	Cost ÷ number of aircraft movements
Long-term debt per passenger	Long-term liabilities ÷ number of passengers

Source: Wyman (2012), Granberg and Munoz (2013, p. 4), Hazel, et al. (2011), Pyles (2014)

4.13.3 Profitability and market ratios

These ratios are calculated using information mostly derived from the income statement, as shown in Table 4-13.

Table 4-13: Profitability and market ratios

Ratio	Calculation
Revenue per passenger • Total revenue • Aeronautical revenue • Non-aeronautical rev	Revenue ÷ number of passengers
Aeronautical revenue per aircraft movement	Aeronautical revenue ÷ number of aircraft movements
Non-aeronautical revenue as percentage of total revenue	(Non-aeronautical revenue / total revenue) ×100
Concession revenue per passenger	(Concession revenue + retail revenue) ÷ number of passenger
EBITDA per passenger	EBITDA ÷ number of passengers
Profit margin	Net income ÷ total revenues
Return on assets	Net income ÷ total assets
Return on equity	Net income ÷ equity
Retention ratio	Retained earnings ÷ net income

Ratio	Calculation
Debt service coverage ratio	EBITDA ÷ (interest costs + principal payments + lease payments)
Debt to EBITDA ratio	Total liabilities ÷ EBITDA

Source: Wyman (2012), Granberg and Munoz (2013, p. 4), Hazel, et al. (2011), Pyles (2014)

4.13.4 Liquidity and asset utilisation ratios

These ratios are calculated mostly using information from the balance sheet.

Table 4-14: Liquidity and asset utilisation ratios

Ratio	Calculation
Current ratio	Current assets ÷ current liabilities
Cash ratio	Cash ÷ current liabilities
Total debt ratio	Total liabilities ÷ total assets
Debt-equity ratio	Total liabilities ÷ total equity
Equity multiplier	Total assets ÷ total equity
Time interest earned	EBIT ÷ interest costs
Cash coverage ratio	(EBIT + depreciation costs) ÷ interest costs
Total asset turnover	Total revenues ÷ total assets
Receivables turnover	(Aeronautical revenue + non-aeronautical revenue) ÷ accounts receivable
Working capital turnover	Total revenue ÷ (current assets – current liabilities)

Source: Wyman (2012), Granberg and Munoz (2013, p. 4), Hazel, et al. (2011), Pyles (2014)

4.14 Graphs

The purpose of this module will be to create graphs for the analysis of the financial plans. Graphs will enable the user to visualise the results of the ABS and the Financial Model, and decipher a trend over the time period in question. The graphs will be used to portray the time trends of the performance ratios presented in Section 4.12. They will also show the breakdown of certain elements. For example, the proportion of aeronautical revenues, non-aeronautical revenues, and non-operating revenues. It should be noted that the implementation of the graphs module has not been carried out in the Financial Model, since it was not considered an integral part of the Thesis Project. However, it should be implemented before being tested with users. For the purposes of this report, the Excel Model was used to create graphs. Future implementation should add this functionality to the ABS Financial Model.

5. Results

According to the Project Management Body of Knowledge (PMBOK) (Association for Project Management, 2000), verification and validation describes two independent procedures used for checking that a product, in this case the ABS Financial Model, meets certain specifications, and fulfils its intended purpose. On the one hand, verification is the evaluation of whether or not it complies with a regulation, requirement, specification, or imposed condition, is usually an internal process, and is concerned with the question: are we building the product right? Validation, on the other hand, is the assurance the ABS Financial Model meets the needs of the customer and other identified stakeholders, often involves acceptance and suitability with external customers, and is concerned with the question: are we building the right product? The verification and validation process is shown in Figure 5-1 below.

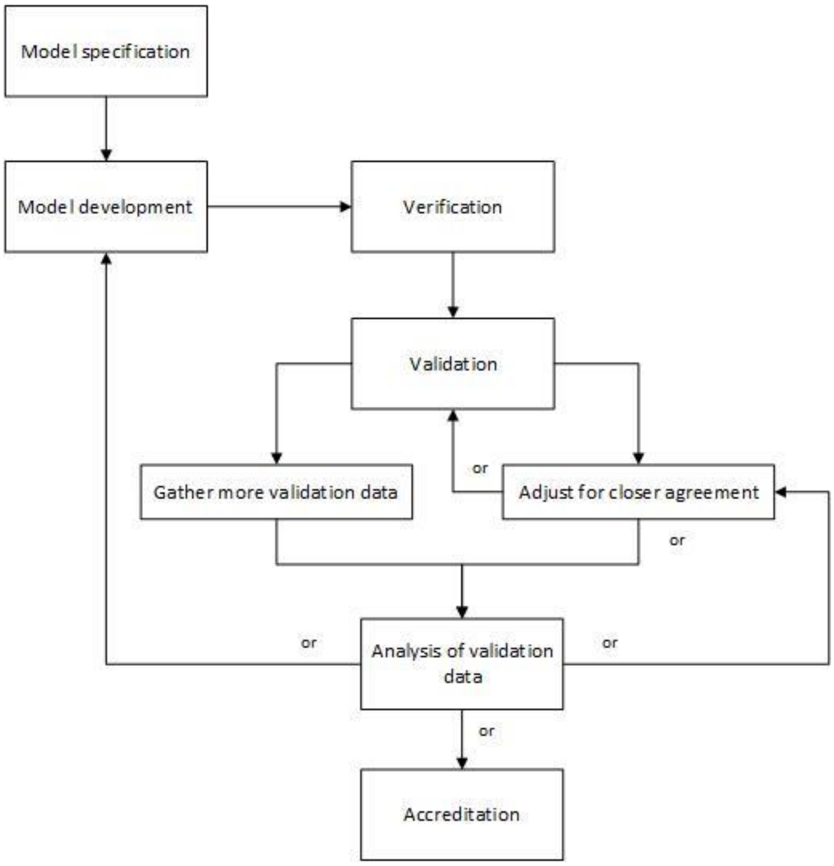


Figure 5-1: Verification and validation process

Source: adapted from MITRE (2015)

In order to carry out a verification and validation of the ABS Financial Model, the case study of Hartsfield-Jackson Atlanta International Airport (hereafter referred to by its IATA code: ATL) was utilised. This will be done by creating a base year for ATL in 2010, and modelling a period of a total of five proceeding years using the ABS, including that of 2010, which will then be verified using actual real-world historical data. Thus, the financial plan analysis will be for the 2010 – 2014 period. It should be noted that currently, there is no real-world data available for the 2014 fiscal year.

The layout of Chapter 5 is as follows. The characteristics of ATL that were used in the verification and validation of the model will be presented in Section 5.1, and the verification and validation of the results are discussed in Sections 5.2 and 5.3 respectively.

5.1 ATL characteristics

This section will present the data used to create a case for ATL, and run a simulation using both the original ABS program and the ABS Financial Model.

5.1.1 Introduction to ATL

ATL is owned and operated by the City of Atlanta through the Department of Aviation, and has been the busiest airport in the world by passenger traffic since 1998, and the busiest airport by number of aircraft movements since 2005. ATL serves 150 U.S. destinations and more than 75 international destinations in 50 countries (ATL, 2014a). It accommodated a total of over 911,000 aircraft movements, and almost 94.5 million passengers in 2013 (ATL, 2014b), averaging more than 250,000 passengers and 2,500 aircraft movements daily (ATL, 2014a). According to a comprehensive ranking of global airports, it has also been ranked the most efficient airport in the world in terms of operational and management efficiency, and cost competitiveness for the past 11 years (Williams, 2014).

It is for these reasons that the ATL Airport is used as a test case, in order to ensure that the model is able to deal with any discrete math issues inherent at the extremes, such as overflow of variables, and to ensure that the upper limits in the data validation safeguards are valid.

It should be noted that for the purposes of the ABS Financial Model, the fiscal year of ATL is from July 1st to June 30th of the next year. It will be assumed that this will correspond to the calendar year that the fiscal year ends in, and that any deviations in airport performance figures will be negligible. This is because the performance values presented in the airport's financial reports will be used for validation, as these correspond to the fiscal year. Finally, since the airport is publicly owned, there will be no possibility to finance the airport using equity. Otherwise, the airport is run as a stand-alone, self-supporting business entity (ATL, 2010).

5.1.2 Flight schedule

The flight schedule contains the details of the aircraft operations for the peak day of interest. In order to build the flight schedule, an OAG (previously known as Official Airline Guide) Schedule for Atlanta Airport for 2010 was imported into the ABS. Information found on the SkyVector Website (2014) was used to replace missing airports in the database with nearby airports (see Table 5-1) which were similar in characteristics, although LZU could not be replaced due to a persistent error in the database.

Table 5-1: Replacement of airports in ABS

Replace	With
BKG Branson Airport	SGF Springfield-Branson National Airport
LZU Gwinnett County Airport	PDK DeKalb–Peachtree Airport

Information contained in the Airline Codes website (Airline Codes, 2015) was used to replace the IATA aircraft type codes in the OAG schedule with the aircraft manufacturer model numbers present in the ABS database (see Table 5-2), and an effort was made to find the closest replacement if the original was not available in the database.

Table 5-2: Replacement of aircraft in ABS

IATA - ABS	IATA - ABS	IATA - ABS	IATA - ABS	IATA - ABS
318 - A318	733 - B737300	752 - B757300	CR9 - CRJ700	M11 - MD11
319 - A319	734 - B737400	757 - B757300	CRA - CRJ100	M80 - MD81
320 - A320	735 - B737500	763 - B767300	CRJ - CRJ200	M83 - MD83
321 - A321	738 - B737800	764 - B767400	E70 - EMB170	M88 - MD88
332 - A330200	73G - B737700	767 - B767200	E75 - EMB170	M90 - MD93
333 - A330300	73H - B737800	772 - B777200	E90 - EMB190	PAG - CNA
343 - A340300	73W - B737700	777 - B777300	ER4 - EMB145	SF3 - S360
346 - A340600	744 - B747400	77L - B777300	ERD - EMB145	
717 - B717	74F - B747400	CR7 - CRJ700	ERJ - EMB135	

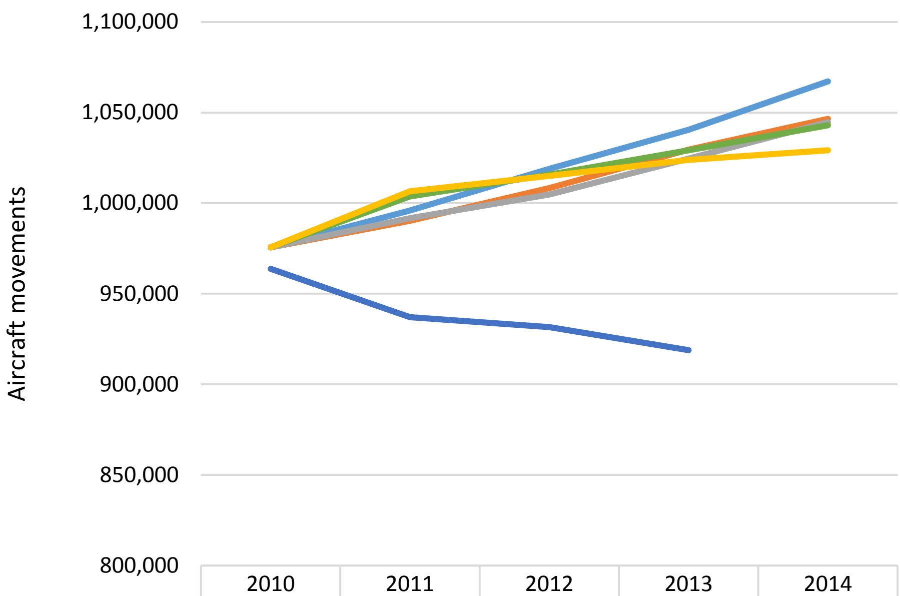
Source: Arline Codes (2015)

Table 5-3 shows the settings used to create the flight schedules for the next four years. In order to arrive at the passenger growth rate, the average real world growth rate was calculated. It should be noted that when the real-world growth rates were used, the trend produced by the ABS and Financial Model closely resembled the real-world situation. However, in order to produce a realistic run where the performance data of the proceeding years was not known, a uniform growth rate across all the years was chosen.

The aircraft growth refers to the part of the growth used for replacing aircraft in the base schedule with larger aircraft (Wijnen, Roling, & Heblij, 2006), and was set at 100%. It was not possible to choose a number larger than 100%, although this was the real-world situation since ATL experienced an increasing number of passengers, but a decreasing number of aircraft movements. Thus, this is one shortcoming of the original ABS where this kind of situation cannot be modelled. The use of a value of 100% means that there will be the minimum increase in aircraft movements, as the increase in passengers will be accommodated by an increase in aircraft size. The effects on aircraft growth rate is shown in Figure 5-2 on the next page. From the graph, although the 100% growth rate gives the highest initial growth rate, this eventually tapers out. Further investigation is needed to determine the reason for this anomaly in higher aircraft growth percentages. However, even with a 100% aircraft growth rate, the real-world conditions were not able to be replicated. This should be kept in mind when analysing the financial performance produced by the Financial Model, as it will help to explain any discrepancies.

Table 5-3: Flight Schedule Editor

Value	Base - 2010	2011	2012	2013	2014
Source	OAG 2010 schedule	Base - 2010	2011	2012	2013
Design day	15^{th} peakday	n/a	n/a	n/a	n/a
Pax growth [%]	n/a	2.5	2.5	2.5	2.5
Freight growth [%]	n/a	0	0	0	0
Growth type	Normal	Normal	Normal	Normal	Normal
Years	n/a	1	1	1	1
AC growth [%]	n/a	100	100	100	100



	2010	2011	2012	2013	2014
0 Percent	975,528	995,976	1,018,893	1,040,399	1,067,193
25 Percent	975,528	990,335	1,008,315	1,029,469	1,046,392
50 Percent	975,528	991,745	1,004,791	1,024,533	1,044,629
75 Percent	975,528	1,003,733	1,015,719	1,029,117	1,042,866
100 Percent	975,528	1,006,553	1,015,014	1,023,828	1,029,117
Real-World	963,806	937,104	931,554	918,757	

Year

Figure 5-2: Aircraft growth percentages

5.1.3 Runways

The runway configuration in the ABS consists of one or more runways, and the types of operations to be carried out (arrival, departure, or both). The runway configuration influences the airside capacity and delay figures, by determining the legal capacity of the runway configuration using FAA guidelines through the ABS' use of the Upgraded FAA Airfield Capacity Model.

The runway configuration in ATL consists of five parallel runways, with two independent sets of dependent pairs (Runways 8L-26R and 8R-26L, and Runways 9L-27R, and 9R-27L), and a single independent runway (10-28), all oriented in the east-west direction. All runways can accommodate aircraft up to Airplane Design Group (ADG) V, while only one of them (9L-27R) can accommodate ADG VI aircraft (Airbus A380). Although the runway configuration of ATL could be imported from the INM model in the ABS, it was outdated and did not include the 5th runway (10-28) which was completed in 2006.

Runway 9L/27R was lengthened by 153 metres to the east in July 2012. Although this extension is expected to reduce payload restrictions, it is not expected to increase capacity. In the ABS, it was not possible to specify a different runway length for 2013 - 2014, as this would change the runway length of the 2010 - 2012 situation. For these two reasons, the runway extension was not implemented in the ABS. This increase in total runway length will thus not be reflected in the calculation of the runway maintenance and utility costs. A summary of the information used to create the runway configuration can be found in Table 5-4. In the ABS, counter runways were created for each of the five runways, to allow for operations in the opposite direction on the runway.

Table 5-4: Runway configuration

Runway	Length (m)	Width (m)	Firefighting category – ADG	x-coordinate [m]	y-coordinate [m]
08L-26R	2,743	46	III – V	820	3,254
08R-26L	3,048	46	II – V	881	2,948
09L-27R	2010: 3,624 2013: 3,777	46	I – VI	8	1,605
09R-27L	2,743	46	III – V	8	1,283
10-28	2,743	46	II – V	0	0

Source: ATL (2014a)

The x- and y-coordinates of the runways' western ends were determined using GPS coordinates found on the AirNav.com website (AirNav LLC, 2015), with the western end of runway 10-28 serving as the origin. These were then converted to a distance values using an online GPS coordinate-to-distance converter (Veness, 2014). The runways all have a heading of 90 degrees, since they are in an east-to-west configuration. When visually compared with the ATL Airport Plan, shown in Figure 5-3 (a more detailed plan can be found in Figure F-1 in 0), it was found to be satisfactorily equivalent, in terms of the scale and distances.

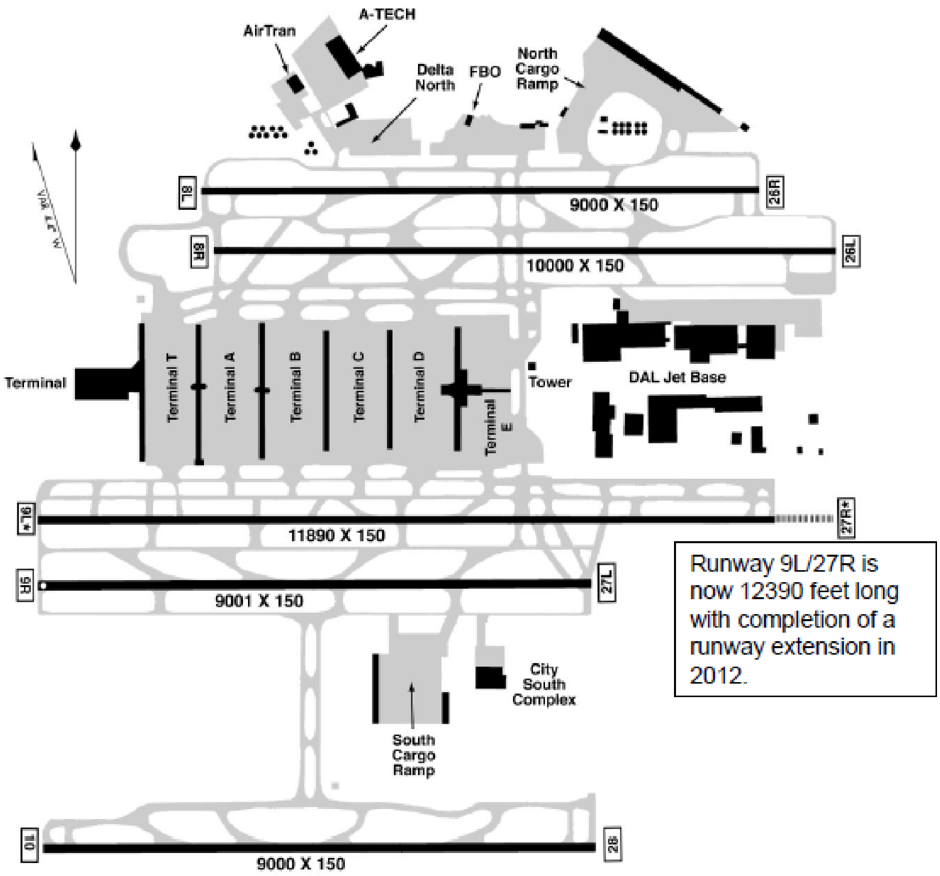


Figure 5-3: ATL Airport Plan 2010

Source: FAA (2014b)

5.1.4 *Weather and yearly case*

The weather effects considered by the ABS only include visibility and cloud base, and these have an important effect on runway capacity. Therefore, the user has the ability to select the weather that will be used to perform capacity calculations, and is applicable for the entire day. There are four major weather conditions experienced at ATL, due to distinct operational differences in runway configurations, and these are displayed in Table 5-5 below for the Fiscal Years 2009 and 2010. Runway 28/10 is used according to arrival/departure priority, thus in the ABS, it will be assigned the strategy of *mixed mode* operations. These will serve as the basis for defining the runway configurations, and the proportion of peakday cases to create the yearly case. It should be noted that for the purposes of the ABS, only three distinctions will be made between Visual Meteorological Conditions (VMC), Instrument Meteorological Conditions (IMC) 1 and IMC 2. It will be assumed that the same configuration and weather applies for the entire day, while the effects of weather will be reflected when defining the composition of peakday cases to make up the yearly case. Finally, the same runway, weather, and yearly configurations will be used for all five years, as it can be assumed that the average weather conditions will not vary significantly.

Table 5-5: Occurrence of weather at ATL (2009 – 2010)

ABS/ICAO classification	VMC		IMC 1	IMC 2
ATL classification	Visual	Marginal	Instrument	Low instrument
Occurrence [%]	88		7	5
Ceiling [m]	>1,097	305 < c < 1,097	152 < c < 305	<152
Visibility [km]	11.3	4.8 < v < 11.3	1.6 < v < 4.8	<1.6
Arrival runways	26R, 27L (28)		8L, 9R (10)	
Departing runways	26L, 27R (28)		8R, 9L (10)	
Capacity rate [/hr]	216 - 226	201 - 208	175 - 190	168 - 169
ABS spacing strategy	Near		Medium	Far

Source: (FAA, 2014a)

5.1.5 Terminals

The layout of the terminal buildings (Figure 5-3) defines the landside capacity of the airport, and so it is important to model this to match the real-life airport conditions as closely as possible. The user has the option of defining the terminal setup, and the terminal parameters. The terminal setup is related to the physical characteristics of the airport, while terminal parameters define the performance characteristics of the airport.

Due to a lack of information, the default values were used for the terminal parameters. For terminal parameters, the ATL Airport Diagram (FAA, 2014b) was used to estimate the overall terminal dimensions, since the runway lengths were known, while the terminal maps (ATL, 2015a) of the domestic and international terminals were used to estimate dimensions within the terminal buildings, such as queuing areas. An overview of the estimated values that were input into the ABS Terminal Editor are shown in Table 5-6. It should be noted that the domestic terminal has only one level which are used for both arrivals and departures, while the international terminal has a separate level for arrivals and departures, and this will be represented accordingly. The total area of the departures hall will be divided evenly between arrivals and departures. Since information could not readily be found, it was assumed that arrival and departure passport controls are evenly split, while security and customs controls are double the number of the departures and arrivals passport controls, respectively. The gross terminal area cannot be individually altered depending on the year in question, and so the gross area in 2010 is used throughout the period of consideration. Thus, the effects of any runway or terminal expansion cannot be analysed due to some shortcomings of the original ABS.

Table 5-6: Terminal setup

	2010	2013
Departure Curb side [m]	280	476
Departure hall [m^2]	23,503	28,987
Check-in Queuing Area [m^2]	74,915	80,355
Check-in Desks [-]	124	209

	2010	2013
Departure Passport Controls [-]	13	20
Security Controls [-]	26	40
Departure Lounges [m^2]	25,000	28,000
Arrival Passport Queuing Area [m^2]	4,273	5,698
Arrival Passport Controls	12	19
Baggage Reclaim Area [m^2]	8,454	13,310
Baggage Devices WB [-]	7	10
Baggage Devices NB [-]	10	14
Arrival Customs Queuing Area [m^2]	4,273	5,698
Customs Desks [-]	24	38
Arrival Hall [m^2]	23,503	42,305
Arrival Curb side [m]	280	476
Total Terminal Area [m^2]	526,091	647,497

Source: ATL (2014b) and (2015a; ATL, 2015b)

5.1.6 FAA dataset

The parameters for the airfield capacity model can be selected using the FAA dataset. For this project, FAA set 1 was chosen with its default values.

5.1.7 Revenues

The revenue editor is used to enter information defining the various operating revenue sources an airport has. A summary of the information used is shown in Table 5-7 and Table 5-8. Passenger service charges are collected in the form of Passenger Facility Charges (PFCs). Landing fees can be collected in three forms: i) basic landing fees; ii) Airfield Improvement Program (AIP) fees; and aircraft parking fees. Signatory airlines account for 98.7% of all aircraft landed weight at ATL in 2010, and so the rates applied to non-signatory airlines were ignored due to their insignificant contribution. For convenience, the same revenue scheme will be used for all the years in the financial plan analysis.

Table 5-7: Aeronautical revenues

	2010
Passenger service charge for O&D pax [$/pax]	4.5
Passenger service charge for transfer pax[$/pax]	4.5
Both arriving and departing pax charged	Departing
Handling charge for O&D pax [$/pax]	0
Handling charge for transfer pax [$/pax]	0
Ratio of pax handling activities contracted out [-]	1.00
Concession fees for pax handling as ratio of revenues	0
Catering charge per departing pax [$/pax]	0
Ratio of catering activities contracted out [-]	1.00
Concession fees for catering as ratio of revenues [-]	0
Aircraft landing (and takeoff) charge [$/t]	2.01
Which A/C are charged	Landing
Hourly parking charge [$/t/hr]	0.14
Average parking time charged [hrs]	2
Aircraft handling fee [$/tonne]	1.12
Ratio of aircraft handling activities outsourced [-]	1.00
Concession fees for aircraft handling as ratio of revenues [-]	0.05
Fuel revenues [$]	5,615,361
Other aeronautical revenues [$]	9,356,617

Source: ATL (2010)

Average spending per departing passenger at ATL was $7.15 in 2007 (Jacobs Consultancy, 2015). The average car parking hourly fee for was determined based on the pricing and composition for the various car parking categories (ATL, 2015c). Rents were estimated using the information found in the 2010 Annual Report (ATL, 2010).

Table 5-8: Non-aeronautical revenues

	2010
Average spending of origin and destination pax [$/pax]	7.15
Average spending of transfer pax [$/pax]	7.15
Ratio of leisure pax [-]	0.6
Ratio of retail revenues contracted out [-]	1.00
Concession fees for retail activities as a ratio [-]	0.12
Number of parking spaces [-]	33,787
Average occupancy rate as a ratio [-]	0.75
Hourly fee [$/hr]	0.43
Ratio of car parking contracted out [-]	0
Concession fees for car parking as a ratio [-]	1
Concession fees from public transportation [-]	38,977,667
Retail space rented out [m^2]	21,554
Retail space rent [$/m^2]	0
Office space rented out [m^2]	404,686
Office space rent [$/m^2]	232
Equipment rental [$]	0
Services provided [$]	0
Advertising revenues [$]	54,000
Other non-aeronautical revenues [$]	17,565,440

Source: ATL (2010)

5.1.8 Costs

The cost editor is used to specify the operating costs (Table 5-9), depreciation (Table 5-10), and capital costs (Table 5-11) that an airport incurs. Terminal utilities and maintenance were assumed to be 60% of the total, runway utilities and maintenance were assumed to be 30% of the total, while other utilities and maintenance were assumed to be 10% of the total. Since the airport is government-owned, it does not pay any corporate income tax. The discount interest rate was set to the value of the US Central Bank's discount rate (CIA, 2015).

Table 5-9: Operating costs

	2010
Personnel costs [$]	90,912,000
Costs of services [$]	15,550,000
Corporate income tax rate [%]	0
Discount interest rate [%]	0.5
Utilities - Terminal buildings [$]	5,052,000
Utilities - Runways [$]	2,526,000
Utilities - Other [$]	842,000
Maintenance - Terminal buildings [$]	49,476,600
Maintenance - Runways [$]	24,738,300
Maintenance - Other [$]	8,246,100
Other - Administration costs [$]	0
Other - Cost of supplies [$]	4,164,000

	2010
Other - Cost of insurance [$]	0
Other - Other operating costs [$]	8,662,000

In order to determine the depreciation costs, a number of simplifying assumptions were made. For all assets owned by the airport before 2010, a simplifying procedure was used by lumping them into three distinct groups, and applying the same rate of depreciation to every item in that group. The assets to be included in later years were also included. An estimation of the depreciation information used in the test case is shown in Table 5-10, since detailed information could not be obtained. A verification of this method proved that it produced a depreciation and amortisation cost in 2010 similar to the real-world value.

Table 5-10: Depreciation costs

Asset	Type of asset	Year	Lifetime [years]	Purchase price [$]	Salvage value [$]
Runways, taxiways & other improvements	Airside	2000	25	2,517,187,000	63,257,000
Terminal, buildings & structures	Landside	2000	25	2,280,207,000	698,162,000
Other property & equipment	Equipment/ machinery	2000	20	159,285,000	1,283,000

Source: (ATL, 2010)

In 1999, the Airport completed its master planning process, which included a number of major projects that would allow the airport to expand to meet the increasing demand for air travel and ultimately reduce the strain it would have on existing facilities and infrastructures. The following is a list of these capital expenditure projects, some of which are still currently in construction (ATL, 2015d):

- May 2006 (FY 2006): Runway 10-28
- December 2009 (FY 2010): Consolidated Rental Car Agency Centre
- December 2009 (FY 2010): ATL SkyTrain
- May 2012 (FY 2012): Maynard H. Jackson Jr. International Terminal
- July 2012 (FY 2013): Extension of runway 09L-27R by 152 meters
- January 2015 (FY 2015): Inbound roadway improvements
- Est. Spring 2015 (FY 2015): Concourse C mid-point expansion and renovation
- Est. November 2015 (FY 2016): New Cargo warehouse C (128,566 gross square feet)

For the purposes of this test run, only the two capital expenditure projects shown in Table 5-11 will be considered. The salvage value was calculated using the same percentage used to define the depreciation costs of the corresponding asset category in Table 5-10.

Table 5-11: Capital projects

Project/Asset	Type	Constr. start	Oper. start	Lifetime [years]	Project cost [$]	Salvage value [$]
International terminal	Landside	2007	2012	25	1,508,000,000	461,724,877
Runway 09L-27R extension	Airside	2011	2013	25	40,000,000	1,005,201

5.1.9 Balance sheet items

Balance sheet items can be categorised into assets, liabilities, and equity. The capitalisation threshold (i.e. the amount paid for an asset, above which an entity records it as a long-term asset, and below which it is charged as an expense to the period incurred) at ATL is $5,000.

With regards to ATL's assets, only the categories of cash, accounts receivable, and land, were deemed relevant. ATL has an investment policy to minimize the inherent risks associated with deposits and investments, thus choosing to restrict investments to discount notes and fixed rate securities with a fixed principal repayment amount, which are current in nature (maturing within a year). This makes them similar to cash investments, so they can be satisfactorily represented with a certain rate of interest. The average maturity of these investments is six months (ATL, 2010). An overview of the information used is shown in Table 5-12. However, for the purposes of this calculation, a lifetime of ten years is assumed.

Table 5-12: Assets

Cash	**Year of deposit**	**Amount of cash [$]**			
End of 2009	2010	104,774,000			
Cash investment	**Year of deposit**	**Lifetime [years]**	**Amount of cash [$]**	**Interest rate [%]**	**Compounding periods/year**
2009 Investment	2009	10	1,237,569,686	0.81	1
2010 Investment	2010	10	-271,098,000	0.81	1
2011 Investment	2011	10	563,084,000	0.81	1
2012 Investment	2012	10	138,175,000	0.81	1
2013 Investment	2013	10	111,844,000	0.81	1
2014 Investment	2014	10	271,034,333	0.81	1
Accounts receivable (AR)	**Credit (months)**	**AR provision (%)**	**Monthly interest (%)**	**Bad debt provision (%)**	
2010 Accounts receivable	3	2.22	0.00	0.86	
Land	**Year of purchase**	**Ownership [years]**	**Purchase price [$]**	**Sale price [$]**	
2010 Land	2000	50	583,067,000	583,067,000	
2010 Noise abatement	2000	50	265,104,000	265,104,000	

The interest rate for accounts receivables was found using the investment income of $26,731,000, and the amount of cash held in the pooled investment fund of $442,954,000 (ATL, 2010). However, the amount of cash was that amount listed as being the cash and cash equivalents at the beginning of 2010 (ATL, 2010).

The large financing amounts required by ATL makes the use of traditional bank loans impractical. As a government-owned enterprise, the issue of equity in the form of stocks is also not an option. For this reason, consideration of equity is not applicable for the case of ATL. ATL relies primarily on the issue of commercial notes for short-term loans, and bonds for long-term loans. Commercial papers issued by ATL have a maturity of a maximum of 270 days, but for the purposes of the ABS, it will be given a value of one year. Bonds can take one of three forms, which denote the revenue source used to secure the bonds:

- General Revenue bonds
- PFC Subordinate Revenue Bonds
- Customer Facility Charge Bonds

The only information available was that of the grants received, and the bonds issues. It should be noted that the bond face value was assumed to be $1000. Since serial bonds are not able to be calculated in the Financial Model, they were treated as term bonds, and the average of the coupon rate range was used. Bonds with a variable interest rate were ignored, since a coupon rate was not specified. This will undoubtedly produce some deviations from the real-world values.

Table 5-13: Liabilities and equity

Accounts payable (AP) name	Credit [months]	AR provision (%)	Interest (%)		
2010 Accounts payable	3	3.57	0		
Grants name	**Year**	**Payment [years]**	**Amount [$]**		
2010 Grant	2010	0	17,151,000		
2011 Grant	2011	0	48,400,000		
2012 Grant	2012	0	29,379,000		
2013 Grant	2013	0	40,076,000		
Bonds	**Year of issue**	**Years to maturity**	**Face value [$]**	**Coupon rate [%]**	**No. of bonds issued**
Series 2000A,B,C	2001	21	1,000	5.50	506,160
Series 2003RF-A	2004	10	1,000	4.75	18,570
Series 2003RF-D	2004	15	1,000	4.82	90,645
Series 2004A	2005	28	1,000	5.13	164,165
Series 2004B	2005	28	1,000	5.25	58,655
Series 2004F,G	2005	24	1,000	4.63	128,465
Series 2004C	2005	28	1,000	5.00	293,070
Series 2004J	2005	24	1,000	4.63	235,860
Series 2006A	2007	24	1,000	5.73	196,345
Series 2006B	2007	24	1,000	4.35	20,000
Series 2010A	2011	30	1,000	4.81	177,990
Series 2010C	2011	20	1,000	5.63	488,835
Series 2010B	2011	15	1,000	3.50	385,420
Series 2011A,B	2012	19	1,000	4.50	417,325
Series 2012A, B, C	2013	20	1,000	3.50	473,010
Accumulated earnings	**Year**	**Amount [$]**			
Net position 2009	2010	4,014,816,000			

5.1.10 Financial case

A separate financial case was created for each of the years between 2010 and 2014, to take into effect the different yearly cases from the original ABS. However, it should be noted that the results for these will be different from those calculated in a financial plan, which takes into account the effects of the previous years, and not just a standalone year. The financial cases were created in both the ABS Financial Model and Excel Model.

5.1.11 Financial plan

Ideally, the financial plan should be created using the financial cases from 2010 to 2014. However, this was only done in the Excel Model, and not in the ABS Financial Model, due to complexity issues and time constraints.

5.2 Verification

Verification is the process of determining whether a model implementation and its associated data accurately represent the developer's conceptual description (Department of Defense, 2009). It is an iterative process whose aim is to determine whether each step in the development of the simulation model fulfils the requirements imposed by the previous phase, and is internally complete, consistent, and correct enough to support the next phase (MITRE, 2015). It should be noted that in order to conduct a fair verification, especially with regards to the design analysis, the test case of ATL airport was only chosen after the design and implementation of the Financial Model was completed. This was done to ensure that a truly generic model was created which would be able to suit most airport situations, rather than designing a model that was tailored to the situation at ATL, which would create a bias for the design analysis.

The following verification methods were used:

- *Testing:* unit test, integration test, system test.
- *General analysis:* consistency checking, style checkers, robustness analysis (crash-proof).
- Design analysis
- Specification analysis

5.2.1 Testing

Testing refers to the verification of the accuracy of the model, with regards to the results calculated. The tests carried out can be classified as follows:

1. *Preliminary testing:* to ensure that the program did not crash, or produce run-time errors, or any other obvious types of errors.
2. *Accuracy testing:* to compare the results gotten from the Financial Model, with the expected results. This was mainly done using an Excel Model, and in some instances, hand calculations.
3. *Boundary testing:* tests were run using the minimum and maximum allowable values, in order to test that the program performed as expected at these extremes.

Initially, the use of the decimal data type produced problems in the Microsoft Access database, since only a certain precision and scale could be specified. It was decided to change the data type to the floating point type, which would not have the same issue. However, the use of the single data-type was found to produce inaccurate results due to rounding errors, albeit with a slight improvement in performance (faster speed in calculations). In order to remedy this problem, values were stored as single in the database, and were converted back to decimal before being used in calculations, which led to more accurate results. However, since the single data-type could only hold seven significant figures, some accuracy was lost in the results, which explains a slight deviation between the results of the Financial Model and the Excel Model. However, this loss in accuracy was deemed to be acceptable, as the aim of the Financial Model was to provide a basis for comparison of various decision's on an airport's financial performance, rather than determining financial forecasts to a high degree of accuracy. The results of the testing carried out for each module is explained in further detail below.

Project Selection

This was tested by checking the information displayed by the ABS Main Screen in the *Project* group-box. Different project folder locations were chosen, to ensure that the right database was being connected to. The database file was checked to ensure that the correct tables and columns were created, with the intended data-type.

Editors

The behaviour of the editor forms was initially found to have a number of bugs. For example, a save operation, with empty controls for which the user had not supplied any input, was found to cause a null exception error at a later point, when calculations were attempted. Other fixes were made to ensure that the user inputs were being saved in their intended columns and tables.

Yearly case module

Testing for this class was challenging due to the need to manipulate of a lot of data from the OAG schedule. Verification was limited to a superficial level. For example, the number of aircraft movements in a peak day case was compared to that in the database. Verification was combined with validation, since it would be very time-consuming to carry out all the required calculations manually, since it involved thousands of records. Thus, the results produced by the Yearly Case was compared with real-world data (see Subsection 5.3.2), and found to be satisfactory.

The results were initially found to be much higher than the real-world data. However, it was found that hourly time periods in the MS Access database tables were specified according to 15 minute increments, resulting in each aircraft being counted four times. The selection algorithm was modified to only include hourly time periods, e.g. 12:00 – 13:00, which remedied this problem, and the results are shown in Table 5-14 below.

Table 5-14: Yearly case module results (ABS Financial Model)

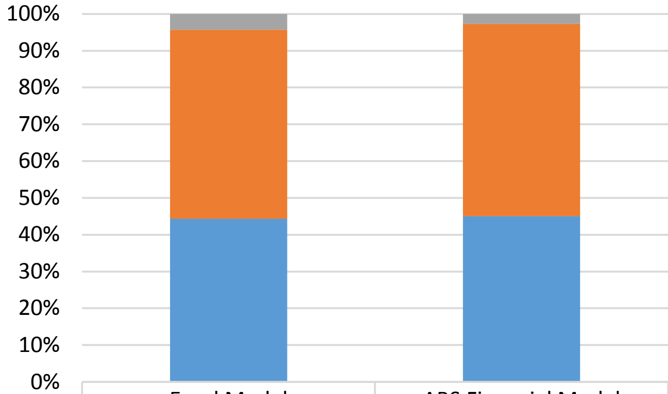
	2010	2011	2012	2013	2014
Area of terminal buildings [m^2]	526,091	526,091	526,091	526,091	526,091
Runway length [m]	14,901	14,901	14,901	14,901	14,901
Total passengers	87,850,382	89,840,216	92,010,915	94,113,220	96,003,633
Arrival passengers	44,088,776	45,020,587	46,065,216	47,056,610	47,931,305
Departing passengers	43,761,606	44,819,629	45,945,699	47,056,610	48,072,328
O&D passengers	63,462,187	64,676,396	66,635,560	68,517,515	70,275,720
Transfer passengers	24,388,195	25,163,820	25,375,355	25,595,705	25,727,913
Arriving transfer passengers	12,251,388	12,621,573	12,718,526	12,824,293	12,894,805
Arriving O&D passengers	31,837,388	32,399,014	33,346,690	34,232,317	35,036,500
Departing transfer passengers	12,136,807	12,542,247	12,656,829	12,771,411	12,833,108
Departing O&D passengers	31,624,799	32,277,382	33,288,870	34,285,199	35,239,220
Total aircraft movements	975,528	1,006,553	1,015,014	1,023,828	1,029,117
	2010	2011	2012	2013	2014
Arriving aircraft	487,764	503,276	507,508	511,914	514,558
Departing aircraft	487,764	503,276	507,508	511,914	514,558
Total A/C MTOW [tonne]	31,083,268	38,053,151	41,002,838	44,031,486	45,944,293

Revenue module

The results for the revenue calculations, according to the Excel Model are shown in Table 5-15. Since the implementation of the financial plan was lacking, only the results of the financial case produced by the ABS Financial Model was verified, as shown in Figure 5-4. It is evident that the results closely matched each other.

Table 5-15: Revenue module results (Excel Model)

[All values in $]	2010	2011	2012	2013	2014
Passenger based revenues	196,927,227	201,688,331	206,755,646	211,754,745	216,325,476
Aircraft based revenues	66,829,026	81,814,275	88,156,102	94,667,695	98,780,230
Revenue from fuel	5,615,361	6,874,508	7,407,385	7,954,527	8,300,086
Total other aeronautical revenues	14,971,978	16,960,751	17,908,433	18,874,404	19,533,579
Total aeronautical revenues	278,728,231	300,463,356	312,820,181	325,296,844	334,639,285
Retail revenues	0	0	0	0	0
Car parking revenues	95,517,032	95,517,032	95,517,032	95,517,032	95,517,032
Concession revenues from outsourcing	116,093,958	118,191,549	120,219,191	122,192,573	123,921,665
Real estate revenues	93,887,152	93,887,152	93,887,152	93,887,152	93,887,152
Total other non-aeronautical revenues	17,619,440	17,741,406	17,859,440	17,974,334	18,075,061
Total non-aeronautical revenues	323,117,581	325,337,138	327,482,814	329,571,091	331,400,909
Interest from accounts receivable	0	0	0	0	0
Interest from investments	10,024,314	7,891,831	12,516,735	13,737,338	14,754,547
Income from grants and subsidies	17,151,000	48,400,000	29,379,000	40,076,000	33,751,500
Total non-operating revenues	27,175,314	56,291,831	41,895,735	53,813,338	48,506,047
Total revenues	629,021,127	682,092,325	682,198,730	708,681,272	714,546,240



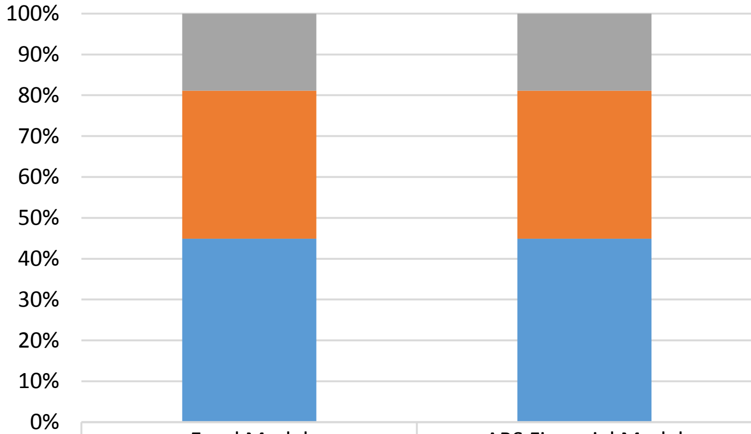
	Excel Model	ABS Financial Model
Non-operating revenues	$27,175,314	$17,151,000
Non-aeronautical revenues	$323,117,581	$323,063,600
Aeronautical revenues	$278,728,231	$278,728,200

Aeronautical revenues   Non-aeronautical revenues   Non-operating revenues

Figure 5-4: Verification – 2010 Revenues

Cost module

The Excel Model's results for the cost module can be seen in Table 5-16, while a verification of the ABS Financial Model's results is shown in Figure 5-5. As can be seen, the results of the two models are quite similar, with the slight deviations explained by rounding errors.



	Excel Model	ABS Financial Model
Dividend costs	$0	$0
Tax costs	$0	$0
Interest costs	$88,233,332	$88,233,300
Depreciation costs	$169,339,100	$169,339,100
Operating costs	$210,169,000	$210,169,000

Operating costs   Depreciation costs   Interest costs   Tax costs   Dividend costs

Figure 5-5: Verification – 2010 Costs

Table 5-16: Cost module results (Excel Model)

[All values in $]	2010	2011	2012	2013	2014
Personnel costs	90,912,000	92,971,180	95,217,529	97,393,100	99,349,395
Cost of services	15,550,000	15,902,212	16,286,437	16,658,557	16,993,170
Total cost of utilities	8,420,000	8,420,000	8,420,000	8,420,000	8,420,000
Total cost of maintenance	82,461,000	82,461,000	82,461,000	82,461,000	82,461,000
Lease costs	0	0	0	0	0
Administrative costs	0	0	0	0	0
Costs of supplies	4,164,000	4,214,881	4,270,387	4,324,144	4,372,483
Costs of insurance	0	0	0	0	0
Total other operating costs	12,826,000	12,982,725	13,153,695	13,319,278	13,468,172
Total operating costs	210,169,000	212,737,117	215,538,661	218,251,935	220,691,737
EBITDA	418,852,127	469,355,208	466,660,069	490,429,338	493,854,503
Depreciation from cap. projects	0	0	0	29,893,575	31,007,712
Total depreciation costs	169,339,100	169,339,100	169,339,100	199,232,675	200,346,812
EBIT	249,513,027	300,016,108	297,320,969	291,196,663	293,507,691
Interest costs accounts payable	0	0	0	0	0
Interest costs from bonds	88,233,332	88,233,332	137,805,762	156,585,387	173,140,737
Interest costs from loans	0	0	0	0	0
Total interest costs	88,233,332	88,233,332	137,805,762	156,585,387	173,140,737
Taxable income	161,279,695	211,782,776	159,515,207	134,611,276	120,366,955
Taxes	0	0	0	0	0
Net income	161,279,695	211,782,776	159,515,207	134,611,276	120,366,955
Earnings per share	0	0	0	0	0
Shareholder dividends	0	0	0	0	0
Retained earnings	161,279,695	211,782,776	159,515,207	134,611,276	120,366,955

Balance sheet module

The results of the balance sheet module, as calculated by the Excel Model, are presented in Table 5-17. For convenience, the following entries with zero values, were not included in Table 5-17:

- Other current assets (current assets)
- Intangible assets (non-current assets)
- Current portion of long-term debt (current liabilities)
- Loans payable (long-term liabilities)

Table 5-17: Balance sheet module results (Excel Model)

Assets [$]	2010	2011	2012	2013	2014
Cash amount	104,774,000	-97,671,507	490,618,442	1,185,812,814	1,254,181,828
Accounts receivable	6,886,071	7,211,855	7,409,089	7,607,172	7,759,115
Total current assets	111,660,071	-90,459,652	498,027,531	1,193,419,987	1,261,940,943
Land assets	848,171,000	848,171,000	848,171,000	848,171,000	848,171,000
Infrastructure and improvements	4,797,394,000	4,797,394,000	4,797,394,000	4,797,394,000	4,797,394,000
Fixtures and equipment	159,285,000	159,285,000	159,285,000	159,285,000	159,285,000
Improvements (capital projects)	904,800,000	1,206,400,000	1,528,000,000	1,548,000,000	1,548,000,000
Other assets	966,471,686	1,534,116,666	1,673,410,883	1,786,160,820	2,059,390,531
Accumulated depreciation	1,693,391,000	1,862,730,100	2,032,069,200	2,231,301,875	2,431,648,687
Total non-current assets	5,982,730,686	6,682,636,566	6,974,191,683	6,907,708,945	6,980,591,844
Total assets	6,094,390,757	6,592,176,914	7,472,219,214	8,101,128,932	8,242,532,787
Liabilities and equity [$]	**2010**	**2011**	**2012**	**2013**	**2014**
Accounts payable	7,503,033	7,594,715	7,694,730	7,791,594	7,878,695
Current bonds payable	0	0	0	18,477,612	0
Total current liabilities	7,503,033	7,594,715	7,694,730	26,269,206	7,878,695
Bonds payable	1,567,820,181	2,528,978,111	2,921,216,905	3,345,449,182	3,362,176,428
Total long-term liabilities	1,567,820,181	2,528,978,111	2,921,216,905	3,345,449,182	3,362,176,428
Total liabilities	1,575,323,215	2,536,572,826	2,928,911,635	3,371,718,388	3,370,055,123
Owner's/shareholder's equity	0	0	0	0	0
Retained earnings	4,176,095,695	4,387,878,471	4,547,393,679	4,682,004,955	4,802,371,910
Total equity	4,176,095,695	4,387,878,471	4,547,393,679	4,682,004,955	4,802,371,910
Total liabilities and equity	5,751,418,909	6,924,451,298	7,476,305,314	8,053,723,343	8,172,427,033

Performance indicators module

The aim of this module is to present information to the user in a form that is easy to comprehend, and will allow comparison of the financial performance over a number of years (financial plan), or between various financial cases and plans. It can also be used to set policy, for example, setting a minimum desired performance in a certain area/ratio, and working towards this goal.

Table 5-18: Productivity/efficiency ratios results (Excel Model)

	2010	2011	2012	2013	2014
Total cost per pax [$]	5.32	5.23	5.68	6.10	6.19
Operating cost per pax [$]	2.39	2.37	2.34	2.32	2.30
Employee cost per pax [$]	1.03	1.03	1.03	1.03	1.03
Total cost per A/C movement [$]	479.48	467.25	514.95	560.71	577.37
Operating cost per A/C movement [$]	215.44	211.35	212.35	213.17	214.45
Long-term debt per pax	17.85	28.15	31.75	35.55	35.02

Table 5-19: Profitability and market ratios results (Excel Model)

	2010	2011	2012	2013	2014
Total revenue per pax [$]	7.16	7.59	7.41	7.53	7.44
Aeronautical revenue per pax [$]	3.17	3.34	3.40	3.46	3.49
Non-aeronautical revenue per pax [$]	3.68	3.62	3.56	3.50	3.45
Aeronautical revenue per A/C movement [$]	285.72	298.51	308.19	317.73	325.17
Non-aeronautical revenue as percentage of total revenue [%]	51.37	47.70	48.00	46.50	46.38
Concession revenue per pax [$]	1.32	1.32	1.31	1.30	1.29
EBITDA per pax [$]	4.77	5.22	5.07	5.21	5.14
Profit margin [-]	0.26	0.31	0.23	0.19	0.17
Return on assets [-]	0.03	0.03	0.02	0.02	0.01
Return on equity [-]	0.04	0.05	0.04	0.03	0.03
Retention ratio [-]	1.00	1.00	1.00	1.00	1.00
Debt service coverage ratio [-]	4.75	5.32	3.39	3.13	2.85
Debt to EBITDA ratio [-]	3.76	5.40	6.28	6.88	6.82

Table 5-20: Liquidity and asset utilisation ratios results (Excel Model)

	2010	2011	2012	2013	2014
Current ratio [-]	14.88	-11.91	64.72	45.43	160.17
Cash ratio [-]	13.96	-12.86	63.76	45.14	159.19
Total debt ratio [-]	0.26	0.38	0.39	0.42	0.41
Debt-equity ratio [-]	0.38	0.58	0.64	0.72	0.70
Equity multiplier [-]	1.46	1.50	1.64	1.73	1.72
Time interest earned [-]	2.83	3.40	2.16	1.86	1.70
Cash coverage ratio [-]	4.75	5.32	3.39	3.13	2.85
Total asset turnover [-]	0.10	0.10	0.09	0.09	0.09
Receivables turnover [-]	87.40	86.77	86.42	86.09	85.84
Working capital turnover [-]	6.04	-6.96	1.39	0.61	0.57

5.2.2 User interface

It was discovered that the original ABS program was prone to crashing if the user did not follow the path envisioned by the developer. The ABS manual thus had specific instructions to ensure that this did not happen. Another problem area was in the creation of schemes and cases, where it was not possible to quickly make changes to an existing scheme or case, and save it under a different name. Each time a new scheme or case was created, all information had to be entered again, which could prove time-consuming. Although the Financial Model initially suffered from similar pitfalls, care was taken to improve its robustness and user-flexibility by continually iterating the user interface. The following features were implemented:

- User confirmation when deleting or overwriting saved data, to prevent accidental loss of unsaved data.
- Disabling of buttons depending on the context, to prevent improper or unintended use. In some cases, a pop-up message prompted the user with the right action to perform.
- Allowed easy switching between unit and aggregate types of input, to reduce user workload.
- Ability for the user to quickly make numerous schemes and combinations, by saving a current scheme under a different name.

5.2.3 Design analysis

Design analysis refers to the verifying the design of the model and its relationships with real-world data and situations. In the case of the ABS, this was done using the test case of ATL, to determine whether assumptions made in the Financial Model still remained valid for ATL.

The following verifications were found:

- *Basis of accounting and presentation:* The accrual basis of accounting is utilised.
- *Interest from cash deposits:* ATL maximizes investment income by pooling cash in order to achieve maximum cash yields on short-term investments of otherwise idle cash. These investments are highly liquid, with maturities of three months or less.
- *Depreciation:* The method of depreciation used by ATL is the single line depreciation method, which is consistent with that chosen by the ABS
- *Costs of services:* ATL Department of Aviation is one of a number of departments maintained by the City of Atlanta. Costs of general services such as purchasing, accounting, budgeting, and personnel services represent services provided to the Department by other City departments (ATL, 2010). In the case of other airports, this would be, for example, services outsourced to consulting or specialist firms.
- *Bonds and notes:* From 2010 onwards, ATL plans to eliminate all variable debt instruments. This is fitting for the Financial Model, which can only receive input for fixed-rate debt instruments.

A number of discrepancies were found between the model and ATL's real-world situation. Although the Financial Model is meant to be generic, and thus cannot suit the situation found in all airports, it is still useful to identify these differences, in order to anticipate any discrepancies they may produce in the results. These include:

- *Basis of accounting and presentation:* Only the Financial Accounting Standards issued prior to November 30, 1989 are used. This might lead to slight differences with the model's presentation and calculation of results. ATL uses various funds for various projects, and classifies some assets as restricted since they can only be used for a specified activity.
- *Classification of transfer passengers:* Transfer passengers are not taken into consideration at ATL since passengers on connecting flights need to pick up their luggage, and recheck them (ATL, 2015b).
- *Classification of passenger charges:* ATL classifies its PFCs as non-operating revenues, since in the US, these are only to be used for capital expenditure projects approved by the FAA. This will be the case in the US, but not in other parts of the world. The normal practice is to classify passenger service charges as aeronautical revenues.
- *Passenger and aircraft handling:* Since the airport does not carry out passenger handling or catering services, the revenues from these activities will instead be reflected in

concession revenues. Landmark aviation is the Fixed Based Operator at ATL, and none of their pricing plans for ATL were freely available on the internet, which is in contrast with some European airports, which provide this information.

- *Corporate income tax:* ATL does not have to pay any corporate income taxes, in contrast with the numerous privately owned airports worldwide.
- *Investment in stocks and bonds:* Since ATL is a government (publicly) owned airport, it has legal requirements imposed on it with regards to how it invest its money. Thus, it is not allowed to use investment vehicles other than cash yields (cash investments) which carry a lower degree of risk, and are more liquid in nature.
- *Different accounting methods:* Various categories of cash flows, for example are classified differently. For example, the purchase of assets and capital projects are classified as investing activities in the Excel Model and ABS Financial Model, in accordance with the IAS 7 (Deloitte Global Services Limited, 2014d), while ATL classifies them as financing activities.
- *Numerous additional categories:* It was found that ATL defined a lot more categories than were used in the Excel Model, especially in the Balance Sheet and Statement of Cash Flow. For example, current assets included categories such as: restricted other assets; due from other funds; prepaid expenses; and materials and supplies net of allowance. Most of these are one-time unique costs which are difficult to model, and perhaps other airports do not report this assets in the same way.
- *Methods of financing:* the only method of financing ATL utilises is bonds and notes. Although there is a for ATL plan to move away from variable debt bonds, some results will contain discrepancy, especially in the case of serial bonds (which mature at regular intervals, until all the bonds have matured), which produce very different payment schedules to term bonds.
- *Equity:* equity is classified as net assets, and displayed in three components: i) invested in capital assets, net of related debt; ii) restricted net assets; and unrestricted net assets. This is not reconcilable with the way equity is classified in the Financial Model.
- *Balance sheet:* The specification of equity is missing, and ATL specifies a new category, net assets, which is the difference between assets and liabilities.
- *Assumptions:* The preparation of financial statements requires management to make estimates and assumptions that affect reported amounts. Without knowing these assumptions, it will be difficult to arrive at the same results found in the financial reports of ATL. This is especially true for the reporting of assets and liabilities.

Thus, an emphasis was placed on giving the user flexibility in testing the effects of various assumptions. Additionally, a number of design choices were made, where the emphasis was placed on minimizing user input, and making the model as flexible as possible. Any user should be made aware of the resulting limitations (simplifications) of the model.

5.2.4 Specification analysis

Specification analysis may be carried out using the following factors to evaluate the model's performance.

- *Usability:* Efficiency, Flexibility, Portability, and Reusability
- Maintainability
- Expandability

Usability was ensured by following a similar approach and layout to that of the original ABS program. A lot of attention was paid to the user interface to ensure that the Financial Model was intuitive and easy to use, and that safeguards were implemented, in the form of *If* and *Try-Catch* statements, to ensure that it was very difficult for the user to crash the program (described in Subsection 5.2.2). True usability can only be achieved when the ABS program is upgraded to the VB.NET language. Currently, the two programs can be bundled in the same installation file to ensure portability. Unlike the original ABS program, the Financial Model can be used on 64-bit operating systems.

Maintainability and expandability are made easier by the use of: modules; extensive commenting within the program; and extensive documentation of program (reasoning and logic behind the various expressions and relationships) in this report. Thus, it should theoretically be much easier for a different developer to become familiar with the code, and make changes/upgrades to it (see Section 6.3 for improvements that have already been identified).

5.3 Validation

Validation is the process of determining the degree to which a simulation model and its associated data are an accurate representation of the real world from the perspective of the intended uses of the model (Department of Defense, 2009). It compares the observed behaviour of elements of a system with the corresponding elements of a simulation model of the system, and determines whether the differences are acceptable given the intended use of the model. If these differences are not acceptable, the model is adjusted, or errors are identified and rectified. The following validation methods will be used (MITRE, 2015):

- *Face validity and user evaluation*: asking professors knowledgeable about the system whether the model and/or its behaviour are reasonable. For example, evaluating the logic in the conceptual model correct, and the model's input-output relationships.
- *Historical data validation and predictive validation*: by using 2010 as the base year, and using the ABS to model the performance of the airport for the proceeding 5 years, of which data exists for a majority of these, the behaviour of the model can be compared with that of the actual airport system.

The ways in which these analyses were carried out for the ABS Financial Model is presented in Subsections 5.3.1 and 5.3.2, along with an analysis of the results.

5.3.1 Face validity and user evaluation

The current approach to AMP that ATL Airport follows is shown in Figure 5-6 below, which is similar to the approach suggested for use with the ABS and the Financial Model.

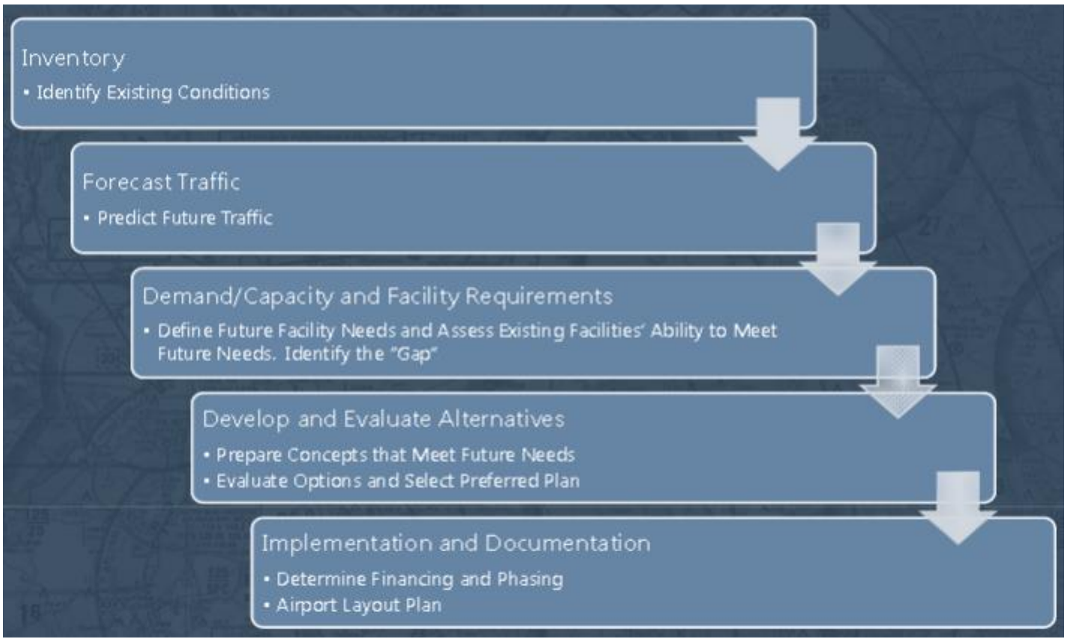


Figure 5-6: ATL planning process
Source: ATL (2012)

On face value alone, the results produced by the ABS seemed to be reasonable, and since various guidelines related to financial reporting and accounting, and airport planning were followed, the methodologies should, in theory, be sound. The aim of the ABS is not to model the real-world with an extremely high degree of accuracy, but rather to allow the user to explore different options quickly. This was achieved, since the user is able to see how individual changes in policy or assumptions affect the financial performance of the airport.

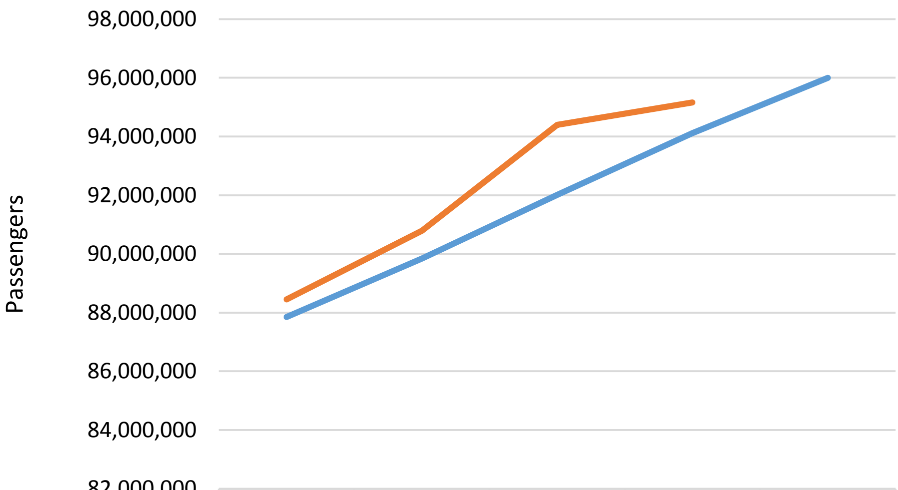
Since uncertainty is implemented in the original ABS, it was deemed redundant to implement this in the Financial Model. Corporate finance is a definitive art, based on accounting principles, methodologies, and assumptions, and this is the approach that was taken in developing the Financial Model.

5.3.2 Historical data validation and predictive validation

A historical data validation is carried out using the base year 2010, while the predictive validation is carried out using the years 2011 to 2014 to determine whether the data predicted by the ABS and the Financial Model were close to the real-world actual data. To carry out a further validation, the results of the 2014 annual financial report can be compared with the results of the ABS Financial Model, when it becomes available. Validation for each of the modules is described and presented below. An overview of the real-world data of ATL used to validate this model can be found in Appendix F.

Yearly case module

A comparison of the total passengers produced by the Financial Model with real-world values is shown in Figure 5-7. It is evident that the Financial Model was able to model the total number of passengers experienced to a satisfactory level of accuracy, using the Yearly Case class which converted the peakday activity produced by the original ABS program into a yearly activity.

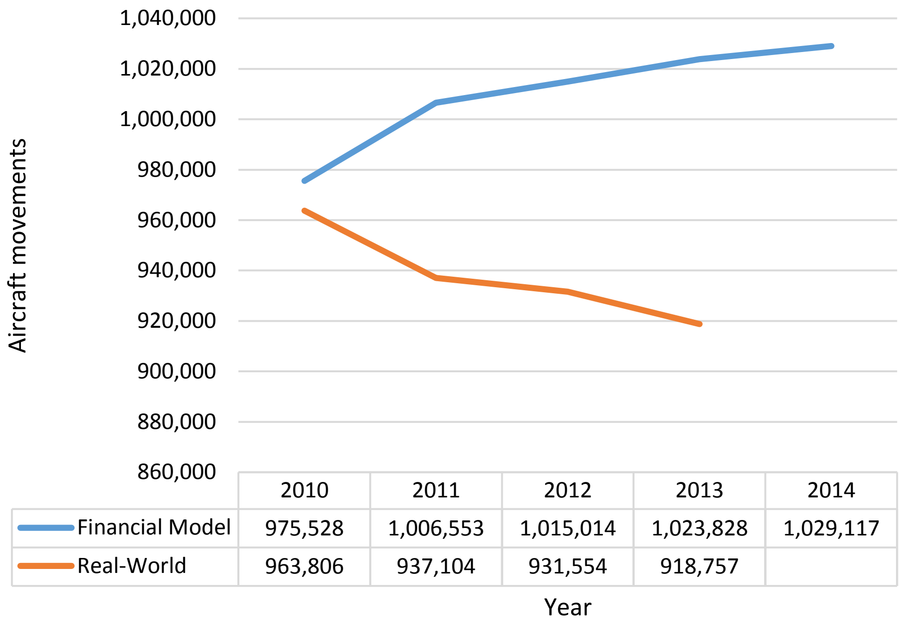


	2010	2011	2012	2013	2014
Financial Model	87,850,382	89,840,216	92,010,915	94,113,220	96,003,633
Real-World	88,453,708	90,788,019	94,393,355	95,155,011	

Year

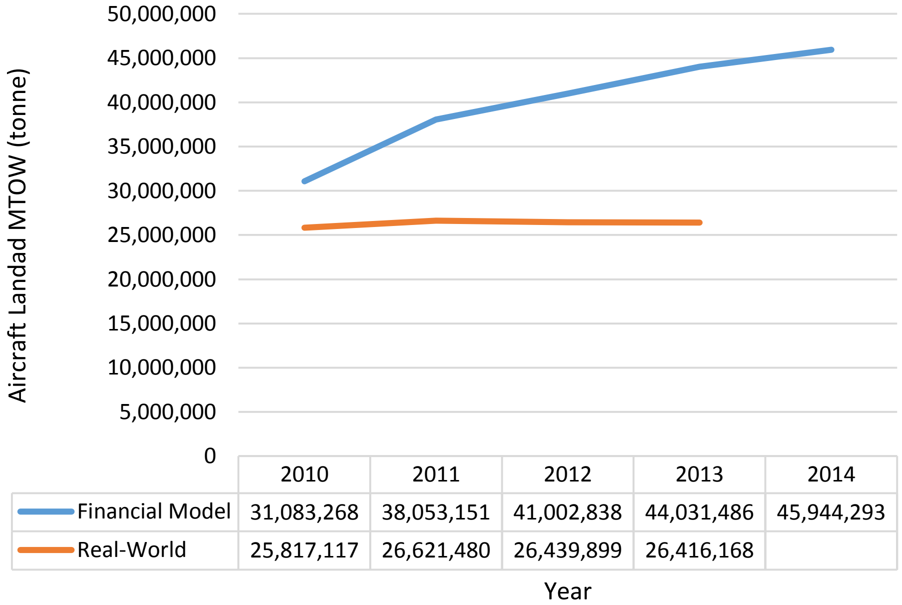
Figure 5-7: Total passengers - Validation

From the comparison of the total aircraft movements in Table 5-8 on the next page, it was found that the ABS modelled an increasing number of aircraft movements, while the real-world situation was the opposite, due to airlines trimming the number of flights system-wide, in a bid to become more efficient. The original ABS program is not able to capture small nuances like this, which the programmer likely did not envision (see section 5.1.2). The effects of this deviation is that the reported revenues from aircraft landing and parking fees, will likely be higher than the real-world values.



	2010	2011	2012	2013	2014
Financial Model	975,528	1,006,553	1,015,014	1,023,828	1,029,117
Real-World	963,806	937,104	931,554	918,757	

Figure 5-8: Aircraft movements – Validation



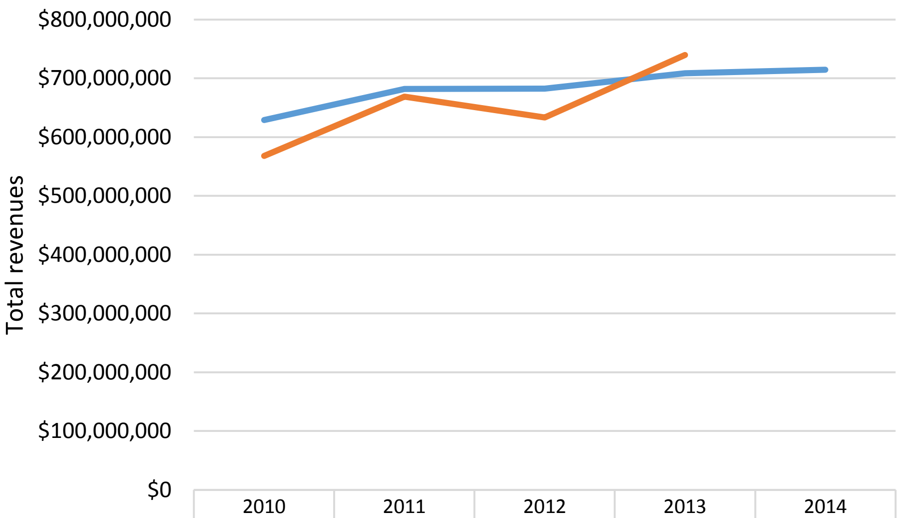
	2010	2011	2012	2013	2014
Financial Model	31,083,268	38,053,151	41,002,838	44,031,486	45,944,293
Real-World	25,817,117	26,621,480	26,439,899	26,416,168	

Figure 5-9: Aircraft landed MTOW – Validation

The comparison of the aircraft landed weights in Figure 5-9 above showed a deviation in the results produced by the ABS with that produced in real life. One explanation for this is the discrepancy in the aircraft movements modelled by the ABS, explained above. A second explanation for this is that the MTOW is used in the Financial Model, while the real-world values likely reflect the actual landed weights of the aircraft, which most certainly are lower than MTOW, due to the absence of fuel after a flight, and the fact that not all flights will experience a full load factor. The decreasing number of aircraft movements, coupled with an increase in aircraft landed weights, suggests that airlines are increasing their aircraft sizes and achieving higher load factors.

Revenue module

The final output from the revenue module is the total amount of revenues. Figure 5-10 below shows the comparison of the excel model with the real-world values, for total revenues. A comparison for operating and non-operating revenues can be found in Figure G-1 and Figure G-2 (Appendix G), respectively. As can be seen from the calculations, a uniform growth in total revenues is predicted. This is because a uniform passenger growth rate was chosen in the ABS, to make it more realistic. If the growth rate for each year was specified according to the real-world data, the Financial Model would have been able to model the changes in revenue more closely. It should be noted that other external factors which are not accounted for in the model may have caused an unexpected increase/decrease in the revenue levels. For example, in 2010, revenues were increased by increasing the charge for replacing security badges at the airport. With foresight, it would have been possible to include these developments. Overall, the revenue module was found to produce results which closely resembled the real-world values, and its overall trend.



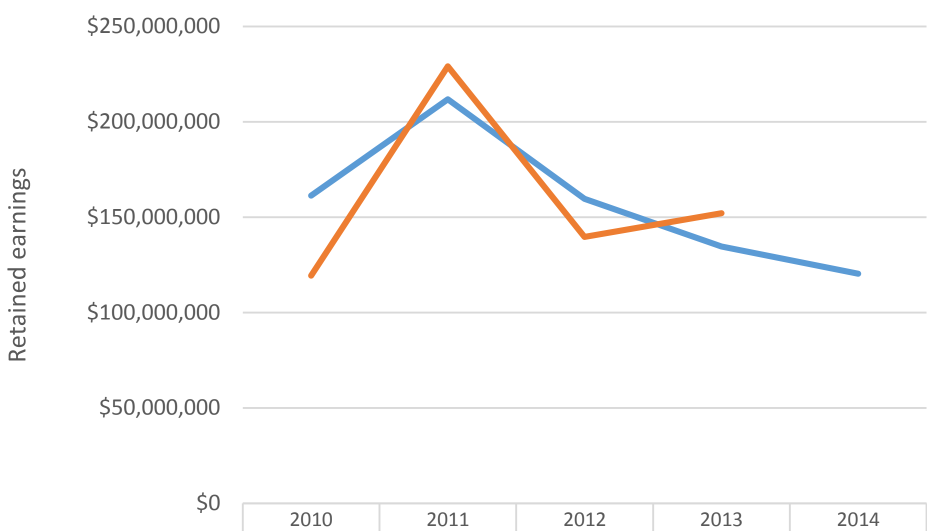
	2010	2011	2012	2013	2014
Excel Model	$629,021,127	$682,092,325	$682,198,730	$708,681,272	$714,546,240
Real-World	$568,146,000	$668,710,000	$633,616,000	$739,598,000	

Year

Figure 5-10: Total revenues – Validation

Cost module

The final output from the cost module is the retained earnings, or change in net position, as referred to by ATL. Figure 5-11 on the next page shows the comparison of the excel model with the real world values. The validation of operating costs (Figure G-3), depreciation costs (Figure G-4), and interest costs (Figure G-5) can be found in Appendix G. The biggest deviation was found in the operating costs (Figure G-3), which was caused by a decrease in salaries and employee benefits due to the economic situation. A hiring freeze was maintained which required cost justification for all vacancies during the year, and resulted in some positions not being replaced (ATL, 2011). Given the fact that that personnel costs comprise of almost 50% of the total operating costs, this deviation is quite reasonable.



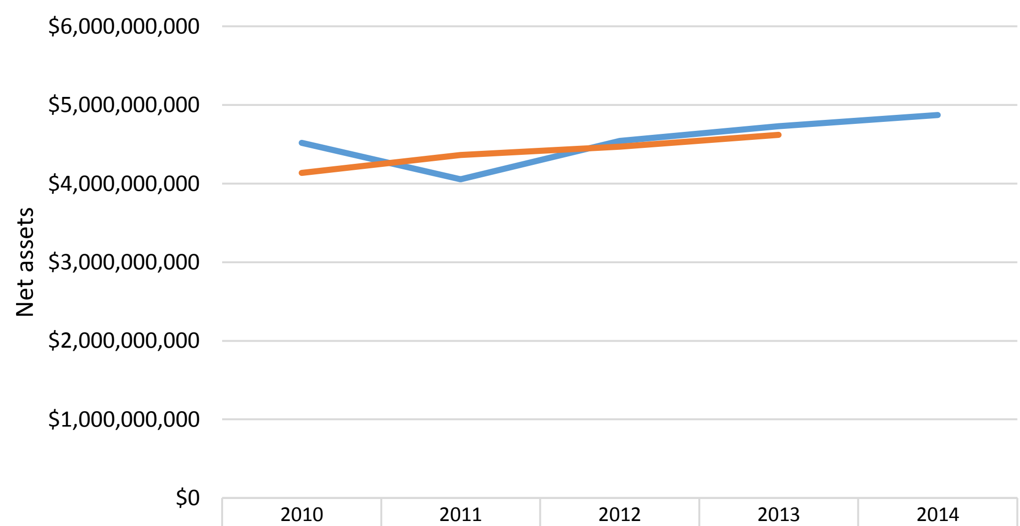
	2010	2011	2012	2013	2014
Excel Model	$161,279,695	$211,782,776	$159,515,207	$134,611,276	$120,366,955
Real-World Model	$119,281,000	$229,124,000	$139,618,000	$152,014,000	

Year

Figure 5-11: Retained earnings – Validation

Balance sheet module

The final outputs of the balance sheet module in the Excel Model are: total assets; total liabilities; and total equity. It should be noted that although the usual approach is to 'balance' the balance sheet by making sure that the assets are equal to liabilities and equity, ATL does not follow this accounting convention, instead choosing to use a category known as net assets, which is the difference between assets and liabilities. This is shown in Figure 5-12 below, where it is immediately evident that the balance sheet module is able to predict the overall trend, with a significant deviation in 2011.



	2010	2011	2012	2013	2014
Excel Model	$4,519,067,542	$4,055,604,088	$4,543,307,579	$4,729,410,543	$4,872,477,664
Real-World	$4,134,097,000	$4,363,221,000	$4,468,588,000	$4,620,602,000	

Year

Figure 5-12: Net assets – Validation

Unlike a private entity which finances its operations with contributions from its owners, or the issuing of new securities (stocks), ATL finances its operations solely through government grants, levying certain charges on the airport's users, and the issue of debt (bonds and commercial notes). The fact that ATL performs well financially, means that it receives healthy profits. The possible reasons for the deviation in the total assets (Figure G-6) and total liabilities (Figure G-7) can be found in Subsection 5.2.3.

Cash flow module

The main output of the cash flow module is the net change in cash. A comparison of the results produced by the Excel Model, and the real-world values, is shown in Figure 5-13 below. As can be seen from Figure 5-13, and Figure G-8 to Figure G-10 (Appendix G), the cash flow module did not produce reasonable results. The main reasons to explain this were presented in Subsection 5.2.3. Since the model was tested, and produced the expected results, the problem most likely lies in the interpretation of the financial statements, or a fundamental difference in accounting practices and the Financial Model's assumptions. One such difference is in the classification of activities, or the fact that the model does not consider as many variables as ATL records in their statements.

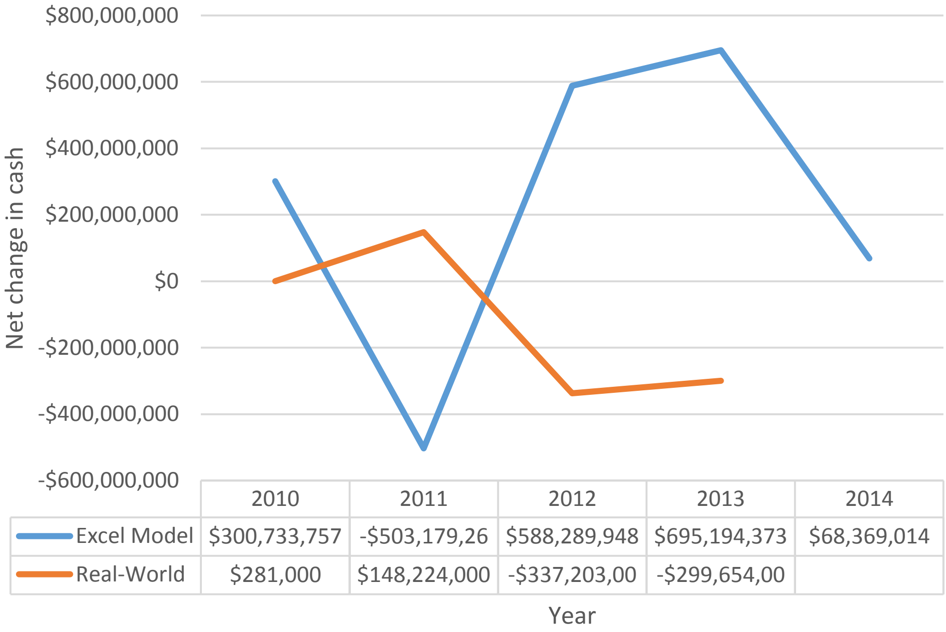


Figure 5-13: Net change in cash - Validation

5.3.3 Comparison to the previous ABS Financial Model

In order to gauge the utility of the Financial Model, it was compared to its predecessor, from here on referred to as Old Model. Since there was no access to the program, a comparison was carried out using the thesis report that documented the design and implementation of the Old Model (Zawadzki, 2003). It was found that the calculations of some categories of revenues and costs were more detailed. On one hand, this would likely allow for more accurate results, but on the other hand, it would require a lot of input from the user. However, the way that investments are dealt with is too rigid, and will produce results that are not useful. It also does not allow for a determination of the airport's balance sheet items, and its cash flows, which are crucial in determining an airport's overall financial position, and its ability to stay solvent, respectively. Table 5-21 to Table 5-24 provide a quick overview of the results of this comparison, carried out for each of the Old Model's modules, whereby the reason given refers to the Old Model.

Table 5-21: Comparison with Old Model - Revenues

Revenues	Verdict	Reason
Passenger fees	Similar	Assumes arriving pax is equal to departing pax, which is not always the case
Landing fees	Better	Can define aircraft into categories which needs more user input
Aircraft parking fees	Better	Can define aircraft into categories which needs more user input
Handling fees	Worse	Too complex with too many inputs
Retail	Better	Allows for the consideration of visitor spending, and fun shoppers
Car parking fees	Worse	Requires more user input to define different categories
Real estate	Better	Allows for manipulation of the occupancy of office area, while the Financial Model requires the user to change the amount of space rented out
Utilities	Worse	These revenues should be included in the real estate revenues, as treated in the Financial Model
Other	Worse	Does not allow for defining subcategories within this category, while the Financial Model does
Total	Similar	Has similar categories to the Financial Model

Table 5-22: Comparison with Old Model - Costs

Costs	Verdict	Reason
Employee	Better	Based on car park area, number of runway systems, number of passengers, and number of aircraft movements. However, results in a lot of user input
Depreciation	Worse	Straight line depreciation. Assumes that one m^2 has the same price. Doesn't take inflation or other factors into account which may cause huge variations
Maintenance	Similar	Maintenance is linked to area of facilities. Includes maintenance for the office area and car park
Utility service	Worse	Assumes charging of utilities to renters, which should be included in real estate revenues
Retail	Worse	Financial model does not include this category of cost. If retail services is carried out by airport, these costs will be reflected in other categories e.g. employee costs, admin costs, and cost of supplies. If they are outsourced, this will be reflected in the concession revenues
Administration	Better	Assumes a fixed component as well as a variable component, while the Financial Model only assumes a variable component
Other operational	Similar	Assumes a variable component, and is a percentage of total costs
Interest	Worse	Only considers loans as a method of financing which is too simplistic, while the Financial Model includes grants, stocks, bonds, and loans as financing sources
Total	Worse	Does not include tax costs, costs of supplies, and costs of insurance

Table 5-23: Comparison with Old Model - Investments

Investments V1	Verdict	Reason
Replacements	Different	Is set equal to depreciation costs. This is overly simplistic, as replacement investments are supposed to increase the value of the airport (and its assets) to enable it to remain competitive
Expansions	Worse	Only takes into account car park, real estate, terminal buildings, and runway system. However, there are many investments which may not improve capacities for these categories, but still have a large impact on the airport's finances. There is no way to properly model all of these possibilities. The Financial Model allows the user to add these possibilities
		Is linked to the passenger growth. However in some cases, passenger growth may not correspond to an increase in aircraft movements (as is the case with ATL), and so airside capacity will not be affected
Total	Worse	Does not include other forms of income for an airport e.g. interest on cash, stocks, bonds, etc.

Table 5-24: Comparison with Old Model – Improvements to investments

Investments V2	Verdict	Reason
Net Present Value	Similar	Was used in balance sheet calculations for loan and bonds principal repayments for the Old Model. This concept was also utilised in the Financial Model in the form of *future value*
	Worse	Free cash flow in the Old Model includes depreciation, which is not a tangible cash flow. Rather cash flow occurs at time of purchase, or during construction
	Worse	It is impossible to isolate the effects of a capital project into projected revenues and costs. The author acknowledged this, and approximates it using 30%. It is better to create a system which is able to make quick examinations of different assumptions and scenarios, rather than restricting the user to one assumption that may not be valid for their case
Distribution of Net Present Value	Worse	Statistics is used on only one fictional situation found at one airport to come up with a generalisation for the Old Model, and using this as validation is unscientific to say the least

It should be noted that the above comparison is inherently subjective, despite an attempt to remain impartial and unbiased. Thus, an evaluation should be carried out by a third-party who is unbiased, to confirm these observations. However, a lot of the advantages of the Financial Model over the Old Model are apparent, even if this is only in terms of the additional capabilities it offers. The user is able to identify expansion needs based on the capacity output of the ABS program, i.e. when desired capacity requirements are exceeded. Feasibility of a certain financing option should be carried out by examining the cash flow outputs, to ensure that the airport is able to remain solvent, and to determine the break-even point of the project. Another shortcoming of the Old Model is that it did not give any thought to providing a familiar form of output, in order to help the user to digest and analyse the information produced. The Financial Model attempts to tackle this by producing financial statements, and proposing the use of performance indicators and graphs. Finally, the Financial Model allows for an accrual basis of accounting, which more closely resembles real-world conditions, as payments are usually never made/received on time.

6. Epilogue

6.1 Summary

The overall aim of this thesis project was to investigate the further development of a Decision Support Suite, the ABS, for use in Airport Strategic Planning. In order to accomplish this, an examination of problems with the status quo was required. The current traditional approach to airport planning was identified as being Airport Master Planning, and its problems include: a rigid and inflexible nature; a narrow focus; the inability to deal with uncertainty effectively; and an ineffective and inefficient problem solving process or framework. Due to the numerous prominent airport planning failures, airports have realised the pressing need for a new approach to airport planning, and have started to implement elements of new approaches to various degrees. These include numerous approaches which suggested elements such as: paying more attention to the assumptions used and analysing the impacts these have on each other; dynamically adjusting plans and designs over time; phased implementation depending on whether conditions are met; preparation of mitigating actions; and signpost monitoring, to name a few. In order to support these new approaches, computer-based systems were developed in order to aid airport planners. However, none of these systems developed under the auspices of research projects have been deployed and used in their entirety in real-world airport operations.

The ABS is one such system, although its deployment is limited to an airport strategic planning course at the TU Delft Faculty of Aerospace Engineering. After an examination of the original ABS, various improvements to current models and modules, as well as additional models and modules which could be added, were identified. The biggest issue preventing the ABS from realising its full envisioned potential was its inability to perform any kind of financial analysis. This had previously been attempted, but due to the inaccuracy of results it produced, was removed from the ABS. For this reason, the main focus of the thesis project was to develop a financial model for the ABS. A literature review in Chapter 2 was carried out in order to determine the best way to model an airport's finances, and assess its financial performance.

Chapter 3 then presented the design of the model's architecture. This started with an elaboration of the key design principles, the development process, the logical and functional views, and defining the possible use cases for the Financial Model. Chapter 4 detailed the actual implementation of the model, and the various design decisions and assumptions made during this process. The inputs were gotten from the operational information calculated by the original ABS, and the use of so-called editors (cost, revenue, and balance sheet editors) for the input of financial parameters. A financial case could then be created from a combination of these schemes, and would cover the span of one year, while a financial plan would be composed of a combination of financial cases, and could cover a period of up to 20 years. Chapter 4 presents the equations used to calculate the various financial parameters required, as well as the rationale and logic behind them. These equations were derived from a number of sources: the previously attempted Financial Model; literature providing guidelines on airport design and planning; and various literature providing guidelines on financial accounting and modelling. Finally, outputs are created in the form of all the major financial statements (income statement, balance sheet statement, and statement of cash flows), while performance indicators or ratios used in airport benchmarking, and graphs were proposed to display these results in a useful manner to the user.

Chapter 5 included the verification and validation of the Financial Model. It was found that the Financial Model produced satisfactorily accurate results, especially with regards to the operational indicators of the yearly case, but the accuracy of the financial results seemed to be dependent on having access to more detailed financial information. However, a preliminary validation of usefulness of the Financial Model was carried out with a hypothetical airport and test case (ATL), and the financial model was found to produce satisfactory results for the income statement and balance sheet statement. The cash flow statement did not produce satisfactory results, due to a number of reasons, the most important being a fundamental difference in the accounting practices, assumptions, and categories considered. A superficial validation showed that the Financial Model allowed the user the ability to quickly explore various policies and scenarios, and determine which plan produced robust performance over different scenarios. Other strategies, such as sale-and-leaseback, the determination of airport charges, determination of break-even requirements, or the structure of funding for a capital project, could also be explored.

Chapter 6 presents the epilogue of the report, and presents a summary, conclusions made, and recommendations for future projects.

6.2 Conclusions

The identified shortcomings of AMP, and the shortcomings of the previous Financial Model were used to drive the development of the current Financial Model, leading to the following research questions (Section 1.6):

1. What lessons can be learnt from past and current efforts to build computer-based systems to tackle airport strategic planning?
2. What are the main features of an effective framework to utilise the ABS Financial Model, and implement its results?
3. What is the importance of a financial analysis or forecast in an airport's decision-making and strategic planning?
4. What are the most important elements in an airport's financial planning, and how can an airport's operations be translated into financial results?

These research questions will be answered in Subsections 6.2.1 to 6.2.4, while Subsection 6.2.5 will discuss the extent to which the research objective was fulfilled.

6.2.1 Research question 1

What lessons can be learnt from past and current efforts to build computer-based systems to tackle airport strategic planning?

It was found that in order for effective airport planning to take place, the computer-based tool should not just focus on analytical process and forecasting, but should also focus on the entire process surrounding good practices of airport strategic planning. The entire problem-solving process (formulation, analysis, and interpretation) should be acknowledged, and the tool should be designed accordingly. The focus should be on the user of the system, the design of a simple and easy-to-use user interface, and designed around the envisioned use cases, in order to create a relevant tool that will be useful to the user.

Previous systems attempted to develop a single optimisation model, and use advanced techniques for forecasting an airport's future performance. Although airport planners currently use Spreadsheet based models for quickly exploring various policy options and assumptions, these are not very user-friendly, and are not generic in nature. An example is that the learning curve for another user will be steep, and if an airport's situation changes, the model may need to be adapted. The best solution seems to be a combination of the two approaches, and this proof-of-concept is presented in the ABS Financial Model. The importance of an airport strategic planning tool is not the accuracy of forecasts, but an accurate representation of the magnitude of effects of different policy options and assumptions on the airport's performance. A policy which is found to be robust across various scenarios (and assumptions) in the ABS Financial Model will likely be robust in the real-world. The use of the ABS as a tool, in combination with an effective framework with various state-of-the-art approaches to airport strategic planning (see Subsection 6.2.2), means that the airport will be very responsive to any uncertainty that arises in the real-world, allowing them to mitigate any negative effects.

6.2.2 Research question 2

What are the main features of an effective framework to utilise the ABS Financial Model, and implement its results?

In order to avoid the static nature of AMP, the ABS should not just be used as a planning tool, but instead should be used an ongoing financial control tool to: identify any significant deviations from the plan; determine the reasons for this deviation; and determine what actions should be, and can be taken (Dempsey, 2008). Strategic planning should be an ongoing process with much shorter intervals between subsequent planning sessions (Kwakkel J. , 2010).

A focus should be placed on the decision-making process of creating various scenarios and plans, and make sure that a policy is robust across a majority of these scenarios. Close attention should be paid to the stakeholders (Wijnen R. , 2013), and they should be included in the planning process. The ABS should not just be seen as a tool for receiving the input data, but attention should be paid to the planning process itself, by taking the following steps:

1. Define the objectives, scenarios, assumptions, constraints and possible plans/policies.
2. Define the base year and situation, and collect and process all the required information.
3. Evaluate the plans across all the scenarios.
4. Make changes to the plans using iterations, until the desired performance criteria is achieved, and a good plan is identified. Include stakeholders in this process.
5. Brainstorm and identify vulnerabilities.
6. Define a monitoring plan during implementation of the plan, which includes *signposts* and *hedging actions* or *contingency plans* in case a vulnerability occurs (Dewar, Builder, Hix, & Levin, 1993, pp. xii-xiv).
7. Acquire *options* (de Neufville, 2003), to be exercised if certain predefined conditions are met.
8. Allow for learning over time, i.e. the plan should be changed when new information becomes available and assumptions are validated or disproved.

Attention should be given to other types of uncertainties, such as regulatory context, technological breakthroughs, and demographic developments, and the impacts these would have on the assumptions and scenarios used. The following are factors in the aviation industry, which should be paid attention to when carrying out airport strategic planning:

- Economic and political conditions
- Financial health of the airline industry
- Airline service and routes
- Airline competition and airfares
- Airline consolidation and alliances
- Availability and price of aviation fuel
- Aviation safety and security concerns
- Capacity of the national ATC system
- Capacity of the airport

6.2.3 Research question 3

What is the importance of a financial analysis or forecast in an airport's decision-making and strategic planning?

Without a financial analysis or forecast, the airport will be unable to make effective decisions, and carry out a proper cost-benefit analysis. Without finances, a business will not be able to operate, and so a financial analysis of a plan or policy is perhaps the most crucial element in airport strategic planning. Financial feasibility models can determine the potential of a given project against its anticipated cash flow streams, through the ability to attract project financing, cover expenditures, or produce a positive net present value. The financial performance or position of the airport can be improved, by exploring various strategies and their effects. A few examples are described below:

- *Changing the payment schedule of long-term debt:* to take advantage of favourable interest loans, or paying off a loan when cash is unexpectedly made available.
- *Sale and leaseback:* to improve the effect on the bottom line and on tax, since lease payments are tax deductible as a business expense. It can also make cash available to the business in the short-term.
- *Dividend strategy:* determine whether to pay out dividends or reinvest these into the business. The effects of a share repurchase can be explored in order to improve the financial position of investors and the firm.

It is a good idea to create a projected income statement, to compare with actual performance. This will help the decision maker to determine whether income or expense variations from the plan are a problem of the budget, management of the airport, or external factors. This will help them to determine what corrective action should be, and can be, taken.

6.2.4 Research question 4

What are the most important elements in an airport's financial planning?

An airport's financial situation can be viewed as having two distinct areas of revenues (cash inflow) and expenses (cash outflow). Within these, they can further be segregated under operating and non-operating revenues and expenses. Operating revenues and expenses can directly be linked to the operational traffic that an airport experiences, and are relatively easy to model. Non-operating revenues and expenses, on the other hand, can take many different forms, and will depend on the airport's individual situation.

A very important element identified is the determination of an airport's vision, as well as its unique value proposition which sets it apart from other airports. This exercise will help the airport decision maker to place importance on a few factors, which will help guide the strategic planning of the airport, and allow them to set a preliminary budget which will maximize the chances of attaining its vision, and increasing value to its stakeholders. For example, ATL has chosen the following areas as important ways to achieve financial health (ATL, 2013):

- Allowing for operating margins that satisfy debt service coverage over 150%
- Keeping airline payments at very low levels relative to other airports
- Maximising non-aeronautical revenues to ensure ATL's financial flexibility so goals are achieved and customer service is supported

This means that when additional revenues are needed for a project, the airport will try its best not to increase airline charges, but perhaps look ways to increase its non-aeronautical charges, perhaps by raising the amount of concessions it charges car rental companies.

6.2.5 Research objective

The research objective was formulated as follows.

> *Develop a generic Financial Model for the ABS that gives the user a high degree of control and flexibility, in order to explore various scenarios and plans, by producing a good estimation of an airport's future financial situation*

The design principles (Section 3.1) were adhered to as much as possible, although in some cases, this was not feasible. This is explained in more detail below.

- *Coordinate and integrate the decision-making tools*
  The fact that the ABS was written using Visual Basic 6, which is a stagnant programming language currently unsupported by Microsoft, meant that it would most likely need to be upgraded to the newer language of VB.NET, in order to give it any real chance in terms of maintainability, and upgradeability. For this reason, the ABS Financial Model was written using VB.NET, which led to these two decision-making tools not being closely integrated. However, the data produced by the original ABS program is used in the Financial Model, with the user only needing to specify the directory that the original ABS project was saved in.
- *Place the user in control*
  The Financial Model allows the user to quickly investigate the effects of changes in (financial) policy on the various scenarios created. The user is also able to define values in aggregate form, or in more detailed form for each category, due to the flexible input approach adopted for assets and liabilities. Data preparation is reduced where possible, for example in the implementation of runway costs where the user is given the option of entering maintenance cost per runway length, or in total maintenance costs for runways.
- *Make the system flexible, adaptable, and easy to maintain*
  This was achieved by creating using smaller, and simpler modules to calculate various aspects of the financial model, rather than one large, complex module. Each calculation was carried out using a separate function, which would make it easier to update and modify.

In conclusion, it was found that the research objective was achieved, since the ABS Financial Model was created as a generic model which could be applied to various airports, while keeping in mind its limitations, assumptions, and methodologies, as shown in Section 5.3. For example, it has the ability to be applied to different structures of airport ownership, and different planning situations, by analysing all the various facets of an airport's financial situation.

The results produced by the model were found to be not very accurate (especially in the case of the statement of cash flow), which is in line with the expectations. This could be attributed to the fact that detailed information was not available, since only aggregate information were presented in the financial reports, and the many assumptions and approximations made. A strategic planning tool is not meant to be accurate, but rather, is intended to allow the user to have a better understanding of how the airport system functions, and quickly visualise and asses the effects of changes in policy. The famous saying that '*the forecast is always wrong*' holds true in the sense that you will never be able to have knowledge of all the factors which may influence the forecast. Rather, it is enough to create various scenarios using various assumptions for the future, and choose one with the best possible level of performance.

Of greater important is that the relationships defined in the model are reasonable, and follow widely accepted conventions and guidelines. This project is envisioned as a proof of concept of the basic working principles and financial model. In this regard, the project achieved its objective. Recommendations to further improve the Financial Model, and make it suitable for real-world implementation and commercialisation, are presented in 6.3.

6.2.6 Value added

The proof-of-concept Financial Model developed in this Thesis Project has potential to dramatically increase the usefulness of the ABS program, and allow it to be truly used as a complete Airport Strategic Planning tool.

The main value added was in the balanced approach using the fields or airport operations and corporate finance. The successes and shortcomings of traditional approaches to airport planning, as well as the previous attempts at similar projects, were critically evaluated, which guided the design of the model. Thus, the proposed solution does not just combine a modelling approach, but also attempts to tackle the problem from the planning and policy analysis approach, and incorporating the two. The initial verification and validation of this proof-of-concept shows promising prospects for bringing the ABS program one step closer to being able to be used in real-world situations. With the implementation of the recommendations (Section 6.3), the author has no doubt that the ABS will have what it takes to become a commercial product (see Appendix H).

From the modelling aspect, several basic and generic relationships were deduced, from both the operational and financial side. Complex issues were simplified as much as possible, to ensure that the model was as generic and flexible as possible. A lot of attention was paid to improving the user interface, and user experience. The functionality to create a new scheme from an existing scheme was missing in the original ABS program, but is useful in reducing the amount of user input required. The use of tables for data input in the original ABS is not very user-friendly, as it is easy to get bogged down by the large amounts of data, or make mistakes by reading/writing data from/into the wrong row. The implementation of user input in the cost and balance sheet editors will mitigate this problem. Furthermore, thought was given to the data output of the model, by identifying the most useful performance indicators identified by a number of studies.

6.3 Recommendations

Although an initial proof-of-concept has been carried out, the most pressing activity to be carried out would be an implementation of the ABS using real-world detailed financial data. This will only be possible with strict non-disclosure and confidentiality agreements in place, as airports are very hesitant in sharing sensitive information.

The ABS and Financial Model should be integrated into one single program, and share the same user interface. Potential users such as students, professors, and users in the airport business sector should be invited to use this new ABS, and offer their reactions and opinions regarding its ease-of-use and intuitiveness; the validity of the results produced; the added value of the financial model to the ABS; and any important elements which are missing, or which might enhance the usefulness of the ABS.

It should be noted that there were a few scope changes during the course of the project, due to various constraints, and so these areas will be a perfect place to start in future projects. This section will present the specific ways in which the original ABS (Subsection 6.3.1) and the Financial Model (Subsection 6.3.2) can be improved.

6.3.1 Original ABS

The following are possible ways to improve the ABS program that were identified through the author's use of the ABS:

- *Implement more robustness:* This can be achieved by anticipating all possible actions a user can make, and guarding against actions which may cause the program to crash. For example, implementing a user prompt to fill in any missing inputs. For the most part, this was implemented in the Financial Model, although extensive testing is required to ensure this is the case, as there may still be situations or actions not discovered or accounted for.

- *Implement more flexibility:* In the current ABS program, the user is not able to create multiple runways configurations and terminal sizes in the same project, which means that the effects of a runway/terminal expansion cannot be explored in the same project, requiring the user to create a separate project.
- Allow for reducing aircraft numbers even when passenger numbers increase, i.e. allow for an AC growth percentage larger than 100%.
- Investigate whether turnaround time of aircraft can be determined from the ABS program.

The improvements identified in Section 1.5 following can also be implemented. Below are just a few examples that are the most pressing:

- *Database:* Update the database entries for aircraft types and airports to include any new entrants since the last ABS update. This will remove the need for users to manually replace unknown aircraft types or airports.
- *Other types of operations:* Develop modules related to demand forecasting in order to be able to capture cargo and general aviation operations.
- *Constraining elements:* Integrate modules with additional capacity constraining elements, such as airspace, taxi-ways, air cargo facilities, and landside access.
- *Terminals:* Allow modelling of multiple terminals, based on their individual characteristics, rather than requiring the user to aggregate all the terminals into one terminal, as is the practice in the current ABS. Terminal queuing can also be integrated into the terminal capacity model.

6.3.2 ABS Financial Model

The following are recommendations that can be made to the Financial Model:

- *Detailed analysis:* The detailed level of analysis could not be implemented due to the different situations found at each airport. Thus, a certain degree of customisation is required, which is only possible using detailed real-world financial data. Elements to be included in the detailed analysis are described in Chapter 4. It is envisioned that the detailed level of analysis will need to be unique for each airport, in order to be truly valid. It will also allow for some simplifications, for example in the way that stocks and bonds were dealt with, to be rectified to more closely reflect the real-world situation found at the airport.
- *Financial plan:* The implementation proved to be too complex, and so only a proof-of-concept was carried out using the Excel Model. Subsection 4.9 presents ways in which the Financial Plan may be initially implemented. The main feature to be implemented would be an automation of the creation of the financial plan, to allow for easier implementation by the user. The user should be able to explore the effects of a policy change, without having to create new schemes and financial cases first. The user should be given more assistance, and various strategies to improve the financial situation of the airport should be suggested to the user. For example, an insufficient cash flow in a certain year, would trigger suggestions for increasing airport user charges, or exploring the use of financing options, with different terms, such as loans with different interest rate and pay-back period.
- *Outputs:* Although financial statements were implemented, the output of financial ratios and graphs were not implemented in the Financial Model, as it was not considered crucial to providing a proof-of-concept.
- *Default values:* Default values should be found, perhaps under the auspices of a benchmark study, where the identities of airports remain anonymous. This will reduce user input, by providing default values according to certain airport characteristics e.g.

the default proportion of an airport's aeronautical to non-aeronautical revenues will differ based on the size of the airport, i.e. the number of passengers it experiences.

- *User evaluation:* Testing was not carried out by potential users of the program, since a few capabilities were missing from the Financial Model, listed above.
- *User manual:* A user manual should be completed when user testing is about to be commenced.
- *Explore the difference in performance of data-types:* The data-type used in the model should be changed, and the effects on the results produced quantified, in order to make the best choice. The main data-types to be compared are single, double, and decimal.

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Appendix

Appendix A Project Planning

Table A-1: Project planning

Task	Start Date	End Date
Exploratory/Initiation Phase	**18/11/2013**	**14/02/2014**
First meeting with supervisors	18/11/2013	
Preliminary research	18/11/2013	18/12/2013
Formulate research objective and questions	06/01/2014	13/01/2014
Write Research Methodologies papers	13/01/2014	19/02/2014
Kick-off meeting	20/02/2014	
Literature Review Phase	**21/02/2014**	**15/04/2014**
Detailed research	21/02/2014	21/03/2014
Write Literature Review Report	21/03/2014	14/04/2014
Submit Literature Review Report	15/04/2014	
Learning VB.NET Phase	**16/04/2014**	**16/05/2014**
Learn VB.NET language	16/04/2014	07/05/2014
Explore ABS program	08/04/2014	16/05/2014
Programming Phase 1	17/05/2014	08/07/2014
Design model	17/05/2014	20/05/2014
Implement GUI	21/05/2014	28/05/2014
Implement and debug database connections	29/05/2014	08/06/2014
Implement and debug calculations	09/06/2014	13/06/2014
Write thesis draft	14/06/2014	
Write mid-term report	27/06/2014	30/06/2014
Submit thesis draft and mid-term report	01/07/2014	
Mid-term meeting	08/07/2014	
Programming Phase 2	**01/09/2014**	**28/01/2015**
Implement and debug calculations	01/09/2014	15/10/2014
Test model	16/10/2014	01/12/2015
Write thesis report	02/12/2014	20/12/2014
Submit draft thesis	20/12/2014	
Green light review meeting	28/01/2015	
Wrap up phase	**29/01/2015**	**20/03/2015**
Implement feedback	29/01/2015	13/03/2015
Prepare for defence	14/03/2015	19/03/2015
Thesis defence	20/03/2015	

Appendix B
Flowcharts of the various classes

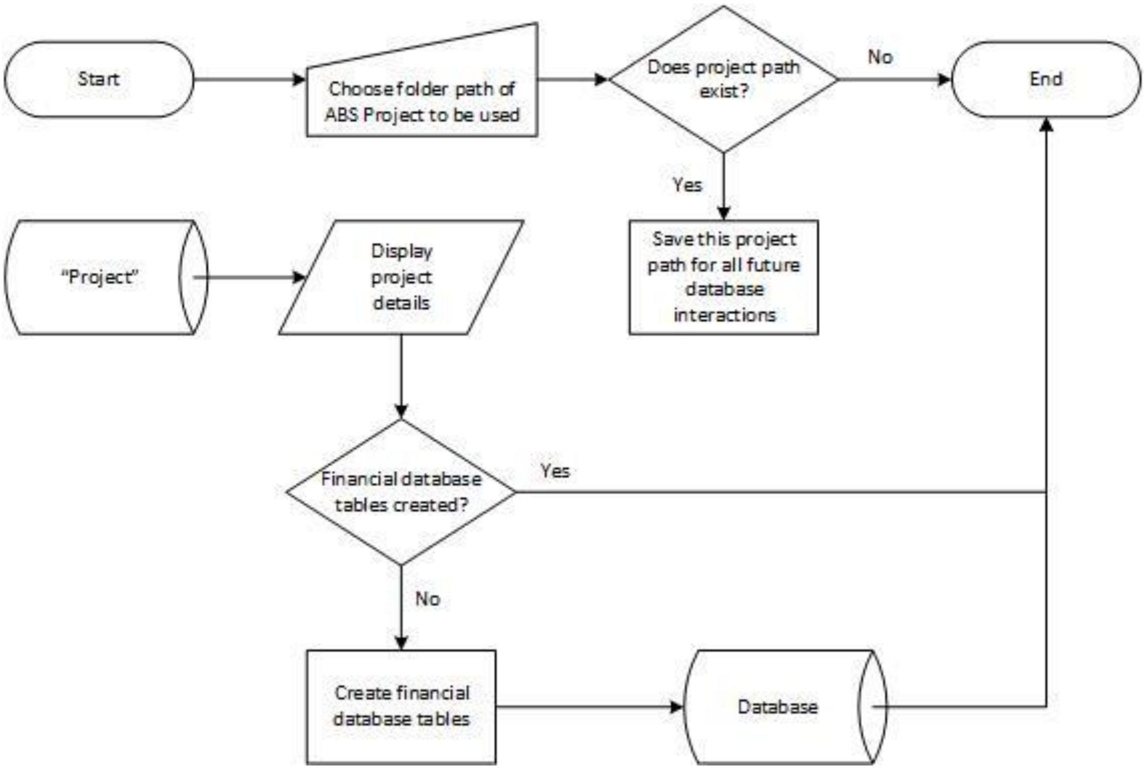


Figure B-1: Project selection procedure

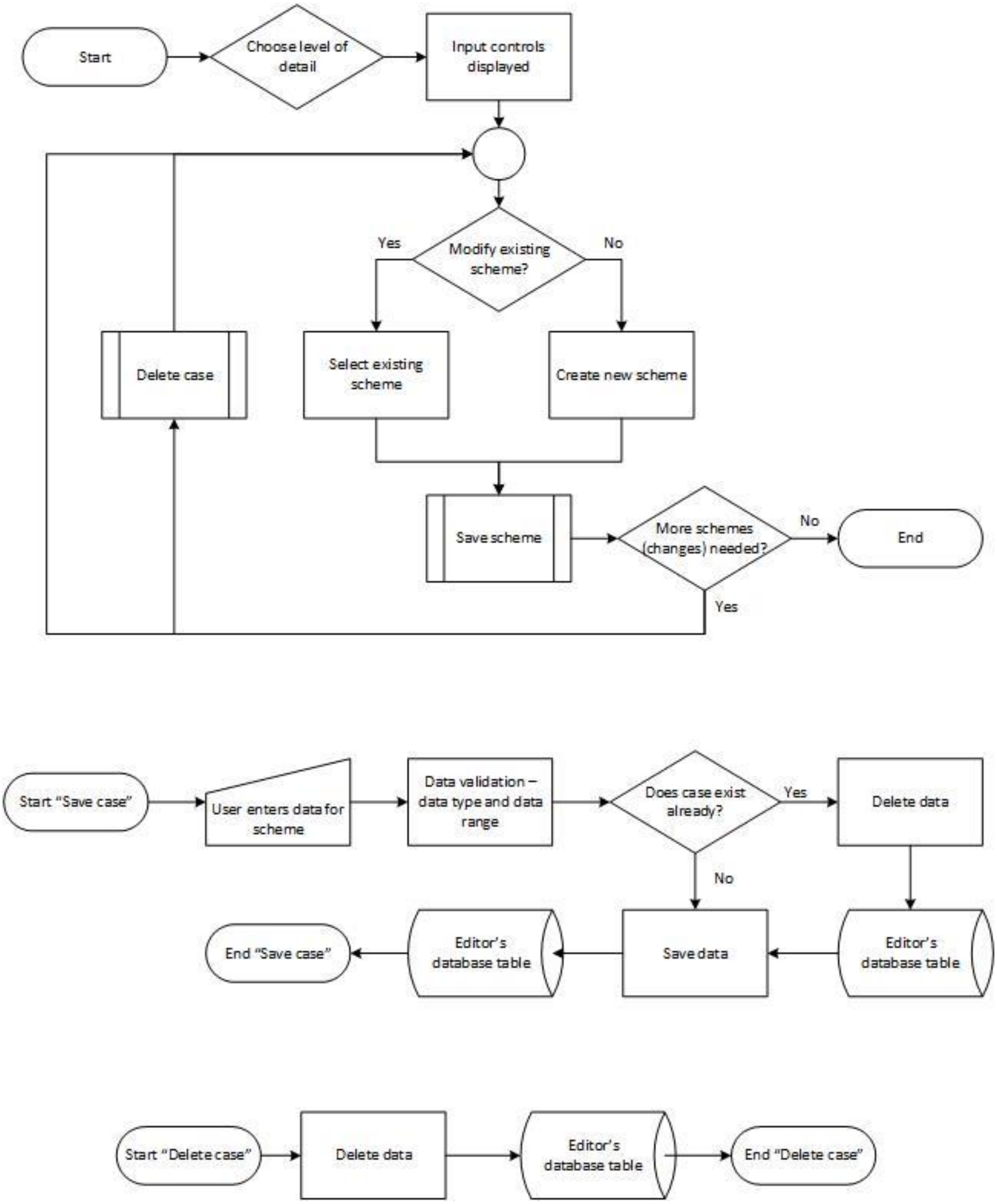


Figure B-2: Flowchart of the Editor modules

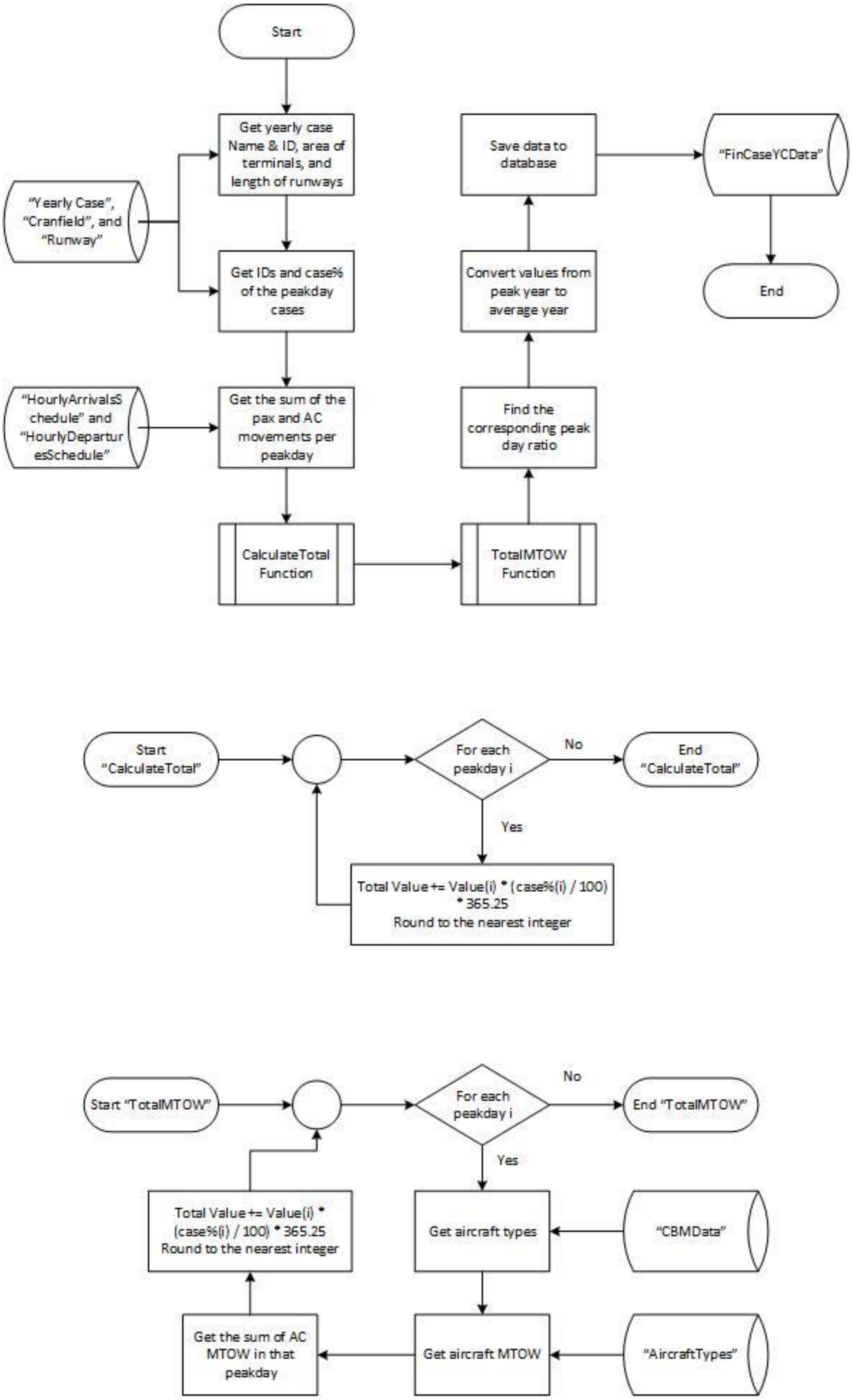


Figure B-3: Flowchart of Yearly case module

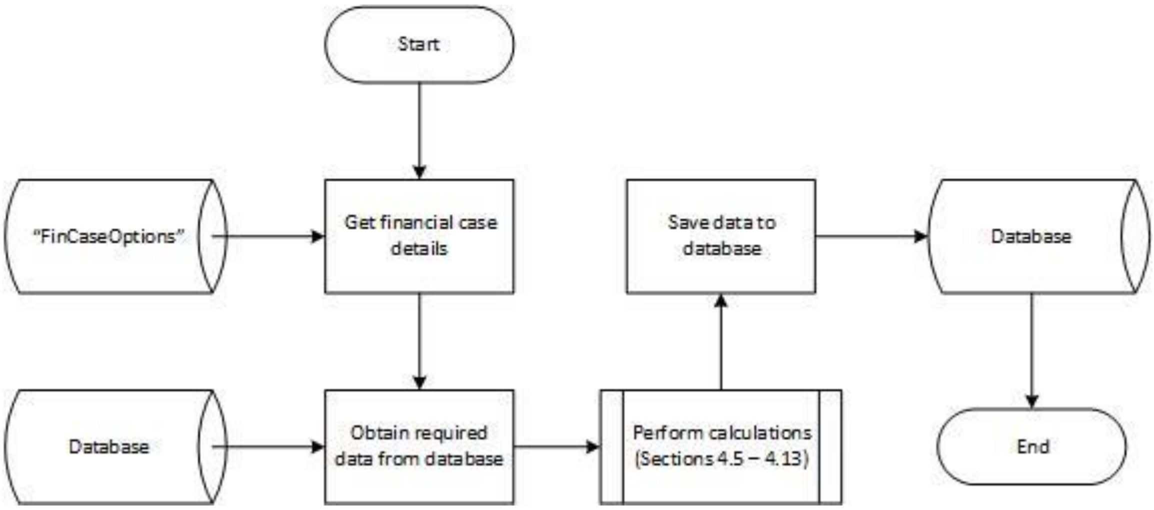


Figure B-4: Flowchart of Calculation modules

Calculation modules: revenues, costs, balance sheet items, and cash flow modules

Appendix C
Database tables

Table C-1: ABS database tables

Database table name	Description
ACAlias	Alternate aircraft names for aircraft type data
Acft_sub	Alternate aircraft names used in INM
Aircraft	INM Aircraft data
AircraftTypes	ABS Aircraft Types
Airports	List of airports with lat-long coordinates
APAlias	Alias codes for airports
ApronArrivalSchedule *	Temporary table used for terminal calculations
ApronDepartureSchedule *	Temporary table used for terminal calculations
AverageDay	INM flight data
CityPairACData	Aircraft data for 'citypairdata' table
CityPairData	Saved citypair data
CityPairs	List of data in CityPairData table
Cranfield	Terminal result data
CurrentTerminalSetup	Terminal layout data
DelayData	Delay parameters (see A.2)
FAAData	FAA Airfield parameters (see A.2)
FAADatasets	Names of the sets of FAA airfield parameters
FAADescriptions	Description of FAADatasets.
FlightScheduleData	Data of all stored flighschedules
FlightSchedules	List of schedules in FlightScheduleData
FSC_Settings	Flight Schedule Creation settings
HourlyArrivalsSchedule*	Terminal Passenger numbers
HourlyDeparturessSchedule*	Terminal Passenger numbers
LOS	Terminal Level of Service parameters
M2OutputData*	Model 2 result data
MovementsPerHour*	Movements per hour
Project	General project data
RequiredTerminalSetup*	Terminal facility data
Runway	All runways
RunwayConfiguration	All runway configurations
RunwayConfScheme	Peak day data (name is misleading)
RunwaySet	Runway set data for all runway configurations
RWUseSchemeData	Runway use scheme data
RWUseSchemes	List of runway use schemes in RWUseSchemeData
Sys_aprt	US airports
Sys_rwy	Runway data for US airports
TerminalParameters	Parameters for terminal calculation
Terminals	List of Terminals
TimeDistributionData	Saved Time distribution data
TimeDistributions	List of data in TimeDistributionData
TrackAssignmentData	INM Track assignment data
TrackAssignmentSets	Names of INM track assignment sets.
Weightclasses	Aircraft weight class data
Wingspanclasses	Aircraft wing span classes
YearlyCase	List of yearly cases

Table	Description
YearlyData	Data for yearly cases

Table C-2: Financial Model database tables

Database table name	Description
frmAeroRevQuick	Input data from the revenue editor – aeronautical revenues
frmNonAeroRevQuick	Input data from the revenue editor - non-aeronautical revenues
frmOpCostQuick	Input data from the cost editor – operating costs
frmDeprCostQuick	Input data from the cost editor – depreciation of assets
frmCapitalProjQuick	Input data from the cost editor - capital projects
frmAssetQuick	Input from the balance sheet editor - assets
frmLiabilityQuick	Input from the balance sheet editor - liabilities
FinCaseOptions	Financial case - combination of schemes
FinCaseYCData	Financial case - yearly case data from ABS
FinCaseRevenue	Financial case - data from revenue calculations
FinCaseCost	Financial case - data from cost calculations
FinCaseBalanceSheet	Financial case - balance sheet
FinCaseCashFlow	Financial case - cash flow
FinCaseRatios	Financial case - ratios
FinPlanOptions	Financial plan - combination of financial cases
FinPlanYCData	Financial plan - yearly plan data from ABS
FinPlanRevenue	Financial plan - data from revenue calculations
FinPlanCost	Financial plan - data from cost calculations
FinPlanBalanceSheet	Financial plan - balance sheet
FinPlanCashFlow	Financial plan - cash flow
FinPlanRatios	Financial plan - ratios

Appendix D
Graphical User Interface

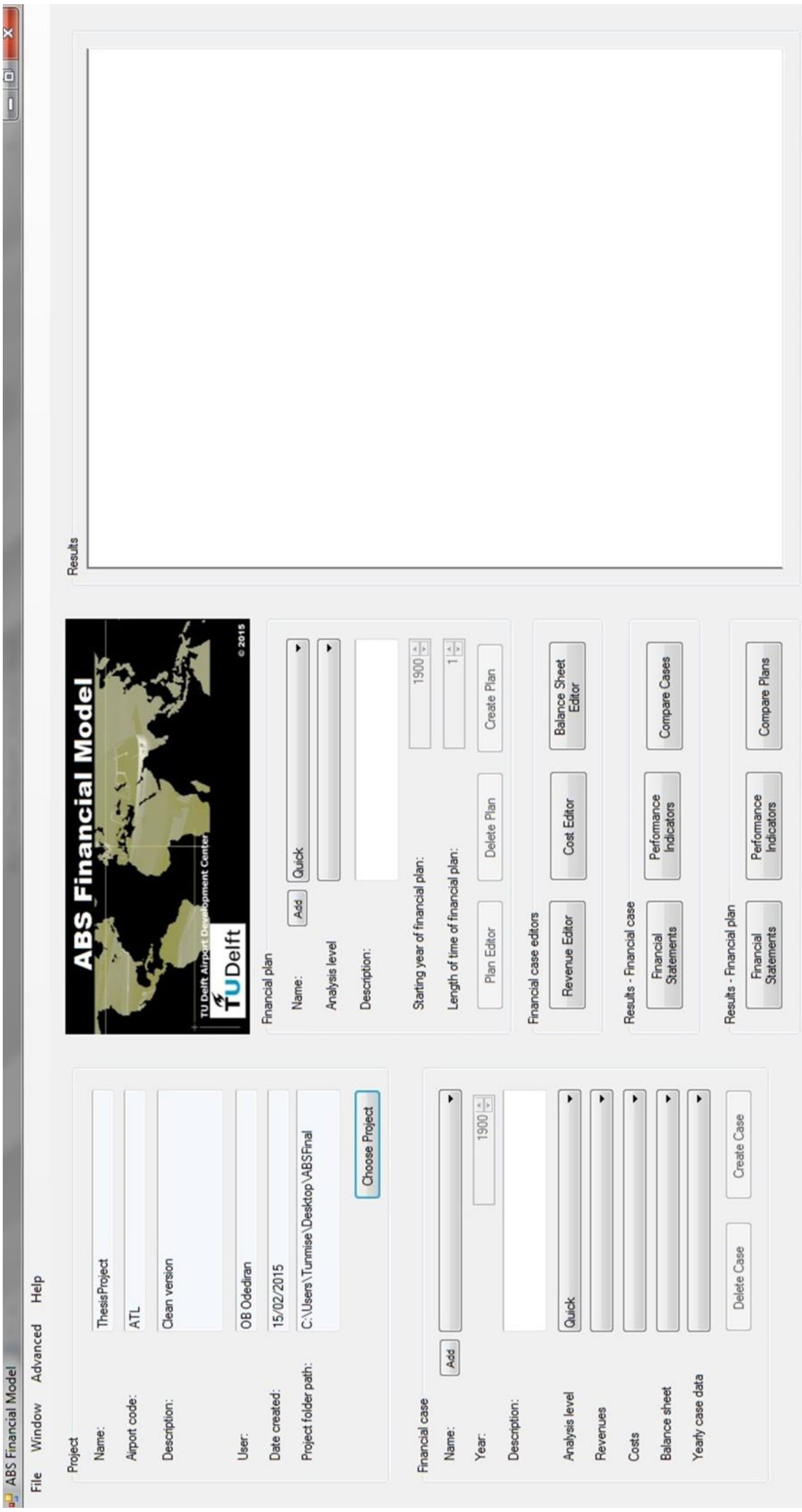


Figure D-1: GUI of Main Screen

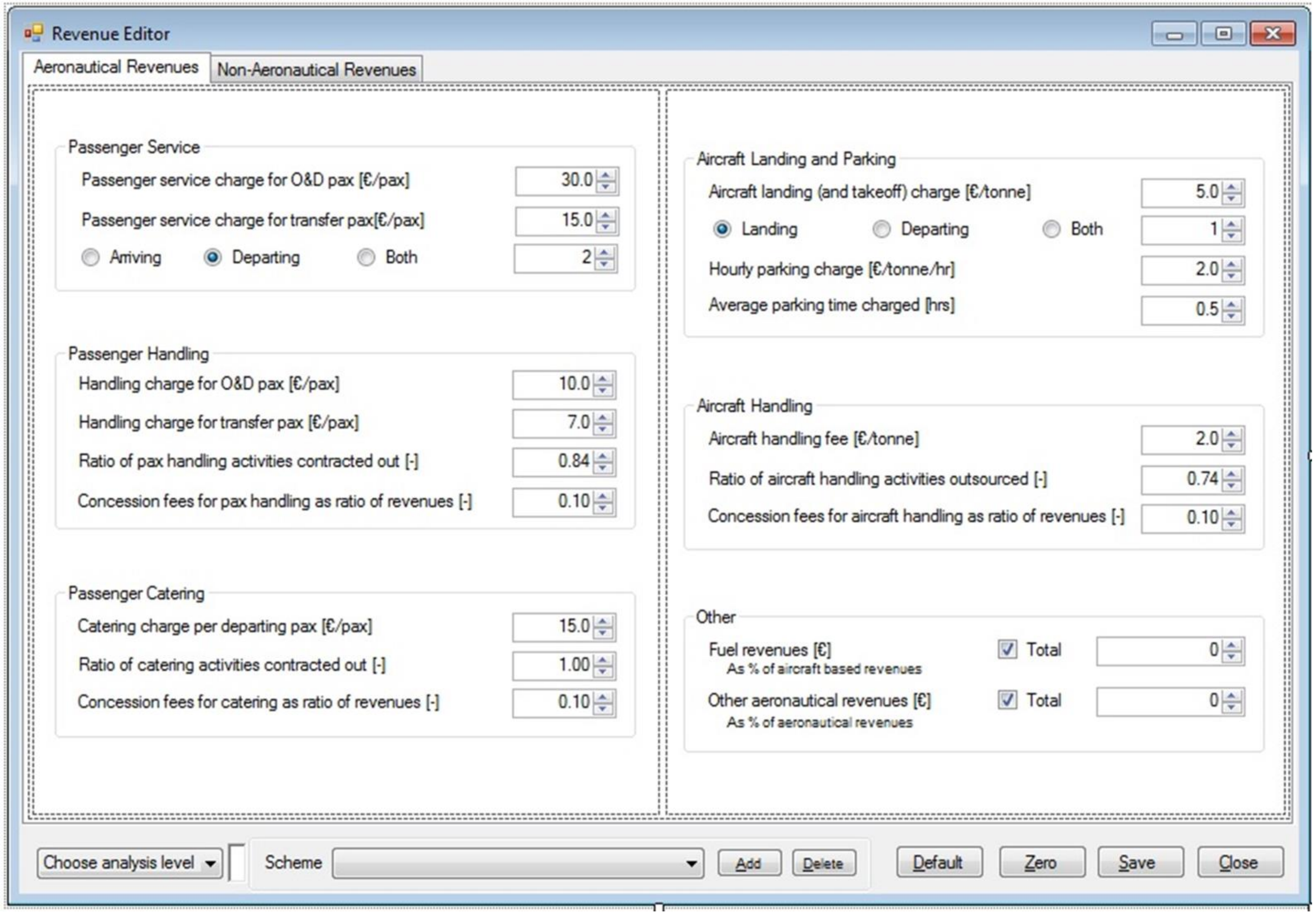


Figure D-2: GUI of Revenue Editor

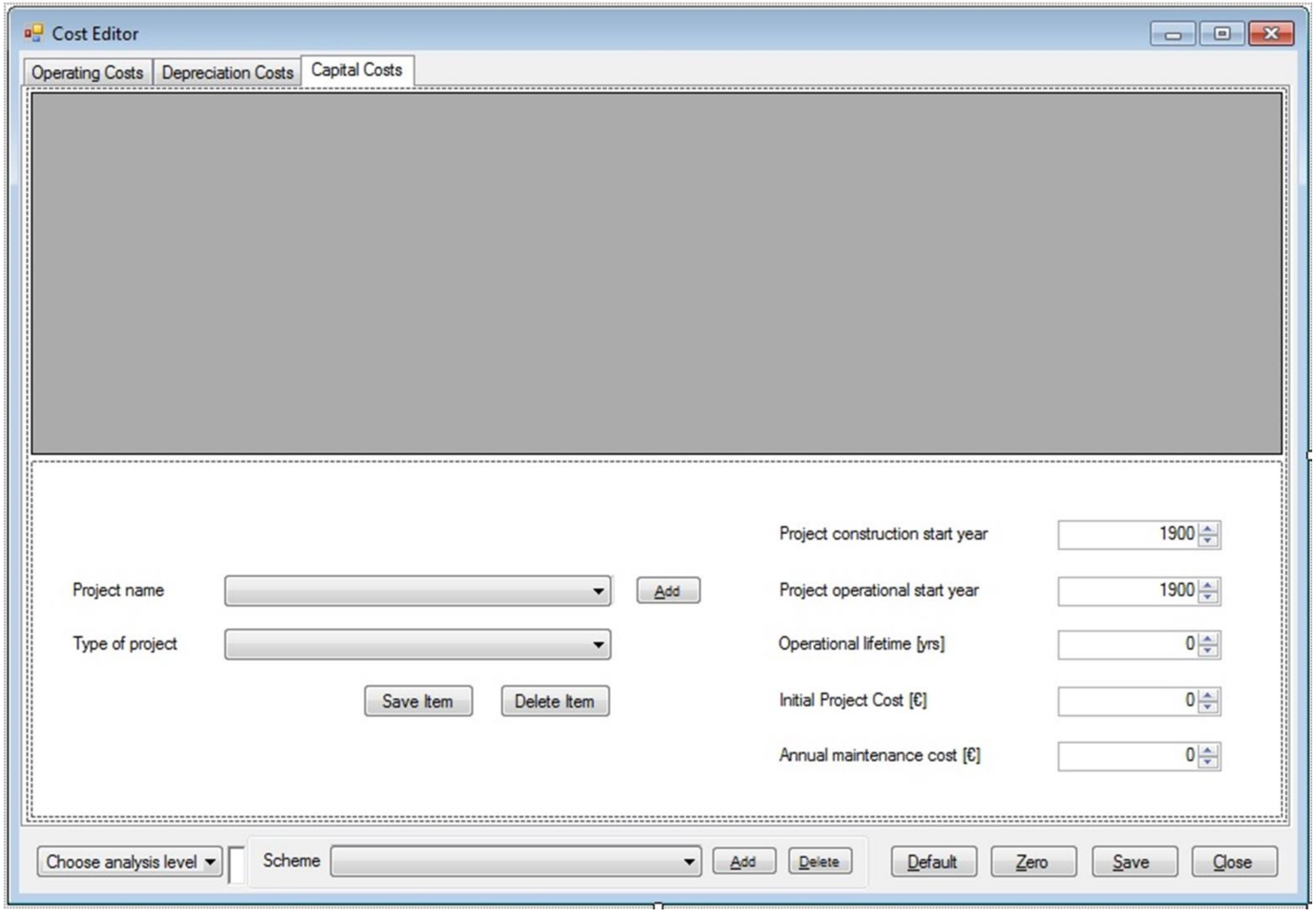


Figure D-3: GUI of Cost Editor

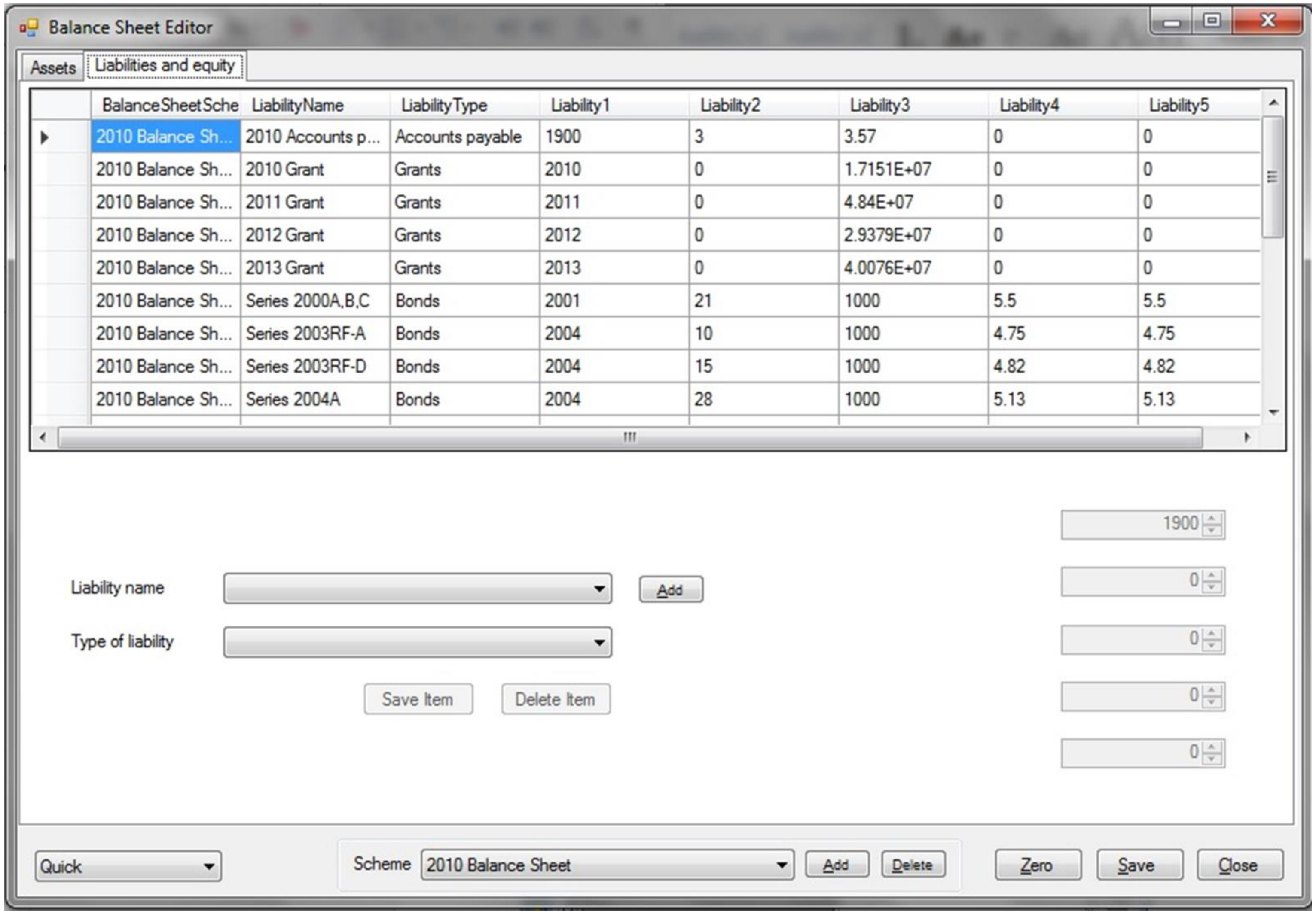


Figure D-4: GUI of Balance Sheet Editor

Appendix E
Data used in the model

Table E-1: Ratio of peakday to average day

Annual pax	Ratio	Annual pax	Ratio	Annual pax	Ratio
10.000	2,666	180.000	1,326	350.000	1,130
20.000	2,255	190.000	1,309	360.000	1,122
30.000	2,045	200.000	1,293	370.000	1,114
40.000	1,907	210.000	1,278	380.000	1,107
50.000	1,807	220.000	1,264	390.000	1,100
60.000	1,729	230.000	1,250	400.000	1,094
70.000	1,666	240.000	1,237	410.000	1,087
80.000	1,613	250.000	1,225	420.000	1,081
90.000	1,568	260.000	1,214	430.000	1,075
100.000	1,529	270.000	1,203	440.000	1,069
110.000	1,494	280.000	1,192	450.000	1,063
120.000	1,463	290.000	1,182	460.000	1,057
130.000	1,435	300.000	1,172	470.000	1,052
140.000	1,409	310.000	1,163	480.000	1,047
150.000	1,386	320.000	1,154	490.000	1,041
160.000	1,365	330.000	1,146	500.000	1,036
170.000	1,345	340.000	1,137		

Source: Ashford, Coutu and Beasley (2012)

Table E-2: Depreciation schedule

Depreciation Item	Period (years)	Average (years)
Buildings (freehold)	20 to 40	30
Buildings (leasehold)	lease period	n/a
Runways & taxiways	15 to 30	23
Aircraft parking areas	15 to 30	23
Furniture and fittings	10 to 15	13
Motor vehicles	4 to 10	7
Electronic equipment	7 to 15	11
General equipment	7 to 10	9
Computer equipment	5 to 10	8
Computer software	3 to 8	6

Source: Adapted from ICAO (2013, p. 4.17)

Appendix F
ATL airport information

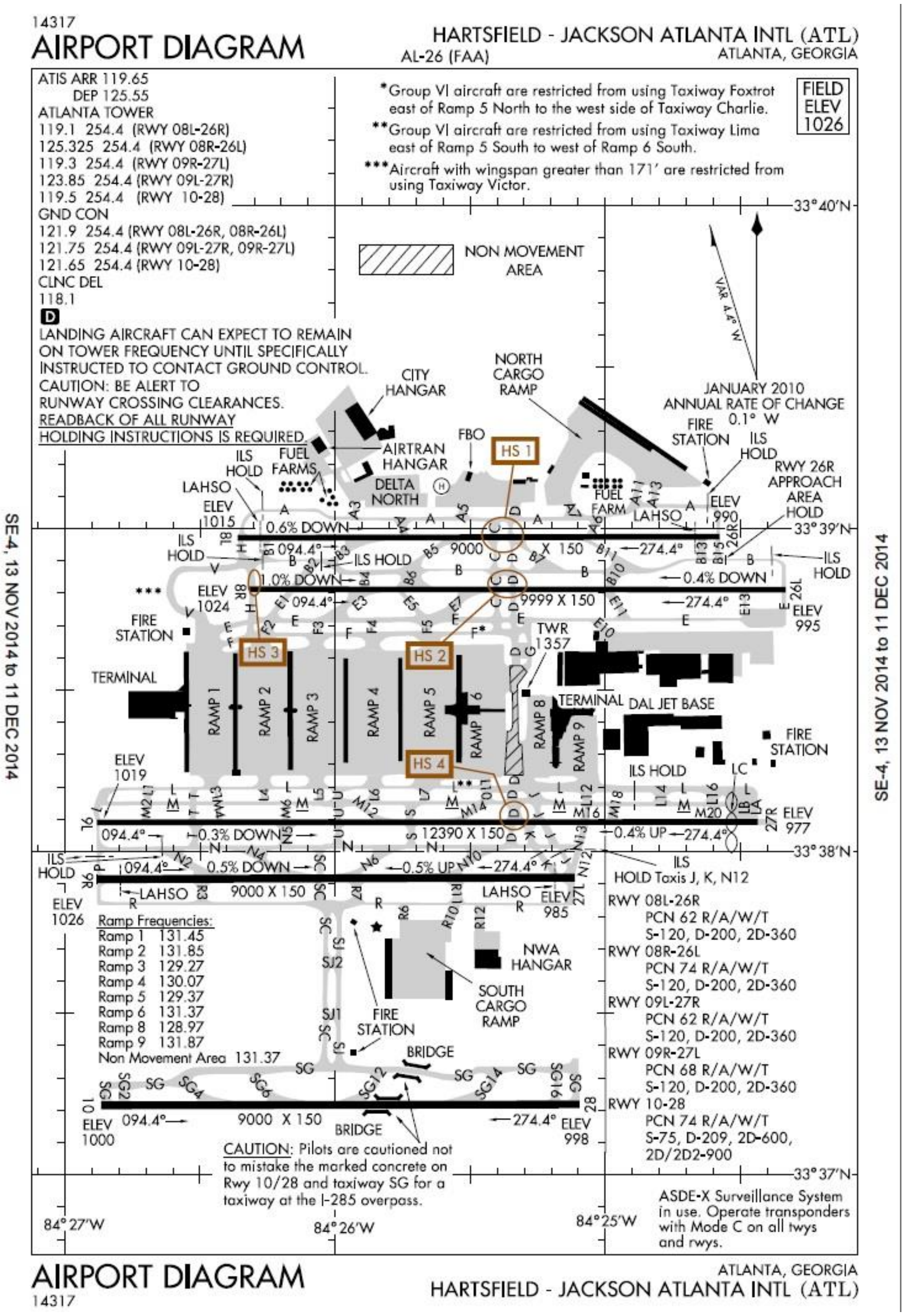


Figure F-1: FAA airport diagram of ATL
Source: (FAA, 2014b)

Table F-1: ATL activity levels (2010 -2013)

	2010	2011	2012	2013
Total Passengers	88,453,708	90,788,019	94,393,355	95,155,011
Arriving passengers	43,078,410	44,596,352	47,246,040	47,628,768
Departing passengers	45,375,298	46,191,667	47,147,315	47,526,243
Total aircraft	963,806	937,104	931,554	918,757
Landing aircraft MTOW	25,817,117	26,621,480	26,439,899	26,416,168

Source: ATL (2013)

Table F-2: Detailed revenue breakdown for ATL in 2010

Airline revenue sources	2010
Total landing fees	62,602,543
Total terminal area rental/charges	50,590,351
Total land rental & other Buildings	14,546,727
Total apron charges	4,339,243
Total fuel sales	5,615,361
Total security reimbursement	12,012,945
Total other	9,356,617
Total airline revenues	159,063,786
Non-airline revenue sources	2010
Terminal area rental/others	12,807,912
Total land and non-terminal facilities	15,851,837
Total Fixed Base Operator	1,743,646
Total concessions	77,783,347
APM Conrac (rental car facility)	6,156,237
Total rental cars	32,821,430
Total parking	95,774,778
Total royal ties from natural resources sales	154,115
Total other	5,398,380
Total non-airline revenues	241,735,446
Non-operating revenues	2010
Total interest income	-38,381,632
PFCs and Customer Facility Charges	186,337,544
Interest on long term debt	-64,572,225
Other revenue	125,357
Total non-operating revenues	102,775,203

Source: ATL (2010)

Table F-3: ATL revenues (2010 – 2013)

	2010	2011	2012	2013
Total Parking, car rental, concessions	202,881,000	222,796,000	229,585,000	246,593,000
Terminal, buildings, rentals	105,495,000	93,190,000	80,578,000	142,893,000
Landing fees	62,603,000	51,897,000	48,009,000	47,416,000
Other	33,248,000	43,330,000	35,960,000	53,484,000
Total operating revenues	400,799,000	411,213,000	394,132,000	490,386,000
Investment income (loss)	(38,382,000)	13,798,000	16,063,000	9,102,000
PFCs	165,022,000	172,673,000	177,899,000	180,077,000
Customer Facility Charges	21,316,000	19,265,000	22,943,000	24,290,000
Other	125,000	2,382,000	-14,943,000	2,243,000
Total non-operating revenues	148,081,000	208,118,000	201,962,000	215,712,000
Capital contributions (grants)	19,266,000	49,379,000	37,522,000	33,500,000
Total revenues	568,146,000	668,710,000	633,616,000	739,598,000

Source: ATL (2013)

Table F-4: ATL costs (2010 - 2013)

	2010	2011	2012	2013
Salaries and employee benefits	90,912,000	82,482,000	79,785,000	82,050,000
Repairs, maintenance, other services	82,461,000	85,945,000	98,258,000	101,742,000
General services	15,550,000	15,300,000	21,997,000	20,504,000
Utilities	8,420,000	9,627,000	8,151,000	8,768,000
Materials and supplies	4,164,000	2,888,000	4,090,000	4,353,000
Other	8,662,000	7,133,000	7,761,000	12,146,000
Total operating expenses	210,169,000	203,375,000	220,042,000	229,563,000
EBITDA	357,977,000	465,335,000	413,574,000	510,035,000
Depreciation	174,124,000	152,395,000	161,642,000	211,110,000
Operating Income (EBIT)	183,853,000	312,940,000	251,932,000	298,925,000
Interest costs	64,572,000	84,010,000	112,314,000	146,718,000
Transfer (to)/from city	0	194,000	0	(193,000)
Increase in net position (retained earnings)	119,281,000	229,124,000	139,618,000	152,014,000

Source: ATL (2013)

Table F-5: ATL assets (2010 - 2013)

	2010	2011	2012	2013
Cash & Cash equivalents	105,055,000	253,279,000	90,043,000	68,975,000
Accounts receivable (without doubtful accounts)	6,891,000	10,931,000	11,382,000	10,433,000
Other current assets	483,424,000	450,302,000	646,773,000	759,055,000
Total current assets	595,370,000	714,512,000	748,198,000	838,463,000
Land	583,067,000	583,098,000	584,230,000	584,230,000
Land purchased for noise abatement	265,104,000	278,255,000	306,797,000	306,797,000
Runways, taxiways, other	2,517,187,000	2,514,575,000	3,024,783,000	3,068,825,000
Terminal, building, structure	2,280,207,000	2,391,374,000	3,566,204,000	3,653,946,000
Other property and equipment	159,285,000	157,861,000	190,334,000	240,986,000
Construction in process (capital projects)	1,124,668,000	1,520,747,000	181,958,000	259,416,000
Accumulated depreciation	1,693,391,000	1,840,196,000	1,999,729,000	2,172,962,000
Net capital (non)-current assets	5,236,127,000	5,605,714,000	5,854,577,000	5,941,238,000
Other non-current assets	873,767,000	1,439,315,000	1,368,336,000	1,195,581,000
Total assets	6,705,264,000	7,759,541,000	7,971,111,000	7,975,282,000

Source: ATL (2011) and ATL (2013)

- *Other current assets:* cash investments, restricted other assets, due from other funds, prepaid expenses, and materials and supplies net of allowance.
- *Other non-current assets:* restricted investments, deferred assets, and due from government.

Table F-6: ATL liabilities (2010 – 2013)

	2010	2011	2012	2013
Accounts payable	7,642,000	5,020,000	20,374,000	15,042,000
Accounts payable restricted assets	45,264,000	49,604,000	39,565,000	29,403,000
Current portion of liabilities	72,379,000	69,078,000	96,945,000	105,688,000
Accrued interest payable	46,984,000	76,662,000	72,281,000	77,813,000
Commercial paper notes payable	148,857,000	314,348,000	0	0
Other current liabilities	37,212,000	37,211,000	42,289,000	16,582,000
Total current liabilities	358,338,000	551,923,000	271,454,000	244,528,000
Revenue bonds payable	2,161,744,000	2,788,402,000	3,178,919,000	3,061,999,000
Other non-current liabilities	51,085,000	55,995,000	52,150,000	48,153,000
Total non-current liabilities	2,212,829,000	2,844,397,000	3,231,069,000	3,110,152,000
Total liabilities	2,571,167,000	3,396,320,000	3,502,523,000	3,354,680,000
Total net assets	4,134,097,000	4,363,221,000	4,468,588,000	4,620,602,000

Source: ATL (2011) and ATL (2013)

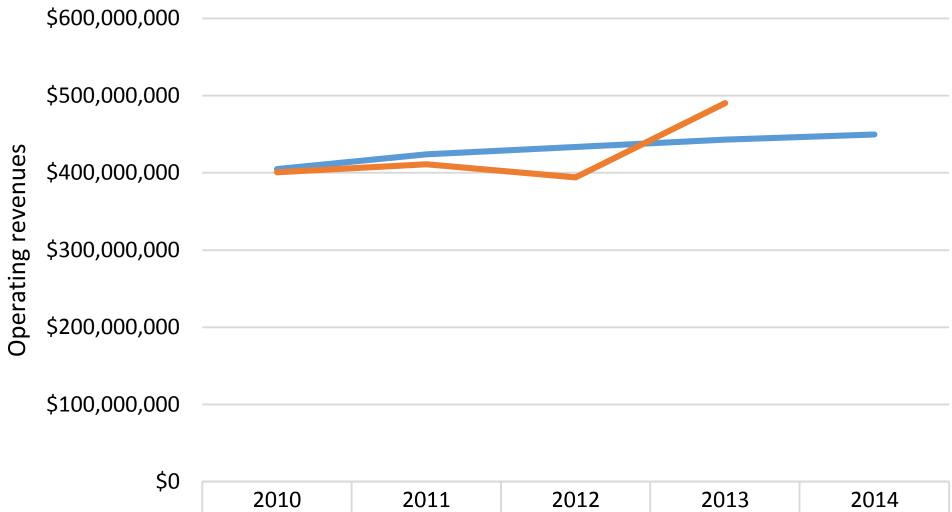
- *Other current liabilities:* accrued expenses, claims payable, due to other funds, contract retention, deposits, and advances.
- *Other non-current liabilities:* other liabilities, accrued workers compensation, other post-retirement benefits, and contract retention.

Table F-7: ATL cash flow (2010 - 2013)

	2010	2011	2012	2013
Receipts from customers and tenants	405,237,000	407,173,000	400,193,000	484,946,000
Payments to suppliers for goods and services	(118,161,000)	(124,976,000)	(134,631,000)	(155,482,000)
Payments to employees	(82,894,000)	(72,332,000)	(74,917,000)	(74,959,000)
Net cash for operating activities	204,182,000	209,865,000	190,645,000	254,505,000
Interest and dividends on investments	26,731,000	17,578,000	12,812,000	21,059,000
Purchases of investments	(774,791,000)	(1,758,421,000)	(264,158,000)	(312,681,000)
Sales and redemptions of investments	1,045,889,000	1,195,337,000	125,983,000	200,837,000
Swap termination payments	(58,470,000)	0	0	0
Change in pooled investment fund	11,899,000	34,342,000	-184,052,000	-125,640,000
Net cash for investing activities	251,258,000	(511,164,000)	(309,415,000)	(216,425,000)
Capital grants	17,151,000	48,400,000	29,379,000	40,076,000
Principal repayments of debt	(108,263,000)	(858,161,000)	(867,292,000)	(96,810,000)
Proceeds from bond/note issuances	55,625,000	1,646,949,000	978,496,000	0
Capital assets	(491,726,000)	(474,498,000)	(411,506,000)	(309,231,000)
PFC and CFC	185,045,000	191,231,000	198,204,000	205,783,000
Contract retention withheld	4,254,000	1,033,000	-8,458,000	-29,140,000
Interest and fees on bonds	(117,245,000)	(105,431,000)	(137,256,000)	(148,412,000)
Net cash for financing activities	(455,159,000)	449,523,000	(218,433,000)	(337,734,000)
Net change in cash	281,000	148,224,000	(337,203,000)	(299,654,000)
Beginning cash	104,774,000	105,055,000	1,426,604,000	1,089,401,000
Ending cash	105,055,000	253,279,000	1,089,401,000	789,747,000

Source: ATL (2011) and ATL (2013)

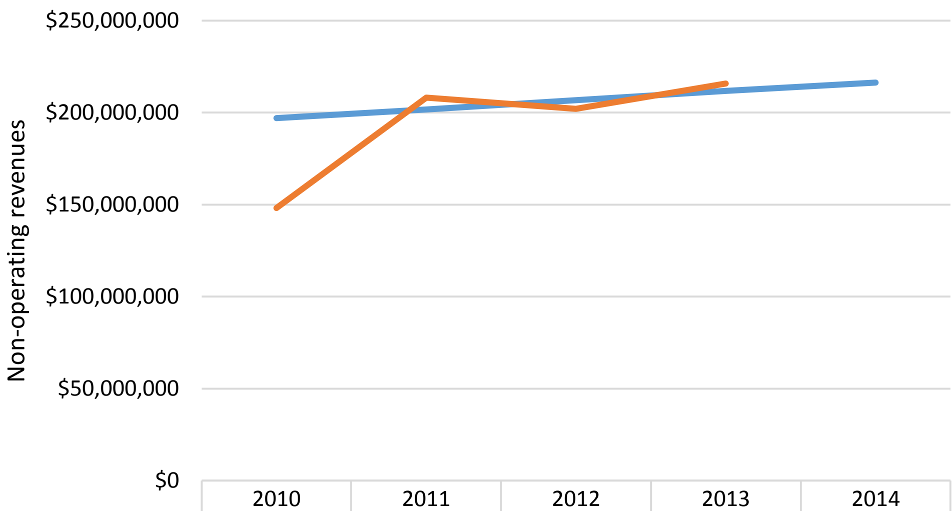
Appendix G
Validation of results



	2010	2011	2012	2013	2014
Excel Model	$404,918,586	$424,112,164	$433,547,349	$443,113,189	$449,714,717
Real-World	$400,799,000	$411,213,000	$394,132,000	$490,386,000	

Year

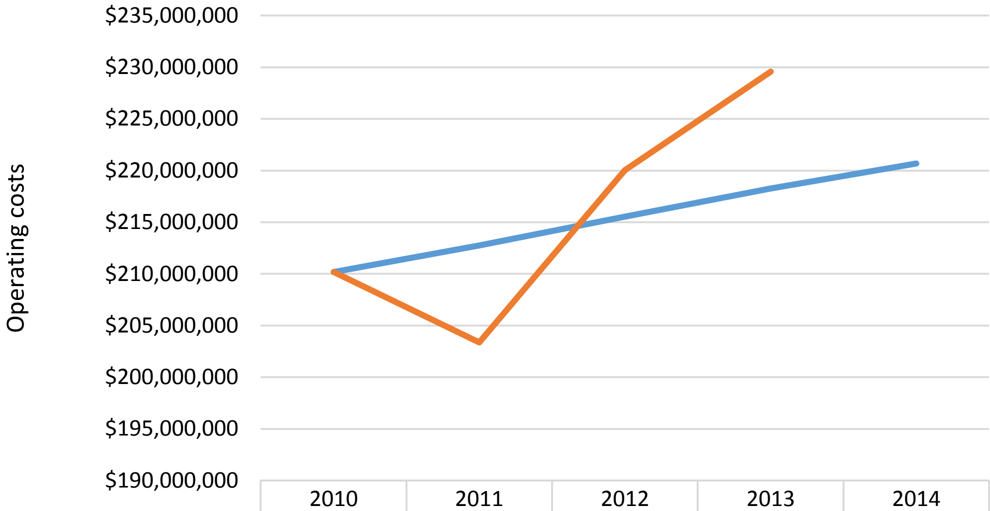
Figure G-1: Operating revenues – Validation



	2010	2011	2012	2013	2014
Excel Model	$196,927,227	$201,688,331	$206,755,646	$211,754,745	$216,325,476
Real-World	$148,081,000	$208,118,000	$201,962,000	$215,712,000	

Year

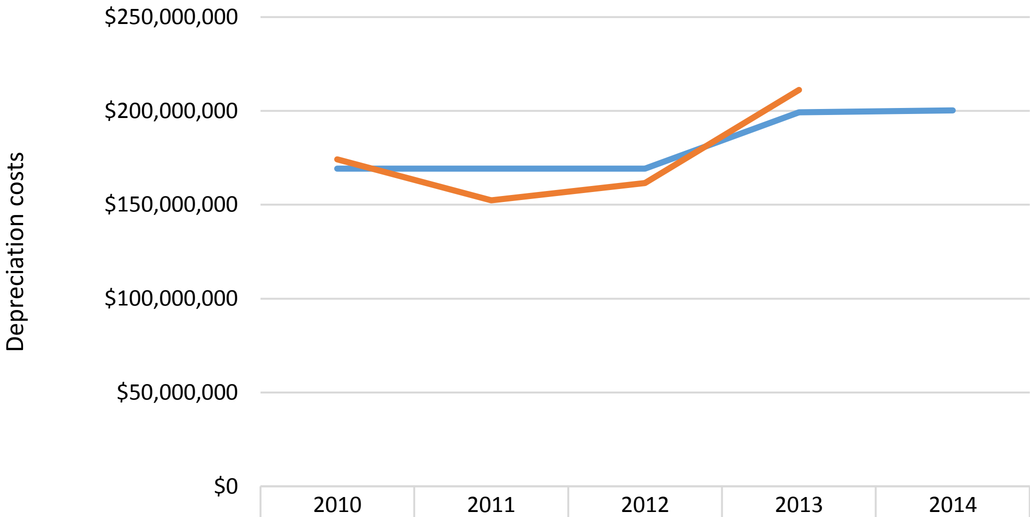
Figure G-2: Non-operating revenues – Validation



	2010	2011	2012	2013	2014
Excel Model	$210,169,000	$212,737,117	$215,538,661	$218,251,935	$220,691,737
Real-World Model	$210,169,000	$203,375,000	$220,042,000	$229,563,000	

Year

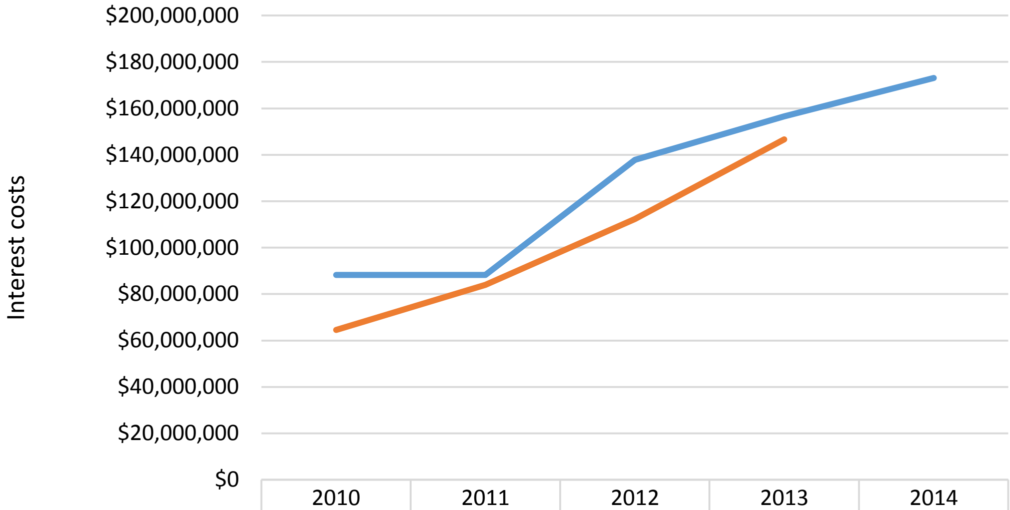
Figure G-3: Operating costs - Validation



	2010	2011	2012	2013	2014
Excel Model	$169,339,100	$169,339,100	$169,339,100	$199,232,675	$200,346,812
Real-World Model	$174,124,000	$152,395,000	$161,642,000	$211,110,000	

Year

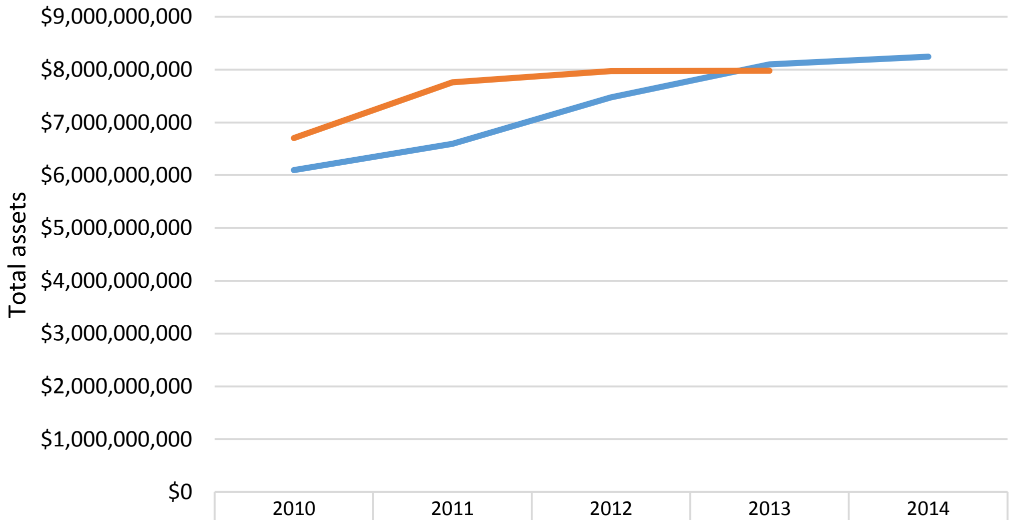
Figure G-4: Depreciation costs - Validation



	2010	2011	2012	2013	2014
Excel Model	$88,233,332	$88,233,332	$137,805,762	$156,585,387	$173,140,737
Real-World Model	$64,572,000	$84,010,000	$112,314,000	$146,718,000	

Year

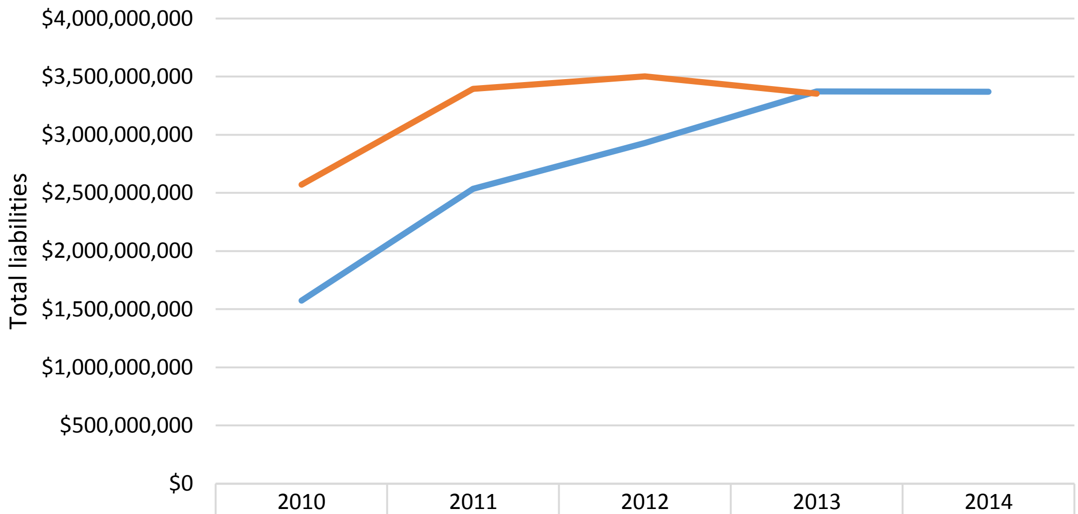
Figure G-5: Interest costs – Validation



	2010	2011	2012	2013	2014
Excel Model	$6,094,390,757	$6,592,176,914	$7,472,219,214	$8,101,128,932	$8,242,532,787
Real-World	$6,705,264,000	$7,759,541,000	$7,971,111,000	$7,975,282,000	

Year

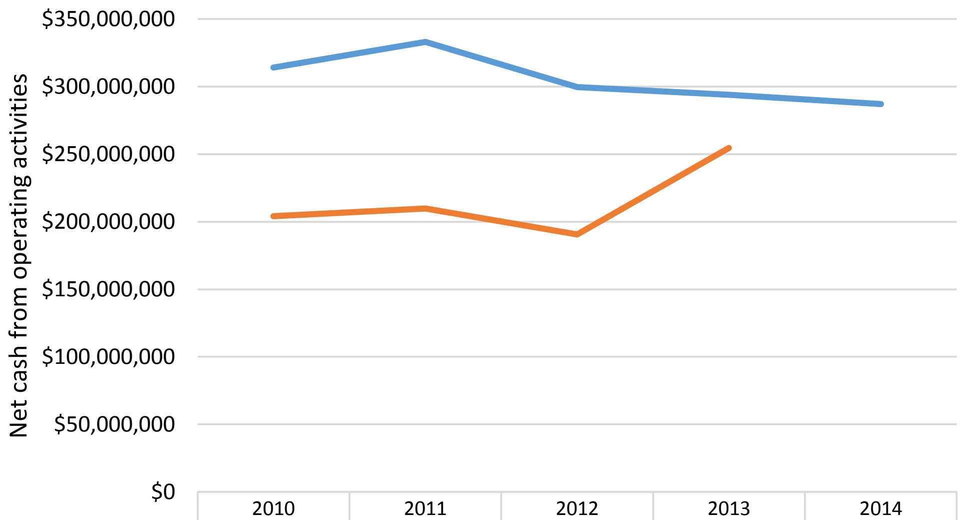
Figure G-6: Total assets - Validation



	2010	2011	2012	2013	2014
Excel Model	$1,575,323,215	$2,536,572,826	$2,928,911,635	$3,371,718,388	$3,370,055,123
Real-World	$2,571,167,000	$3,396,320,000	$3,502,523,000	$3,354,680,000	

Year

Figure G-7: Total liabilities – Validation



	2010	2011	2012	2013	2014
Excel Model	$314,084,757	$333,104,736	$299,760,948	$293,952,373	$287,081,847
Real-World	$204,182,000	$209,865,000	$190,645,000	$254,505,000	

Year

Figure G-8: Net cash from operating activities – Validation

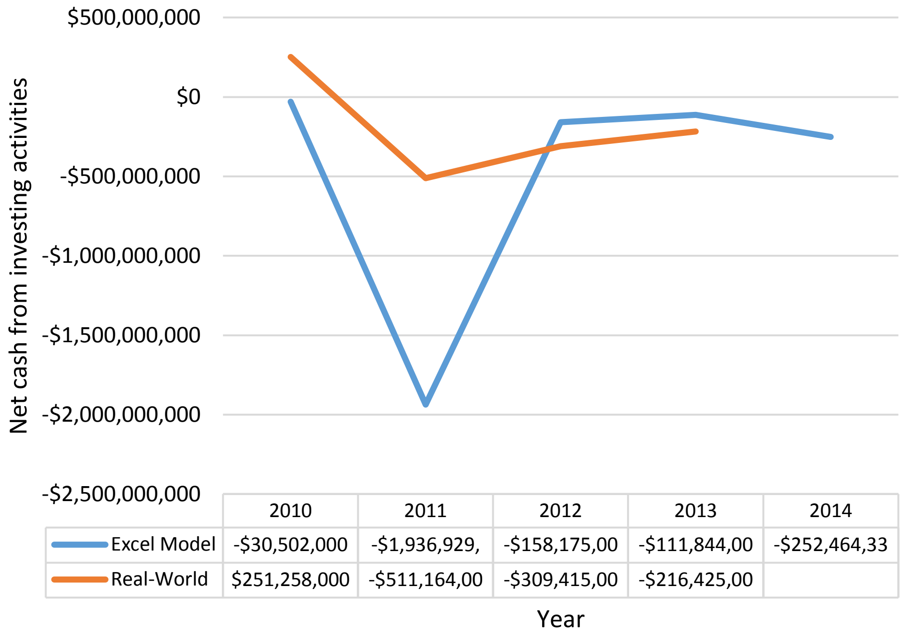


Figure G-9: Net cash from investing activities – Validation

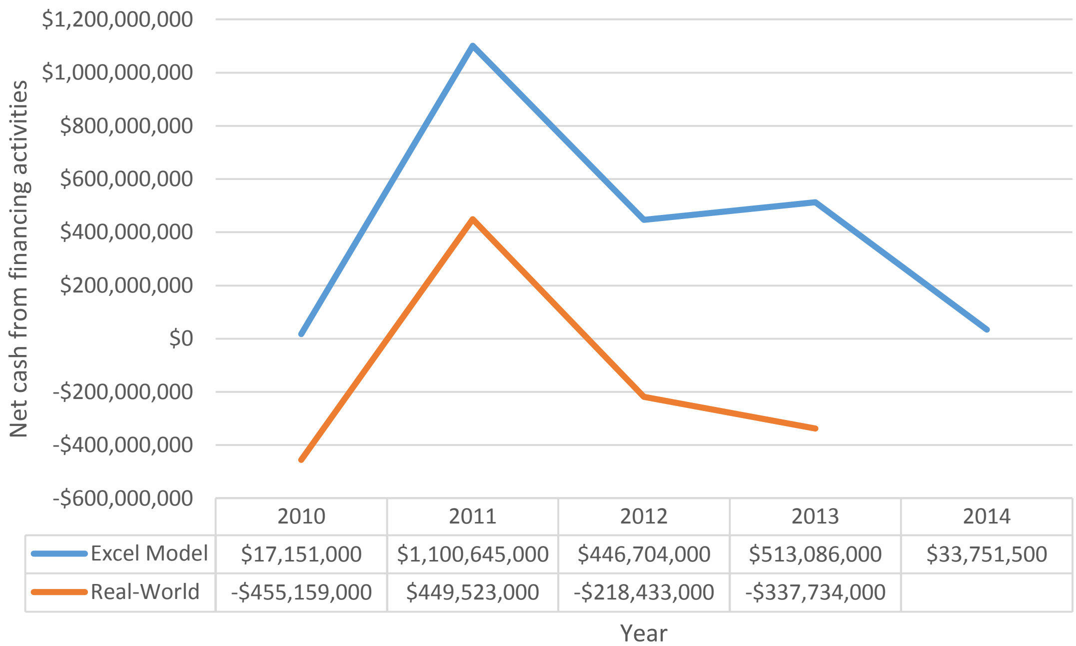


Figure G-10: Net cash from financing activities - Validation

Appendix H
Business plan

1. Executive summary

The purpose of this plan is to obtain funding for the Airport360 startup, by detailing all the important facets of the company, and the plan we have to operate and grow the business. In this executive summary, the most important aspects of the business plan will be presented.

1.1 Description of the company

Airport360 is a startup company that will be established in January 2015 in Delft, The Netherlands. Its sole purpose will be the commercialisation of the Airport Business Suite (ABS) developed by the Delft University of Technology Airport Development Centre (TUD-ADC).

Our mission statement is as follows.

> *To enable current and future generations of airport decision advisors and decision makers in making the best strategic decisions possible, by providing them with the ability to quickly and accurately test various hypotheses, and explore various scenarios, using an easy-to-use and intuitive software program that is tailored to their specific airport*

1.2 Description of product and services

The envisioned product family will be the main focus area of the company, and will share the same name as the company. Three product variations are envisioned:

- **Airport360 Student**: A 'serious game' to train or educate users, by enabling students to apply the theory learnt in practical, albeit simulated, conditions, and teaching them the right mind-set and culture to use in aviation management.
- **Airport360 Pro**: Aid airport decision advisors and makers in airport strategic planning, by allowing airports to test ideas on improving individual systems, and get a larger perspective on how these adjustments will affect the entire airport's operations.
- **Airport360 Game**: A game which gives users (such as aviation enthusiasts) the thrill of managing and running a virtual airport.

For clients of the Airport 360 Student and Airport360 Pro, we will provide the following related services:

- Installation and customisation of the software.
- After sales customer service and support.
- Maintenance and upgrades.
- Consultancy services for Airport360 Pro clients.

1.3 Co-founders

The background, roles, and responsibilities of each of the co-founders are described as follows:

CEO

The CEO will guide the overall business development and strategy of the company, and will be the face of the company. His main tasks in the beginning will be to oversee the commercial aspects of the company such as administration, finances, fund-raising, marketing, and project management.

CRO

The CRO will be in charge of aspects related to aviation operations research and development. This will include all the latest trends in the aviation industry, as well as state-of-the-art in airport strategic planning. The CRO will have responsibility for the hiring and training of air transport operations specialists, who will act as researchers when designing the product, and as consultants in assessing the clients' needs, and providing trainings and other after-sales services.

CIO

The CIO will be in charge of all Information Technology (IT) related aspects in the firm. This ranges from knowledge management systems, to the development and implementation of the product variants. He will be in charge of hiring and training computer programmers, network administrators, and any IT-related support functions. He will also oversee the overall development of the use of IT in the company, and ensure that all IT-related aspects in the various teams and projects are running smoothly.

1.4 Market and customers

Air travel is now widely regarded as a fundamental pillar of our global life, influencing politics, business, and culture all over the world, with 6.3 billion passengers and 96 million metric tons of cargo in 2013 (ACI, 2014). Airports play a crucial role in providing the ground infrastructure that enable air travel, with a total of 41,821 airports worldwide as of 2013 (CIA, 2013). According to Airbus, air travel is forecast to more than double in the next 15 years (Airbus, 2013, pp. 9-10, 14).

Airport360 Student - Aviation management learning institutions

This includes the niche markets of universities, colleges, and institutions which provide training and certification in aviation management. There is currently no such software out there that allows students to apply theory to real-world situations, in a safe manner, and get a feel for the intricacies involved in airport strategic planning. The niche market within this for a potential launching customer will be universities offering aviation management degrees, as they will be more open to adopting new teaching methods and solutions.

Airport360 Pro - Airport planning, consulting, and engineering companies

There is a big need in this market segment to adopt new ways of conducting airport strategic planning, and thus, to employ new software tools which are more suitable to these new approaches. Existing alternatives are usually custom-made and expensive solutions made by consulting firms. Thus, the aim of this program is to enable even someone with a rudimentary knowledge of programming and airport operations to be able to modify the program code to make a satisfactorily accurate representation of the airport situation. The main benefits to the customer will be in cost-saving and time-saving, along with the added usefulness of being able to use the Airport360 Pro as an ongoing day-to-day management tool. The niche market within this segment will be an airport in a developing country, as they will be more willing to improve their management practices, and their airport situation will not be as complex as some of their larger counterparts in a first-world country.

Airport360 Game – Consumer gaming market

This will include the niche market of aviation enthusiasts, as a launching customer segment, since making a game that appeals to the mass public will be very challenging. It will carry an advantage over its competitors by being based on a product that is used in real-world airport management.

1.5 Financial Information

Table H-1 shows the envisioned breakdown of the financing sources we hope to secure for the first three years.

Table H-1: Sources of financing (2015 – 2017)

Equity contributions	Amount
Founder equity	€ 45,000
Total equity financing	€ 45,000
Debt financing	
Loans	€ 75,000
Total debt financing	€ 75,000
Other financing	
Grants/Allowances	€ 40,000
Competitions	€ 20,000
Total other financing	€ 60,000
Total financing	€ 155,000

Table H-2 shows the profit and loss statements for the first three years of operation. Due to the software development time, the company will not be profitable in its startup phase, and will need to acquire various sources financing to cover these net losses. Equity provided by the owners will be sufficient for the first year of operations, and will give them enough time to secure the required funds (Table H-2), initially through micro-financing, using one of the government programs that makes funds available to startups without need for collateral. Various government grants and startup competitions will be entered, and the company will apply to join a business incubator or accelerator, which provide valuable advice and guidance, as well as additional financing in the form of an allowance, or equity purchase. Angel investors and venture capitalists will be approached in preparation for the phase when the company is ready to scale up its operations.

Table H-2: Profit and loss statements

	2015	2016	2017
Total sales	€ 1,990	€ 52,435	€ 141,321
Total operating costs	€ 46,570	€ 96,540	€ 203,240
Net Profit (Loss)	(€ 44,830)	(€ 44,605)	(€ 62,544)

1.6 Business Strengths

The main strengths of the Airport360 startup lies in the founding team, who possess the necessary expertise to ensure the technical and commercial feasibility of the products. Close relations with the TU Delft means that they will receive all the additional technical support, guidance, and advice needed.

From a commercial perspective, the need for the Airport360 Student and Airport360 Pro is present, given the importance and forecast growth in air travel. The branding and recognition of being a TU Delft startup spinoff, as well as access to the network of the TU Delft, means that a big first hurdle in customer acquisition is mitigated.

We are very confident of the chances of success of our startup, and know that as a young, multicultural, and multidisciplinary team, we are well poised to develop an innovative and disruptive solution to an age-old problem in the aviation industry.

2. Industry outlook and business history

The purpose of this section is to examine the conception and subsequent development of the Airport360 company within an industry specific context.

2.1 Industry outlook

Air travel is now widely regarded as a fundamental pillar of our global life, influencing politics, business, and culture all over the world, with 6.3 billion passengers and 96 million metric tons of cargo in 2013 (ACI, 2014). It provides numerous vital economic benefits by contributing to 3.5% of global GDP, and social benefits, by way of bringing together families and friends, bridging cultures and spreading ideas. Airports play a crucial role in providing the ground infrastructure that enables air travel. According to Airbus, air travel is forecast to more than double in the next 15 years (Airbus, 2013, pp. 9-10, 14). There is a total of 41,821 airports in the world as of 2013 (CIA, 2013), although only the larger, more prominent airports will be interested in using a complex airport strategic planning (simulation) software tool.

These trends, combined with the increasing popularity of low-cost airlines and airline mergers means that airports will need to develop new infrastructure to satisfy the changing needs of airlines, and the increase in passenger numbers. Thus, there is a need for decision makers to have access to all the pertinent information, in order to make feasible plans that are as cost efficient as possible.

2.2 The problem

The high complexity of airport systems, and a very uncertain future, compounds the need for a decision support tool which will allow airport planners to not just keep pace with increasing passenger demand, but to anticipate changes, and where necessary, mitigate any adverse effects on the airport, or exploit opportunities. The most widespread approach currently being employed is Airport Master Planning. However, it has a few pitfalls such as: a rigid and inflexible nature; a narrow focus; the inability to deal with uncertainty effectively; and an ineffective and inefficient problem solving process or framework.

In practice, airport planners are dealing with the inefficacy of AMP in various ways, which are usually reactive in nature, but still restricted by the static approach of AMP. These include defining formal procedures for updating the Master Plan, which often consists of semi-independent capital investment projects that allow for the postponement or speeding up of individual projects. It is also possible to solve problems that emerge by making operational adjustments (Kwakkel J. , The treatment of uncertainty in Airport Strategic Planning, 2010). De Neufville and Barber (1991) recommend planning for shorter term horizons and designing facilities in a more flexible manner to serve a range of future needs, to minimize the risk of obsolescence (Ashford, Mumayiz, & Wright, Airport Engineering - Planning, Design, and Development of 21st Century Airports, 2011).

In theory, numerous approaches have been suggested to replace the conventional approach of Airport Master Planning, such as: Assumption Based Planning (Dewar, Builder, Hix, & Levin, Assumption based planning, 1993, pp. xii-xiv); Critical Assumption Planning (Sykes & Dunham, 1995); Dynamic Strategic Planning (de Neufville, 2003); Flexible Strategic Planning (Burghouwt, 2007); and Adaptive Airport Strategic Planning (Kwakkel J. , 2010). A critical component of these approaches is modelling and simulation in order to be able to create future forecasts, which became prevalent in the 1990s as air transport researchers and airport engineers explored practical aspects of airport simulation, and their utilisation to improve airport planning and design practices, and capacity evaluation. No major airport development is now conducted without the use of airport modelling and simulation at some level, particularly in airport master plans, airport-airspace capacity studies, and environmental studies. Numerous computer-based tools are currently being used by airport planners, but these are usually of limited use in airport strategic planning, since: they are usually only related to a single airport performance aspect, configuration, or operation; they usually require a lot of work on the part of the user; and each tool uses different data and assumptions.

The problem with airport strategic planning is not a lack of tools, but rather, the appropriate use of computer-based tools (Odoni, et al., 1997). The following is a list of projects which have been carried out to solve this problem, by providing an integral view of an airport's performance.

- Total Airport Performance Evaluation (TAPE)
- Optimization of Airport Systems (OPTAS)
- Optimisation Platform for Airports, including Landside (OPAL)
- Supporting Platform for Airport Decision-Making and Efficiency Analysis (SPADE)
- Holistic Airport Resource Management and Optimization System (HARMOS)
- Airport Business Suite (ABS)

None of the systems developed in the aforementioned projects have been deployed and used in their entirety in actual airport operations. Possible explanations are that: their decision environment and context were not defined; they focused largely on capacity and delay analysis; there was a strong focus on tools and models, rather than the problem itself; and the usability, robustness, and user interfaces of these systems were severely deficient. This means that there is currently no product on the market which achieves this.

2.3 Business information

Airport360 is a startup company that will be established in January 2015 in Delft, The Netherlands, as a *Besloten vennootschap* (BV), or a private limited liability company. Its sole purpose will be the commercialisation the Airport Business Suite (ABS) developed by the Delft University of Technology Airport Development Centre. The team of co-founders comprises a well-balanced team of recent TU Delft graduates, with backgrounds in the areas of Management of Technology (CEO), Air Transport Operations (CRO), and Computer Programming CIO. In addition to having a diverse academic background, they also have a diverse ethnic background, hailing from three different continents. A more comprehensive insight into the co-founders can be found in Section 8.5. Participation in the Yes!Delft incubator will be pursued, which will provide support to the startup in the form of training programs, knowledge sharing, access to facilities, and access to international networks and investors. Upon creation, the startup will rely solely on the sweat and financial equity of the co-founders, who will provide a contribution of € 15,000 each. They will forego most, or all of their salary in the first three years of operations, and will use part-time jobs, and their own savings to cover their living expenses.

Vision of Airport360:

> *We intend to become the leading provider of airport strategic planning software in emerging markets.*

Mission of Airport360:

> *To enable current and future generations of airport decision advisors and decision makers in making the best strategic decisions possible, by providing them with the ability to quickly and accurately test various hypotheses, and explore various scenarios, using an easy-to-use and intuitive software program that is tailored to their specific airport.*

2.4 Equity distribution and exit strategy

Upon creation of a BV, each of the founders will be allocated 25% of the total shares of the company, with a monthly vesting schedule of 4 years according to their performance. The remaining 25% will be offered to early-stage employees in lieu of a full salary, and to venture capitalists, angel investors, and other interested parties during the various investment seed rounds.

In the case that a founder wishes to leave the BV, the following rules will apply:

- Rights of first refusal whereby if a founder has to leave the company, he must first offer his shares to the other founders

- Texas draw whereby each party is subject to a reciprocal matching offer when trying to buy a leaving partner's shares in the company
- Non-compete clause for a period of two years

The following exit strategies will be used when all the founders are in agreement:

- Dissolution of the company using previously agreed upon indicators of performance
- Strategic acquisition by a larger company if the co-founders feel they do not have the skills, resources, or time to continue to successfully grow the company
- Initial Public Offering (IPO) when the company has matured, and is ready to scale up further, and the founders wish to retain management of the company

3. Product and services

The purpose of this section is to introduce, define, and detail the product variants of the Airport360, and its related services.

3.1 Product background

The Airport Business Suite (ABS) was designed by the Delft University of Technology Airport Development Centre (TUD-ADC). The TUD-ADC links science and technology to business and policy issues by using a problem- and market-oriented approach based on multi-disciplinary knowledge from various branches of science, while applying a systems analysis framework, and considering the full range of stakeholders, and any environmental, spatial, economic, and societal impacts. It provides advanced tools for decision support in the aviation industry that are comprehensive, problem-oriented and customizable. These tools are flexible, adaptable, consistent, and time-saving in nature, allowing an organisation to identify solutions with better quality and lower cost than currently possible, and to provide information at various levels of aggregation. The two projects the TUD-ADC is currently working on are the Holistic Airport Resource Management and Optimisation System (HARMOS), and the ABS (Roling & Wijnen, 2004).

The ABS 'is a computer-based system for decision support that enables users to obtain, through a graphical user interface, consistent information about all facets of the airport's business (for current and future situations) (Roling & Wijnen, 2004, p. 73). Although it was initially envisioned to be used in the airport business sector, it has mainly been used for educational purposes by students at the TU Delft (Roling & Wijnen, 2004, p. 75). It was designed to avoid the pitfalls of Airport Master Planning by providing information at various levels of aggregation, integrate models, databases, and displays in order to help users to identify good solutions. These generic tools are able to be customized to better reflect the needs and circumstances found at the individual airports (Zawadzki, 2003). The ABS was envisioned to be a continuously updated research and development project, carried out in close cooperation and communication with air transport organisations and other stakeholders.

The ABS was envisioned to function in the following ways (Walker, et al., 2003):

- Provide models for rapid estimate calculation of the various aspects of performance of the airport system under a range of (user-defined) situations
- Provide different levels of aggregation, in order to be able to do both quick initial scans and more detailed analyses when required
- Maintain consistency among all of the models
- Present information on the full range of decision-relevant criteria in an integrated, easy to understand format
- Present information on the main factors driving decision-relevant criteria, in order to identify bottle-necks
- Preserve decision-making memory of results for cases already run
- Enable fast and thorough comparisons of any number of 'what-if' cases

The ABS is currently being used at the TU Delft as a teaching tool. However, the ABS in its current state still has a lot of room for improvement before it is able to be commercialised successfully in an airport environment. We at Airport360, believe that these final stages of development are best suited to the auspices of a business, which will speed up the research and development of the ABS, while guiding it in a way that is more suited to the market.

3.2 The Product – Airport360

The envisioned product family will be the main focus area of the company, and will share the same name as the company. Three product variations are envisioned, in order of the scheduled order that they will be developed in:

- Airport360 Student
- Airport360 Pro
- Airport360 Game

Airport360 Student

The launching product will be the Airport360 Student (see Table G-14) which will be targeted at the market of aviation management learning institutions within which resides niche markets such as universities, colleges, and training centres. This product is a serious game, where the main purpose will be to train or educate users, by enabling students to apply the theory they learn into practical, albeit simulated, conditions. In addition to teaching and reinforcing rudiments of aviation management, it will enable the students to understand the reason why these topics matter, and will be a way of teaching them the right mind-set and culture to use in aviation management.

It will be used as a testing platform for the first software version and future upgrades to the software, before implementation in the Airport360 Pro version. Finally, students will be obligated to fill in a user feedback questionnaire in order to be able to improve user experience. The first niche market that will be targeted will be universities providing degrees in aviation management. This product version is currently ready for deployment, due to work carried out by the founders over the past year.

Airport360 Student features include:

- *Tutorial mode* which includes detailed information and tips on the various aspects of an airport, and the software itself
- *Examination mode* which provides sample testing situations/case studies, or allows the teacher to make their own case studies
- *Teacher account* which is able to monitor individual students' work-screens, and define/restrict certain parameters for all students following the course or training module
- Real-time communication and shared work-screens between group members of a project

Airport360 Pro

The second product variant is the Airport360 Pro (see Table G-15) which will be targeted at the niche market of airport planning, consulting, and engineering companies and government agencies. It will be the most comprehensive of all the products, and will aid airport decision advisors and makers in strategic planning, and will only be introduced when the Airport360 Student has been thoroughly tested, and has reached a satisfactory amount of sales.

The aim of Airport360 Pro is to allow airports to test ideas on improving individual systems and get a larger perspective on how these adjustments will affect the entire airport's operations. The different airport sectors can model their systems accurately, utilize resources to meet their goals in the most effective way possible, and communicate these plans to the other airport sectors. It will also have the ability to be fully integrated with the airport's (information) management systems, in order to require as little input and data preparation from the user as possible. This will allow the Airport360 Pro to evolve into a system which complements, and ultimately replaces conventional airport management systems and decision-making frameworks.

Airport360 Pro features include:

- Ability to be integrated with modules and tools from other airport software suppliers
- Ability to explore the behaviour of the system under specified situations or changes in a low risk environment, understand how various components interact with each other, determine sensitivity to unknowns, and identify the most important missing data
- Cost savings and cost avoidance benefits from use of the program
- The ability for a non-programmer to modify the relationships and rules in the simulation model to more accurately match the airport situation in a code-free environment, allowing for easier customisation
- Ability to have various depths of analysis that allow the user to conduct both quick initial scans and more detailed analyses, as required
- Multi-user system to increase the usefulness of the system and promote communication and collaboration between multiple airport sectors. A server-based database will be used, so that all users will have access to the most up-to-date information
- Automation to reduce the amount of manual input required by the user, through integration with existing airport information management systems, such as financial accounting records, or counting solutions using video monitoring to provide input data for the program
- Ongoing technical support, maintenance, and upgrades

Airport360 Game

The third and final product variant will be the Airport360 Game, which will be initially targeted at the consumer niche market of aviation enthusiasts. It will be the most watered down version of the Airport360 Student in terms of simulation capabilities, and will be more geared towards entertainment, while still retaining an authentic real-world feel. Although there are currently a few competitors in this area, this product will have the stamp of authenticity of being based on the program that real-world airport managers use. There will be two main versions of this product: an offline version which is meant for aviation enthusiasts eager to experience the realism of airport management; and a free online version, for the masses, which will also include a mobile app version.

4. Market examination

The purpose of this section is to carry out an assessment of the application of the product and its related services, in relation to consumer buying cycles. A quick overview is given of the three main market segments identified. It should be noted that this section will need to be refined after a more in depth market research and analysis is carried out, in order to:

- Compile a list of potential customers
- Discover any competitors not already known
- Discover any additional market trends which may impact the success of the product in any way

Customer discovery will also be carried out through attending various networking events, and arranging interviews with potential clients and suppliers. The aim is to choose the best niche market segment i.e. universities providing aviation management courses, and to expand to other customer segments after success in the first niche market is achieved. This will allow the team to focus on understanding the specific needs of each customer segment, instead of attempting to achieve too much in the beginning, and consequently lose focus. The next customer segment will only be approached if certain success indicators are met e.g. acceptance rate of users, number of licenses bought, etc.

4.1 Aviation management learning institutions

This includes universities which offer various types of aviation management degrees, such as: ENAC; RMIT University; IUBH School of Business and Management; KTH Royal Institute of Technology; Embry-Riddle Aeronautical University; and Singapore Aviation Academy, to name a few. There are also various other institutions and organizations which provide certification and training in aviation management, such as IATA, using either physical or online modes of teaching. The demand for these institutions will likely increase, in order to match the forecasted rise in air travel. This rise, combined with changing trends in air travel will require new airport needs, and thus new methods of airport management. These institutions will increasingly look to newer, state-of-the-art methods of teaching, in order to differentiate themselves, and ensure the quality and relevance of their programs. Airport360 Student will allow students in these institutions to apply theory to real-world situations, in a safe manner, and get a feel for the intricacies involved in airport strategic planning. There is currently no such software out there that serves this purpose. Thus, these institutions deal with this through a combination of: theory lessons and project work to apply this knowledge; talks by airport executives; and excursions to airports. However, it is evident that these methods fall short of the benefits afforded by a fully-fledged airport simulation software program. The use of this program will also allow the students to be imparted with new methodologies and approaches to airport strategic planning, which they can execute using the software. Finally, it will prepare them for using the software in their future career, and can be an asset to add to their CVs.

We believe that these institutions may initially be sceptical of adopting new methods of teaching, but as soon as a new method is proven, they will be very quick to adapt their curriculum to new trends. Dealing with this market will primarily entail a business-to-business relationship, although some elements of business-to-consumer relations will be adopted, in order to pay attention to the main users of the software (students and teachers) and tailor the product to their needs. These learning institutions are accustomed to purchasing licenses for software, which will also give their students access to these software.

4.2 Airport planning, consulting and engineering companies

This includes airport consultancies and airport decision advisors. There is a big need for customers in this market segment to adopt new ways of conducting airport strategic planning, and thus, to employ new software tools which are more suitable to these new approaches. It should be noted that the existing alternatives are usually custom-made, expensive airport simulation solutions implemented by consulting firms. Thus, the aim of this program is to enable even someone with a rudimentary knowledge of programming and airport operations to be able to modify the program code to make a satisfactorily accurate representation of the airport situation. The main benefits to the customer will be in cost-saving and time-saving, along with the added usefulness of being able to use the Airport360 Pro as an ongoing day-to-day management tool, rather than, for example, once a year when an external firm is hired to undertake an airport assessment. This means that deviations from the plan will be caught as early as possible, and the plan can be adjusted accordingly, and mitigating actions taken.

In contrast with airports, which may be government owned, consulting firms are for-profit firms in the private sector. This means that they will have a higher level of dispensable income, and thus be willing to commit more to the purchase of the licenses. Additionally, they can also be charged according to the number of airports at which they implement the Airport360 Pro. This will also make them a more discerning customer who will have to be thoroughly convinced of the benefits of choosing the product, before making a financial commitment. Thus, having the product validated by prestigious universities beforehand will make market penetration within this segment easier. A preliminary list of airport design and consulting companies is shown in Table H-3.

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Table H-3: List of airport design and consulting companies

Company	Details
Atkins	Airport design and planning
Adacel	Operational Air Traffic Management (ATM) systems and advanced simulation & training solutions
ATCANZ	Airport operational support, management, consultancy, and training
Aviation Consultants Ehmanns	Master planning, operational improvement & optimization, efficiency advisory, and forecasting
Deerns Airport Engineering Consultancy	Design of airport building, services, utilities, consultancy, and engineering services
IKUSI	Passenger information suite, operational suite, airport non-aviation revenue increase suite, integrated security suite, airport processes optimisation solution, slot management and coordination solution, operational solution for multi-airport, and multi-system airports
LFV Aviation Consulting	Feasibility studies, master plans, airport design, construction, and project management
NACO, Netherlands Airport Consultants B.V.	Airport master planning, facility planning & design, and infrastructure planning & design
One Works S.p.A.	Architecture, infrastructure and urban engineering services, and airport planning & design
Parsons	Airport planning and design
RPS Group PLC	Airport planning & development consultancy

Source: Airport Suppliers (2009)

4.3 Aviation enthusiasts

This will include the niche market of aviation enthusiasts, since making a game that appeals to the mass public will be very challenging and require a product that will be a very simplified version of the Airport360 Student. The Airport360 Game will be managed under a subsidiary of the company, or will be licensed out to a more experienced game developer, in order to be able to retain focus on the core paying customers of aviation consultancies and airport companies. The main reason for targeting this market with the Airport360 Game will be to create an additional revenue stream.

5. Competition

The results of the preliminary competitor analysis is presented in this section, although it should be noted that this is by no means an exhaustive and comprehensive list. A more in depth competitor analysis still remains to be carried out. The competitors for each of the product variants will be considered separately.

5.1 Airport360 Student

No direct competitors for this product could be found. However, various learning institutions may have developed a program in-house, as was the case with the ABS at the TU Delft, or may use off-the-shelf products for simulation of certain aspects of an airport e.g. passenger queuing. The main advantage the Airport360 possesses the ability to use only one integrated program which is able to simulate all aspects of an airport's operation.

5.2 Airport360 Pro

Table H-4 shows the competitors of the Airport360 Pro, which provide fully integrated software to model and simulate all (or most) aspects of an airport. The main perceived drawback of these programs is the amount of data input and preparation required, as well as customising it to fit the airport's unique situation. An expensive team of consultants is usually needed to carry out an in depth study at the airport in order to achieve this. Furthermore, other drawbacks to using these product may be uncovered during customer discovery, and should be used to guide the development of the Airport360 Pro, to avoid the same pitfalls.

It should be noted that software which only simulate specific processes of an airport were excluded, since the advantage of the Airport360 over these is evident: they lack the same level of integration, and so the use of multiple specialised programs means that the process may not be as efficient and intuitive.

It is likely that the five competitors identified in Table H-4 enjoy a comfortable and established position in the market, which may make it difficult to entice their customers to switch to the Airport360 Pro. The barriers to entry quite high, since the airports and companies currently using the competing products will be unwilling to become early adopters of the Airport360 Pro due to the inherent costs and time associated with such a move. In addition, they will be unlikely to adopt an untried and untested program such as the Airport360.

Table H-4: Competitors for the Airport360 Pro

Company	Product	Details
Airport Research Centre	CAST 3D Airport Simulation	Simulation, planning and optimisation systems for pedestrian, vehicle and aircraft traffic to model processes of landside, terminal, airside, and airspace
FlexSim Software Products, Inc	FlexSim	Visualise and optimise airport processes in 3D, customize modelling experience and analyse the airport system
Simio	Simio Simulation Software	Use simulation as a way of testing ideas on improving individual systems and get a larger perspective on how those adjustments will affect the entire organization
Company	**Product**	**Details**
SIMTRA	PathPlanner	Software for airside planning, design and operations. Tool for analysing aircraft and vehicle movement on airport aprons and taxiways, assessing stand clearances and jet blast impacts, and simulating complex pushback manoeuvres
topsystem Systemhaus GmbH	AIRPORTSTAR	Strategic and operational planning of flight operations. Direct integration with other information systems. Fee and tariff management, price calculation for flight events up to invoice generation and dispatch

5.3 Airport360 Game

A number of competitors were identified in this segment (Table H-5), but they were all received poorly by critics. Thus, it is anticipated that there will not be strong barriers to entry due to a lack of dominant and established competitors. In case the first release is successful, additional revenue streams can be generated by releasing sequels, and expansion packs.

Table H-5: Competitors for the Airport360 Game

Company	Products	Details
Layernet	Airport Simulator (2011)	Players are in charge of developing and building up an airport. Very simplified representation.
Krisalis Software	Airport Tycoon 1 (2000) Airport Tycoon 2 (2003) Airport Tycoon 3 (2003)	Business simulation game
FOG.com	Sim Air traffic	Free web-based game simulating the experience of an air traffic controller

6. Marketing

The purpose of this section is to present the promotion and sales strategies to be used for the various Airport360 product variants. Since each variant is geared to a different market segment and customer, the marketing techniques used will be different. However, certain marketing techniques will be employed, which will be applicable for all product variations.

- *Customer discovery*: using a number of interviews and conversations with potential customers, the best smallest market will be chosen, and then expanded from there. This will allow us to understand the specific needs of each customer
- *Niche marketing*: A strategy which targets very defined and specific segments of the consumer population, and focuses all efforts on reaching these segments. It is particularly effective for small companies, such as ourselves, with limited resources. It avoids the use of mass production, mass distribution and mass advertising, instead focusing on exploiting niche markets through research and developing expertise, monitoring the market, in order to be able to move to another niche if required
- *Precision marketing* is a marketing technique that retains, cross-sells and upsells existing customers. In the case of the Airport360 Student and Pro, this will be done through the use of long-term contracts, with a lot of attention paid to after-sales services
- *Inbound channels*: 'pull messaging' to let customers find you organically through blogs, SEO, E-books, white papers, webinars, and social media. This will be done in the early stage of the marketing of each product, when the product is yet to be released, or just released
- *Outbound channels* rely on 'push messaging' for reaching customers e.g. print ads, trade shows, and cold calling, which will be used when the product has been released, and additional customers need to be found
- *Ideal early channel*: Content Marketing uses a combination of Content, Search Engine Optimization (SEO), and Social Media to work. The premise is to incrementally test various aspects of our Problem/Solution using inbound channels like blogs, white papers, and webinars. SEO and Social Media serve to further enhance the reach of our content

The following steps will be followed when carrying out a market and customer discovery:

- Decide what data will be collected and how it will be gathered
- Collect data and integrate data from various sources
- Develop methods of data analysis for segmentation

- Establish effective communication among relevant business units (such as marketing and customer service) about the segmentation
- Implementing applications to effectively deal with the data and respond to the information it provides

6.1 Aviation learning institutions

There are over 500 universities worldwide that offer Aerospace/Aeronautical Engineering degrees. Some of these universities offer some form of management or operations specialisation, which means that this potential market is quite large. In order to gain some credibility, the branding and acceptance of the TU Delft will be garnered in an effort to penetrate the market by speeding up the acceptance of the Airport360 Student for use in other learning institutions. The TU Delft is willing support the development of the Airport360, as its success will increase its own reputation. An attractively priced product, combined with an acceptance period, means that these learning institutions will be more willing to take the risk, and give the Airport360 Student a try. Next, leading universities in the vicinity of the Netherlands, such as RWTH Aachen University and ETH Zurich (QS, 2014) that offer aviation management specialisations, will be approached. Once these universities are successfully converted into paying customers, the product will gain further validation, and will become very attractive to the rest of the universities. The main way of reaching the prestigious universities will be through personal contacts of professors and alumni at the TU Delft, who will be able to provide an introduction to the relevant professors and heads of departments in the universities. Various channels will be used to increase academic recognition of the product, through publication in scientific journals and papers, and attendance of conference events and similar events. Testimonials from professors and students who use the product will also be collected.

In order to reach other universities, cold calling will be used. A single pricing plan will be used for universities, which will include a training workshop for the people who will administer the program. This will be negotiable based on the specific needs of a customer, for example, if they require a higher degree of customisation to suit a particular airport case study. We believe that learning institutions will be quick to adopt the Airport360 Student, as it will allow a more immersive learning experience for their students. Our aim is for the Airport360 Student to be established as the new standard in teaching aviation management, within three years. Since it will involve business-to-business relations, direct sales will be utilised. Although there will be online and print advertising, these institutions will only be able to make a purchase by directly contacting the company, which will allow for a more personalised approach with human interaction.

6.2 Airport planning, consulting and engineering companies

There are a number of airport related companies and organisations who could benefit from the use of the Airport360 Pro:

- Airport consultancies
- Airport associations (such as ICAO)
- Government agencies which oversee development of the national transport infrastructure (such as the FAA)
- Airport organisations
- Airport suppliers and related businesses

The success of the Airport360 Pro hinges on the ability of our company to partner with universities and research centres, as well as established (accreditation) organisations in the airport consulting industry, to provide a solution which is validated and certified as the new standard in airport planning software. This can include organisations such as Airports Consultants Council (ACC) and ACI, or governmental bodies such as the FAA and the European Aviation Safety Agency (EASA). Once these partnerships are properly cultivated, the marketing efforts will become much easier, and customers will approach the company of their own accord through in-bound marketing.

Since it will involve business-to-business relations, direct sales will be used. The initial target airports and consulting companies will be based in developing countries, where cost savings will be more important. These airports will be identified, and contacted via cold-calling, by using introductions from TU Delft professors. These airports will not be very large and complex, and so a comprehensive and sophisticated software package will not be needed. This will allow the Airport360 team to be able to gain experience, and build up a reputation. Once airport and aviation consulting firms hear about the successes of the Airport360 in the real-world, they will be more willing to consider using it. The early adopters will be eligible for a negotiable discount, using an early adopter loyalty scheme.

Once the software is sufficiently tested in the real-world in these developing countries and emerging markets, the key to success will be to choose the right airport in first-world countries to use as a validation for the software. This will be one of the leading airports in the world, which is willing to innovate in the way they conduct airport planning. An advantage that Airport360 will have is the fact that it aims to bring a revolution into the practices surrounding airport strategic planning, and will promise a disruptive effect on the market. The key at this stage will be attending airport-related trade shows and conventions, getting publications in online and print versions of aviation-related media, and word-of-mouth advertising. Various companies will also be cold-called. It should be noted that the final prices to be charged will be determined based on the costs of development, but will be competitively priced in the market compared to getting a number of specialised software tools that would perform similar tasks.

6.3 Aviation enthusiasts

Although this will involve the consumer market as an end-user, business-to-business model will be pursued, in order to ensure scalability. Thus, these business customers will be responsible for the actual product sales. The main selling point of the Airport360 Game will be the fact that it is based on the software that actual airports use in their daily operations, providing a high level of authenticity. There will be different difficulty modes, depending on the skill of the user, and the level of realism they require.

Airport360 will manage the advertising of the product, in order to ensure uniformity, and that corporate identity and values are being portrayed correctly. Online marketing and social media will be used to build up hype for the product prior to launch, and pre-orders will be taken, in order to gauge the public interest. A special launch event at one of the partner airports will be organised, in order to garner media attention. Online and print advertising will be targeted at websites and physical locations that aviation enthusiasts are likely to frequent. Possible examples include:

- Aviation discussion forums
- Plane spotting forums
- Visitor area at airports used for plane spotting
- Aviation industry labour union events or offices
- Airport shops

7. Operations

The purpose of this section is to trace the product and service development from inception and production, to the market.

7.1 Facilities and equipment

An office will be provided by the TUD-ADC in the faculty of Aerospace Engineering. This will allow close cooperation with professors, PhDs and students, due to being in physical proximity. It will also provide the TU Delft branding to the company. Since the Airport360 is a software development company, there will be no need for manufacturing or logistics considerations, which will make operations much simpler to manage. The main equipment required will be the necessary IT hardware needed to develop and test the software.

7.2 Production methods

Due to the startup nature of the Airport360 business, it will need to run as lean as possible, in a bid to keep costs as low as possible. One way of achieving this will be to hire students looking for internships and graduation projects, or to collaborate with PhDs and professors carrying out research projects in similar fields. However, the use of interns will be limited to non-critical functions, in order to ensure that the company is able to consistently meet its deadlines.

The Lean Startup methodology proposed by Eric Ries (2011) will be followed. The main principles will be applied in the following ways:

- *Validated learning* involves business-hypothesis-driven experimentation utilising customer feedback during product development is integral through key performance indicators and actionable metrics. Split testing will be used, i.e. an A/B experiment in which different versions of the product will be offered at the same time to two different groups of users. Differences in behaviour will be observed, and the impact of each product will be measured using an actionable metric
- A *Minimum Viable Product* (MVP) will be released, which is a version of a new product which allows a team to collect the maximum amount of validated learning about customers with the least amount of effort. It will be used to test fundamental business hypotheses, and help the team to begin the learning process as quickly as possible
- After the MVP, *iterative product releases* will be made to meet the needs of early customers, to reduce market risks, and to sidestep the need for large amounts of initial funding, and expensive product launches and failures
- *Lean manufacturing* – no waste (waste is any expenditure of resources with a goal other than creation of value for end customer). Additional immediate quality checks are carried out to identify mistakes early on. Close connections are maintained with partners and customers

7.3 Roadmap of the Airport360 business

The technology roadmap of the Airport360 business is shown in Figure H-1 on the next page. Collaboration with the TU Delft means that a discovery of customer requirements (TU Delft) and user requirements (students) was conducted in a thorough manner, in order to drive the design of the Airport360 Student. Valuable feedback was gleaned from students and professors who were familiar with the shortcomings of the ABS. Continued collaboration with the TU Delft will be pursued in order to implement the state of the art in research owned or conducted by the TU Delft. The expertise and networks of the TUD-ADC and professors will be exploited. Use will be made of Masters and PhD students in order to be able to leverage the new ideas of bright young minds in solving age-old problems through the provision of internships and graduation projects. While this learning was taking place, continued development of the Airport360 Student software was carried out, while other universities and a launching airport customer were identified and approached.

Development of the Airport360 Student will be completed at the time of the company's official creation in the beginning of 2015. Part of the team will focus on implementing the Airport360 Student with the launching university customers. The plan is to continue to iteratively develop the software, to ensure that it is able to be used in different universities, and can be suited to various teaching environments and needs. The aim is to first focus on learning institutions in the Netherlands, and expand to aviation learning institutes within the EU, before expanding to other parts of the world.

The rest of the team will further develop the Airport360 Student into the Airport360 Pro with the launching airport customer. Once sufficient testing has been carried out, and the Airport360 Pro has been proven in the real-world, accreditation will be sought from various airport authorities and organisations. This will make it easier to attract customers. The first airport to be chosen will be in the developing country as a testing ground, while the second customer will be Schiphol Airport, which is one of the leading airports in Europe, and whose acceptance of the software will be used to drive sales.

	2015	2016	2017	2018	VISION
Airport360 Student	Use research collaboration with the TU Delft to create upgrades/improvements to all product versions				Become the program of choice for aviation management learning institutions worldwide, which will complement a new approach/ methodology in airport strategic planning
	Continuous improvement and development based on feedback from customers				
Airport360 Pro	Testing and development with launch airport customer	Continuous improvement and development based on feedback from customers			Become one of the leading suppliers of professional airport simulation and strategic planning software
Airport360 Game		Market research; Development of MVP	Development of MVP; User testing	Development of upgrades and expansions after launch	Create an airport simulation game which people of different skill-levels can enjoy

Figure H-1: Roadmap for the Airport360 company

At the start of 2016, work will commence on the Airport360 Game, since it will be in a market segment unfamiliar to the founders and employees. Only if the results of the market feasibility study prove positive, will development of the MVP be commenced, in partnership with an established games manufacturer. This will allow the team to focus on their core products of the Airport360 Student and Airport360 Pro. The expertise of the partner will be relied on in any non-technical decisions related to the release and marketing of the game. The Airport360 Game will be released to the public at the start of 2018.

It should be noted that the first three years will prove very crucial in determining whether the Airport360 core product variants are able to gain traction, in order to increase our chances of attracting equity funding through investment rounds by the end of 2017.

8. Administration and management

This section will present the management philosophy, and accompanying processes and procedures that will be used in the company. It is now widely accepted that the management and organisational culture of a company is very important to its chances of success.

8.1 Management philosophy

As a startup with young founders, we will foster a management culture of enablement, fairness, and open communication. We realise that in addition to being administrators and controllers, good managers must be innovators, creators and influencers, focusing on people and personal development. Thus, all employees will be given variety, learning opportunities, and additional responsibilities, and be positioned for success. Expectations will be clearly discussed, while giving employees the freedom to get the job done. This means that an emphasis is placed on making our employees happier and more effective in their daily jobs, without the need for fancy titles. We will be ready and willing to change to adapt through learning from past experiences and mistakes. We will lead by example, but delegate where necessary, and the relationship between the founders and employees will be based on trust and earned respect from behaviours and skill sets.

Since the founders are recent university graduates, most of the staff will be of a younger age, which will contribute to an informal but innovative culture, with a very flat structure of hierarchy. In order to foster an ownership culture, all early-stage employee will be offered a stake in the company, depending on their performance. The aim of the company will be to bring the best young minds together, in order to solve a real-life problem and ultimately become a game-changer in the aviation industry. A can-do attitude will be prevalent, with the idea that anything is possible if we put our minds to it.

8.2 Organisation structure

The Airport360 Company is envisioned as requiring the following main areas of expertise:

- Business development and commercial aspects (CEO)
- Operations research (CRO)
- IT development (CIO)

Start of company – Informal, flat structure

It is envisioned that the organisational structure at the start of the company will be flat, due to the small nature of the company. Each of the co-founders will be responsible for one of the aforementioned areas (Figure H-2), including employees within these areas, and will have ultimate responsibility for anything falling under their area. It should be noted that an informal structure will be in place, since it will be composed of a tightly knit team of co-founders who work and play together. A flat, informal structure will allow us to accomplish work faster, and retain a high level of flexibility and adaptability due to shorter lines of communication, while better emotional support to the team members.

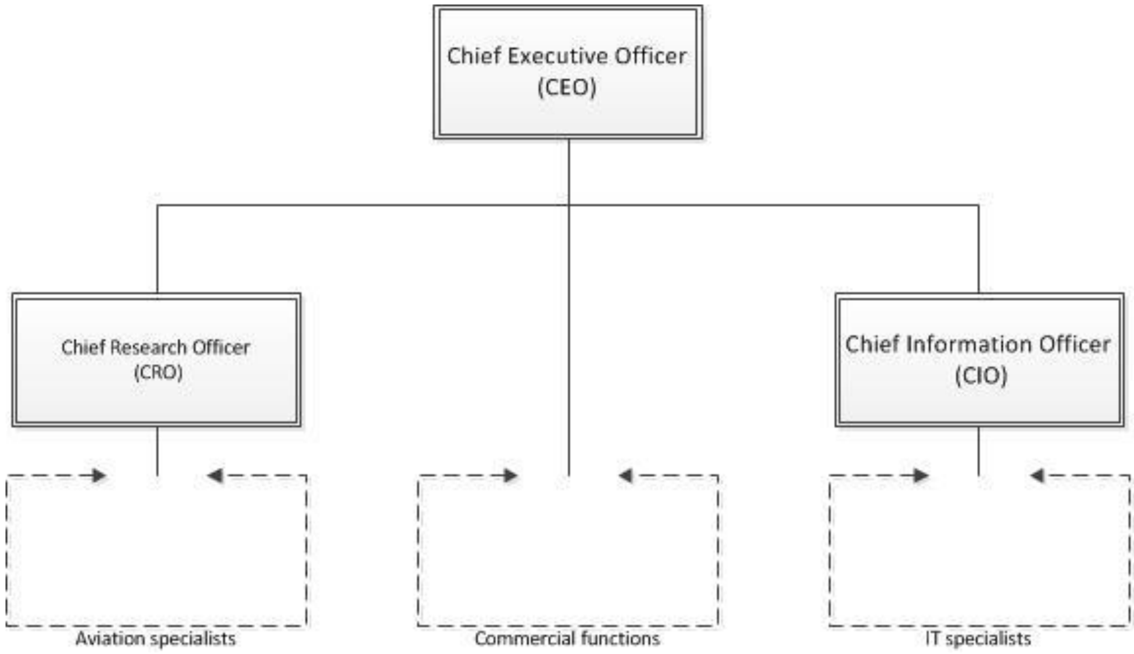

Figure H-2: Organisational structure (start phase)

Growth of company – Matrix team structure

When time comes for the company to grow, for example after a successful round of funding, the matrix structure (Figure H-3) will be gradually introduced in order to provide efficient communication and collaboration within small interdisciplinary project-based groups that have all the tools they need to deliver the product. A matrix organisational structure is one that combines the functional structure (each portion of the organisation is grouped according to its purpose), and divisional structure (each portion of a company is grouped according to projects, products, or market areas).

It will allow the company to become more scalable, and will allow it to complete multiple projects simultaneously for different customers. It will work using a team mentality, with a team being allocated to each customer. An employee may work in more than one team, if needed. A Chief Operations Officer (COO) will be hired to allow the CEO to focus on higher level tasks such as business development, and quality control, rather than the day-to-day running of the business. The CRO and CIO will also be required to focus on higher level tasks. A matrix structure will allow for decentralised decision making by team leaders who are more familiar with the market and the clients, allowing for a fast response to change. There will also be efficient use of business support functions such as marketing and finance rather than having a different service unit in each project team, and more flexible use of resources, as certain expert employees may be able to split their time between different projects. Most importantly, a work environment with a very flat and fluid community structure where employees feel like they belong, and are able to grow together with the company, will be fostered.

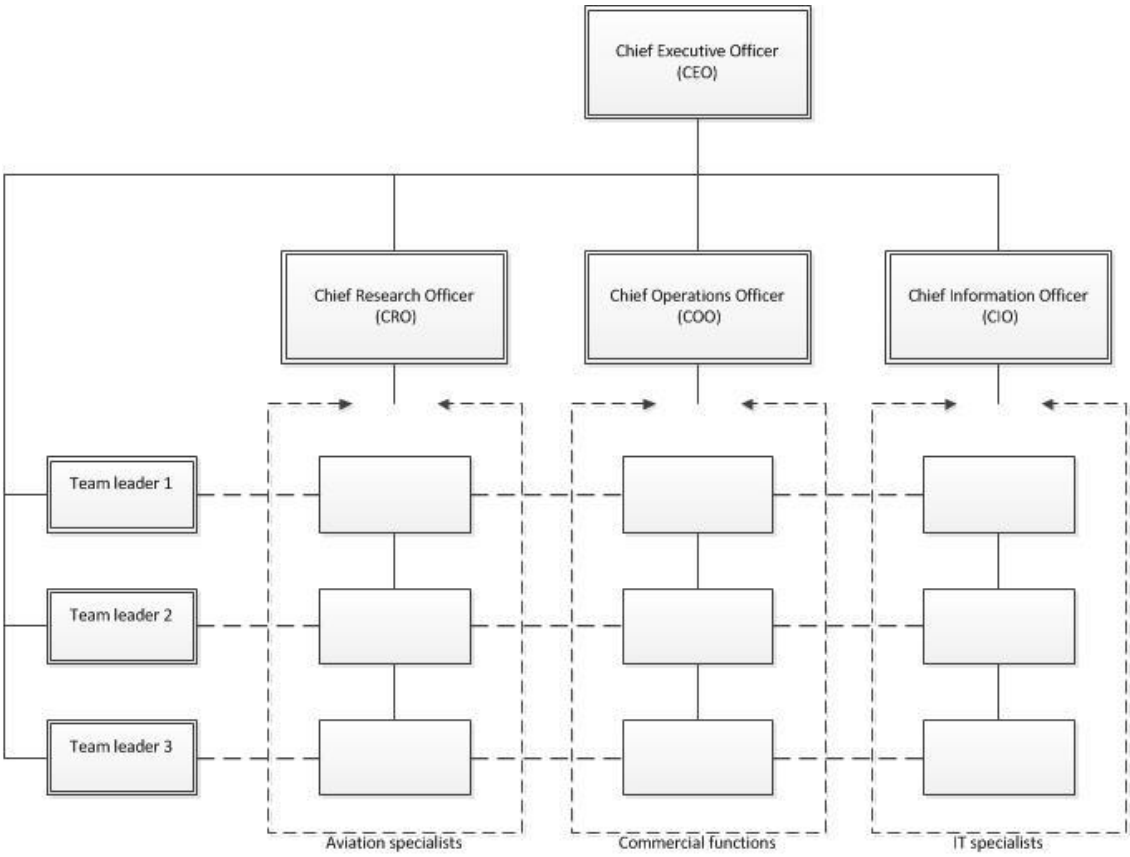

Figure H-3: Organisational structure (growth stage)

8.3 Background and responsibilities of co-founders

The background, roles, and responsibilities for each of the co-founders are described as follows:

CEO

The CEO has a Masters in Management of Technology from the Technology, Policy and Management Faculty of TU Delft. He will guide the overall business development and strategy of the company, and will be the face of the company. His main tasks in the beginning will be to take care of all the commercial aspects of the company such as administration, finances, marketing, and fund-raising (investors, banks, grants, etc.), in order to allow the other two co-founders to focus on the technical development of the product. During the growth stage, the CEO will be able to delegate the tasks of marketing and finance to the COO.

CRO

The CRO has a Masters in Air Transport Operations from the Aerospace Engineering Faculty department of Control and Operations at TU Delft. He will be in charge of everything related to aviation operations research and development. This will include all the latest trends in the aviation industry, as well as the most current methods of airport strategic planning. He will be the main point of contact with the TU Delft, and potential clients, as he will be more suited to communication with these parties. Thus, he will assist the CEO in defining marketing and sales strategies that would be relevant to the potential customers. The CRO will have responsibility for the hiring and training of air transport operations specialists, who will act as researchers in designing the product, and as consultants in assessing the clients' needs, and providing trainings and other after-sales services.

CIO

The CIO has a Masters in Software Technology from the Electrical Engineering, Mathematics and Computer Science Faculty department of Computer Science at TU Delft. The CIO will be in charge of all Information Technology (IT) related aspects in the firm. These range from knowledge management systems, to the development and implementation of the various product variants. He will be in charge of hiring and training programmers, network administrators, and any IT-related support staff. He will also oversee the overall development of the use of IT in the company, and ensure that all IT-related aspects in the various teams and projects are running smoothly.

8.4 Decision-making

As all co-founders will be equal partners in the endeavour, they will all have an equal voting right. Since each co-founder has a different field of expertise, they will be given the responsibility to make operating decisions in their areas of responsibility, although they will be required to inform the other co-founders in weekly meetings. In more important decisions, a majority will be required to pass decisions. Strategic decisions which will potentially have a huge impact on the company e.g. the decision to drop a product variant, or to have an Initial Public Offering (IPO), will require a unanimous decision.

8.5 Personnel

As the company is a startup, its co-founders will have an immense influence on the success of the company. The following are the employees which the company will employ, and will fall into three main categories, while Table H-6 shows the numbers of employees in each category:

- Administrative personnel: human resources, finances, sales and marketing, etc.
- Aviation specialists: consultants, researchers, modellers, etc.
- IT specialists: programmers, web developers, IT architecture and systems administrators, graphics designers, interaction designers, etc.

Table H-6: Numbers of personnel

	2015	2016	2017
Co-founders	3	3	3
Administrative personnel	0	0	1
Aviation specialists	0	1	3
IT specialists	1	1	2
Interns	1	2	2
Total	**5**	**7**	**11**

Table H-7 on the next page shows the organisational budget. The owners will not receive a salary in 2015, and will only receive a very nominal compensation in the next two years, instead choosing to reinvest these into the company. This is to instil a lean culture among the employees, and motivate them to do more with less. Likewise, all full-time employees will be offered the minimum salary in the first three years, along with stock options based on their performance. For each of these positions, a consideration will be made towards outsourcing tasks to consultants or free-lancers where possible, in order to keep operations as lean as possible, and to only employ people in periods when they are most needed. An allowance is made for outsourcing and professional fees, as can be seen in the income statement (Table H-7 on next page).

A certain profile will be looked for in all hires. Professionals with industry experience will be targeted for full-time employees. A focus will be on candidates used to smaller organisations, who are independent, flexible, well-balanced, and have demonstrated an affinity for taking initiative. They will have to be entrepreneurial-minded and willing to take risks, and understand that they are directly responsible for the success of the company, since an ownership culture will be fostered through the practice of offering all employees stock options. Salaries of the founders and employees will only be renegotiated after a successful round of funding.

Table H-7: Organisational budget

Employees	2015	2016	2017
Co-founders	€ 0	€ 9,000	€ 18,000
Administrative personnel	€ 0	€ 0	€ 18,000
Aviation specialists	€ 0	€ 18,000	€ 54,000
IT specialists	€ 18,000	€ 18,000	€ 36,000
Interns	€ 3,600	€ 7,200	€ 7,200
Total	**€ 21,600**	**€ 52,200**	**€ 133,200**

9. Potential Problems and Solutions

This section will present the risks and litigation concerns, as well as the problem solving strategies that we aim to use to change these issues into opportunities.

9.1 Risks

The following risks are identified:

- Lack of acceptance of products by customers
- Inability to penetrate the market due to established competitors (e.g. through their use of price cutting)
- Poor performance of economy may lead to lower demand for products, due to the volatility of the aviation industry
- Project delays due to unanticipated complexities

9.2 Litigation

Potential problems arising from litigation may take the following forms:

- Improper integration of third-party research into the products
- Liability for mismanagement caused by using the Airport360Pro

9.3 Future competition

Future competition may enter the market once it is proven that there is a high demand for the product. Alternatively, established competitors may respond to our market entry by adapting their product, services, and/or pricing to remain competitive with our products.

9.4 Problem solving skills

The main ways to deal with the potential problems identified in Sections 9.1 to 9.3 will be as follows:

- A meticulous process of customer discovery will be used in order to drive the design of the products, and make sure that these are in line with the customers' needs and wants. Attention will be given to networking and cultivating the right customer relationships
- Customers will be reminded that a decision support tool is not just useful in prosperous economic times to explore expansion options, but can also be used in hard times to determine how to cut costs, and make operations as efficient as possible
- In order to minimise project delays, rigorous controls and reporting structures will be put in place to make sure that all team members are working according to expectations. All team

members will be intimately involved in the planning process, where their insight will prove useful
- Meticulous attention will be paid to Intellectual Property Rights, and use will be made of an IP lawyer, to ensure that no laws are being infringed
- Strategic partnerships will be entered into, which will allow other companies to provide the software for their modules in the product, which will allow for a shorter development time. It will be up to the companies to modify their modules in order to be fully compatible with our product. Royalties will then be negotiated
- The legal structure of contracts/agreements will be designed so as to absolve any liability for mismanagement. It will always be argued that no simulation or management decision support tool is perfect, and that their results still require evaluation by a human agent
- The main barriers to entry which will be developed and cultivated by our company:
    - Intimate knowledge of the state-of-the-art in aviation research
    - Extensive network within the industry
    - Extreme customer-centric approach to development of products

10. Financial information

This section will show how we aim to secure the needed funding and assistance through worksheets and projections detailing our financial plans, methods of repayment, and future growth opportunities.

10.1 Sources of financing

Table H-8 shows the various sources that will be used to finance the company in the first three years of operations. The main categories include equity and debt. Equity refers to the sale of shares to an investor or the public, whereas payments are paid to these owners in the form of dividends. Debt refers to borrowing money which needs to be repaid over a period of time, with interest. A third category can also be defined whereby the amount of money does not need to be repaid, but rather, certain conditions need to be met, such as the case with government grants, or business competitions.

Table H-8: Sources of financing (2015 – 2017)

Equity contributions	Amount
Founder equity	€ 45,000
Total equity financing	€ 45,000
Debt financing	
Loans	€ 75,000
Total debt financing	€ 75,000
Other financing	
Grants/Allowances	€ 40,000
Competitions	€ 20,000
Total other financing	€ 60,000
Total financing	**€ 180,000**

The founders will make equal contributions of € 15,000 each, which will be sufficient to cover the costs in the first year of operation. A micro-financing loan will be taken out to cover the costs of the second year of operations, using one of the various vehicles the government makes available to startups. These allow startups to take out a loan with favourable conditions, and absent of collateral, which the government itself will provide. At the same time, various business competitions will be entered, in order to increase visibility and publicity for the company, and for the chance to win the prize money. In addition to this, government grants, and allowances from business incubators and accelerators will be viewed as a possible source of income, to ensure the company is able to run in the third year.

Angel investors and venture capitalists will only be approached in the second year, when the business model has been validated, and the company has secured paying customers. The ability of the firm to secure grants and allowances will determine the urgency with which angel investors and venture capitalists are approached. Joining a business incubator or accelerator, and participating in business competitions, will give the company access to these entities.

10.2 Projected income

The fundamental objective of most businesses is to make profits. Consideration needs to be given to the sources of revenues for the company. Although a preliminary pricing scheme is given in Table H-9, these need to be refined using market research and discovery. Pricing is not unlike any other business model hypothesis, and should be tested using validated learning loops.

Table H-9: Airport360 Product Pricing

Airport360 Student	Purchase	Annual	
TU Delft	Free	Free	
University	€ 995	€ 495	
Training centre	€ 1,995	€ 995	
Airport360 Pro	**Purchase**	**Annual**	**Per airport**
Launching airport	Free	Free	
Airport, government agency	€ 9,995	€ 2,499	
Consultancy	€ 7,495	€ 1,500	€ 2,500
Airport360 Game	**Purchase**	**Annual**	**Upgrades**
Consumer - Pro Version	€ 40	n/a	Paid
Online - Commercial Version	Free		Paid, with ads

The early adopter, TU Delft, will be given the software free of charge, since they will provide research and expertise in the development of the products. Likewise, the launching airport will not be charged for the software, since the company will develop and test the Airport360 Pro at their airport.

Clients of Airport360 Student and Airport360 Pro will pay a purchase fee, and an annual fee, which will include all after-sales services such as maintenance and incremental upgrades. The annual fee will be increased with any significant upgrades to the product. Any airport or university that requires substantial modifications to the generic product, an extra fee will be negotiated, on an individual basis, and will be tailored to the needs of the customer. Instead of offering free trials, 'acceptance periods' will be used, whereby the clients are given a money-back guarantee in the event that they are not satisfied with the product. This ensures that the client will have made a financial commitment before trialling the product, which will increase retention rates.

The company will allocate a number of 'development hours' each year for product enhancements that are driven by customer feedback. This will give the customers comfort as they will be assured that the product will not be easily 'abandoned', and that the product will be continuously upgraded to for example, meet new standards or requirements in aviation law, or to incorporate state-of-the-art methods used in airport planning.

A 'price protection' clause will be implemented to provide certain customers price protection in the event that prices are lowered for future customers, thus alleviating any fears of a future cost disadvantage. It will also give the company leverage in future deal negotiations, by having a self-induced constraint on the amount that the company is able to charge.

The sales forecast is shown in Table H-10 below. This will serve as a basis for the profit and loss statements presented in Section 10.3.

Table H-10: Sales forecast

Airport360 Student	2015	2016	2017
TU Delft	1	0	0
University	2	5	10
Training centre	0	2	6
Airport360 Pro	**2015**	**2016**	**2017**
Launching airport	1	0	0
Airport, government agency	0	3	6
Consultancy	0	1	4
Airport360 Game	**2015**	**2016**	**2017**
Consumer - Pro Version	0	0	0
Online - Commercial Version	0	0	0
Total revenues	**€ 1,990**	**€ 52,435**	**€ 141,321**

10.3 Profit and loss statements

The most important financial statement a startup should have is the profit and loss statement, since this shows at what point it can hope to break-even, and start to recoup investment. Table H-11 shows the general assumptions used, when creating the profit and loss statements.

Table H-11: General assumptions

	2015 - 2017
Payroll taxes	20%
Interest rate on loan	10%
Corporate income tax	20%
Depreciation of Hardware & Equipment	5%

Table H-12 shows the profit and loss statement for the company over a three year period. From this, it is evident that the company will not be profitable in the first three years, due to a low amount of sales in the beginning, the software development and customer acquisition processes. This is especially true in the first year, when the company will focus most of its efforts on the development of the Airport360 Pro. Employment costs contribute to the highest proportion of costs, and this was reduced as much as possible through the offer of minimum wage along with stock options. The sources of funding will be used to ensure the company is able to sustain itself, until the first round of funding, as shown in Table H-13 on the next page.

Table H-12: Profit and loss statements

	2015	2016	2017
Total sales	€ 1,990	€ 52,435	€ 141,321
Operating costs			
Employment costs	€ 21,600	€ 52,200	€ 133,200
General and administrative	€ 500	€ 1,000	€ 2,000
Marketing expenses	€ 250	€ 2,500	€ 5,000
Professional fees and outsourcing	€ 8,000	€ 12,500	€ 15,000
Software licenses	€ 1500	€ 2500	€ 2500

	2015	2016	2017
Insurance costs	€ 1,000	€ 2,500	€ 6,000
Travel costs	€ 500	€ 3,000	€ 4,000
Rent and utilities	€ 2,400	€ 2,400	€ 2,400
Hardware and Equipment	€ 5,000	€ 5,000	€ 2,500
Miscellaneous costs	€ 1,500	€ 2,500	€ 4,000
Payroll taxes	€ 4,320	€ 10,440	€ 26,640
Total operating costs	€ 46,570	€ 96,540	€ 203,240
EBITDA	-€ 44,580	-€ 44,105	-€ 61,919
Taxes	€ 0	€ 0	€ 0
Depreciation	€ 250	€ 500	€ 625
Net Profit (Loss)	**(€ 44,830)**	**(€ 44,605)**	**(€ 62,544)**

Table H-13: Net cash flow

	2015	2016	2017
Total sales	€ 1,990	€ 52,435	€ 141,321
Operating costs	€ 46,570	€ 96,540	€ 203,240
Net Profit (Loss)	(€ 44,830)	(€ 44,605)	(€ 62,544)
Funding	€ 45,000	€ 75,000	€ 60,000
Net accumulated cash flow	**€ 170**	**€ 30,565**	**€ 28,021**

Table H-14: Lean canvas of business model for Airport360 Student

PROBLEM	SOLUTION	UV PROPOSITION	UNFAIR ADVANTAGE	CUSTOMER SEGMENTS
- Theory vs. Practice Challenge to show students how to apply theory to real-world situations (practice)	- Simulation game - Academic validity - Sharing learning through collaborative project work	Airport360 Student – Serious gaming and simulation software for aviation students. Bring theory to life!	- Accumulated expertise, and research of the TUD-ADC, - TU Delft as a testing environment	Universities Learning centres Users Roles: - Teachers/trainers need to familiarize themselves with the program - Students will use the program as a learning tool
EXISTING ALTERNATIVES - Similar projects to the ABS have never been fully implemented in real life conditions - Combination of project work and theory lessons - Excursions to airports	KEY METRICS - Approval rate of students - Approval rate of professors - Sales/Licenses for universities and learning centres - Publicity in the aviation	HIGH LEVEL CONCEPT Serious gaming for aviation students	CHANNELS - Academic conferences and journals - Existing aviation networks, organizations, and frameworks	EARLY ADOPTERS

COST STRUCTURE	REVENUE STREAMS
1. Personnel costs 2. Office 3. Customer development	Purchase of license: € 995 Annual license: € 495/year

Table H-15: Lean Canvas of business model for Airport360 Pro

PROBLEM	SOLUTION	UV PROPOSITION	UNFAIR ADVANTAGE	CUSTOMER SEGMENTS
1. Traditional approaches to AMP proven inadequate 2. Need for airport decision makers to explore various scenarios and plans quickly 3. Need to be able to easily visualize results	Consultancies will have access to a product which is able to accurately model and forecast the activities of an airport management (information) systems.	Airport360 Pro - Simulation platform to aid airport decision advisors and makers in strategic planning	- Expertise, research, and world renown branding of the TU Delft. - 'Expert' endorsements	- Airport consultancies - Airport organizations - Aviation government authorities
EXISTING ALTERNATIVES - Custom made, expensive solutions for airports made by consulting firms	KEY METRICS - Sales/Licenses for consultancies and airports - Track record: proven cases of success - Publicity in the aviation community	HIGH LEVEL CONCEPT Decision Support System to be used in Airport Strategic Planning	CHANNELS - Academic conferences and journals - Existing aviation networks, organizations, and frameworks - Conventional means of advertising/promotion - Word of mouth	User roles: - Decision advisors (e.g. airport consultants, experts) - Decision makers (airport management, government bodies)

COST STRUCTURE	REVENUE STREAMS
1. Personnel costs 2. Office 3. Customer development	- Purchase license: € 9,995 (Consultancies: € 7,495) - Annual license: € 2,499 (Consultancies: € 1,500) - Consultancies (per airport): € 2,500