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AIRLINE PILOTS' PERCEPTIONS OF ADVANCED FLIGHT DECK AUTOMATION

by

PREVENDREN NAIDOO

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DECLARATION

I, Prevendren Naidoo, declare that the dissertation entitled *Airline Pilots' Perceptions of Advanced Flight Deck Automation*, which I hereby submit for the degree Magister Philosophiae (Human Resources Management) at the University of Pretoria, is my own work and has not previously been submitted by me for a degree at this or any other tertiary institution.

All the resources used for this study are cited and referred to in the reference list by means of a comprehensive referencing system.

I, Prevendren Naidoo, declare that Idette Noomé (MA, English) from the University of Pretoria has edited the language in this document.

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Prevendren. Naidoo. Date

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SUMMARY

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PREVENDREN NAIDOO

SUPERVISOR : PROF. DR L.P. VERMEULEN
DEPARTMENT : HUMAN RESOURCES MANAGEMENT
DEGREE : M.PHIL HUMAN RESOURCES MANAGEMENT

Human factor issues related to flight deck automation require thorough knowledge of airline pilots' perceptions of advanced automated aircraft. This understanding is important in designing effective training programmes and developing the standard operating procedures (SOPs) of an airline that are needed to fly these aircraft safely.

The purpose of this study was to identify the core components of advanced flight deck automation and to construct a valid and reliable instrument to measure the perceptions of airline pilots with regard to automated flight deck systems on modern commercial jet aircraft.

An Automation Attitude Questionnaire, the AAQ, was constructed and distributed to all the pilots employed at a major South African carrier. The subsequent data, received from 262 respondents, was interpreted and then analysed using the SPSS and StatsPac statistical software packages.

Exploratory factor analysis indicated that five distinct factors were responsible for a significant portion of the variability in pilots' perceptions of advanced flight deck automation systems and training on those systems. After analysis, these factors were labelled 'comprehension', 'training', 'trust', 'workload' and 'design'.

The results indicated that those pilots who operated mainly Airbus-manufactured aircraft types had a statistically significantly more positive perception of the design of the automation system than those of their counterparts who flew mainly Boeing-manufactured aeroplanes. Co-pilots who operated primarily on the company's long-range aircraft expressed significantly more positive perceptions of advanced flight deck automation training than the line captains dedicated to long-range flying. It was found that captains flying the company's short-range aircraft also held a more positive perception of automation training than captains operating long-range aircraft.

The biographical variables of age, years of flying experience and total flying hours, appeared to be negatively related to both the comprehension and training dimensions of advanced flight deck automation. However, the mere opportunity to fly these advanced automated aircraft seemed to affect pilots' perceptions of these systems more positively than negatively.

Finally, the overall responses of the majority of participants in this study were very positive with regard to the five core factors related to perceptions of advanced flight deck automation.

It is suggested that future studies of this nature should incorporate a larger sample consisting of cross-cultural carriers in the global industry. This will confirm the external validity of the present study and support the transfer of findings to other airline pilot populations.

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Chapter 1

INTRODUCTION

1.1 BACKGROUND

'To err is human, and to blame it on a computer is even more so' (Stokes, 2007:197). This quote, coined by a famous 20th century American writer, highlights an aspect of the love-hate relationship between human beings and computers and machines. The aircraft as a machine was first documented and conceptualised by the genius of Leonardo Da Vinci, and was included in his codex on the flight of birds (Paolo, 2001). The modern jet airliner has evolved from that first flight of the imagination and is the culmination of that dream, integrating in its complex technology almost all of humankind's scientific thought to date. In other words, in that singular creation, the modern jet airliner, one can observe subtle traces of all the sciences – nuances from business, biology, psychology and meteorology, to advanced theories in calculus and materials engineering. Only computer technology has paralleled aviation in its rapid evolutionary advance; and the modern jet airliner is the proud heir of both fields of human endeavour, combining aviation and computer technology in an elegant fusion.

It all started only a century ago when Orville Wright famously took the controls of the magnificent Wright 'Flyer' and became airborne for a distance approximately the length of a modern Boeing 747-400 (Crouch, 2003). However, the wooden flyer had initially stalled during the Wright brothers' first attempt at flight, and this was arguably the first ever man-machine aviation-related accident, as described in this paragraph by Wilbur Wright after the incident: '…the power is ample, and but for a trifling error due to lack of experience with this machine and this method of starting, the machine would undoubtedly have flown beautifully' (Crouch, 2003:43). The aircraft that Orville flew on that important day in history was also the starting point in the aviation advances from an extremely manual mode of flight to the point of automation and computerisation found on the modern flight deck today.

The first fatal aircraft accident occurred only five years after this famous first flight, when a single passenger flying with Orville Wright was killed. An analysis of this accident in a report later submitted by Orville Wright revealed startling facts about the inherent weaknesses and one additional fundamental limitation of the system, namely the human pilot: 'The machine would not respond to the steering and lateral balancing levers, which produced a most peculiar feeling of helplessness' (Crouch, 2003:56).

As aviation advanced, it was obvious to entrepreneurs that this new technology could be leveraged to build viable and profitable businesses. Newer, more modern aircraft would need to fly further and for longer to ensure significant financial profits. However, once again, the human operator was the limiting variable in this business strategy – pilots were subject to fatigue on long flights. In order to reduce human fatigue, the autopilot was invented to take over the more mundane and simpler operations involved in flying the aircraft (Kabay, 1996). In 1914, Lawrence Sperry demonstrated that his invention, an automatic system, could pilot an aircraft by keeping his hands away from the controls to show observing onlookers, thus conceiving flight deck automation (Scheck, 2007). This early design was simple, in that it incorporated a gyroscopically stabilised heading and attitude indicator, connected to a hydraulically operated rudder and elevators, permitting the aircraft to fly straight and level on a compass course with very little pilot attention (Scheck, 2007).

The inevitable next step in the design of future aircraft was a reduction in the workload of the human operator. Any reduction in human workload comes with an equivalent increase in automation. Some scholars, such as Skitka, Mosier, Burdick and Rosenblatt (2000), have argued that the elimination of the human element in aviation will reduce errors and prevent accidents, whilst enhancing overall efficiency. History, however, has demonstrated that this ideal is still far from possible in the complex modern environment. Computers (conceived, designed and built by human beings) still have a latent flaw – the human hand involved in any computer's basic design.

For the foreseeable future, it is still only a trained, educated, experienced human being that can come close to the intuitive capacity needed to function effectively in the highly complicated, dynamic and multi-faceted aviation environment (Kabay, 1996). The future designs for the jet airliners of tomorrow envisaged by the leading aircraft manufacturers still require human beings to remain on the flight deck and still envisage that the pilot *must* be in control. The introduction of the jet engine and the ever increasing density of aircraft in a limited airspace have significantly increased the volume of extraneous variables affecting flight. The pilot is thus still needed to use the abundance of information readily available on the flight deck, to manage the automation system placed there to enhance safety, and ultimately to engage in the complex choreography of the man-machine interface in real time (Kabay, 1996).

The introduction of automation to the modern jet flight deck has resulted in a debate ‘for’ or ‘against’ such automation. Proponents of automation have argued that restricting computerisation may stifle technological research in aviation, thus limiting the benefits of efficiency and enhanced profits brought about by this technology. However, others have argued that more computers on the flight deck will not necessarily reduce pilot workload and may actually increase a pilot’s attention to, and involvement with programming and monitoring (Risukhin, 2001).

It is a statistically documented fact that commercial jet air travel is still the safest mode of transportation known to mankind – and this is why society is often confused, shocked and horrified by any accidents involving advanced automated aircraft (Risukhin, 2001). In trying to answer the question of why such accidents happen, one must include in one’s scrutiny the new problems and challenges presented by the introduction and utilisation of computerisation in aircraft (Risukhin, 2001). It is thus important to understand the human perception of an advanced automated environment in the execution of the safe operation of these aircraft. A negative or false perception of technology and automation may have an adverse impact on safety issues, but over-familiarity with the system may bring about boredom, fatigue and complacency.

1.2 PROBLEM FORMULATION

In the last two decades, aircraft accident analysis has begun to focus increasingly on the pilot’s awareness of the autopilot system state and its proper functioning (Bagshaw, 1996). Accidents such as the ones involving an A320 in Bangalore in 1990, an A320 in Warsaw in 1993, an A300-600 in Nagoya in 1994, a B757 in Cali in 1995, and a B757 in Puerto Plata in 1996, are only some of the advanced commercial jet aircraft accidents that have puzzled and frightened society.

The Cali accident was summarised by Ishibashi, Kanda and Ishida (1999).

> At 21:42 eastern standard time on 20 December 1995, American Airlines Flight 965, a Boeing 757-223, crashed near the summit of El Deluvio, northeast of Cali in Colombia. The PNF (pilot-not-flying) received instructions from the air traffic controller to proceed directly for a straight-in landing for the southerly runway via the Rozo navigational beacon. The PNF then proceeded to enter a direct ‘R’ into the flight management system (FMS) and executed without a confirmation or an order from the PF (pilot flying). ‘R’ is the identifier of the Rozo navigational beacon, but, in the FMS database, ‘R’ was registered as Romeo (as opposed to Rozo) beacon, which is 066 degrees and 141 miles away, and so the aircraft began to turn to the left.
>
> When the airplane was descending to approach runway 19 in Alfonso Bonilla Aragon International Airport, it began to turn to the left of the cleared course and approached a mountain range. The flight could not return to its course and ultimately crashed into the mountainous terrain. Of the 169 people on board, only four passengers survived.

They summarised the Nagoya accident as follows (Ishibashi *et al*. 1999):

> At 20:16 Japan standard time on 26 April 1994, China Airlines Airbus Industrie A300B4-622R, approaching Nagoya Airport for landing, began to climb steeply and stalled.
>
> At approximately 1 070 ft pressure altitude, the ‘GO’ lever was triggered for some unknown reason, commanding the aircraft into a ‘GO AROUND’ (GA) mode, thereby increasing engine thrust through the engine control computers. The flight levelled off at approximately 1 040 ft pressure altitude. The captain (PNF) warned the first officer (PF), ‘You triggered the GO lever’, and instructed him to disengage the auto-throttle and to descend to the normal path. The PF operated nose down, and then the aircraft gradually returned to the normal glide path. AP (Autopilot) No 2 and No 1 were engaged simultaneously. Both APs were used for about 30 seconds. The APs were engaged despite the ‘GO AROUND’ mode, so the PF needed further nose-down operation. The AP followed the GA logic and added full power, and trimmed the pitch up. The Trimmable Horizontal Stabilizer (THS) gradually moved from 5.27 to 12.30 degrees, which is close to the maximum nose-up limit. This subsequently induced a stall condition. The airplane crashed near the landing zone of the airport. Of the 271 persons (256 passengers and 15 crew members) on board, 264 persons (249 passengers and 15 crew members) were killed.

There is a vast difference in design between the aircraft being built today and the wooden contraption flown by the Wright brothers in 1903. The modern airline pilot is challenged by the current design and complexity of the flight deck. Wiener (1993) contends that the humans who need to operate these advanced systems require a radically different training method and paradigm shift in order for them to cope adequately with advanced aircraft. There are many possible reasons for the difficulties pilots have understanding the aircraft's automated systems. It appears, at least anecdotally, that one of these reasons may be a difference in perspective between the engineers who designed the system and the pilots who use it (Degani & Heymann, 1999).

Advanced aircraft are being conceived, designed and constructed by highly educated science graduates on a global scale, from the Massachusetts Institute of Technology (MIT) to the University of Hong Kong. Can they be creating such complexities in these machines that they have actually now reached the limit of the average person's processing ability? Should airlines be recruiting specially trained university graduates with specific cognitive skills who are capable of understanding the complexities of this new technology? Is it possible to measure the perceptions that humans hold in respect of modernisation, automation and computerisation, and its impact on subsequent behaviour?

The question of whether manufacturers are relieving pilot workload or ultimately increasing it is still under debate. According to Bagshaw (1996), although the overall trend is lower, highly automated aircraft have a relatively higher accident rate by mere virtue of the systems' complexity. As operating margins become even smaller, airline companies are forced to invest in technologically modern aircraft due to their efficiency, lower maintenance costs and eco-friendly status, simply to remain competitive within a global market and balance the triple bottom line. However, with new and advanced systems come new human factor issues, challenges and problems.

For many years, aviation psychology has focused on human factor issues that took the machine as a primary causation variable (Rigner & Dekker, 2000). Automation has created a new problem with working within a different flight deck philosophy. The stage is thus set for researchers to gather empirical data regarding attitudes and perceptions about operating highly advanced automated aircraft, because it is now important to consider that negativity can bring about reduced job performance, resulting in turn in adverse human behaviour and safety critical issues (Sarter & Woods 1992; Olson & Sarter, 2000). According to Walters (2002) research has only recently uncovered the inherent limitations in human information processing. This is a weak link in a complex systemic environment (Walters, 2002). As information is derived from a number of sources, the human brain is required to integrate, then interpret and eventually take action appropriately in real time. In the past, it was thought that human error was simply a mistake – an error, omission, or lapse. Increasingly, information about human behaviour reveals that we now must assume that weaknesses will occur: the challenge is then to determine how this imminent weakness can be mitigated (Rigner & Dekker, 2000).

A person's behaviour on the modern flight deck is influenced to a certain degree by his or her belief system, which directly affects the perception of his or her work environment (Fishbein & Ajzen, 2001). The perceptions people hold about their working environment can be either negative or positive, and thus influence the efficacy of a safe operating system. Organisations may find it competitively sustainable to know and analyse the behaviour of employees who are trained to operate their strategic capital investments, in this case, pilots flying aeroplanes. Knowledge of people's perceptions may well provide an early warning system for an organisation by revealing problematic trends. This also provides a starting point for changes in training methodologies, corporate culture and governance principles, thus enhancing safety and ultimately enhancing the bottom line. An industry-wide study undertaken by Boeing (a leading aircraft manufacturer) found that nearly 60% of fatal accidents worldwide are caused primarily by flight crew behaviour. Thus, today, human factor issues, more than ever before, tend to form a major part of aviation-related research (Kabay, 1996). Consequently, research into the effects of automation on human factors in aircraft will be an invaluable source of information, especially for emerging aviation organisations in the developing world.

1.3 PURPOSE OF THE STUDY

With due consideration of the above-mentioned problems, the aim of this study was to find answers to the following research questions:

- Is the Automation Attitude Questionnaire (AAQ) a valid and reliable instrument to measure perceptions related to advanced flight deck automation in a Southern African airline?
- Is there a relationship between airline pilots' biographical characteristics and their perceptions of advanced flight deck automation?
- Is there a statistically significant difference between Boeing and Airbus pilots' perceptions of advanced flight deck automation?
- What are the current perceptions of the research group of pilots towards advanced flight deck automation systems?

A comprehensive literature study was performed to answer the research questions and to reach the research objectives. The purpose of the literature study was to identify automation principles, and identify the behaviour most commonly found in safe pilots. On completion of the literature study, a measuring instrument, namely a questionnaire, was constructed. Principles of highly advanced flight decks as discussed in the literature study were used as a basis to create an item pool measuring airline pilots' perceptions regarding their working environment. Existing questionnaires on perceptions of advanced automated flight decks were also used as a starting point in constructing the questionnaire which measured pilots' attitudes regarding computerisation in cockpits.

With the above research questions in mind, the *primary objective* of the research was to construct a valid and reliable measuring instrument to identify the core factors related to airline pilots' perceptions of advanced flight deck automation.

The *secondary objectives* of this study were:

- to obtain sufficient empirical data about automation perceptions from the research population;
- to identify areas in which Boeing pilots and Airbus pilots agree (converge) or disagree (diverge) regarding their perceptions about automation systems;
- to determine the relationship between pilots' biographic characteristics (age, gender, seniority category, and so on) and their perceptions of advanced flight deck automation; and
- to determine the proportion of the research group with positive perceptions, versus those with negative perceptions of advanced flight deck automation.

1.4 OUTLINE OF THE STUDY

This research report consists of six chapters.

Chapter 1 addresses issues, the formulation of the problem and the purpose and objectives of the study and presents an outline of the study.

Chapter 2 provides a theoretical overview of aircraft automation. The concepts 'automation', 'perception' and 'behaviour' are clarified. The challenges facing global aviation are highlighted. The progress and pitfalls of flight deck automation and its impact on human factor issues are briefly discussed. Automation issues such as complacency and automation bias, mode confusion and loss of manual flying skills are discussed with a view to indicating how they relate to flight deck automation perception.

Chapter 3 deals with various aspects of attitude and behaviour in an attempt to explain the possible effect(s) of a pilot's perception(s) of highly advanced flight decks. One of the primary benefits of human factor and attitude conceptualisation is that it can be used to explain a wide variety of airline pilot behaviours. A study of pilots' perceptions of automation will serve no purpose unless it can be used by management to influence and rectify pilot behaviour by means of appropriate training.

Chapter 4 deals with the research approach. It explains the research methodology, including the design and administration of the questionnaire, the study population and sampling, and the collection of data. The response rate and the statistical research methodology used are also discussed.

Chapter 5 focuses on the interpretation and discussion of the research results. The results of the factor analysis, item analysis, reliability, analysis of variance, and correlation are discussed.

Chapter 6 contains the summary and recommendations of the study. Recommendations for influencing airline pilots' perceptions about the modernisation and computerisation of the flight deck are provided to ensure an operating environment that is conducive to safety. The focus in the discussion of the results, is answering the research questions. Only statistically significant findings with practical implications are discussed, and the implications for management are pointed out. The limitations of the study and suggestions for future research are also outlined.

Chapter 2

AIRCRAFT AUTOMATION: A THEORETICAL PERSPECTIVE

2.1 THE ORIGINS AND DEVELOPMENT OF AIRCRAFT AUTOMATION

When the term ‘automation’ is used in the aviation industry, it provokes fear and uneasiness in some airline pilots, but it paradoxically evokes a sense of comfort and confidence in others. This contrast has arisen ever since advanced computerisation has first been integrated in the flight deck.

The introduction of the automated weaving loom by Jacquard in the 1800s first introduced people to the possibility that a machine could take centre stage. Indeed, the term *Luddite* was derived from the first employees who began a protest in fear of losing their livelihoods to machines that might be more efficient and capable than humans. The term *Luddite* is today used to refer to anyone who has a fear of technology and those considered technologically impaired (Ramtin, 1991).

The oil price crisis of the 1970s provided the initial impetus for aircraft manufacturers to rethink aircraft cockpit design. In attempting to find a competitor for the then very popular Boeing 727, Airbus Industries designed a successor to its A300 aircraft. The A320 family of aircraft from Airbus Industries incorporated more advanced computer technology and automation (Kingsley, 2006). This was by far the most advanced aircraft of its time, incorporating a modern avionics and computer suite. The engineers of the time determined that only a computer had the capability to control a commercial jet to the precise requirements of efficiency that was required by the phenomenal oil price (Kingsley, 2006).

Airbus Industries introduced advanced features such as a fly-by-wire flight control system, composite primary structures and centre-of-gravity control, using fuel located in the tail plane of the aircraft. A two-person flight deck working in an electronic flight instrument system (EFIS) environment (glass cockpit) was the radical and most visible change to the commercial jet. The net result was that the A320 consumed 50% less fuel than the Boeing 727. Thus, it can be said that it was a financial imperative that sparked the need for aircraft automation.

Beauden (1989) further suggested that the reason for the changes and advances in flight deck design was a desire to achieve the following advantages:

- a lowering of pilots' mental and physical workload;
- economy in personnel (by relieving the flight engineer of duties, the designers were able to build an aircraft that requires only two pilots);
- precision in automation to create accuracy in the flight path; and
- a reduced need for maintenance because of the reliability of the system.

The advanced flight deck incorporates flight data information on cathode ray tubes (CRTs) and liquid crystal displays (LCDs) – the main reason that many observers refer to these systems as 'glass cockpits' (Risukhin, 2001).

According to Risukhin (2001), the complete digitised flight deck system consists of the following systems:

- electronic attitude director indicators (ADIs);
- electronic horizontal situation indicators (HSIs);
- data management systems (FMS) and symbol generators to drive the electronic indicators;
- navigation system control and display units (ND); and
- air data systems.

The ergonomic design of the modern flight deck consists of

- forward-facing crew seats;
- flight controls providing the required visibility of the CRTs;

- electronic flight instruments (primary flight display, navigational display) mounted horizontally next to each other; and
- a central panel fitted with two CRT displays to provide warning information and systems and engine parameter monitoring – in the Airbus, Electronic Centralised Aircraft Monitoring (ECAM) and Systems Display (SD); and in the Boeing, an Engine Indicating and Crew Alerting System (EICAS).

Air traffic has increased globally at a phenomenal pace. The dark side of this picture is a rapid increase in aircraft collisions due to the sheer lack of capacity that results from limited airspace. To compensate, modern flight decks incorporate a state of the art Traffic Collision and Avoidance System (TCAS) and Controlled Flight into Terrain (CFIT) avoidance equipment, such as GPWS and enhanced GPWS. According to Hopkin (1988) and Risukhin (2001), the concepts associated with these systems are

- ground proximity warning systems (GPWSs);
- radio-altitude-based alerts (RAs);
- look-ahead terrain alerts;
- terrain display and Enhanced GPWS;
- windshear alerts;
- airborne collision and avoidance systems (TCASs);
- resolution advisory (RA);
- traffic advisory/avoidance (TA);
- proximate traffic display; and
- other traffic display.

The quantum leap in flight deck design and layout can only be understood when it can be scrutinised visually. Therefore, a comparison of an analogue flight deck versus a modern digital flight deck system is presented in Figure 2.1 (below).

Modern digital flight deck: **Traditional analogue flight deck:**

Figure 2.1: Flight deck comparisons

(Source: Flight Deck pictures, http://www.airliners.net/, 2007)

The comparison in Figure 2.1 illustrates the extent of digitisation in a modern commercial jet flight deck. Many of the traditional analogue systems have either been combined or completely eliminated in the advanced glass cockpit. Research conducted by Parasuraman and Riley (1997) has, however, uncovered potential design flaws or traps in this transition from the analogue cockpit (with more pilot control) to the digital cockpit (with less control given to the pilot).

2.2 FLY-BY-WIRE TECHNOLOGY

A distinction must be drawn between standard automation systems and the newer Fly-By-Wire (FBW) automation systems. Traditionally, all aerodynamic surfaces were controlled from the cockpit by the pilot via a crude system of cranks, mechanical linkages and levers. According to Thom (1988), the basic cockpit controls are arranged as set out in Figure 2.2.

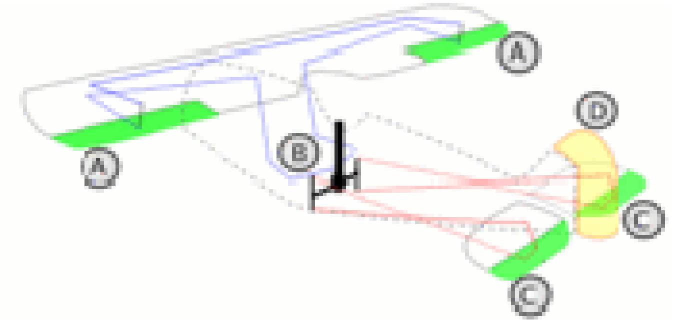


Figure 2.2: Primary cockpit controls

(Source: Thom, 1988)

- A, C: *Ailerons and elevators:* A control yoke attached to a column induces roll or pitch, primarily thorough aerodynamic surfaces referred to as ailerons, when the yoke is turned or deflected left or right. This control yoke also moves control surfaces called the elevators when it is moved backwards or forwards, inducing a pitch moment up or down.
- B, D: *Rudder pedals and rudder:* The rudder pedals control yaw by moving the rudder left or right. Therefore a left foot forward will move the rudder left, inducing a yaw of the aircraft nose to the left.

Fly-By-Wire (FBW) designs on commercial jet aircraft are primarily found on the new generation Airbus type aircraft. The word ‘fly-by-wire’ simply means an electrically-signalled only control system. Other airline jet manufacturers, such as Boeing, still maintain a traditional means of flight control, using hydraulically actuated control systems through mechanical linkages between the flight deck and the aircraft surfaces (Taylor, 1998). Boeing's control system still includes a yoke, similar to a steering wheel, which is the primary means the pilot has to control the direction of the aircraft. By contrast, Airbus uses a ‘side-stick controller’, a joystick to the pilot's left and the co-pilot's right side. This side-stick is connected to a computer ‘box’, which continuously monitors pilot input during manual ‘hands-on’ flying. The fundamental difference between the two manufacturers, however, is that the pilot cannot override the computer on the Airbus aircraft. The FBW system will not allow the pilot to make any extreme manoeuvre outside of the aircraft’s flight envelope in normal flight. Boeing engineers, on the other hand, believe that the pilots should still be able to maintain *total* control of the aircraft, even if this means operating outside of the normal parameters, without computer intervention.

In the FBW system, the control inputs from the pilot operator is first interpreted by a computer and only then transmitted via electrical signals to an appropriate hydraulically actuated aerodynamic surface (Taylor, 1998). Although the pilot may require full manual control of the aircraft at some point, the inputs from the flight deck can still be overridden by the monitoring computer system if the computer deems the action to be outside the flight envelope. In other words, the auto pilot and computer brain will not allow the pilot total control of the aeroplane in its entirety. According to the Airbus flight training manual (2006), the objective of the computer controlled ‘law’ is to provide the following handling characteristics within the normal flight envelope (regardless of aircraft speed, altitude, gross weight and centre of gravity):

- the aircraft must always be stable and manoeuvrable;
- the same response must be consistently obtained from the aircraft; and
- the actions on the control stick must be balanced in pitch and in roll.

- The flight 'laws' as governed by the many computers continuously monitoring the aircraft flight envelope and design capability do, however, still allow the pilot
- full authority to achieve maximum aircraft performance;
- instinctive and immediate reaction, in the event of an emergency; and
- a reduced possibility of over-controlling or overstressing the aircraft.

A demonstration of the latest FBW technology has shown that, using this technology, harsh or abrupt pilot control inputs could not put the aircraft in an uncontrollable state (Wallace, 2000). During an emergency situation, a pilot may aggressively pull back hard on the aircraft side stick. The computer immediately interprets this, automatically setting the engines to maximum thrust and retracting the speed brakes (the aerodynamic surfaces which cause drag). This allows the aircraft easily to power out of an undesirable situation, without overstressing the airframe, and remaining within the flight envelope, whilst relieving pressure on the pilot (as only one input had to be made). Extreme pilot control inputs in a more traditional aircraft (with no computer monitoring protection) might cause substantial airframe damage.

2.3 FUTURE DEVELOPMENTS

As technology improves, it is inevitable that aircraft design and manufacturing will evolve. In pursuit of increased efficiency and advantages resulting from this learning curve, the use of computer technology in the cockpit will increase.

- **Fly-By-Optics**

  Advancements in fibre optic technology in the telecommunications industry have created new options for aircraft manufacturers. Reduced electromagnetic interference and faster rates of data transfer are some of the main reasons for replacing traditional wiring (Stengel, 1993). The greater transfer speeds are sometimes referred to as 'Fly-By-Light'; and the data transferred remains the same as that in the original wire system.

- **Power-By-Wire**

  The advantages of FBW technology allow reduced weight in modern aircraft. By developing self-contained units that produce hydraulic power where needed, designers have reduced weight, eliminating bulky circuits (Stengel, 1993). An electrical power circuit replaces hydraulic power lines. In developing the 787, Boeing has gone so far as to eliminate the bleed air system in its entirety. Pneumatic power is provided to different systems by an individual, self-contained unit for each system. The greatest benefits from these new methods are weight savings, the possibility of making redundant power circuits and tighter integration between the aircraft flight control systems and its avionics systems (Stengel, 1993).

- **Intelligent Flight Control System (IFCS)**

  The ultimate extension in the FBW technology is the Intelligent Flight Control System (Wallace, 2000). The IFCS compensates for the loss of flight controls by intelligently integrating the use of engine thrust and other avionics to compensate for severe failures such as a loss of hydraulics, loss of rudder control, loss of ailerons, loss of an engine, and so on.

- **Augmented reality displays**

  An investigation conducted by Alter and Powell (1999) suggests that errors are significantly reduced when one compares performance using augmented symbology, such as pathway-in-the-sky versus the conventional general instrumentation. The data obtained indicated a reduction in pilots' total workload when they flew precision approaches using the pathway-in-the sky technology. The study demonstrated the advantages of implementing further computer technologies in the cockpit.

Figure 2.3 illustrates what a pathway-in-the-sky augmented in real time may look like to a pilot.

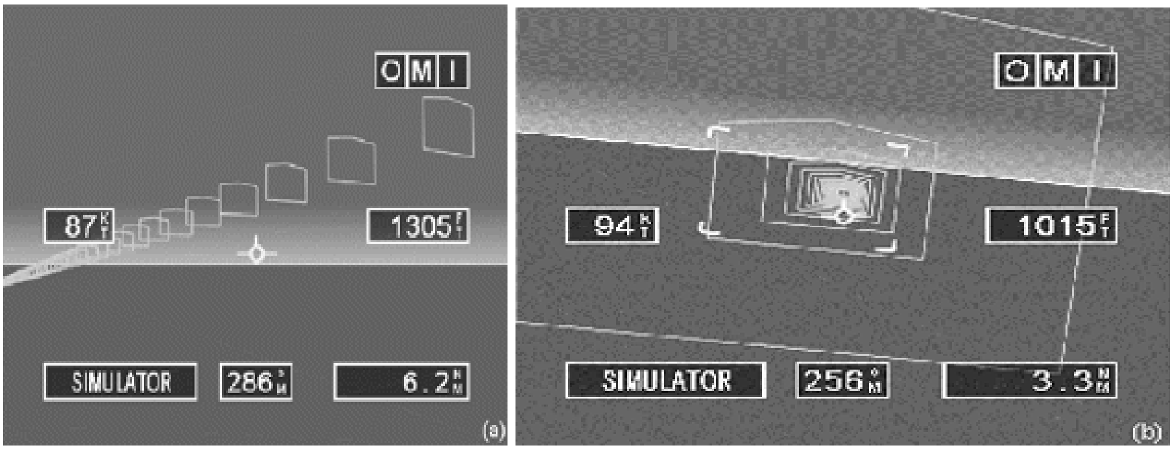


Figure 2.3: Airplane on intercept to final approach and on final approach inside tunnel

(Source: Alter & Powell, 1999: 35)

A latent failure identified in modern flight management systems was the increasing amount of time being spent by pilots looking inside the cockpit. Augmented symbology is designed to eliminate this adverse effect of flight deck automation systems. When the pilot is allowed to interact with both the aircraft instrumentation and real world information, advantages in safer operations are gained from the pilot’s improved situational awareness.

2.4 SUMMARY

This chapter highlights the benefits and problems associated with computerising the flight deck. A discussion of the machine component in the man-machine system was the main focus. Industrialisation and economic efficiency is the fundamental force driving research in the field of aircraft automation. It was quickly discovered that human beings are often the limitation in the system.

The invention and evolution of computer technology was a new concept that was soon put to use in the design of the modern aircraft. Integrating information technology into aircraft design was the logical next step in eliminating the inaccuracies caused by human fallibility. Having people in the mix also costs money. However, people still are, and will continue to be a fundamental component in the design, implementation and control of highly advanced automated systems.

The discussion examined the origin and development of the flying machine and automation. Early aircraft engineers were simply interested in building a flying machine and little consideration went into the design of the flight deck. Given the many advances in technology and computer science, designers began to focus on cockpit design. Modern materials allow for lighter and more efficient technology to be integrated on board the flight deck. By creating computer systems to manage the aircraft, some crew positions, such as that of the navigator and flight engineer, could now become redundant (refer to Section 3.4). This saves airline companies and manufacturers money, as businesses and states increasingly invest in the aviation industry.

There appears to be no limit to the exponential advances in technology currently being made globally. Any improvement in technology is quickly absorbed into the aviation industry. The main reason for this quick assimilation is that advances in technology correlate very closely with improvements in flight safety measures. The more human beings evolve, the more it appears that the flight deck changes. The changes brought on by advances in technology create further challenges in the link between human resources and aviation management. This chapter has discussed advances in the fields of modern FBW and fly-by-light systems. These advances will affect aeroplanes' human operators in many ways still unknown to human factor experts, thus an analysis of this nature (the human-machine dyad) is important. The next chapter focus specifically on the human element, which, as has been shown, still occupies the most important position in the man-machine system.

Chapter 3

FLIGHT DECK AUTOMATION ISSUES AND HUMAN BEHAVIOUR

3.1 INTRODUCTION

‘Automation is the allocation of functions to machines that would otherwise be allocated to humans’ (Funk, Lyall, Wilson, Vint, Niemczyk, Surotegu & Owen, 2000:56). The term ‘automation’ has long been difficult to define. However, many researchers in the field of automation have agreed that the term ‘generally means replacing human functioning with machine functioning’. The term flight deck automation generally means ‘that some tasks or portions of tasks performed by the human crew can be assigned, by the choice of the crew, to machinery’ (Wiener, 1989:121).

The integration of automation into commercial aircraft flight decks has contributed to greater efficiency, productivity and overall safety (Wiener, 1993). However, several unique human factor issues have been raised by both the civil aviation authorities and by human behaviour experts (Billings, 1997; Palmer, 1995; Parasuraman, & Riley, 1997). These human factor issues relate to concerns about poor interface design, pilot complacency and over-reliance on automation, a loss of manual flying skills, and pilots' lack of understanding of the new equipment.

3.2 AUTOMATION ISSUES

Extensive research contributions by aviation scholars in the field of automation issues have been documented in the public domain and can be accessed via the website, notably at http//www.flighdeckautomation.com. The contributors to this site have identified *92 critical issues* affecting pilots with regard to automation and the operation of advanced aircraft. Clearly, it is beyond the scope of this study to list all 92 issues identified, analysing various sources and surveying actual operators. However, Funk, Lyall and Riley (1995) have ranked the top ten automation issues in terms of the strength of the evidence on these issues.

The top ten issues affecting pilots operating an advanced aircraft as determined by Funk *et al*. (1995) by means of meta-ranking and confirmed by Funk and Lyall (2000:5) are:

- *Understanding:* 'Pilots may not understand the structure and function of automation or the interaction of automation devices well enough to perform their duties', safely.
- *Situational awareness:* 'The behaviour of automation devices, what they are doing now and what they will do in the future, based upon pilot input or other factors, may not be apparent to pilots. This may result in reduced pilot awareness of automation behaviour and goals'.
- *Complacency:* 'Pilots may become complacent because they are overly confident in the flight management system and uncritical of automation. Such complacency leads to a failure to exercise appropriate vigilance, sometimes to the extent of abdicating responsibility to it'. This can lead to unsafe conditions.
- *Design:* 'Displays (including aural warnings), display formats and display elements may not be designed for detectability, discriminability or interpretability. This may cause important information to be missed or misinterpreted'.
- *Training:* 'The training philosophy, objectives, methods, materials or equipment may be inadequate to train pilots properly for safe and effective automated aircraft operation'.
- *Inappropriate usage:* 'Pilots may use automation in situations where it should not be used'.
- *Complexity:* 'Automation may be too complex, in that it may consist of many interrelated components and may operate under many different modes. This makes automation difficult for pilots to understand and use safely'.
- *Surprise events:* 'Automation may perform in ways that are unintended by, unexpected to, and perhaps inexplicable to pilots, possibly creating confusion, increasing pilot workload to compensate, and sometimes leading to unsafe conditions'.

- *Dissemination of information:* ‘Important information that could be displayed by automation is not displayed, thereby limiting the ability of pilots to make safe decisions and actions’.
- *Reduced skill:* ‘Pilots may lose the psychomotor and cognitive skills required for flying manually, or for flying non-automated aircraft, due to extensive use of automation’.

An analysis by Rudisill (1991) of the results from an international survey conducted by the Royal Aeronautical Society on advanced automation revealed issues closely aligned with the top ten issues as reported in the automation data base. The results of this examination resulted in the following issues and recommendations from Rudisill (1991):

- *General issues related to automation*: The general agreement among participants was that automation was a good thing. However, concerns were raised that inexperienced pilots may be led into a false sense of security by the automatics. One solution proposed to resolve this issue is to provide mechanisms for inexperienced pilots to gain and develop a firm base in piloting skill.
- *Flight deck design issues*: In general, Rudisill’s (1991) respondents were happy with the overall design in the automated cockpit. Issues were raised, however, regarding the interpretation of flight instrument displays and unnoticed events in map shift (loss of accuracy in navigational displays). Rudisill (1991) suggests that transition training for new ‘glass’ pilots should emphasise self-discipline and vigilance in monitoring raw data information.
- *Understanding how to use automation*: The general response from Rudisill’s (1991) participants regarding the integration and use of automation elements was positive. Some issues raised in this respect concerned pilots’ lack of knowledge about the intended behaviour of the aircraft in certain modes of flight. Pilots should have the ability to disconnect the automation and take manual control in the event of adverse aircraft behaviour in critical phases of flight to mitigate uncertainty (Rudisill, 1991).
- *Crew coordination and personal issues*: Respondents commented that ‘automation may reduce workload in low workload flight phases and may increase workload in

> high workload flight phases; also, workload may be increased dramatically during abnormal situations and failures' (Rudisill, 1991:290). It was also noted that crews were affected by boredom and complacency during periods of low workload. Again, crew discipline and improved systems knowledge helps to minimise this kind of problem.

Other studies conducted by Mosier, Skitka, Heers and Burdick (1998) have found extensive evidence that the advanced flight deck and the extensive use of automation have created an environment of automation bias and flawed heuristics (as a short-cut to decision-making, a symptom of complacency) which may threaten safety. As early as the 1990's, research conducted by Parasuraman, Molloy and Singh (1993), Parasuraman and Riley (1997), identified the need to optimise pilot workload in order to reduce boredom and mitigate the consequences of complacency. The identification of work optimisation is more important on an advanced flight deck than it was a generation ago, on a more traditional analogue flight deck. A review of recent commercial jet aircraft accidents has revealed that new technology has on occasion resulted in critical human behavioural issues that could not have arisen with older-generation aircraft, for example, the flight management system input error in the Boeing 757 accident in Cali.

Damos, John and Lyall (2005) also examined how the frequencies of 23 activities varied as a function of cockpit automation. The study examined general 'house-keeping' activities and communication, as well as flight path control, which may be regarded as one of the most fundamental factors in reducing aircraft accidents and incidents. That is, maintaining the correct flight profile is what keeps an aircraft in the correct (safe) three-dimensional space. Human factor errors emerge when the pilot has to cope with and integrate an excessive number of sources of information. Paradoxically, behavioural errors can also occur when the workload is too low. This conflict appears to be a problem that contributes to human error on the advanced flight deck (Kantowitz & Casper, 1988).

An apparent rise in the number of incidents and accidents never before contemplated by human factor experts have emerged as a symptom of the increasing use of automation throughout the world (Skitka *et al.*, 2000). An accident trend analysis has revealed that human error contributes to at least sixty per cent of aircraft accidents and incidents. One can observe from the trend gradient in Figure 3.1 that a spike occurs at the point when any new technology is introduced. The gradient begins to taper off over time as advantages are gained from learning curve affects.

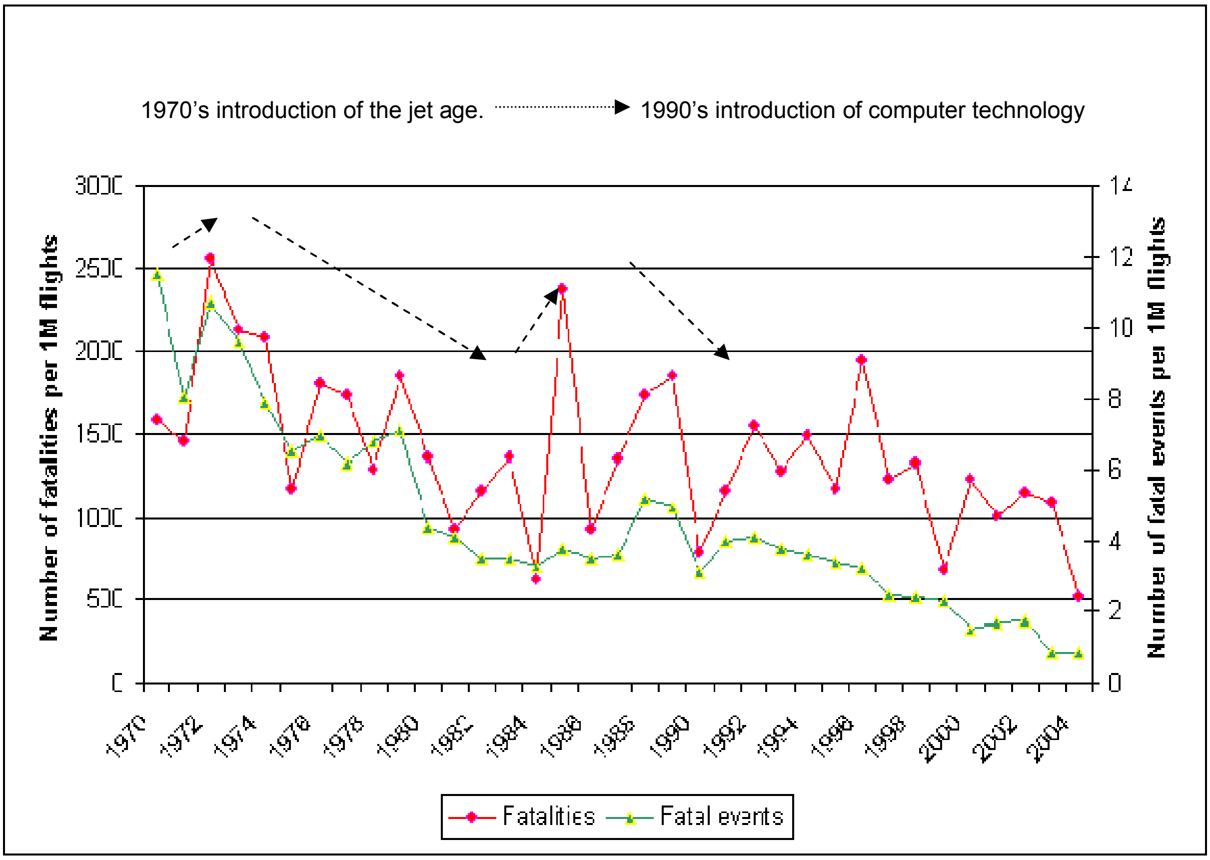


Figure 3.1: Airline accident statistics

(Source: Accident Statistics, http://www.airdisaster.com/statistics/, 2007)

It is clear from Figure 3.1 that major changes occurred (as expected) between the years 1984 and 1988, as well as between 1996 and 1998 – points when new technology was introduced into the flight deck.

Given the exponential increase in technology, adverse human factor issues have paralleled technology, evolving to a new level of sophistication. Research suggests that the increased presence of computers (such as flight management computers, FMC's) on board modern flight decks have resulted in some flight crew members' spending an increasing amount of 'heads-down' time during critical phases of flight, a key contribution to distractions resulting in an incident (Damos, John & Lyall, 2005). Traditionally, the operation of analogue flight deck aircraft meant that pilots were often making an exceedingly large number of minute mistakes. The modern advanced flight deck incorporates highly sophisticated computers which now take care of the mundane or routine aircraft operations. Any mistakes committed by the human operator on a modern flight deck are more likely to result in a catastrophic disaster (Edwards, 1988). For example, the use of reduced thrust take-offs have become an everyday method of reducing wear and tear on jet engines. However, a mistake in the input of the correct temperature into the flight management computer may result in disaster if the aircraft fails to accelerate during the take-off phase (when the assumed temperature is far higher then is actually required). This highlights the fallibility of the basic computer-human dyadic. Experts in the field refer to this as *GIGO* or 'garbage-in-garbage-out' (Damos *et al*., 2005). In other words, this dyadic is only as strong as the weakest link, the human being.

According to James, McClumpha, Green, Wilson and Belyavin (1991), early research in the field of automation led to various conflicting theories. It was found in some studies that many pilots indicated the perception that flying skills were greatly degraded by the use of advanced automation systems. By contrast, other theorists argued that there was a perception that automation reduced workload and fatigue, thus improving overall flight safety. A qualitative examination of information gained from the use of the Automation Attitude Questionnaire (AAQ) in the current study reveals comments from the respondents which are in line with the top ten automation issues:

- 'New generation equipment is safer to operate and manage, however, pilots can lose basic flying skills due to lack of "hands on" actual flying.'

- ‘My biggest negative about advanced automation is: the more sophisticated the system, the more stressful it is when it fails. The reversion from super helpful to useless is what I find the most stressful, e.g. in Airbus aircraft. I’ve been flying glass cockpits for 23 years. Youngsters deal better with automation but lack flying skills and a healthy dose of fear when the automatics fail or are degraded. Older pilots have better handling skills and common sense when it is called upon, i.e. over-reliance on automation is NOT a good thing, but in a “normal” operation it is a great help.’
- ‘In general, advanced automated flight decks provide much higher levels of safety – provided the crew is correctly trained and apply the correct SOP. However, over reliance on automation leads to complacency which allows inexperienced crews to make mistakes or fail to recognise dangerous situations arising. Automation cannot replace experience; it only augments it!’
- ‘I feel that my conversion from “Traditional” to “Glass” cockpit operations was grossly inadequate and rushed. I feel that there was insufficient technical coverage. This has all been proved to me by the ongoing training carried out at the six-monthly intervals and the ongoing technical information constantly disseminated by the company.’
- ‘In my opinion, complacency is a threat and we need good self-discipline in order to remain vigilant.’
- ‘Generally glass cockpit aircraft have made airline flying a lot safer. Although the pilot must continually guard against complacency. It takes time for the pilot to become comfortable and knowledgeable in the use of the glass cockpit. During this transition, performance is low and must be monitored. Once experience has been gained, performance rapidly increases but best practices must be maintained in order to monitor system performance.’
- ‘Situational awareness is far greater in the glass cockpit. Understanding the system in the automated aircraft is important. During “normal” aircraft operations, the glass cockpit is great. When “abnormal” aircraft situations occur, it can become very complicated compared to more traditional flight decks.’

3.2.1 Mode confusion

The issue of understanding and comprehending what state the system or computer is in warrants a separate discussion. Understanding the machine plays a vital role in interacting with it. Reliable knowledge and systems understanding are a fundamental basis in operating an advanced aircraft to the levels of safety that it was initially designed for. The construct 'comprehension' was found to be responsible for a significant portion of the variability in the attitude and behaviour of the airline pilot. It has often been remarked by pilots: '[W]hat is it doing now, what will it do next, why did it do that' (Edwards, 1988:15). Often, when one probes more deeply into this phenomenon, one finds that the human operator did not completely grasp the mode in which the flight management system was.

Confusion of the actual mode or state of the automation system can be fatal, as described by Perrow (2000) in respect of the Air India A320 accident. In this incident, the failure of the crew to understand the descent mode of the aircraft inadvertently resulted in a controlled flight into terrain (CFIT) accident. The crew commanded the aircraft into an 'open descent' state (not comprehending that this mode was unsuitable for a non-precision approach), where there would be no control of the glide path by the computer, resulting in a descent far faster than that which was required for that specific profile. Mode confusion can occur in everyday situations too, for example, many people have annoyed themselves by accidentally pressing the answer button and disconnecting the telephone after picking it up. This can happen when people fail to realise (comprehend) that the cordless telephone automatically answers the call when it is lifted from its cradle. Understanding how the system works would have prevented this – the answer button is only used when the handset is not in its cradle. Similar situations of mode confusion occur on the modern advanced flight deck.

Palmer (1995) contends that mode confusion is simply an automation 'surprise', in that a technical system behaves differently from what the user expected. These surprises on advanced flight decks are of concern to the Federal Aviation Administration (FAA) and other aviation authorities and require a thorough knowledge loop in the mindset of the pilot to mitigate any severe consequences. A surprise occurs when there is conflict between a person's mental model and reality (Lankenau, 2001). However, Palmer (1995) points out that if the user does not have the required knowledge and is therefore expecting nothing, no surprise will occur when something does (or does not) happen.

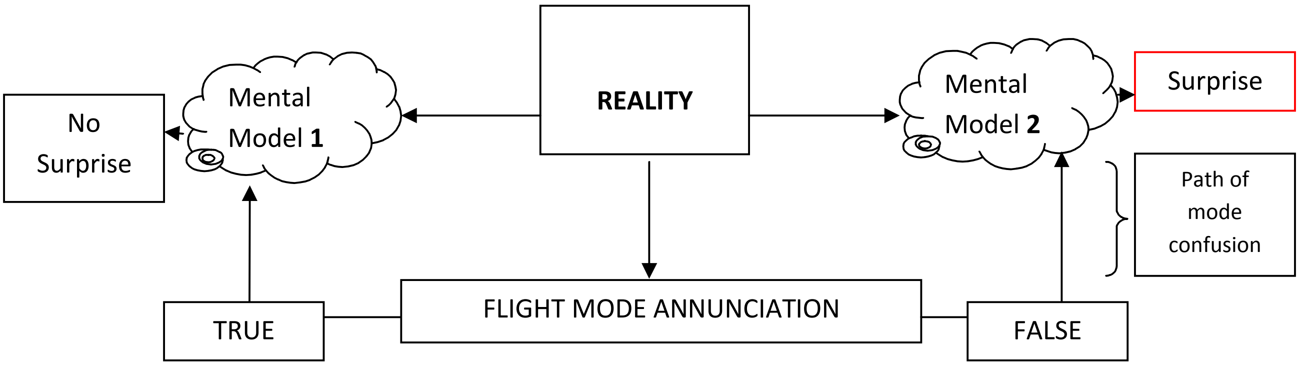


Figure 3.2: Mental model of mode awareness

(Source: Lankenau, 2001: own derivation from the text)

As described in Figure 3.2, Lankenau (2001) suggests that a user who operates advanced aircraft may perceive reality in two states, either correctly (true) or incorrectly (false). The difference between the two perceptions of reality can result in a surprise or no surprise for the user. The state of the computer's reality on an advanced flight deck is represented by its flight mode annunciator (FMA), as illustrated in figure 3.3. The most important display in a glass cockpit, the FMA (which is conveniently located directly in front of the pilot as part of the primary flight display) provides the user with information on its mode. A thorough understanding of this display can prevent mode confusion. However, other sources of reality from the physical environment are still available to the pilot, bypassing the FMA, such as raw data information (navigational beacons, distances, ATC radar and so on), which may help overcome a false perception of the automation mode or state, thus enabling the user to prevent unsafe consequences of a false perception.

Lankenau (2001) summarised mode confusion in three basic events from which problems may occur:

- the user makes an incorrect **observation**;
- the user has incorrect **knowledge** about the system; or
- the user has the correct knowledge, but **retrieval** is incorrect.

Figure 3.3: Modern Primary Flight Display (PFD) with Flight Mode Annunciator (FMA)

(Source: Phoenix Simulation Software, http://www.phoenix-simulation.co.uk/, 2007)

Figure 3.3 shows the location of the modern flight decks' Primary Flight Display (PFD). Its position in the cockpit places the FMA directly in the pilot's line of sight. The information displayed on the top of the PFD by the computer informs the human being of the aircraft's current state, or mode, in no uncertain terms. The location of the FMA occupies prime 'real estate' in the flight deck thus indicating its fundamental importance in understanding the machine.

3.3 LEVELS OF AUTOMATION

According to Olson and Sarter (2000), pilots operating highly advanced flight deck systems may engage in three different strategies in the coordination of human-machine intentions and actions. These automation management strategies can be conceptualised as *management-by-consent*, *management-by-exception*, and *full automation*. Strategic management of automated systems involves the negotiation of multiple goals and activities, rather than manually overriding the computer system whenever a conflict arises in the human-machine interface (Sarter & Woods, 1992; Olson & Sarter, 2000).

In defining and describing automation, Wickens and Hollands (2000) devised a ten-layer taxonomy describing automation at different levels, on a scale ranging from high autonomy to a lower level of computer non-participation. According to Wickens and Hollands (2000), there are ten levels of automation ranging from high to low, as set out in Figure 3.4.

HIGH	Ignore the human. The computer decides and acts autonomously.
	Decide whether or not to inform the human.
	Will inform the human only when asked to do so.
	Executes tasks as required and then informs the human.
MEDIUM	Automatic execution of task only after allowing the human a specific time frame in which to veto decision.
	Executes the human-approved suggestion.
	Computer suggests one alternative.
	The computer offers a complete set of decision/action alternatives.
LOW	The computer offers no assistance: the human must take all actions.

Figure 3.4: Levels of automation

(Source: Wickens & Hollands, 2000:15)

Figure 3.4 suggests that automation itself is not a hard-and-fast rule. The decision-making process is a complex array of executions and the user cannot simply hand over control of the aircraft to the computer system. In flying an aircraft, the decision-making activity between human and machine may lie in a quadrant comprised of a mixture of the different levels of automation (dynamically moving up and down Wickens and Hollands's range). For instance, in controlling fuel distribution and balancing, some advanced systems are at the top end of the automation hierarchy. On the highly advanced Airbus A340-600 aircraft, the pilot is ignored and the computer decides autonomously which tanks fuel will be pumped into or out of in order to maintain an optimum centre of gravity for the most efficient aerodynamic configuration. But on the lower level of the automation scale, the same aircraft computer cannot make any decisions and may offer no assistance during a different scenario. This may occur when it is required to decide whether or not a diversion to an alternate airfield may be necessary due to a situation where the fuel levels on board are very low. This provides some understanding of the complexities involved on the advanced flight deck which the human operator and computer need to deal with every day. In using Wickens and Hollands's range, it is easy to see how the decision-making process on an advanced flight deck can move up and down the scale in a dynamic and real time environment.

A blurring of boundaries in the human-machine system has occurred in the transition from analogue flight systems to digital flight automated systems. The result requires a paradigm shift in the in-house training methodologies airlines use (Rigner & Dekker, 2000). Rigner and Dekker (2000) suggest that the integration of flight deck automation issues at different stages of training, including *ab initio* training, multi-crew cooperation training and crew resource management (CRM) training, will improve an organisation's future pilots' perceptions and enhance knowledge about automation. Organisations will then have pilots who are far more aware of the levels of control afforded to them in flying automated aircraft, thus making them more capable operators.

3.4 FLIGHT DECK POSITION

Early design of cockpits in commercial jet aircraft assumed the use of at least four flight deck crew members (Walters, 2002). This included the pilot (captain) and co-pilot (first officer), navigator and flight engineer. This complement increased by another three members for long-haul flights exceeding eight hours. In some instances, foreign non-English speaking carriers also employed a radio operator to interpret all incoming air traffic control information. The need for all these crew members created a very cramped and crowded working environment. The integration of computer technology into the flight deck allowed for the elimination of all but two primary positions. Computers were given the task of managing the navigation, engine and fuel control, leaving the monitoring of the aircraft's systems to two pilots. The long-haul advanced flight deck commercial jet aircraft operated by most airlines today require two primary crew members at the controls at all times, with an in-flight relief pilot available to allow either the captain or co-pilot time to rest.

The organisation from which the sample in the current study was drawn hires pilots at a very junior level, referred to as in-flight-relief pilots (Flight Operations Manual, 2007). Their sole purpose is to increase flight-and-duty periods (FDP) by relieving the primary flight deck crew members of duty above 20 000 feet and in particular during the cruise. They are sometimes also referred to as cruise-pilots. These pilots (in many cases very experienced regional pilots) hold this designation for a two-year duration prior to moving on to becoming primary flight crew members.

As pilots gain more experience in the airline and after they have completed their 'probationary' period as cruise-pilots, they may move on to become instructor first officers (PIs) or simply stay on as line first officers on narrow-bodied aircraft. PIs normally move on to become training captains (after obtaining many years of experience) and line first officers (co-pilots) upgrade to line captains. This process of upgrading from first officer status to captain status may take, on average, 12 years with this specific airline. The most experienced pilots (based on years of service) are usually the senior training captains on long-haul aircraft, whilst the most junior members at the company are the new hire in-flight-relief pilots.

The respondents of the AAQ in the sample in the current study consisted of two primary groups. They could be crew members operating as either short-range pilots or long-range pilots. The company Flight Operations Manual (FOM) defines a short-range sector as 'the operation of scheduled and non-scheduled flights by the Company within a circle having a radius equal to or less than a distance of 1250 nm from Johannesburg International Airport' (FOM, 2007:720).

3.5 AUTOMATION PERCEPTION AND FLIGHT DECK BEHAVIOUR

3.5.1 Introduction

According to Fredricks and Dossett (1983:12), 'attitude is the key to understanding human behaviour'. People's perceptions have a similar impact on attitude and are considered the root of behavioural issues. Understanding the components of a pilot's perception is necessary to understand the behaviour of flight deck crew operating advanced automated aircraft. Studies conducted by Vermeulen, Wilson and Mitchell (2004) on perceptions in respect of gender bias in the aviation industry demonstrate the importance of perception, attitude and behaviour in the airline industry.

According to Rigner and Dekker (2000), positive perceptions of automation enhance a pilot's commitment to a safe operation. On the other hand, a negative perception will lead to disrupted thought, irrational decision-making, a bad attitude and unsafe acts or negligence.

3.5.2 Perception

The fundamental objective of this study is to measure people's perception of a particular construct, namely advanced automation. A literature study of concepts related to human perception and the latest theory on the subject is thus needed to gain tools to measure perception in the area under review. Without attempting to over-analyse the topic, this section discusses the basic concepts related to perception issues.

3.5.2.1 Basic perception theory

Early research in the field of human perception focused primarily on the immense amount of empirical data gathered prior to the 1980s. Towards the end of the 1980s and in the early 1990s, scientists began to integrate this empirical knowledge with a more theoretical foundation (Mattei, 2001). As psychologists began to understand more about the human psyche in various research and laboratory settings, more concrete theories began to emerge. According to Gollwitzer (1999), five lines of theory were developed in human perception principles:

- *Psychophysical aspects of vision:* Binocular fusion and colour perception is studied in this area of research. Modern automation design uses more colour and variations in font style to enhance safety and reduce misinterpretation. These colours and displays influence automation perception positively (and for some users negatively). One example is the colour coding used on the Airbus type aircraft, where in some cases the electronic centralized aircraft monitoring system (ECAM) displays a 'Land As Soon As Possible (LAND ASAP)' message. According to the Airbus flight crew training manual FCTM (2002):
  - a red 'LAND ASAP' indicates a high level of emergency – actions must not be delayed, and the closest airport should be considered for diversion; and
  - an amber 'LAND ASAP' indicates that the flight crew must assess the seriousness of the situation, and possibly consider selecting the nearest suitable airport for diversion.
- *Visual grouping by proximity:* This is also called the Gestalt law of perception. The principle of organisation by grouping is the fundamental focus of this line of research. The psychological influence of grouping has an impact on a pilot's perception of automation, either negative or positive, when more information is available via larger liquid crystal display (LCD) screens. Surveys reveal that some information on the aircraft status is lost due to an overload of incoming data presented on these screens (Billings, 1997). The fact that pilots no longer need to 'scan' their instruments (in other words, make a conscious effort to look at specific flight instrumentation) means that certain aspects of flight information may be overlooked. The modern 'glass' flight deck has the capability of providing a pilot with instantaneous wind and groundspeed information from its complex air data computer that is not readily available in traditional flight decks. This is regarded as extra information, and some pilots may tend to overlook it during high stress situations, as it forms part of the data presented on the combined LCD screens, grouped with

other primary flight information data (airspeed, altitude, artificial horizon, vertical speed, and so on). This information is, however, extremely important during an approach and landing in a large wide-bodied automated commercial jet, especially during approaches in wind and rain. So critical is this information that some aircraft have landed deep, skidding off the end of the runway, whilst experiencing an adverse tailwind component. However, if the wind component was to pulsate during any adverse wind changes during an aircraft's final approach, more attention would then be drawn to this data to attract the pilot's attention (because this is not the case at present). Perceptions are influenced negatively when pilots feel that they may be receiving too much information all at once and at the same time do not understand when and how to extract pertinent information. This complaint (information overload during non-normal situations) is a concern to researchers studying the transition of pilots from analogue to digital flight deck instruments (Damos *et al*., 2005).

- *Structural description of visual form:* This line of research focuses on constructs used to formally describe visual structures, for example, pattern interpretation, pattern classification and symmetry perception. Patterns on board the newest generation of automated flight decks now employ square 'dials', as opposed to the traditional round 'dials'. Basic flight information data such as airspeed, vertical speed and altitude are now displayed digitally. These displays appear to influence a pilot's perception positively, as the computer can now offer information regarding *trends* in airspeed, altitude, vertical speed, and so on, providing the pilot with an advanced warning of change. Analysis of qualitative aspects of this study's questionnaire however, discovered that this fundamental change in design has had some negative impact on older generation pilots, who feel that the flight deck has now become unorthodox, thus requiring more training.
- *Perception and production of sound*: Auditory perception, mainly in the field of music, such as key-finding, melody, harmony, and so on, is the basis of this line of research in perception theory. Using this information, design of the automation system makes very good use of sound in providing information to the pilot. Variances in tones and pitch indicate to the operator what the extent of the non-

normal or emergency situation is. For instance, a triple click or cavalry charge summons the downgrade of an autopilot system on a modern Airbus type aircraft. By contrast, a loud and continuous ‘ding’ indicates a serious malfunction, such as an engine failure or fire (Airbus FCTM, 2002). These auditory aspects have greatly influenced the perceptions of pilots new to the advanced flight deck (Kabay, 1996), and in many cases, positively. By using a further sense, hearing, cognitive effort is reduced and more processing power from the human brain is made available to deal with unusual, high stress situations. The automation’s ability to lower stress levels has greatly improved users’ perceptions of the types of aircraft that employ these systems.

Research conducted by Little (1999) in the field of human perception built on the five earlier perceptual paths and condensed it for simpler understanding. Two primary phenomena, immediate perception and normal perception, were found to dominate the thinking process within the human mind:

- *Immediate perception:*

  This is a total *physical* awareness of one’s environment, via neural pathways in the brain. Information is gained physiologically from a human being’s various senses (smell, taste, touch, sight, hearing). On board the flight deck of a highly advanced aircraft, the human operator is immediately aware of the functioning of the automated system through the use of coloured lights (sight), audio cautions and warnings (sound).

- *Normal perception:*

  *A*ccording to Little (1999), normal perception by a human being is the *psychological* interpretation of the environment by that person. However, it should be noted that psychological interpretation may not always correlate with physical and physiological reality. In the context of highly automated aircraft systems, research conducted by Mosier *et al*. (1998) discovered an alarming increase in the use of cognitive heuristics in the ‘glass’ flight deck. Automation bias is the use of automated cues as a replacement for vigilant seeking and processing of incoming perceptive information.

3.5.3 Basic human behaviour theory

The reason for developing instruments to measure perception is to support scientists in assessing and predicting human behaviour. People may do certain things in a certain way and for certain reasons as a direct result of their perception of phenomena. Theory surrounding human behaviour is vast and comprehensive, so, only aspects thought to be necessary for the purposes of this study (on measuring perception) are touched on in the next section.

3.5.3.1 Flight deck behaviour

Studies conducted in the social sciences have established a definite link between perception and overt behaviour (Fishbein & Ajzen, 2001). Behaviour towards an object is determined by the person's negative or positive perception of the object. Fishbein and Ajzen (2001) further postulate that an individual's measurable perception may be an explanatory device for the person's behaviour. In the context of aircraft operation, a pilot's attitude may be defined as a *learned* predisposition to respond to a task, procedure, system or object in a *consistently* favourable or unfavourable manner (Clark & Paivio, 1990).

Standard operating procedures (SOPs) have become a fundamental component in training pilots to operate advanced automation. The SOP maintains vigilance in task execution and prevents inadvertent safety violations. Some flight deck crew surveyed indicated a dislike for the newer automated aircraft SOPs and therefore displayed a negative perception of the system. A respondent surveyed in the qualitative analysis of the Automation Attitude Questionnaire (AAQ) in the current study commented as follows: 'Hand flying glass cockpit aircraft is much easier because you have much more information available with situational awareness etc. The problem is that our SOPs discourage us from hand flying the aeroplane and that does have a negative impact on confidence and my ability to physically fly the aircraft.'

This statement implies that some pilots find it easier to fly traditional aircraft manually and these pilots may feel more constrained in an advanced flight deck. The standard operating procedure (SOP) of many large airlines encourages the use of the automation for as long as feasibly possible. This practice is prudent in adverse weather conditions, where the auto pilot system has been found to be far safer and more reliable in landing a large aircraft than humans are (Helmreich, 1997).

Early studies conducted by Ritter (1967) according to Risukhin (2001) of Air Force cadets found that by measuring a recruit's attitude, it was possible to determine or predict his or her ultimate overt behaviour. The results of Ritter's research found that initial poor attitudes toward the training programme resulted in overt behavioural characteristics such as dropping out. Advanced flight deck training consists of a paradigm shift in moving away from the traditional thinking about flying to a managing of the system. A poor attitude may result in a higher failure rate of traditionalists during line or route training, and weaknesses are eventually exposed during non-normal operations. According to Fishbein and Ajzen (2001), the behavioural, normative and control beliefs people hold about performing a particular behaviour are influenced by a wide variety of biographical differences. Thus, there may be differences between the beliefs held by male and female, young and old, educated and uneducated, dominant and submissive individuals, and between individuals who have an authoritarian and those who have a democratic leadership orientation on the flight deck.

Researchers have suggested that past behaviour and habits may play a significant role in present actions or behaviour (Fishbein & Ajzen, 2001). This can explain why it seems that there may be difficulties in the transition training of pilots shifting from analogue to digital flight decks. Experts have posited that past behaviour should be added to the theories of reasoned action and planned behaviour in determining accident and incident causation in advanced aircraft. The frequency with which behaviour was performed in the past strengthens a habit. *Muscle memory* is a well-known term used in aviation circles when trying to explain an error, omission or lapse on the flight deck. Older pilots, who began their aviation careers in the early 1970s, have thousands of hours on traditional analogue aircraft. It is only in the latter part of their careers that they have had an opportunity to operate digital aircraft. Heuristic evaluation and reversion has been the cause of at least one advanced commercial jet accident. This may have occurred as a result of not understanding the advanced automated system and instead using strategies (reverting to basics) only appropriate to a traditional analogue flight deck (Bagshaw, 1996).

According to the theory of *planned* behaviour, human actions may be considered to be guided by three kinds of action (Gollwitzer, 1999):

- *Behavioural beliefs* (understanding the likely **consequences** of certain behaviour): Incomplete training or a lack of adequate information will hamper a pilot's ability to operate an automated aircraft confidently. It was found that this lack of confidence created a negative perception in the mind of the operator.
- *Normative beliefs* (what you believe others **expect** from you): The normative belief, based on an orthodox school of flying aircraft, states that a pilot should be able to fly 'stick and rudder', in other words, without the use of the auto pilot system. This was always the expectation of the flying instructors during all pilots' initial flying training experience. However, when pilots feel that they are being robbed of the opportunity to enhance their physical flying skills, an immediate negative perception of the system is displayed. Nevertheless, the manufacturers of advanced aircraft still claim that these planes can be flown like any other aircraft, and when things do not go as planned, the automatics should be disconnected (Airbus FCTM, 2002).
- *Control beliefs* (belief about the presence of **factors** that may further or hinder your progress, which are considered out of your control): Complacency is still regarded as one of the major threats to the operation of automated aircraft (Parasuraman & Riley, 1997). Pilots may indicate a very positive perception of automation systems, however, this may be a false impression and must be looked at more objectively. A lack of understanding and incomplete knowledge loops may give rise to the fallacy that advanced flight deck automation is infallible. These systems are invariably considered out of the control of the pilots who fall into this category, and they therefore resign themselves to the comfort of safety in technology.

3.6 INTEGRATION OF CONCEPTS

After analysing the literature, the concepts examined can be integrated into the following model:

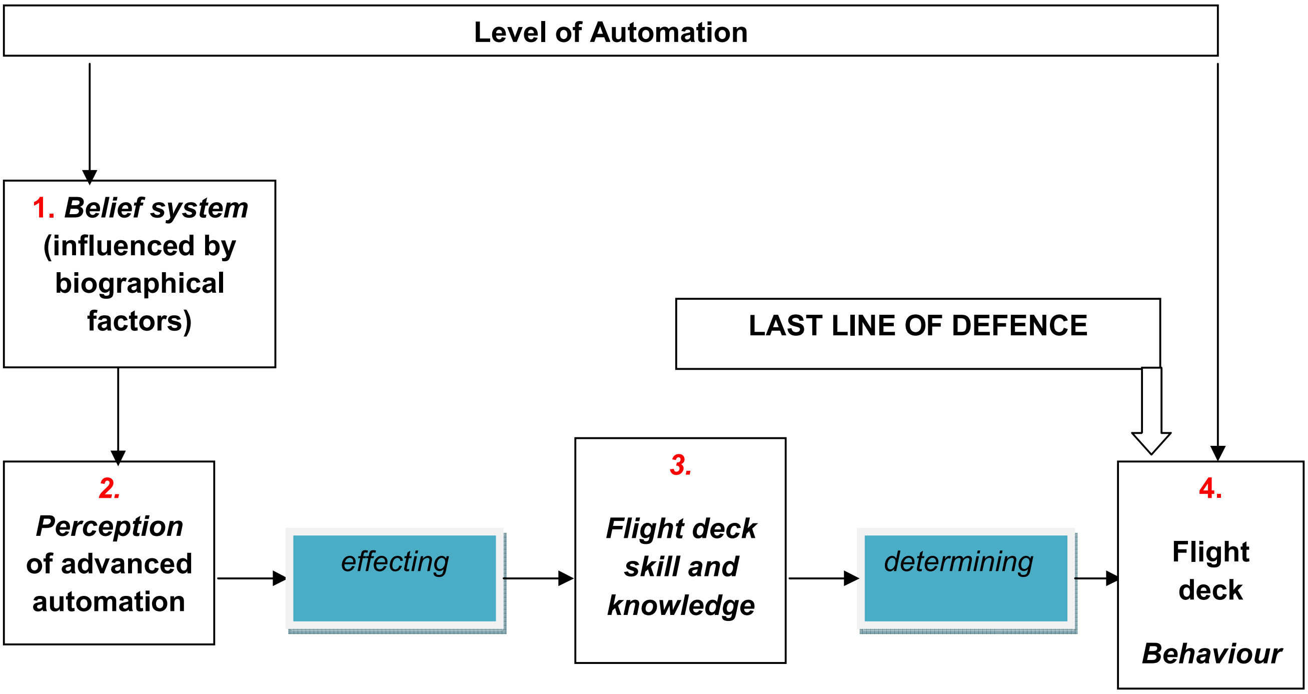


Figure 3.5: The link between belief and behaviour on an automated flight deck

The fundamental objective of the current study is to measure airline pilots' perception (Point 2 in Figure 3.5) of automation by analysing their belief system (assessing various biographical variables, Point 1 in Figure 3.5). The impact of these variables affects the final outcome, as behaviour on the flight deck (Point 4 in Figure 3.5). The model portrays how a pilot may be considered the last line of defence in a flawed system. Measuring perception in order to understand behavioural issues in advanced aircraft is a primary area of concern in mitigating accidents.

3.7 SUMMARY

This chapter has highlighted the definition of automation and focused on human beings in the human-machine system. Levels of automation were discussed to describe the impact of computer modes and strategies available to pilots in performing various flight deck duties. Analysis of aircraft accidents was used to emphasise the importance of changing philosophies in aircraft design and its impact on safety. Concern generated by researchers prompted further examination.

The revolution that has occurred on the modern flight deck warranted an illustrative comparison to gain a tangible understanding in differences. The same pilots who originally flew analogue systems are now required to operate and function in advanced digital environments. Researchers and regulators are so concerned about the impact that this transition may have on flight safety that a dedicated website documenting 92 issues affecting human beings and automation was created. Critical cross-field areas of concern were highlighted in the chapter concerning such issues as, automation bias, loss of skills and mode confusion.

Automation systems are not unique to the aviation industry, and many engineers deal with their implementation in other fields of science, manufacturing and business. The levels at which a system becomes automated must be understood by the user, and these levels have been adapted to suit aircraft control. Computers can thus play a positive or a negative role, by either aggravating or mitigating a situation. It is important to study and understand just how human perception and behaviour may affect the safety of the automated system.

This chapter has highlighted the need to analyse the perceptions of airline pilots with regard to advanced aircraft automation. The findings may provide important information that can be used to understand and to manage pilots' beliefs and behaviour on the automated flight deck.

Chapter 4

RESEARCH AND STATISTICAL METHODOLOGY

4.1 INTRODUCTION

In this study, a quantitative research design was used. The research was non-experimental in nature. In the previous chapters, a theoretical discussion has been provided of automation, related issues and concepts; perception, attitude and behaviour. This chapter deals with the methods and instruments used to conduct the empirical research for the study, as well as the statistical methodology. The topics to be addressed in this chapter include the design, layout and administration of the questionnaire, the collection of data, the population, the sampling method, the response rate, statistical methods, descriptive, comparative and associational statistics, statistical significance and practical significance (effect size).

4.2 RESEARCH METHOD

Kantardzic (2003) suggests that the process in the scientific investigation of a particular phenomenon can be deemed a research project if specific steps are followed. To complete this study, it was necessary to approach it using the principles of project management.

4.2.1 Research approach

To answer the proposed research questions systematically, an empirical quantitative study was conducted, using a self-administered survey instrument (a questionnaire). According to Mouton (2001), the logic of an empirical research study follows a simple route with four components. The research problem, research design, empirical evidence and conclusions are the components which comprise a logical path in the completion of a research project. This was the basic format followed in this study.

The following research process, as proposed by Mouton (2001), was used to complete the study effectively:

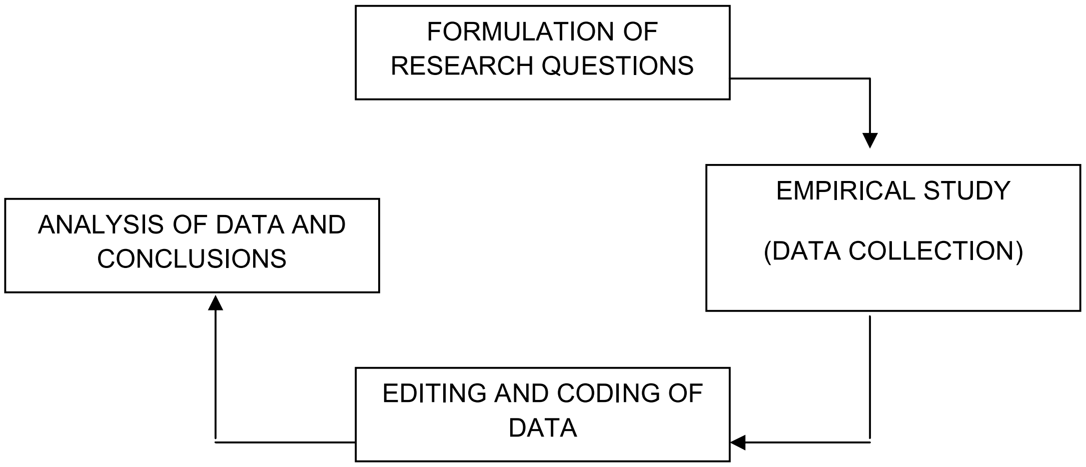


Figure 4.1: Components of the research process

(Source: Mouton, 2001: 47)

A quantitative study was conducted, preceded by an in-depth review of the literature related to advanced flight deck systems. The biographical data to be used as the independent domain of the research was collected via the survey questionnaire. The dependent domain consists of the human operators' belief system, as explored in the survey questionnaire's specific items. This survey data was then subjected to various statistical techniques (as described in this chapter) in order to gain an understanding of the fundamental factors responsible for most of the variation in the respondents' perception of automation. Cooper and Schindler (2003) contend that subjecting empirical evidence (observable, concrete data) to statistical procedures helps a researcher to evaluate ideas and test hypotheses to establish a scientific method. Thus, the method of investigation undertaken was observed to fall in the quadrant of rationalism (formal structured proof) and empiricism. This type of exploration tends to uncover key factors (Mouton, 2001).

The overall process of the research undertaken can be broken up into five specific phases, as set our below.

Phase One: This phase consisted of a theoretical review of the literature available on the topic. The fundamental area that the review focused on was aircraft automation, aviation safety, crew resource management, human behaviour theory and related concepts.

Phase Two: In this phase, a valid and reliable instrument was constructed to assess pilots' perceptions of advanced flight deck automation.

Phase Three: During this phase the questionnaire, the Automation Attitude Questionnaire (AAQ), related to automation attitudes was administered to determine the perceptions of pilots on those factors regarded as important on the advanced flight deck.

Phase Four: This phase consisted of capturing and coding the data obtained from the AAQ. After the data had been organised and coded, it was analysed by means of two statistical software packages.

Phase Five: In this phase, the results of the statistical analyses were reported and the principal findings of the study were discussed. The limitations of the present study, suggestions for future research and recommendations to management were presented.

4.2.2 Data collection

According to Kantardzic (2003), there are five ways of gathering data:

- a literature study;
- an observation;
- the distribution of questionnaires;
- the use of checklists; and
- measurement.

According to Michael and Lewis (1995), a data collection *process* is necessary in a formal research setting, as it ensures that the data collected is both defined and accurate. Meeting these requirements enables the researcher to conduct valid and reliable hypothesis testing in a predetermined and scientific manner. Michael and Lewis (1995) also contend that data collection should be seen as a process consisting of quantifiable steps.

Firstly, the type of data that is to be used must be *selected*. If the data is continuous, it will have the characteristic of divisibility. However, for this study, the use of a measurement scale implied the use of discrete data. This type of data can be subdivided, ideally in the use of questionnaire-based research.

Secondly, an assessment must be made of where the data will be *captured* – for example, data may be collected using a computer programme or filing system. In this study, using SPSS for Windows, the data was thus used as input into a computer programme for calculation.

The concept of *data mining,* as used by Davidson (2007), is a more appropriate term for the work done in this study. Data mining can be described as the action of extracting information gained from the enormous data set generated from modern experimental and observational techniques (Davidson, 2007). For example, the data gathered from the AAQ generated a 97x262 matrix. This adds up to approximately 25 414 pieces of usable information. In the past, conventionally, analysts gleaned information from recorded data manually, but, due to the increasing volumes of data available to modern scientists, computer-based methods are now necessary and available for the extraction of data from this mine. A new process of applying computer-based methods is now used to convert the captured data into useful information and knowledge (Davidson, 2007). The relevant data that is collected appears in words and numbers. Sophisticated software packages assist researchers in this process. In this study, the computer package that was used was SPSS for Windows Version 15 and the software package of StatPac Inc.

The primary method of data collection was a seven-point Likert type scale in a self-administered questionnaire consisting of 85 items related to pilots' perceptions of automation (see Section 4.3). On the basis of the preliminary literature review and in the design of the questionnaire, the following relevant constructs were borne in mind in connection with the collection of the data:

- the *reliability* of the computer-driven automatics;
- the operator's flight management system (FMS) *inputs*;
- the *outputs/feedback* generated by the computerised automation system;
- the *skills* and overall level of mastery required;
- the necessary *training* required for competency;
- the flight deck crew *interaction* and resource management;
- the *monitoring/procedures* required to maintain overall vigilance;
- the overall *workload* of managing an advanced automated system; and
- the basic *design* of the system.

4.2.3 Levels of measurement

Data describing the research variables can be separated into four distinct scale categories: ratio, interval, ordinal and nominal type values (Cascio & Aguinis, 2005).

The biographical information was collected using the nominal scale of measurement. This is the most basic scale in the collection of data, in that numerals assigned to each category stand for the name of the category. The number assigned (for example, Boeing aircraft = 1, Airbus aircraft = 2) has no particular order or rank.

The core of the questionnaire, which consisted of 85 construct items, made use of an approximate interval scale. Possible answers were coded with numerical values and represented indefinite quantities, such as the extent to which the respondents agreed with the statements.

4.2.4 Scaling of the items

The use of a Likert scale to measure responses permits the simplification of the survey questionnaire by giving it structure. It was also decided to use a seven-point scale to measure the perceptions of the participating pilots, because of the inherent limitations of equal interval measurements in psychological scaling and the need to limit central tendency bias (Clausen, 1998). According to Schepers (1992), the equal interval quality of a scale is lost if more than two points are anchored. It is therefore better to use an intensity response scale in which only the two extreme categories are labelled. The error of ‘central tendency’ can be further eliminated by avoiding statements which reflect extreme positions (for example: ‘I **never** disconnect the autopilot in adverse weather conditions’).

Shepherd (1998) also contends that a seven- or even a nine-point scale tends to give the items more granularity. This is because a five-point scale allows for only two levels of agreement or disagreement, whereas more than nine categories in the scale will create a cognitive overload. A seven-point scale thus provided more accurate and sufficient data to permit the analysis of results using both descriptive and inferential statistics. A further justification for the use of a *seven-point* Likert scale was also found in the argument by Gravetter and Wallnau (2002) that using a larger number of intervals in the scale (seven in this case) allows a researcher to conduct a more accurate calculable investigation through the use of powerful parametric and non-parametric statistics.

However, Pett, Lackey and Sullivan (2003) identified the following biases associated with the use of scales in psychological measurement:

- **central tendency bias** (respondents avoid extreme answers);
- **acquiescence bias** (respondents tend simply to agree with the statements presented); and
- **social desirability bias** (respondents answer questions in such a manner as to make their organisation appear in a favourable light).

4.3 THE QUESTIONNAIRE

The physical layout of a questionnaire plays a vital role in a respondent's decision as to whether or not to complete it. Aaker, Kumar and Day (1995) regard the quality of the paper, the clarity of reproduction and the appearance of crowding as important factors. In this study, the questionnaire was printed on good quality blue paper and was bound in a booklet format. Ample space was allowed between the questions as well as between the sections. Clear instructions on how to complete the questionnaire were also provided (see appendix D for contents of the booklet). However, the booklet format is not maintained in Appendix D, which conveys only the content of the questionnaire rather than the exact format.

4.3.1 Introduction

After the exploration of the literature available on the topic (see Chapters 2 and 3), it was decided to use (as a point of departure) selected aspects of the 92 critical issues identified in the world-wide automation database to which various researchers had contributed. Items for the research questionnaire were generated by analysing the fundamental framework of a previous study conducted by James, McClumpha, Green, Wilson and Belyavin (1991) of the Royal Aeronautical Society (RAeS), conceived on the basis of initial research undertaken by Wiener (1989). A list of 78 items was compiled, based on the investigation into automation attitudes conducted by James *et al.* (1991).

First, 33 items were selected from the original list of 78 to populate the current research questionnaire. Second, a further 35 items were extracted from the RAeS study. These items were adjusted and adapted to ensure clarity and relevance in the context of the South African airline that participated in the current study. Afterwards, these items were added to the research questionnaire. Third, after discussions with experts and an analysis of the literature, a further 17 new items were generated and were included in the final questionnaire. After factor analysis of the 85 items, 13 of the 33 original items, 13 of the 35 adjusted items and six of the 17 new items were retained (see Chapter 5). Written permission was granted by the Royal Aeronautical Society (see Appendix B) for the use of its items in the questionnaire that was used in the current study. This questionnaire is referred to as the Automation Attitude Questionnaire (AAQ).

In its final form (as used in the study), the AAQ consisted of three sections. Section 1 related to the pilots' biographical information. Section 2 consisted of the items related to automation perception, attitude and behaviour. This second section attempted to determine what behaviour, decisions and practices are perceived to be more important or less important in judging highly advanced aircraft automation systems. Section 3 was added to gain qualitative input from respondents (see Appendix D).

4.3.2 The layout of the questionnaire used in the study

The questionnaire consisted mainly of closed-ended questions. The reason for using this type of question is in principle that they provide facts or statements, are easier to answer and require far less time to complete than open-ended questions (Mouton, 2001).

The layout of the questionnaire is explained in Table 4.1.

Table 4.1: Layout of the Automation Attitude Questionnaire (AAQ)

Section	Topic of section	Number of questions
1	Biographical data	11
2	Perceptions of automation	85
3	Open questions	2
Total number of questions:		**98**

Section 1 consisted of 11 questions related to the respondents' personal particulars. These questions focused on eliciting information on the respondents' gender, age, highest educational qualification, level of experience, total flying time, flying experience in digital flight decks, primary status or function at the airline, type of aircraft flown, level of computer literacy, and where the respondents had received initial (*ab initio*) flying training.

The second section of the questionnaire contained 85 questions (statements) related to the respondents' perceptions of what influences their behaviour in a digital flight deck environment. It consisted of a seven-point Likert-type scale with anchors ranging from 1 = 'strongly agree' to 7 = 'strongly disagree'. The respondents were asked to reflect on their perceptions of advanced flight deck automation using this seven-point Likert scale, where only the extremes of the scale were defined.

Section 3 of the questionnaire consisted of two open-ended questions. Here the respondents were provided with an opportunity to list the various aircraft types they have had experience on and to provide either positive or negative comments on the topic under review. This provided valuable information for a qualitative analysis of the written statements from the participants.

4.3.3 Distribution and instructions on the completion of the questionnaire

The next step involved the distribution of the questionnaires to all the pilots employed by the target airline (see Sections 4.4 and 4.4.1 for more detail). Each crew member owns a personal letter box at the flight operations department of the company. The questionnaire, together with a covering letter, was posted in each box.

The covering letter explained the purpose of the questionnaire and was signed by the study leader. Appendix C contains a copy of the covering letter. The initial part of the survey questionnaire contained an introductory letter and information on how the participants should complete the questionnaire.

Guidelines for conducting good sociological research dictate adherence to a strict code of conduct. This is a necessity in research of this nature because similar to other social processes, there may be both positive and negative consequences for individuals and organisations participating in the study (Frankel & Siang, 1999). The study maintained the strict ethical framework that should be associated with any research conducted on human subjects, based on the following concepts established by the American Sociological Association (ASA) and highlighted by Frankel and Siang (1999):

- *Autonomy:* This principle asserts that study subjects should be treated with respect and as autonomous agents. It affirms that people with diminished autonomy should be given the required protection. This also implies that the research can only be undertaken with the informed consent (be it tacit or explicit) of the respondents and that they are aware of the risks and benefits associated with the study.
- *Beneficence:* This principle involves maximising the possible benefits and good for the subjects, whilst minimising any risks or harm.
- *Justice:* Results harvested from the study may come at a cost to certain participants. Justice in this context seeks a fair distribution of the burdens and benefits associated with the research undertaken, so that certain individuals or groups do not bear disproportionate risks whilst others gain all the benefit.

Although inserting additional paragraphs of writing to a questionnaire may inevitably lower the response rate due to an increase in perceived crowding (Aaker *et al.,1995)*, it was decided that it is a necessity in maintaining the behavioural researcher's ethical code of conduct. These ethical concepts were thus fully explained to all participants in the covering letter that accompanied the questionnaire.

4.3.4 Coding of the data

Each questionnaire was edited to identify omissions, ambiguities and errors in the responses. Questionnaires that were completed in such a way that the results could be distorted were discarded. Illegible or missing answers were coded as 'missing'. This simplified the data analysis. Care was taken not distort any interpretations of the data.

Coding the closed-ended questions was fairly uncomplicated, because the questionnaire made provision for response values on a seven-point Likert scale. Once the response values had been entered into a computer, a software program, the *Statistical Package for the Social Sciences* (SPSS) for Windows, was employed to generate the relevant diagnostic information.

The majority of items in the survey were in a negative format. The reversing of the Likert scale then provided a reflection of perception in a traditional manner, where a high score indicated a positive perception of automation and vice versa. Each item was analysed separately for any scale inconsistencies and then reverse-scored if necessary to produce a measure where a low score indicated a negative perception of automation systems and a high score provided an indication that the respondent had a positive perception of automation.

4.4 SURVEY PROCEDURES AND SAMPLING

4.4.1 Procedures

According to Gravetter and Wallnau (2002), inferential statistics rely on the probability connection between a sample and its population so as to scientifically use the sample to draw conclusions about the population. Cooper and Schindler (2003) have defined a population as the entire set of elements that will be under investigation and from whom the researcher would like to determine certain characteristics. The population under review consisted of all the flight deck crew employed at a large South African airline (N=800). In this study, a purposive sample of airline pilots were asked to participate in the survey. The target group were all pilots operating advanced automated aircraft at the same airline and were all licensed as aviators by the South African Civil Aviation Authority.

An agreement between the researcher and the management of flight operations at this airline was concluded, initiated by a written letter to the Chief Pilot to ask approval for the use of the population mentioned above (see Appendix A for a copy of the letter). This also implies that the study had the full cooperation of the company, facilitating unhindered completion. To obtain an acceptable response rate, the potential respondents were reminded in the covering letter that their chief pilot had endorsed the research (see Appendix C).

The survey questionnaire was distributed to all the targeted persons in the population. Of the 800 questionnaires sent out, 265 were returned, of which three were unanswered. This represented a return rate of 33% usable questionnaires (n=262). According to Tabachnick and Fidell (2007), this number of responses is adequate for an exploratory factor analysis. The sample ranged from lower entry pilots (in-flight relief crew) to high level pilots (senior training captains on long-range flights). It also represented diversity in terms of the type of aircraft flown, pilots' age and level of experience. Biographical information was elicited from all the respondents in the first section of the questionnaire.

4.4.2 Description of the sample

In order to measure any statistical differences between categories, biographical data was requested from the participants. Briefly, the biographical information consisted of data about the respondents'

- gender;
- age;
- level of education;
- position;
- aircraft type;
- computer literacy;
- initial flying training;
- expert years;
- total flying time logged; and
- total digital flying time logged.

Table 4.2 contains a summary of the biographical variables relating to the sample.

Table 4.2: BIOGRAPHICAL DATA OF RESPONDENTS

VARIABLE	FREQUENCY	PERCENTAGE
GENDER		
Male	245	93.5%
Female	17	6.5%
POSITION		
Dedicated in-flight relief pilot	16	6.1%
Co-pilot (Short Range)	60	22.9%
Co-pilot (Long Range)	49	18.7%
Captain (Short Range)	48	18.3%
Captain (Long Range)	53	20.2%
Training Captain (Short Range)	11	4.2%
Training Captain (Long Range)	18	6.9%
Other	5	1.9%
AGE		
25 – 35 years	59	22.5%
36 – 45 years	88	33.6%
46 – 55 years	67	25.6%
56 – 65 years	48	18.3%

Continued on next page

Table 4.2 continued

LEVEL OF EDUCATION		
High school	163	62.5%
Diploma	33	12.6%
Bachelors degree	40	15.3%
Post Graduate	25	9.6%
INITIAL FLYING TRAINING		
Military	131	50%
Cadet	21	8%
Self (Part-Time)	72	27.5%
Self (Full Time)	37	14.1%
EXPERT YEARS		
4 to 15 years	63	24%
16 to 25 years	89	34%
26 to 35 years	65	24.8%
36 to 46 years	44	16.8%
Missing	1	0.4%

Continued on next page

Table 4.2 continued

TOTAL DIGITAL FLYING TIME LOGGED		
0 to 2 000 hours	33	12.6%
2 001 to 3 000 hours	53	20.2%
3 001 to 4 000 hours	46	17.6%
4 001 to 5 000 hours	48	18.3%
5 001 to 6 000 hours	20	7.6%
>6 001 hours	60	22.9%
Missing	2	0.8%
TOTAL FLYING TIME LOGGED		
1 500 to 7 900 hours	65	24.8%
7 901 to 11 200 hours	69	26.3%
11 201 to 16 000 hours	56	21.4%
16 001 to 27 000 hours	69	26.3%
Missing	3	1.1%

4.4.2.1 Gender

For the purposes of this study, it was imperative to understand whether males and females have different opinions on automation issues.

It was significantly noteworthy that both genders responded to the study. The sample's responses consisted of responses from 245 males (93.5%) and 17 females (6.5%). These numbers reflect the current low proportional representation of female pilots in the

South African commercial aviation industry (SACAA, 2007). Traditionally, the majority of South African pilots were trained in the armed forces; and females have only been allowed to participate since 1996.

4.4.2.2 Age

Since the respondents' ages ranged from 25 to 65 years (a spread of 40 years), it was decided to group the ages into four categories. As is indicated in Table 4.2, the age groups '25 to 35 years' and '36 to 45 years' represent 56.1% of the respondents. Respondents in the age groups '46 to 55 years' and '56 to 65 years' represent the remaining 43.9%.

This information suggests that the organisation has a relatively mature workforce. The average age of the sample was 44.17 years (SD = 9.567). The airline organisation from which the sample was drawn may be referred to as a 'legacy carrier'. This term implies that many younger pilots need to build up sufficient experience at smaller airlines so as to eventually work for such a 'legacy carrier'. Competition is so fierce that only the most experienced pilots are hired, which explains the mature age of so many of the respondents at the company.

4.4.2.3 Level of education

The academic educational qualifications of pilots do not seem to play a significant role at the airline, since 62.5% of the respondents have only a high school qualification. However, it must be noted that extremely good grades are required at high school level for selection into the military or cadet flying training programme. Although a professional flying licence is not academically recognised at present, headway is being made in equating an Airline Transport Pilot Licence (ATPL) to a higher diploma.

The syllabus completed by a pilot in order to attain an ATPL is of such a thorough and academically demanding nature that possession of this licence entitles the bearer to become a commander of the largest commercial jet aircraft. Since obtaining higher academic qualifications plays no role in obtaining the privilege of commanding modern jets in South Africa, many pilots do not pursue further studies. However, in the United States, to become a commander, a tertiary qualification is a requirement.

A small percentage of the sample (9.6%), do however, possess postgraduate qualifications. These qualifications are necessary for pilots who want to pursue flight management positions at the company. Possession of a graduate degree also plays an important role in selection for the military and cadetship flying programmes.

4.4.2.4 Flying position

It was important to identify the various positions that a pilot may occupy at this organisation. In order to understand how each group of pilots is affected by automation, it was imperative to separate and distinguish between the different pilot groups. The majority of the respondents (80.1 %) were from the co-pilot (short range), captain (short range), co-pilot (long range) and captain (long range) sector. Respondents who fell into the training (pilot instructor) groups occupied a more specialised field, in other words, instructing or training other pilots, so it was expected that these groups would contain fewer pilots (11.1 %). A smaller proportion (6.1 %) comprised the dedicated in-flight relief pilot. This group was also expected to be smaller, as it is an entry level position at the company. The line pilots (consisting of co-pilots and captains) formed the largest group engaged in flight operations at the company, as they are the day-to-day operators of the company's aircraft, the workforce. Their core job description is to operate the aircraft safely from Point A to Point B, according to company schedules and rules.

4.4.2.5 Aircraft type

Since it was imperative to understand whether pilots flying Airbus and pilots flying Boeing aircraft have different opinions on automation issues, it was significant that pilots in both groups responded to the study. In early 2001, the organisation embarked on an expensive fleet recapitalisation plan. This plan called for one common type of aircraft, namely the Airbus. However, due to operational constraints and contractual obligations, the entity continues to operate a mixture of both Boeing and Airbus aircraft. As expected, the questionnaire elicited more responses from pilots who fly Airbus type aircraft (63.4%), because the airline now flies more of this type of aircraft.

The population from which the sample was drawn was also important. Many of the pilots at this organisation are highly experienced in flying both types of aircraft, providing an ideal platform for a study of this nature. Also, the majority of the most senior pilots in Southern Africa (people whose opinions are highly regarded in the industry) can be found at this particular company.

4.4.2.6 Computer literacy

Advanced flight deck automation is closely related to advances in computer and information technology. To gauge the impact of computer know-how on a pilot's perception of automation, it was imperative to obtain responses from respondents with varying degrees of understanding of computers. Half of the respondents (50%) rated their level of computer literacy as 'average'. This result was expected, as there is no minimum computer literacy requirement to become a pilot. Selection criteria for cadetships and military pilot training only require applicants to have suitable levels of competence in mathematics and science at high school level. Computer science is considered to be less important. It is hoped that the results from this study will serve as a pioneering impetus for the inclusion (or not) of a minimum computer literacy competence level as a criterion.

4.4.2.7 Initial flying training

Legacy carriers have a reputation for being the 'last stop' company for many airline pilots. In the past, there were very few civilian flight training schools. The South African Air Force was the primary training facility for most of the qualified pilots in South Africa. It was therefore not surprising to find that the sample consisted mainly of military-trained pilots (50%), and that the remainder were self-sponsored or cadetship individuals (41.6%). Traditionally, if a person did not have the financial means required and was not successful in being selected for the South African Air Force, flying as a career was only a dream. However, the organisation used in this study introduced a sponsorship programme in 1995 to counteract the reduction in military flying training since 1994. A small percentage (8%) of the sample came from this ‘cadet’ group.

4.4.2.8 Expert years

Since the spread of the number of years of flying experience was very large (approximately 40 years), it was decided to group the respondents into four categories. As indicated in Table 4.2, the majority of the respondents had 16 to 25 years of flying experience (34%) and 26 to 35 years (24.8%) of flying experience. The average number of years of flying experience was 23.76 years (SD = 10.382). This result was in line with the expected findings, given the maturity of the respondents.

Automation is a relatively new development in aviation technology, which implies that, for many of the pilots in this sample, most of their years of expert experience were built up flying analogue type aircraft. Expert years are directly correlated to both the total flying time logged and the digital flying time logged. Legacy carriers are famous for the strong unionisation of their pilots and their rock solid seniority system. This implies that the longer a pilot is employed by this carrier, the more opportunities he or she may have to fly his or her preferred choice of aircraft.

The average pilot in this sample had between 6 000 and 16 000 flying hours of total flight time experience, with a mean of 12 239.72 flying hours (SD = 5 646.374). This is once again related to age and the number of years employed. The total digital flying time logged was expected to be significantly lower than the total flying time, as digitization is relatively new. The average respondent indicated approximately 3 000 to 6 000 hours of experience on digital flight decks. The mean digital flight hours logged by the sample was 4 691.13 hours (SD = 2 530.004). The reason for this may be found in the fact that the carrier only began to receive and put into operation modern equipment in the last ten years or so.

4.5 STATISTICAL ANALYSIS

The information gathered from all the returned questionnaires was subjected to a specific quantitative statistical procedure and analysis. To determine which of the factors were regarded as the most important to the target population, the data from the sample was processed using SPSS for Windows.

One of the problems that is often raised in survey research is whether the statistical technique used for the interpretation of the data is, in fact, the most suitable one available. Two types of statistical methods were available to the researcher, namely, parametric and non-parametric methods. The conventional assumptions about the population scores in a parametric test are that they are normally distributed, that the variances of the groups are equal and that the dependent variable is an approximate interval scale. By contrast, the non-parametric method, often referred to as a *distribution-free* method, does not rely on assumptions that the data are drawn from a given probability distribution (Field, 2005; Morgan, Leech, Gloeckner & Barrett, 2007).

4.5.1 Descriptive statistics

The research data was described by means of a frequency analysis. Descriptive statistics were included to summarise the data from the frequency distribution, as recommended by Blalock (1979). The scores of the respondents in the sample were used to analyse the distribution of the various variables and the items included in the AAQ, as suggested by Cooper and Schindler (2003). The following distribution statistics were applied to determine the characteristics of the distribution of the scores of the sample:

- *The arithmetic mean and median:*

  This measure of data is used in socio-psychological research to indicate central tendencies. It is commonly referred to as the mean and the median. Blalock (1979) mathematically defines the mean as the sum of the scores divided by the total number of cases involved. The sum of the deviations of each score from the mean will always equal to zero.

The position of the middle case when data is ranked from high to low is commonly referred to as the median of the scores. According to Blalock (1979), the median divides the scores in half. Blalock (1979) contends that the value of the mean is affected by extreme scores; the mean is pulled in the direction of skewness. However, if the distribution is perfectly symmetrical, the positions of the mean and the median will coincide.

- *Standard deviation:*

  The most frequent and useful measure of dispersion in a distribution of scores is the standard deviation (Blalock, 1979). The value of the standard deviation describes the spread of the scores of the sample from the mean and gives the researcher an idea of the areas under the normal curve.

- *Skewness and kurtosis:*

  According to Cooper and Schindler (2003), the measure of the shape of the distribution curve is commonly referred to as its skewness and kurtosis. Cooper and Schindler (2003) also describe the non-dimensional index value of a distribution's skewness (*sk*) as characterising only its shape, where a value of zero implies symmetry. Kurtosis (*ku*) is a non-dimensional measure of the curve's peakness or flatness. Cooper and Schindler (2003) mention three forms of a distribution's kurtosis:

  - peaked or leptokurtic, a positive value of kurtosis;
  - flat or platykurtic, a negative value of kurtosis; and
  - mesokurtic or intermediate, a value of kurtosis close to zero.

4.5.2 Test for normality

In trying to determine whether the data set was suited for parametric or non-parametric analysis, the **Kolmogorov-Smirnov** test for analysing the normality of distributions (often called the K-S test) was used. According to Field (2005), the K-S test is used to decide whether a sample comes from a population with a specific distribution. The hypothesis regarding the distributional form (that is, the data following a specified distribution) is rejected if the test statistic is greater than the critical value obtained from the SPSS table. The K-S test helped in choosing between the two families of statistical methods, as choosing between a parametric or a non-parametric test can be tricky. Tests that do not make assumptions about the population distribution are referred to as non-parametric. All commonly used non-parametric tests rank the outcome variable from low to high and then analyse the rankings.

4.5.3 Exploratory factor analysis (EFA)

The central theoretical concept of an exploratory factor analysis is determining the relationship between surface phenomena (observed empirical evidence) on the one hand, and internal attributes (latent variables) or factors on the other (Tucker & MacCallum, 2003). Factor analysis entails the use of analytical procedures in the reduction of a complex matrix of data. It is used to discover any correlations between large volumes of empirical observations to identify specific factors that possess common characteristics (Nunnally & Bernstein, 1994). In other words, EFA is a specific technique used to simplify a questionnaire mathematically so as to draw out the underlying dimensions responsible for the primary variation of the dependent variable (Pett *et al*., 2003).

In this study, EFA was therefore performed to uncover the sub-dimensions of the construct being measured (‘the perceptions of automation’) by exploring the internal structure and validity of the AAQ. The interval type data collected from the respondents was subjected to EFA by means of principal axis factoring and then rotated by the promax procedure with Kaiser’s normalisation to generate a factor solution for the AAQ. The promax rotation was used because it has the advantage of being fast and conceptually simple. Its name derives from procrustean rotation, because it tries to fit a target matrix which has a simple structure (Reyment & Joreskog, 1993). This technique is popular when a researcher does not know the exact number of factors that can accurately describe the construct of interest (Tabachnick & Fidell, 2007). In order to determine the number of item factors that may be significant in affecting the variability of the constructs under study, Pett *et al*. (2003) recommend the use of Cattell's scree test or Kaiser's eigenvalue rule to extract these common factors.

Pett *et al.* (2003) recommend the use of a traditional statistical computer package such as SPSS for Windows for this type of analysis. However, before EFA can be performed, the suitability of the data for each of the factor analyses must be determined. Bartlett's test of sphericity and the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy were used in this study to assess the compliance of the data sets with the inter-correlation and distribution requirements for factor analysis.

4.5.4 Item analysis and reliability

The internal consistency of the retained factors of the AAQ was assessed by calculating Cronbach's alpha. The calculation of the value of Cronbach's alpha coefficient for an instrument indicates the level to which the items in the instrument describe the same attribute. Clausen (1998) advocates the use of the alpha coefficient as a sound measurement of error variance. It is also used in the analysis of a dimension's strength once the existence of a single factor has been determined. In other words, internal consistency implies a high degree of generalisation across the items within a test. An acceptable cut-off for Cronbach's alpha is 0.70. This means that the coefficient should be 0.70 or higher for a set of items to be considered a consistent scale (Cortina, 1993). In this study, Cronbach's alpha was applied to calculate the internal consistency of the items for each of the factors after the final round of rotation and extraction.

4.5.5 The Mann-Whitney U and Kruskall-Wallis tests

Due to the skewness of the distribution, in this study, it was best to use non-parametric tests. The methods used in this study took advantage of the simplicity of the Mann-Whitney U test and Kruskall-Wallis test. These tests are commonly referred to as distribution-free tests. As non-parametric methods, their applicability is much wider than the corresponding parametric methods. Because non-parametric methods rely on fewer assumptions, they are also more robust (Field, 2005; Stuart, Ord & Arnold, 1999). A non-parametric or distribution-free statistical test does not depend on any assumptions about the form of the sample population or the values of the population parameters.

The Mann-Whitney U test is a non-parametric test used to assess whether two samples of observations come from the same distribution. This test is used when the assumptions of the t-test are violated, in that the dependent variable data set is non-normally distributed or ordinal (Field, 2005; Morgan *et al.*, 2007). The Mann-Whitney U test is only slightly less powerful then Student's t-test. The non-parametric Mann-Whitney U test is used with a between-groups design with two levels of the independent variable, such as (in this case), two aircraft types (Boeing and Airbus). Z-values are calculated that 'can be used to approximate the significance level for the test. In this case, the calculated z is compared to the standard normal significance levels' (Winks, 2008:108).

The Kruskall-Wallis test is a non-parametric test that can be applied to assess whether three or more independent samples of observations have the same distribution. The Kruskall-Wallis test is used as an alternative to its parametric one-factor ANOVA counterpart when the ANOVA's normality assumptions are not met, or when data are ordinal. The test uses mean ranks to determine whether scores differ across groups and a chi-square distribution to estimate the statistical level of significance for the test (Field, 2005; Morgan *et al.*, 2007).

4.5.6 Comparison of proportions or percentages

To compare the proportions in the sample with 'positive' or 'negative' scores regarding flight deck automation, the differences between percentages were calculated. In mathematics, two quantities are called **proportional** if they vary in such a way that one of the quantities is a constant multiple of the other, or equivalent if they have a constant ratio. According to Cohen, Cohen, West and Aiken (2003), percentages also express the same concept as proportions. Percentages can vary between zero and 100. A hundred per cent is exactly the same as a proportion of one.

For the purpose of finding any statistically significant difference in the percentages, a researcher can choose test statistics for testing the hypothesis H_0: $p_1=p_2$ (there is no difference between the population's proportions) against the alternate hypothesis, H_1: $p_1 \neq p_2$ (the population's proportions are not equal) (Cohen, *et al.,* 2003; Lawshe & Baker, 1950). In this study, the one sample t-test between proportions was used to estimate the significance of the difference between percentages in the sample distribution. This t-test can compare any two percentages, on condition that both are related to the same variable and that the percentages come from a single sample – in other words, the denominators represent the same people (Lawshe & Baker, 1950). The analyses in this study were done with the aid of the StatPac statistics calculator software package.

4.5.7 Correlation analysis

Relationships or associations also play an important role in the analysis of data. Whenever it is necessary to determine the relationship between two variables, measures of association or correlation analysis must be employed. Correlation analysis is not only directed at discovering whether there is a *relationship* between two variables, but it also analyses the *direction* and *magnitude* of the relationship (Gravetter & Wallnau, 2002).

Because the assumptions of the normality of the scores were noticeably violated, it was decided to use Spearman's rho method to calculate the correlations between the different variables. Spearman's rho is a non-parametric correlation statistical analysis that determines the extent to which changes in one variable (in most cases, the independent variable 'X') are associated with changes in another variable (in most cases, the dependent variable 'Y') (Cooper & Schindler, 2003). In principle, Spearman's rho is simply a special case of the Pearson product-moment correlation. However, the Spearman statistic is based on the correlation of the ranked data, as opposed to using the actual raw scores (Field, 2005; Morgan *et al.*, 2007).

The difference between Pearson's coefficient and Spearman's rho also lies in the type of data being used. Pearson's *r* requires interval or ratio data, whereas Spearman's rho only requires ordinal data (Myers & Well, 2003). The appeal of Spearman's correlation is that it has a range between -1.0 and +1.0, which can be easily interpreted by a researcher (Blalock, 1979). Blalock (1979) contends that *rho* is really a measure of the linear relationship between variables, because it is a measure of the strength of the goodness-of-fit of the least squares straight line; however, this association by no means proves causality. The strength of the association between two variables shows only the degree of covariation between the variables, as a researcher cannot rule out the existence of the influence from extraneous variables (Cooper & Schindler, 2003). Gravetter and Wallnau (2002) also emphasise that the fact that a relationship or correlation may exist between two variables does not necessarily imply causation.

Since association refers to the strength of a relationship, high levels of association between independent variables may lead to a misinterpretation of results and research inferences. To address this dilemma, partial correlation analysis was performed to determine the size of the unique portion of variance between only two variables, while controlling the effects of the other independent variables, as recommended by Field (2005:134-136).

4.5.8 Practical significance

Statistical significance tests are used to show when differences between groups are significant (Pett *et al.,* 2003). The p-value is a criterion of this, indicating the probability that the obtained value could be computed under the assumption that the null hypothesis (example, that there is no difference between the means) is true. A small p-value (for example, a p-value smaller than 0.05) is considered sufficient evidence that the result is of statistical significance at the 95 per cent level of confidence.

However, statistical significance does not necessarily imply that the result is important in practice, because these tests have a tendency to yield small p-values (indicating significance) as the size of the data set increases. According to Field (2005), practical significance can be understood as a large enough difference to have an effect in practice. When a relationship between variables is large enough to be important, the test statistic or correlation effect size is compared to various cut-off points or values, as recommended. In many cases, it is necessary to know whether a relationship between two variables is practically significant – for example, between pilots' level of education and their perceptions of advanced automation. The statistical significance of such relationships can be determined by using the correlation coefficients (r).

In this study, to assess the significance of the z-statistic of the Mann-Whitney U test, the coefficient 'r' was computed by using the following conversion formula suggested by Field (2005) and Morgan *et al*. (2007):

$$r = z/\sqrt{(N)}$$

The effect size was determined by using the absolute value of 'r' and relating it to the cut-off points for practical significance recommended by Cohen (1988):

- r = 0.10 small effect;
- r = 0.30 medium effect; and
- r = 0.50 large effect.

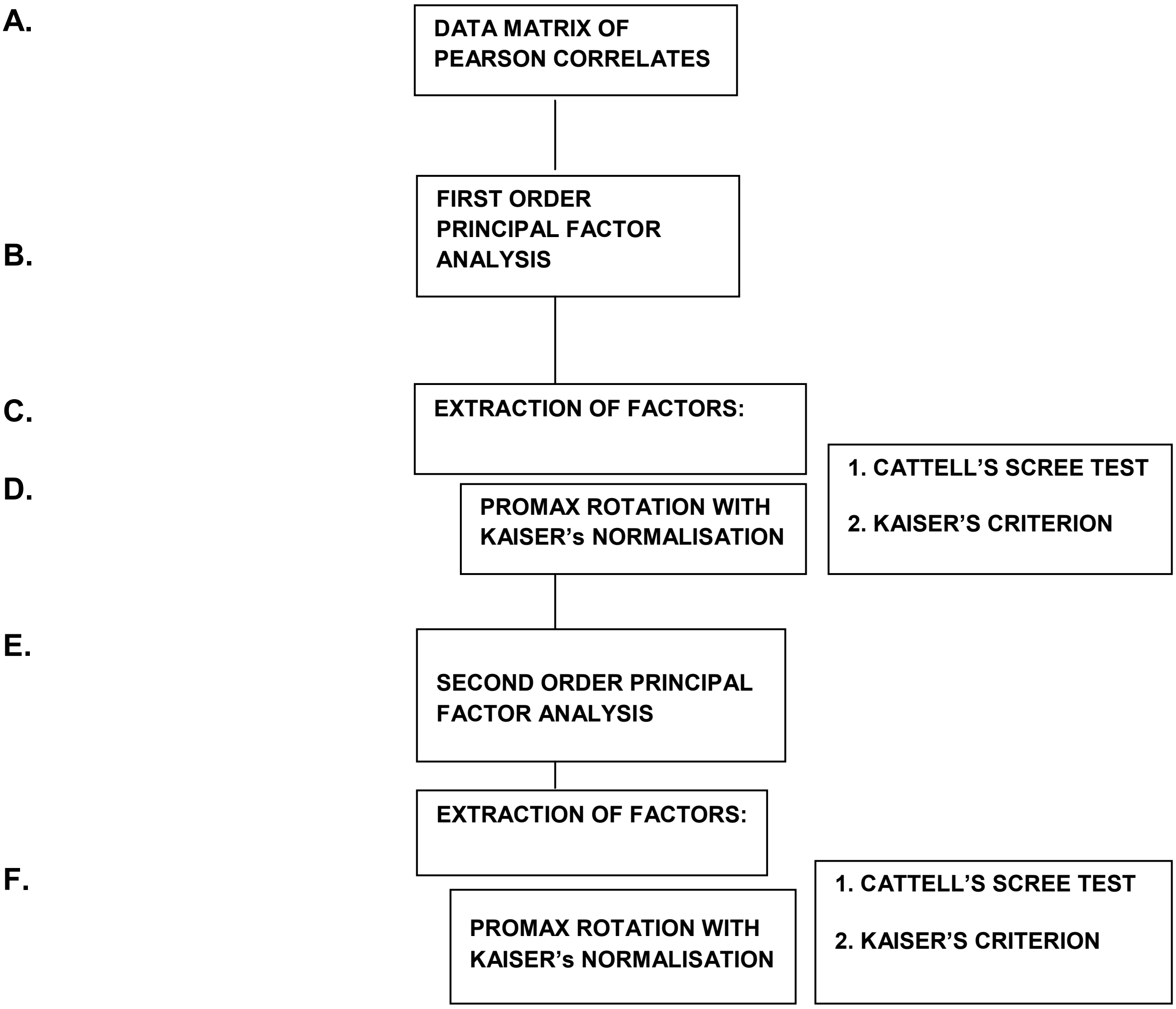
It is important to note that in this context effect size does not refer to cause and effect relationships between variables, but merely provides a value that quantifies the practical significance of findings (Rosenthal, Rosnow & Rubin, 2000).

4.6 SUMMARY

Chapter 4 has reviewed the methodology and research steps covered in the study. The discussion dealt with the population, method of sampling, the design and layout of the questionnaire, the type of questionnaire used, the design of questions, and the statistical methods used in the study.

This chapter has focused mainly on the statistical applications involved in determining the perceptions of airline pilots towards advanced flight deck automation. Statistics such as factor analysis, reliability analysis, analysis of item distribution, analysis of the difference in the sum of ranks (using the Mann-Whitney U and Kruskall-Wallis tests) and correlation analysis were presented to provide a basis for a discussion of the results, as set out in the next chapter. Practical significance and effect sizes were discussed and specific cut-off points were recommended as guidelines to determine whether the results were practically significant or not. The analysis of the data, the results and findings is discussed in Chapter 5.

A graphic summary of the research statistics used in this study is presented in Figure 4.3.



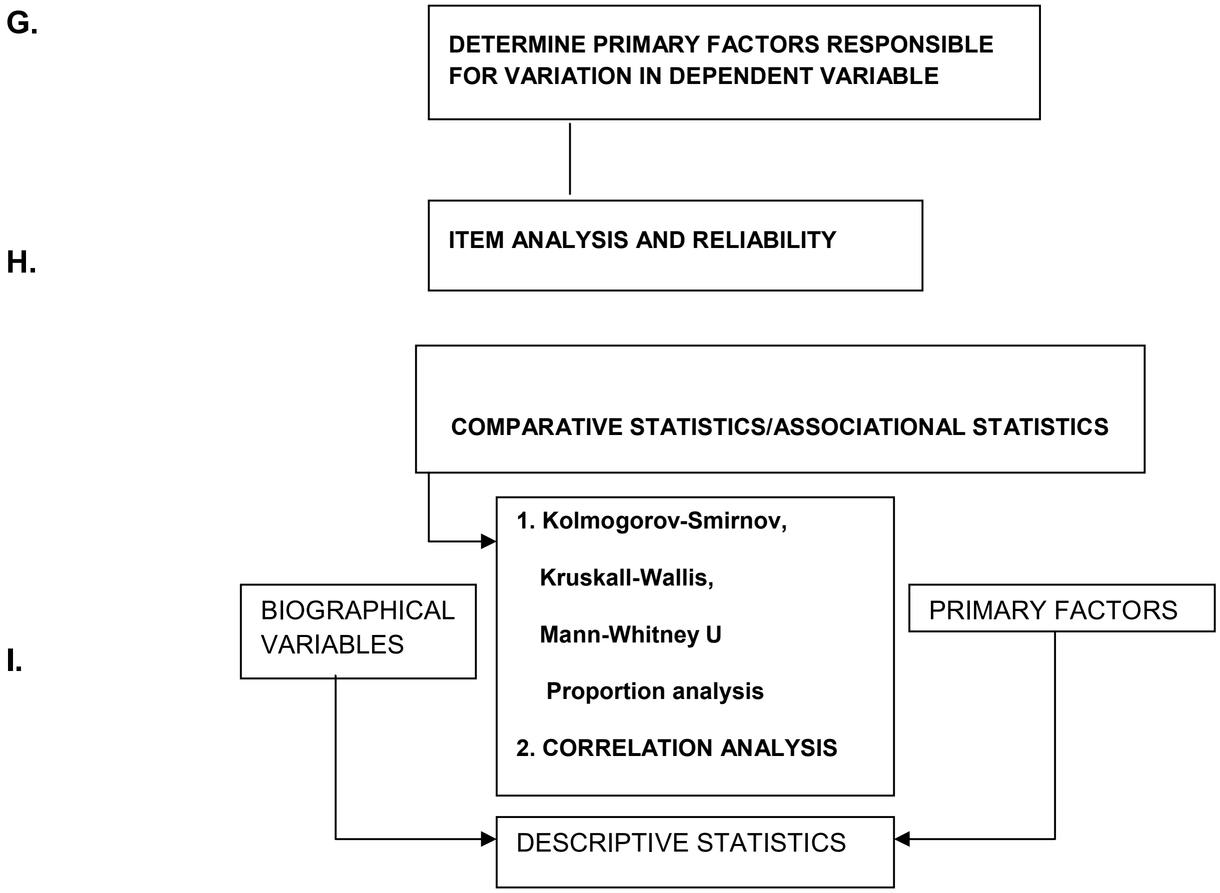


Figure 4.3: Components of the statistical process

Chapter 5

RESULTS

5.1 INTRODUCTION

The preceding chapters provided a theoretical overview of the research topic. The results obtained by applying the methods described in Chapter 4 are presented in this chapter. These results are also presented in terms of the research objectives set out in Chapter 1. The sequence in which the results are presented and discussed is the following:

- the Exploratory Factor Analysis (EFA) results that present the groupings or constructs measured by the questionnaire;

- the Cronbach alpha coefficient results that give an estimation of the internal consistency or reliability of the factors;

- the distribution of the data (mean, standard deviation, skewness and kurtosis) and the results of the goodness-of-fit test of the scores on the factors;

- the Mann-Whitney U test results, which show any statistically significant differences between the mean rank scores of two different groups in the sample;

- the Kruskall-Wallis test results, which indicate whether the means of the rank scores differ significantly across three or more subgroups in the sample;

- Spearman's rho correlation results, which show the association between two or more variables;

- the partial correlation results, which reveal the unique relationship between variables;

- the results of the one-sample t-test between proportions, which indicate the differences between percentages in the sample distribution; and

- the practical significance of findings, according to the criteria proposed by Cohen (1988).

5.2 EXPLORATORY FACTOR ANALYSIS

The essence of the study was to determine the fundamental factors responsible for the majority of the variability in the dependent variable (perception of automation). Exploratory Factor analysis (EFA) was used to discover patterns in the variations in the values of the variables and to assess whether the AAQ measured substantive constructs or factors that correlate highly with the variables, and that are also independent of one another (Clark & Watson, 1995).

The EFA was carried out by means of principal axis factoring, and was rotated using the promax procedure ($\kappa = 4$) with Kaiser’s normalisation to an oblique solution. This allows a researcher to seek the lowest number of factors that can account for the common variance in a set of variables.

In the first round of EFA, the 85 items of the AAQ were inter-correlated and rotated to form a simple structure by means of the promax rotation. Owing to the size (85 X 85), the inter-correlation matrix is not reported in the study. Based on Kaiser's (1961) criterion (eigenvalues larger than unity) according to Pett, *et al*. (2003), 25 factors were postulated. The 25 factors explained 67.787% of the variance in the factor space of data. The factor analyses yielded more factors in the real test space than was expected. This is probably due to the presence of differentially skew items, as described by Schepers (1992). However, the Scree plot presented in Figure 5.1 suggests that there are actually six significant constructs. According to Cattell's Scree test, all factors can be omitted after the one which starts the elbow in the downward curve of the eigenvalues.

Next, the items included in the six factors were scrutinised; and the items which had factor loadings lower than 0.35 were omitted. A total of 33 items were retained and were subjected to a second round of EFA with promax rotation. The Kaiser-Meyer-Olkin (KMO) test for measuring sampling adequacy and Bartlett’s test of sphericity displayed satisfactory results. Both diagnostic tests confirmed that the data was suitable for factor analysis. The calculated KMO value of 0.902 was greater than 0.7. Bartlett’s test of sphericity [χ^2 (528) = 3470.758, $p<0.01$] confirmed that the properties of the correlation matrix of the item scores were suitable for factor analysis.

Based on Kaiser’s criterion, six factors with eigenvalues higher than one were extracted. All the items had loadings greater than 0.36 and the factors were well determined (see Table 5.1). The six factors explained 55.297% of the total variance in the data. An inspection of the Scree plot confirmed that six factors had been properly determined. See Figure 5.2. However, there is only one item that is associated with Factor Six. According to Tabachnick and Fidell (2007:646), the interpretation of factors defined by only one or two variables is ‘risky’, under even the most exploratory of factor analyses. Consequently, Factor Six was disregarded for the purposes of this study.

Factor six yielded a loading of 0.342 after promax rotation with Kaiser’s normalisation. The factor was associated with the item, ‘the feedback I get in response to my inputs is usually too low.’ The item refers to the overall design of the advanced flight deck which was also subsequently explained sufficiently by factor five. Deleting or disregarding of the sixth factor did not impact the overall results of determining and labelling the five core variables responsible for the majority of automation perception.

The results of the principal axis factor analysis for the retained items of the AAQ are summarized in Table 5.1. The factor loadings, percentage variance, sums of squared loadings, squared multiple correlations and factor correlations are reported in Table 5.2.

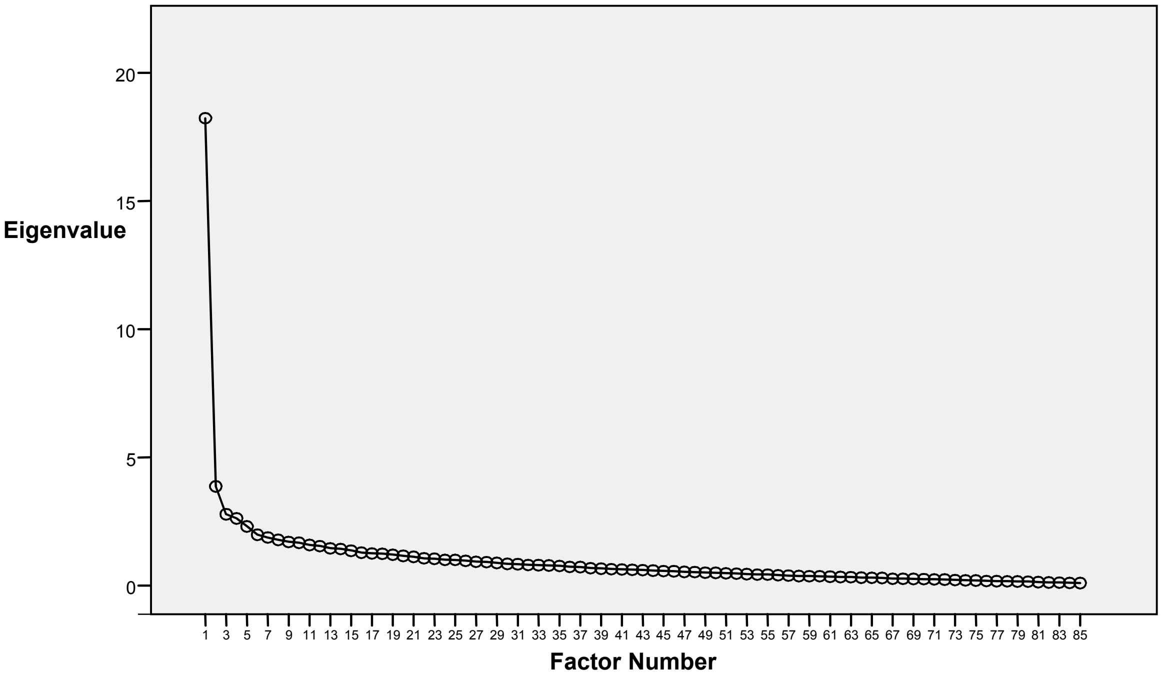


Figure 5.1: Scree Plot. Factor analysis: Perception of digital flight deck automation – 85 factors

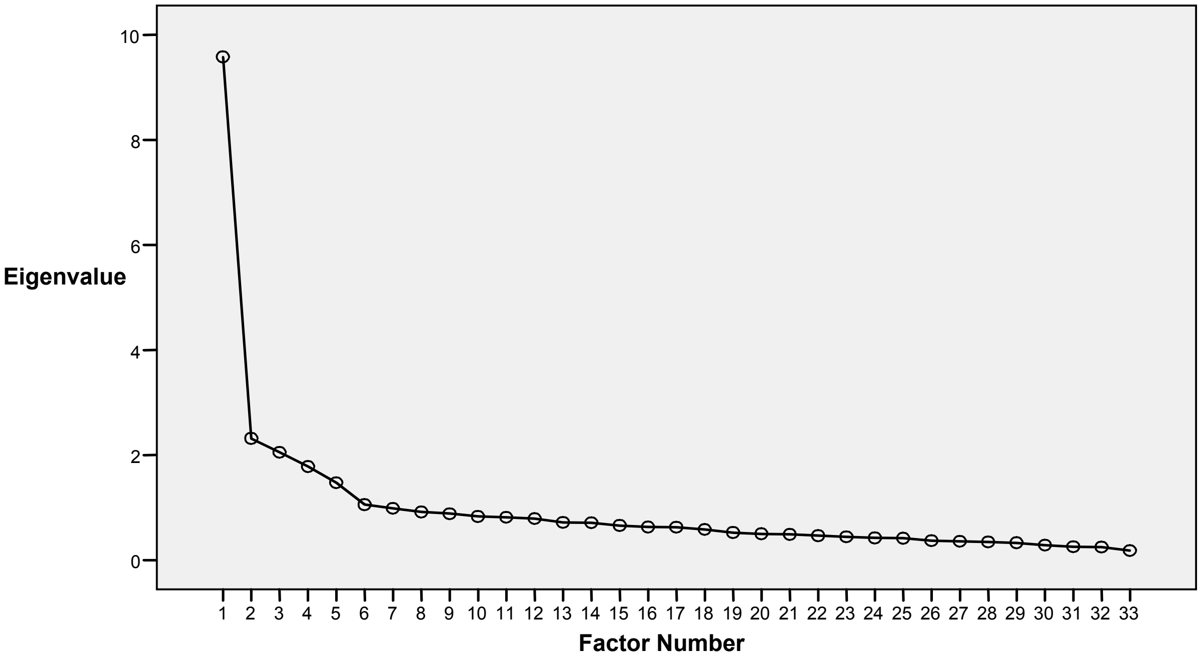


Figure 5.2: Scree Plot. Factor analysis: Perception of digital flight deck automation – 33 factors

Table 5.1: The results of the principal factor extraction and promax rotation of the AAQ items

FACTORS	1	2	3	4	5
Q38. I'm often confused about why the aircraft's automatics respond in the way it does.	0.831				
Q36. I am often surprised by the aircraft's response to my FMS inputs.	0.816				
Q40. I often tend to question the output from the automation system.	0.624				
Q41. I find myself trying to guess what this aircraft is going to do next.	0.610				
Q23. In the event of a partial system failure, it is never obvious which part of the automatic system failed.	0.567				
Q37. I feel that the amount of feedback I get from the automatics is excessive.	0.557				
Q42. The feedback I get in response to my inputs is usually too slow.	0.546				
Q39. Even after receiving adequate feedback from the system, I still won't correct my fault.	0.433				

Continued on next page

Table 5.1 continued

Q56. I think that there should be more simulator training for the conversion onto this aircraft.		0.831			
Q55. The computer based-training was insufficient for me to fully understand this aircraft.		0.694			
Q57. I feel that a lot more hours can be devoted to route training on this aircraft.		0.641			
Q54. I think that there should have been a lot more classroom training for the conversion onto this aircraft.		0.631			
Q58. There is insufficient recurrent training on this aircraft.		0.589			
Q59. The training I received was inappropriate to line operations.		0.444			
Q60. My transition onto this aircraft was extremely difficult.		0.367			
Q78. I feel detached from the aircraft.			0.813		
Q79. I feel exposed to risk by the automation.			0.745		
Q77. The aircraft is always ahead of me.			0.671		
Q80. Whenever I fly this aircraft, I feel a lot more stress then when I flew traditional aircraft.			0.605		
Q75. The automation system greatly decreases my confidence as a pilot.			0.509		
Q64. Automation impedes crew co-ordination.			0.495		

Continued on next page

Table 5.1 continued

Q73. The automation actually increases workload during critical phases of flight.				0.797	
Q72. In the event of a flight plan change, the ‘heads-down’ time required is much more than in traditional flight decks.				0.733	
Q69. I've noticed that there is much more ‘heads-down’ time in this cockpit.				0.575	
Q71. It is very difficult for the crew to maintain a good look-out when flying this aircraft.				0.567	
Q74. In general the overall workload on this flight deck has increased.				0.524	
Q70. The procedures used to operate this aircraft don't suit it at all.				0.367	
Q16. I find that the aircraft automatics are extremely unreliable.					0.646
Q13. The displays in my aircraft make very poor use of colour.					0.590
Q17. The level of reliability and redundancy of the automatics is insufficient to conduct extended range operations.					0.522
Q14. I'm extremely unhappy with the set-up of the displays in my aircraft.					0.500
Q21. If the automatics fail, most of the time I don't try to restore the system.					0.421

Table 5.2: Eigenvalues, percentage variance, sums of squared loadings, squared multiple correlations and factor correlations of the five factors of the AAQ

Factor	**1**	**2**	**3**	**4**	**5**
Eigenvalues	9.577	2.315	2.049	1.780	1.473
Percentage variance	29.022	7.014	6.210	5.393	4.463
Sums of Squared Loadings (SSL)	7.071	5.453	6.797	5.450	3.872
Squared Multiple Correlation (SMC)	0.991	0.974	0.977	0.980	0.930
Factor inter-correlation matrix					
Factor	**1**	**2**	**3**	**4**	**5**
***1.* Comprehension**	-	0.509	0.603	0.515	0.488
***2.* Training**	0.509	-	0.501	0.419	0.250
***3.* Trust**	0.603	0.501	-	0.569	0.412
***4.* Workload**	0.515	0.419	0.569	-	0.351
***5.* Design**	0.488	0.250	0.412	0.351	-

Table 5.2 shows that the five-factor solution explains 51.102% of the total variance in the data. The five factors inter-correlated significantly with one another (r = 0.250 to 0.603). The strength of the correlations indicates that the five factors were closely related in measuring the construct of perceptions on flight deck automation. Although the relatively high inter-correlations suggest overlapping variability, the Squared Multiple Correlations (SMCs) of 0.930 to 0.991 between the item scores and the factor scores indicate that all the factors were sufficiently defined by the relevant items. The factor scores of the respondents were calculated by means of Bartlett's method, as described by Tabachnick and Fidell (2007:651). After studying the contents of the items defining each factor, five descriptive labels were assigned.

5.2.1 Factor 1: Comprehension

This factor includes issues such as how a pilot interprets and understands the functioning of the automated flight deck system. The pilot's ability to interpret and understand the flight mode annunciator (FMA) involves a great deal of understanding and comprehension of what the computerised system is actually doing. The focus of this factor is primarily on how a person understands the computer's logic in executing specific flight path tasks. This factor can be considered to be related to the pilot's 'knowledge loop' or information database.

5.2.2 Factor 2: Training

This factor refers to the training and learning required to get a pilot to an adequate standard or to the level needed to operate the automation system. This factor is a measure of the *quality* of the learning experience. The elements of this factor include the hours (quality, not quantity) spent in classroom training, on simulator training, recurrent training, route training, line training and transition training.

5.2.3 Factor 3: Trust

This factor refers to the level of confidence a pilot has when operating a highly automated or glass-cockpit aircraft. The *trust* factor focuses on aspects such as stress levels due to a sense of increased exposure to perceived risk factors in automation. This factor is a measure of the lack of identification that the pilot may experience with the automation system. A pilot may feel that the aircraft may be ahead of him or her, which results in increased stress levels and the detachment of the human being from the human-machine loop. Specific facets of this factor also refer to impedances in crew co-ordination due to system trust issues.

5.2.4 Factor 4: Workload

The focus of this factor is a pilot's ability to efficiently program and manage the automated system. Elements of the workload factor include the amount of time spent instructing the automation computer via the flight management system and thereafter having it accomplish a specific task correctly. Other elements include the *procedures* required for safely operating the aircraft and the ability to maintain adequate situational awareness.

5.2.5 Factor 5: Design

This factor relates to the reliability of automation and to the setup and presentation of the system. Elements of the design factor emphasise the adequate use of colour in displays, ergonomic design and ease of use, as well as comfort. As an example, a modern and ergonomic flight deck design (Airbus A380 cockpit, 2007) can be viewed from the following website: *http://www. gillesvidal.com/blogpano/cockpit1.htm.*

5.3 FACTORIAL RELIABILITY

5.3.1 Reliability and item statistics

The reliability of the factors of the AAQ was determined by making use of Cronbach's alpha coefficient, as recommended by Field (2005). The average mean correlations between the items of each scale were also calculated to examine the internal homogeneity and unidimensionality of the five factors, as recommended by Cortina (1993) and Clark and Watson (1995). The means, standard deviations, corrected item-total correlation, average mean correlations and Cronbach's alpha for the five factors are set out in Tables 5.3 to 5.7. As indicated in Tables 5.3 to 5.7, the items of each factor correlated significantly (r>0.40) with the total score of the relevant factor. This indicates that the items are related to the construct they signify. DeVellis (2003) regards an item with an item-correlation of more than 0.20 as generally acceptable. Compared to the guideline of ≥0.70 for Cronbach's alpha recommended by Nunnally and Bernstein (1994), the alpha coefficient for all five factors yielded acceptable values (Factor 1 =0.844; Factor 2 =0.817; Factor 3 =0.845; Factor 4 =0.786; Factor 5 =0.700). Furthermore, if any of the items were deleted, this did not increase the internal consistency of a factor. All the mean inter-item correlations of the five factors were within the range of 0.15 to 0.50 recommended by Clark and Watson (1995).The high mean inter-item correlations of 0.45 to 0.63 were probably the result of the specificity of the target constructs. According to Vermeulen and Mitchell (2007), a much higher average inter-item correlation can be expected when one is measuring a narrow construct. The scores on the five factors of the AAQ appear to satisfy the requirements of homogeneity and unidimensionality and can be considered to be representative of the specific factor that they are assessing.

Table 5.3: Reliability and item statistics for Factor 1: Comprehension (n = 262)

	Mean	**Standard Deviation**	**Corrected item-total correlation**	**Alpha if an item is deleted**
Q38. I'm often confused about why the aircraft's automatics respond in the way it does.	5.97	1.105	0.724	0.810
Q36. I am often surprised by the aircraft's response to my FMS inputs.	5.90	1.123	0.722	0.810
Q40. I often tend to question the output from the automation system.	5.58	1.389	0.638	0.817
Q41. I find myself trying to guess what this aircraft is going to do next.	5.91	1.440	0.610	0.821
Q23. In the event of a partial system failure, it is never obvious which part of the automatics have failed.	4.99	1.594	0.475	0.844
Q37. I feel that the amount of feedback I get from the automatics is excessive.	5.96	0.990	0.557	0.829
Q42. The feedback I get in response to my inputs is usually too slow.	5.54	1.502	0.512	0.836
Q39. Even after receiving adequate feedback from the system, I still won't correct my fault.	6.40	0.929	0.519	0.833
Number of items:	**8**			
Average mean correlations:	**0.59**			
Cronbach's alpha coefficient:	**0.84**			

Table 5.4: Reliability and item statistics for Factor 2: Training (n =262)

	Mean	Standard deviation	Corrected item-total correlation	Alpha if an item is deleted
Q56. I think that there should be more simulator training for the conversion onto this aircraft.	5.54	1.492	0.698	0.768
Q55. The computer based-training was insufficient for me to fully understand this aircraft.	4.52	1.901	0.556	0.797
Q57. I feel that a lot more hours can be devoted to route training on this aircraft.	5.77	1.252	0.577	0.792
Q54. I think that there should have been a lot more classroom training for the conversion onto this aircraft.	5.45	1.641	0.644	0.776
Q58. There is insufficient recurrent training on this aircraft.	5.62	1.548	0.544	0.795
Q59. The training I received was inappropriate to line operations.	6.13	1.177	0.498	0.803
Q60. My transition onto this aircraft was extremely difficult.	5.79	1.594	0.433	0.814
Number of items:	**7**			
Average mean correlations:	**0.56**			
Cronbach's alpha coefficient:	**0.82**			

Table 5.5: Reliability and item statistics for Factor 3: Trust (n =262)

	Mean	Standard deviation	Corrected item-total correlation	Alpha if an item is deleted
Q78. I feel detached from the aircraft.	6.33	1.096	0.678	0.809
Q79. I feel exposed to risk by the automation.	6.28	1.077	0.683	0.808
Q77. The aircraft is always ahead of me.	6.50	0.791	0.642	0.821
Q80. Whenever I fly this aircraft, I feel a lot more stress then when I flew traditional aircraft.	6.48	0.904	0.594	0.826
Q75. The automation system greatly decreases my confidence as a pilot.	6.00	1.262	0.569	0.838
Q64. Automation impedes crew co-ordination.	6.21	0.936	0.651	0.816
Number of items:	**6**			
Average mean correlations:	**0.63**			
Cronbach's alpha coefficient:	**0.85**			

Table 5.6: Reliability and item statistics for Factor 4: Workload (n =262)

	Mean	Standard deviation	Corrected item-total correlation	Alpha if an item is deleted
Q73. The automation actually increases workload during critical phases of flight.	5.37	1.707	0.641	0.726
Q72. In the event of a flight plan change, the 'heads-down' time required is much more than on traditional aircraft.	4.82	1.840	0.591	0.743
Q69. I've noticed that there is much more 'heads-down' time in this cockpit.	3.58	1.699	0.465	0.775
Q71. It is very difficult for the crew to maintain a good look out when flying this aircraft.	5.85	1.366	0.583	0.744
Q74. In general the overall workload on this flight deck is much more than on non-automated aircraft.	6.20	1.141	0.528	0.760
Q70. The procedures used to operate this aircraft don't suit it at all.	6.21	0.998	0.494	0.770
Number of items:	**6**			
Average mean correlations:	**0.55**			
Cronbach's alpha coefficient:	**0.79**			

Table 5.7: Reliability and item statistics for Factor 5: Design (n =262)

	Mean	Standard deviation	Corrected item-total correlation	Alpha if an item is deleted
Q16. I find that the aircraft automatics are extremely unreliable.	6.34	1.074	0.540	0.608
Q13. The displays in my aircraft make very poor use of colour.	6.13	1.190	0.438	0.647
Q17. The level of reliability and redundancy of the automatics is insufficient to conduct extended range operations.	6.34	1.163	0.445	0.644
Q14. I'm extremely unhappy with the set-up of the displays in my aircraft.	6.23	1.324	0.424	0.656
Q21. If the automatics fail, most of the time I don't try to restore the system.	6.02	1.197	0.404	0.661
Number of items:	**5**			
Average mean correlations:	**0.45**			
Cronbach's alpha coefficient:	**0.70**			

5.4 DISTRIBUTION OF THE DATA

Before the factors can be used in other statistical analyses, it was also necessary to examine the distribution statistics of the factors or scales of the AAQ. Using descriptive statistics, the mean, standard deviations, skewness and kurtosis of the summated scores for each factor were analysed, as reported in Tables 5.8 and 5.9. The airline company whose pilots responded in this study employs two distinct groups of pilots, which were subdivided further. These two groups operate either *short*-range aircraft or *long*-range aircraft. Short-range aircraft are usually narrow-bodied aircraft carrying approximately fifty per cent fewer passengers than the wide-bodied long-range aircraft. Although the flight deck operations and workload levels are very similar, the average number of approaches and landings per pilot differ on an operational basis for these aircraft. In the sample, there were 114 short-range crew members and 115 long-range crew members, and 33 pilots reported operating as both short-range and long-range crew members. This can occur when the company experiences a shortage of adequately qualified personnel to fly the scheduled routes. Short-range crew may therefore be required to operate as cruise pilots on long range on an *ad hoc* basis.

Table 5.8: Distribution of responses from the three primary pilot groups on the factors of the AAQ

Factor	**Minimum**	**Maximum**	**Mean**	**Std. Dev**	**Skewness**		**Kurtosis**	
Flying both Short-range and Long-range (n = 33)					**Sk Stats**	**Std. Error**	**Ku Stats**	**Std. Error**
Comprehension	27	56	47.06	6.548	-1.232	0.409	1.625	0.798
Training	25	49	39.55	6.760	-0.479	.0409	-0.491	0.798
Trust	28	42	36.70	4.883	-0.370	0.409	-1.419	0.798
Workload	18	42	32.39	6.067	-0.493	0.409	-0.442	0.798
Design	12	35	31.00	4.308	-2.715	0.409	11.294	0.798
Short-range only crew (n =114)								
Comprehension	21	56	46.48	6.946	-1.322	0.226	2.359	0.449
Training	22	49	39.53	6.415	-0.577	0.226	-0.282	0.449
Trust	18	42	38.11	4.312	-1.675	0.226	4.006	0.449
Workload	15	42	31.89	6.243	-0.704	0.226	0.214	0.449
Design	16	35	30.95	3.725	-1.492	0.226	2.851	0.449
Long-range only crew (n =115)								
Comprehension	16	56	45.83	7.379	-1.228	0.226	2.131	0.447
Training	15	49	37.91	8.384	-0.616	0.226	-0.233	0.447
Trust	17	42	37.81	4.797	-1.890	0.226	4.706	0.447
Workload	12	42	32.07	6.298	-0.823	0.226	0.646	0.447
Design	7	35	31.17	4.183	-2.365	0.226	9.489	0.447

Table 5.9: Distribution of the responses from the total sample on the factors of the AAQ (n = 262)

Factor	Mean	Standard Deviation	Skewness		Kurtosis	
			Sk Stats	Std. Error	Ku Stats	Std. Error
Comprehension	46.2672	7.07900	-1.265	0.150	2.124	0.300
Training	38.8206	7.40057	-0.675	0.150	0.011	0.300
Trust	37.7977	4.60646	-1.584	0.150	3.323	0.300
Workload	32.0344	6.22401	-0.728	0.150	0.302	0.300
Design	31.0534	3.99197	-2.085	0.150	7.276	0.300

Earlier discussion in Chapter 4 explored the concept of using either parametric or non-parametric statistics. A parametric test is only appropriate when the population score is normally distributed, the variances of the groups are equal and the dependant variable is an interval scale. If a factor is normally distributed, the skewness and kurtosis should not be more than 2.5 times the standard error (Morgan, *et al.,* 2007). Thus, in Table 5.8 the skewness and kurtosis should not be more than 0.565 and 1.123 for the two main pilot groups, and in Table 5.9, the skewness and kurtosis should not be more than 0.375 and 0.75 respectively, to be regarded as normally distributed.

Inspection of the perceptions of the two main groups and the factors affecting automation perception revealed that the distributions are non-normal in nature. Therefore, a non-parametric statistical technique was considered appropriate in analysing the data. To confirm this result, the factors were further subjected to the Kolmogorov-Smirnov goodness-of-fit test. The results of the Kolmogorov-Smirnov test are depicted in Table 5.10. According to Table 5.10, the two-tailed test for significance indicates that the distributions of the scores for each of the factors are non-normal

($p<0.05$). Thus the Kolmogorov-Smirnov hypothesis that the sample distribution comes from a specific normal distribution was rejected at the 0.05 level. Since the dependent variables were approximately non-normal in distribution, non-parametric statistical methodology was considered appropriate for the comparative and associational analysis of the data.

Table 5.10: Kolmogorov-Smirnov goodness-of-fit test of the distribution of the scores on the factors of the AAQ (n = 262)

Goodness-of-fit	Comprehension	Training	Trust	Workload	Design
Mean	46.2672	38.8206	37.7977	32.0344	31.0534
Standard deviation	7.07900	7.40057	4.60646	6.22401	3.99197
Absolute	0.122	0.098	0.181	0.104	0.161
Positive	0.085	0.084	0.181	0.055	0.161
Negative	-0.122	-0.098	-0.165	-0.104	-0.144
Kolmogorov-Smirnov Z	1.980	1.581	2.927	1.677	2.613
Sig. (2-tailed)	0.001	0.014	0.000	0.007	0.000

5.5 COMPARATIVE STATISTICS

5.5.1 Mann-Whitney U test

The Mann-Whitney U test is appropriate when an independent variable with two categories and one continuous dependent variable with a non-normal distribution are used, and the difference between the mean of the rank scores of the respondents in the various categories needs to be tested. The data sets of the independent variables, gender and aircraft type were categorised in two subgroups (nominal). Therefore, the Mann-Whitney U test was considered appropriate to compare the mean rank scores of the subgroups of the two variables.

When the responses of two subgroups are being compared, the Mann-Whitney U test provides z-values to assess whether or not the two samples come from the same distribution. The z-values for the variables ‘gender’ and ‘aircraft type’ were calculated separately. The z-values and mean rank values for each of the factors from the AAQ are reported in Table 5.11 for gender and in Table 5.12 for aircraft type.

Tables 5.11 to 5.12 indicate how the various subgroups (male/female, Boeing/Airbus) differ with regard to the various domains (factors).

5.5.1.1 Gender

When the 17 female pilots were compared to the 245 male pilots, there appeared to be no significant difference ($p>0.05$) in the mean rank scores of the factors, *comprehension*, *training, trust* and *workload*. However, the mean rank scores of the male pilots (134.48) and the mean rank scores of the female pilots (88.59) did differ significantly on the *design* factor ($U = 1353.0$; $Z =-2.433$, $p = 0.014$, $r = -0.15$). In terms of Cohen’s criteria (1988), the r effect size ($r = -0.15$) should be considered small. It therefore seems that gender has no practical effect on the perceptions of airline pilots in respect of advanced automation of the flight deck. The data from more female participants is, however, required to calculate a valid result. The fact that so few responses could be obtained from female pilots should be regarded as a limitation not only to the current study, but, for the foreseeable future, also to future research. This limitation coincides with data received from the South African Civil Aviation Authority, which reflects a much smaller proportion of female licensed pilots (6.1%) in the South African pilot population as compared to male counterparts (SACAA, 2007).

Table 5.11: Mann-Whitney U test: Comparison of mean rank values by grouping variable gender

Domain	*Gender*	*N*	*Mean rank*	*U*	*Z*	*Sig. two-tailed*
Comprehension	Male	245	130.33	1795.5	-0.952	0.345
	Female	17	148.38			
Training	Male	245	132.20	1911.5	-0.567	0.575
	Female	17	121.44			
Trust	Male	245	133.69	1547.0	-1.795	0.073
	Female	17	100.00			
Workload	Male	245	132.23	1903.0	-0.595	0.556
	Female	17	120.94			
Design	Male	245	134.48	1353.0	-2.433	0.014*
	Female	17	88.59			

***P<0.05**

5.5.1.2 Aircraft type

Table 5.12: Mann-Whitney U test: Comparison of mean rank values by grouping variable aircraft type

Domain	***Aircraft type***	***N***	***Mean Rank***	***U***	***Z***	***Sig. Two-Tailed***
Comprehension	Boeing	93	124.88	7243.0	-0.824	0.410
	Airbus	166	132.87			
Training	Boeing	93	138.82	6899.0	-1.420	0.156
	Airbus	166	125.06			
Trust	Boeing	93	135.19	7236.0	-0.846	0.399
	Airbus	166	127.09			
Workload	Boeing	93	130.41	7681.0	-0.066	0.948
	Airbus	166	129.77			
Design	Boeing	93	102.53	5164.0	-4.452	0.001**
	Airbus	166	145.39			

****P< 0.01**

5.5.1.2 Aircraft Type

Because the values of the scores of the dependent variables were not a normal distribution, the Mann-Whitney U test was also performed to compare pilots flying different aircraft types, namely Boeing or Airbus (see Table 5.12). When the 93 Boeing pilots are compared to the 166 Airbus pilots, there appears to be no significant difference in the mean rank scores of the factors, *comprehension*, *training*, *trust* and *workload* ($p>0.05$). However, the Boeing pilots (102.53) and the Airbus pilots (145.39) did differ significantly with regard to their perceptions of the *design* factor ($U = 5164.0$; $Z = -4.452$; $p = 0.001$; $r = -0.28$), which is also considered to be a small to medium effect size (Cohen, 1988).

The results indicate that pilots who operate the Airbus type aircraft have a statistically significantly more positive perception of the design of the automated system than their Boeing counterparts. It seems that the design of the flight deck of the Airbus type aircraft is related to airline pilots' responding more positively to advanced automation.

5.5.2 The Kruskall-Wallis test

In this section, the effect of various biographical characteristics of airline pilots on their perceptions of advanced flight deck automation is explored. This includes the following characteristics (independent variables): initial flying training, computer literacy and position.

Because the responses of more than two categories were compared and the dependent variable data were non-normally distributed, the Kruskall-Wallis test was regarded as suitable. (Also see Section 4.5.5 for reasons supporting this decision.) The Kruskall-Wallis test calculates the chi-square statistic to compare mean rank scores. The results of the Kruskall-Wallis tests are depicted in Tables 5.13 to 5.15.

5.5.2.1 Initial flying training

Table 5.13: Kruskall-Wallis test: Comparison of the mean rank values by grouping variable initial flying training

Domain	***Initial flying training***	***N***	***Mean rank***	***Chi-square***	***df***	***Sig. two-tailed***
Comprehension	Military Cadet Part-time Full-time	131 21 72 37	126.20 132.86 132.36 144.30	1.720	3	0.632
Training	Military Cadet Part-time Full-time	131 21 72 37	129.85 153.12 122.81 138.47	3.053	3	0.384
Trust	Military Cadet Part-time Full-time	131 21 72 37	136.34 115.76 132.71 117.41	2.820	3	0.420
Workload	Military Cadet Part-time Full-time	131 21 72 37	135.27 114.05 130.01 127.42	1.580	3	0.664
Design	Military Cadet Part-time Full-time	131 21 72 37	134.16 106.21 127.92 139.85	3.171	3	0.366

p>0.05

The respondents were categorised into to four groups, depending on their initial flying training. The results (set out in Table 5.13) indicate that there was no significant difference in the mean rank scores of the different subgroups, namely military, cadet, self-sponsored (part-time) and self-sponsored (full-time). The p-values indicate that there is agreement between the four groups of airline pilots. For these particular groupings in the sample, initial flying training had no significant impact on their perception of advanced aircraft automation. This finding may be attributed to the fact that the particular airline under investigation employs a specific selection process based on standardised criteria. Due to this selection or filtering process, all new recruits form a largely homogeneous group based on their initial skills, knowledge and ability, demonstrating the importance of a structured and thorough recruitment process. Newly hired pilots all need to meet a certain level of expertise.

5.5.2.2 Level of computer literacy

The respondents were asked to indicate their level of computer literacy, namely ‘poor’, ‘average’, ‘above-average’ or ‘excellent’. Based on their subjective assessment, they were grouped into four categories in respect of their computer literacy; and the differences in their scores on the factors were examined. The results of the Kruskall-Wallis test (as reported in Table 5.14) indicate no relationship between the airline pilots’ perceived level of computer literacy and their perceptions of advanced flight deck automation. No significant difference ($p>0.05$) was found in the mean rank scores of the subgroups in the sample. This result suggests that there is no need for a pilot to be computer literate (or to understand information technology) to develop a positive perception towards operating advanced aircraft.

Table 5.14: Kruskall-Wallis test: Comparison of the mean rank values by grouping variable level of computer literacy

Domain	*Computer literacy*	*N*	*Mean rank*	*Chi-square*	*df*	*Sig. two-tailed*
Comprehension	Poor Average Above-average Excellent	15 131 82 32	113.77 137.48 123.46 127.78	2.642	3	0.450
Training	Poor Average Above-average Excellent	15 131 82 32	90.40 132.98 134.32 129.36	4.639	3	0.200
Trust	Poor Average Above-average Excellent	15 131 82 32	143.37 132.62 123.23 134.42	1.434	3	0.698
Workload	Poor Average Above-average Excellent	15 131 82 32	143.50 135.45 123.99 120.81	2.167	3	0.538
Design	Poor Average Above-average Excellent	15 131 82 32	161.03 128.44 128.34 130.17	2.681	3	0.444

P>0.05

Table 5.15: Kruskall-Wallis test: Comparison of the mean rank scores by grouping variable position

Domain	*Position*	*N*	*Mean rank*	*Chi-square*	*df*	*Sig. two-tailed*
Comprehension	In-flight relief	16	116.47	11.063	6	0.086
	Co-pilot (short-range)	60	138.52			
	Co-pilot (long-range)	49	141.01			
	Captain (short-range)	48	115.98			
	Captain (long-range)	53	108.58			
	Training Captain (short-range)	11	165.27			
	Training Captain (long-range)	18	134.25			
Training	In-flight-relief	16	110.16	17.390	6	0.008**
	Co-pilot (short-range)	60	130.66			
	Co-pilot (long-range)	49	151.20			
	Captain (short-range)	48	133.82			
	Captain (long-range)	53	99.86			
	Training Captain (short-range)	11	166.32			
	Training Captain (long-range)	18	115.75			
Trust	In-flight-relief	16	74.84	12.306	6	0.055
	Co-pilot (short-range)	60	126.68			
	Co-pilot (long-range)	49	137.50			
	Captain (short-range)	48	141.36			
	Captain (long-range)	53	119.41			
	Training Captain (short-range)	11	132.32			
	Training Captain (long-range)	18	140.83			
Workload	In-flight-relief	16	115.34	2.188	6	0.902
	Co-pilot (short-range)	60	128.48			
	Co-pilot (long-range)	49	138.99			
	Captain (short-range)	48	129.08			
	Captain (long-range)	53	120.67			
	Training Captain (short-range)	11	132.00			
	Training Captain (long-range)	18	123.97			
Design	In-flight-relief	16	113.28	6.484	6	0.371
	Co-pilot (short-range)	60	126.50			
	Co-pilot (long-range)	49	149.89			
	Captain (short-range)	48	122.13			
	Captain (long-range)	53	119.70			
	Training Captain (short-range)	11	115.64			
	Training Captain (long-range)	18	134.17			

$^{**}P<0.01$

5.5.2.3 Pilots' operational position

As the results set out in Table 5.15 show, the Kruskall-Wallis analysis of variance indicates that the position in which pilots operate in the company is related only to their perceptions with regard to *automation training* – χ^2 (6, N = 255) = 17.390; $p<0.01$. *Post hoc* Mann-Whitney tests were performed to compare the mean rank scores of the different pilot positions on the training factor. The mean rank scores of co-pilots operating long-range aircraft (61.32, n = 49) showed that they were significantly more positive in their perception of automation training than the line captains (42.42, n = 53) dedicated to long-range flying (U = 817.50; Z = -3.226; p = 0.001); with a medium effect size, r = 0.32. There also was a significant difference between the mean ranks of captains flying short-range aircraft (58.17) and captains flying long-range aircraft (44.31) on the training aspect of automation. Captains flying short-range aircraft were significantly more positive (U = 928.00; Z = -2.343; p = 0.019), with (r = 0.23) which is considered a small effect size (Cohen, 1988). A comparison of the mean ranks of five combinations of the short-range and long-range subgroup did not show any significant difference ($p>0.05$) in their perceptions of automation training.

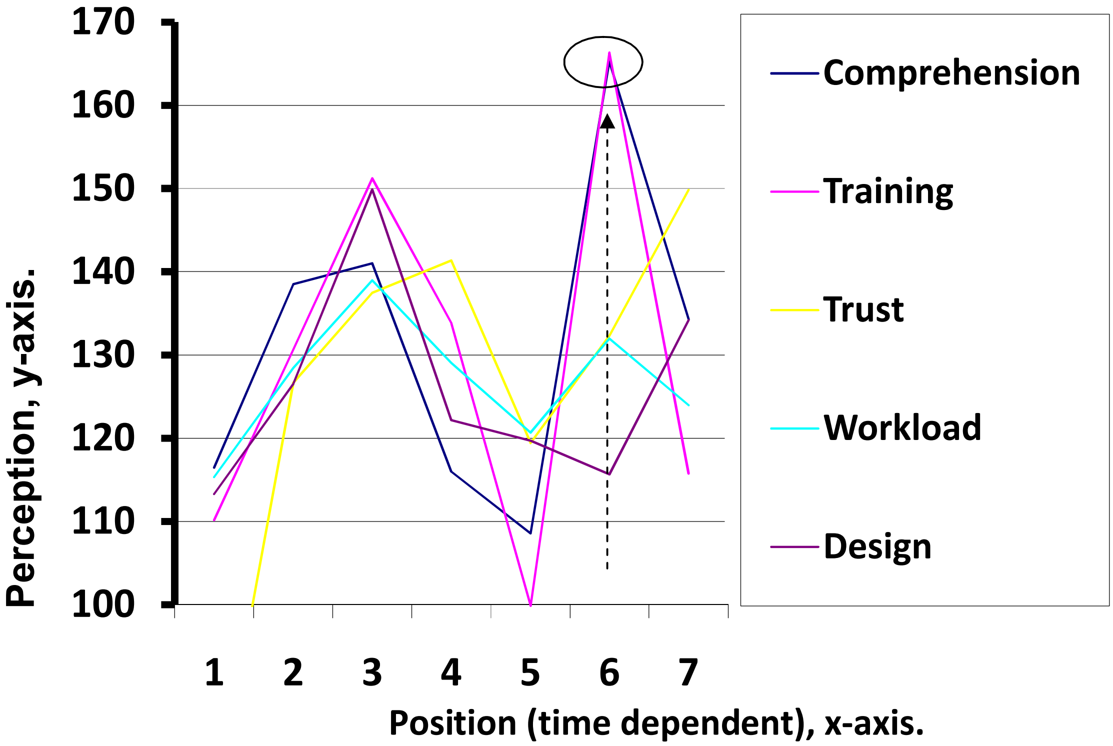
5.5.3 Graphic comparisons of the scores

The scores obtained from the AAQ were depicted graphically (see figure 5.3) in order to gain an overall understanding of the impact of the various factors on the perceptions of the different position groups. As discussed earlier, a pilot progresses through the ranks at a legacy carrier in specific steps, as he or she gains the relevant seniority. This means starting off a career in the organisation as an in-flight relief pilot and eventually (if chosen), progressing to the level of training captain on long-haul aircraft. Thus the independent variable (x-axis) represents this time-line, while the dependent variable (y-axis) displays perception of automation.

Figure 5.3 indicates that there is an apparently less positive perception of advanced flight deck automation in the 'dedicated in-flight relief pilot' and the 'long-range line captain' subgroups. This may be explained by the fact that for the typical in-flight relief pilot in this organisation, flying a modern advanced automated aircraft is a new experience. Inexperience and still 'finding their feet' in a larger company may explain this group's less positive perception of automation. The training syllabus for the relief pilot endorsement is also a much shorter course, compared to the primary crew rating. Less opportunity is provided to gain a more thorough knowledge base. By contrast, the very experienced long-haul captains are also positioned slightly below the curve. The less positive perception in this group may possibly be attributed to the fact that many in this group may have gained the majority of their experience on analogue or traditional type flight decks. The advanced flight deck is a relatively new concept.

The graph also highlights the very strong and positive perception held on advanced automated systems by training captains on short-range duty. This is easily explained by the fact that these pilots have a rich knowledge base about aircraft systems and an advanced understanding of this technology's intricate details. The training environment provides these particular pilots with an opportunity to learn and improve their understanding and skill in operating advanced aircraft continuously. This illustration provides an ideal opportunity to demonstrate the importance of further and continuous learning for a positive impact on perceptions of operating advanced flight deck technologies.

A Mann-Whitney U test was also performed to determine where the main differences in perceptions possibly lay between in-flight relief pilots and line captains (long-range). The test revealed a statistically significant difference in the two groups' *trust* in automated aircraft (U = 264.50; Z = - 2.279; p = 0.023; r = -0.27 – small to medium effect size). A possible explanation for this result is the fact that the two groups differ in their operational flight experience levels and training. A long-range captain completes a full course as a primary crew member, gaining a superior level of understanding, as opposed to an in-flight relief pilot, who receives an abridged training course on the same aircraft. Because of their lack of confidence (based on less experience and less training), the in-flight relief pilots also display a lower level of trust in advanced automation. Also, many of these newly hired pilots have had little or no exposure to highly advanced flight deck automation, as found in wide-bodied aircraft such as the Airbus A340-600, and more recently the Airbus A380.



Key:

1: Dedicated in-flight relief pilot

2: Co-pilot (short-range)

3: Co-pilot (long-range)

4: Captain (short-range)

5: Captain (long-range)

6: Training captain (short-range)

7: Training captain (long-range)

Figure 5.3: Comparison of factors by position on the flight deck

5.5.4 Comparison of the proportion of positive versus negative perceptions

To assess the current perceptions of the airline pilots of advanced flight deck automation systems, the proportion of the distribution of the scores for the total sample for each statement or item was analysed. To analyse the proportion of positive versus negative perceptions in the sample, the responses in the dataset were collapsed and categorised into a negative and a positive grouping. In accordance with the reverse-scored seven-point scale format of the questionnaire, mean scores above 4.0 were interpreted as a sign of a positive perception of advanced automated aircraft systems. A score less than 4.0 was considered a sign of a low to negative perception of automated aircraft systems. Responses 1, 2 and 3 represented negative perceptions and Responses 5, 6 and 7 signified positive perceptions. After the data sets had been collapsed, the one-sample t-test between proportions was performed to determine whether there was a significant difference between the percentages of the sample that responded positively or negatively on the different items.

The t-statistic was significant at the 0.001 critical alpha levels for all the items, demonstrating that a significant portion of the sample held a **positive perception** with regard to automation. The response pattern on Item 69 (I've noticed that there is much more ‘heads-down’ time in this cockpit) in Factor 4 was the exception. The mean score of 3.58 and a t-value of -5.147 (p=0.001) suggests that a significant percentage (59.2%) of the sample agreed with the statement. This indicates that a significant portion of the respondents perceived too much time as being spent looking inside the cockpit (they were distracted by the automation), as opposed to looking outside and gaining situational awareness visually. In general, however, these results illustrated that the majority of the participants in the sample responded predominantly positively towards each of the items in the factors related to advanced flight deck automation (see Appendix E for detailed reporting on the percentages and t-values).

5.6 ASSOCIATIONAL STATISTICS

5.6.1 Correlations

Because of the non-normal nature of the data, Spearman's rho correlation was calculated to explore the association between the biographical data on the airline pilots and their perceptions of advanced automated systems. The Spearman's rho coefficient is a measure of correlation between two or more variables, where the sign of the correlation coefficient indicates the direction of the relationship (Clausen, 1998). Cohen (1988) sets a cut-off point of 0.30 (medium effect) for the practical significance of correlation coefficients. The results of the correlation between the various independent and dependent variables are provided in Table 5.16.

Table 5.16: Spearman's rho correlation between the biographical variables and the factors of the AAQ

	Comprehension	Training	Trust	Workload	Design
Age in Years	**-0.146***	**-0.174****	0.051	0.016	-0.007
n=262 /p	0.018	0.005	0.411	0.801	0.907
Years flying experience	**-0.147***	**-0.143***	0.056	0.004	-0.025
n=261 /p	0.017	0.021	0.370	0.949	0.682
Total flying hours	**-0.0139***	**-0.133***	0.047	-0.019	-0.022
n=259 /p	0.025	0.032	0.454	0.766	0.728
Digital hours	0.087	**0.146***	**0.240***	0.102	**0.126***
n=260 /p	0.164	0.018	0.000	0.100	0.043

**P< 0.01
*P< 0.05

According to the data reported in Table 5.16, the variables age, years of flying experience and total flying hours appear to be negatively related (r = - 0.133 to r = - 0.174) with both the *comprehension* and *training* dimensions of automation. Digital hours correlate positively with the *training, trust* and *design* factors of advanced automation. The effect sizes of the correlations, however, are considered small (r< 0.30). In terms of Cohen's (1988) criteria, the relationships between these biographical variables and the factors of automation have no practical significance.

All the biographical variables are highly inter-correlated. The inter-correlation between age, years of flying experience and total flying hours range from 0.886 to 0.935 (effect size large). The correlations between the previously mentioned three variables and digital hours are more moderate and range from 0.379 to 0.466 (medium effect size).

To determine the unique relationship between airline pilots' digital experience (hours) and their perceptions of automation, partial correlation was consequently calculated. In this application, the effects of age, years of flying experience and total flying hours were 'controlled'. Running this third-order partial correlation analysis has shown only a relatively small positive change in the size of the correlation coefficients. The partial correlations of digital hours with the factors are as follows:

- r = 0.136, p = 0.029 with comprehension;
- r = 0.219, p = 0.001 with training;
- r = 0.257, p = 0.001 with trust;
- r = 0.125, p = 0.046 with workload; and
- r = 0.165, p = 0.008 with design.

Although all the partial correlations were statistically significant (p<0.05), the effect sizes of the correlations should be considered small.

The mere *opportunity* to fly advanced automated aircraft, however, seemed to have an impact in increasing the scores of airline pilots' comprehension, training, trust, workload and design. Social psychologists have long studied the concept of 'contact' or experience as a way of changing perceptions and attitudes positively (Allport, 1954).

5.7 SUMMARY

The results of the study support the theory derived from other research in the field very strongly. The analysis revealed five primary factors which can explain a large proportion of the variability in automation perception. After examining the items associated with them, these five factors were labelled

- trust;
- comprehension;
- training;
- workload; and
- design.

In general, the results of the responses from the participants revealed a **positive** perception of advanced flight deck automation. However, significant differences in specific factors occurred between certain biographical groupings. The results obtained from the Kruskall-Wallis test revealed that there were slight differences of opinion on some of the factors between the pilots in certain positions occupied on the flight deck.

It appears that the training captains (short-range) had a higher mean rank score and thus a more positive perception of advanced automation. It was deduced that the training and line captains operating on the short-range flights had a statistically more positive perception of advanced flight deck automation. In particular, the training captains (short-range) felt that they had better learning experience to cope with these aircraft, as opposed to the captains (long-range) and the dedicated in-flight relief pilot groups. Also, the confidence and trust levels in automation appeared to be very low among the in-flight relief pilots compared to among the other pilot groups. Lastly, it seemed that applicable training, exposure to and experience in operating in a digital environment are likely to boost pilots’ comprehension, confidence and trust in their ability to safely manage automated systems and to fly advanced automated aircraft.

Chapter 6

SUMMARY AND RECOMMENDATIONS

6.1 INTRODUCTION

For some time, the implementation of aircraft automation has been the source of many debates in the aviation world. Problems with mastering automation operation have resulted in specific human factor issues in aviation. As discussed in Chapter 1, the introduction of highly computerised flight deck technology has presented organisations with interesting human resource challenges. These challenges need to be met in order to maintain efficient and optimal operational outcomes. In the current aviation climate, aviation safety and keeping costs to a minimum are two important priorities for an airline's strategic positioning. Accident prevention is a far better option than dealing with expensive accidents.

The discussion in the introductory chapters highlighted the importance of flight safety, as well as its benefits to an airline. A single commercial jet accident can have far-reaching consequences – it may even result in the closure of an organisation. At the coal-face of an airline are its pilots. They are the ones who are ultimately responsible for the safe operation of these highly priced assets. High oil prices have led to increased fuel costs, which mean that airlines must invest in modern fuel-efficient equipment to remain globally competitive. Airline companies that invest in modern, efficient commercial jet aircraft are poised to reap sustainable competitive advantages. These advantages are gained in the reduction of the fuel bill in an industry where fuel accounts for the largest proportion of expenses. The fact that companies are forced to invest in modern automated aircraft mean that flight crew must now interact with computers even more intimately than in the past.

The impact of automation on airline pilots' perceptions has not been researched in the South African context before. One of the challenges facing airlines is to determine what impact such perceptions have on the training of competent pilots in order to ensure successful conversion from traditional, older generation aircraft to new advanced jet aircraft. Against this background, the current study set out to explore the challenges faced by modern advanced commercial jet pilots in a South African context and their perceptions on advanced automation in the planes they fly.

This chapter provides an overview and a summary of the principal findings of the study and also outlines topics for future research. The focus in the discussion of the results is answering the research questions. To avoid over-interpretation of the research results, only statistically significant findings with practical implications are discussed here.

6.2 RESEARCH OBJECTIVES

The primary purpose of this study was to identify the core components (factors) related to airline pilots' perceptions of advanced aircraft automation and to construct a measuring instrument (questionnaire) which could be used to measure perceptions towards advanced flight deck automation.

In an attempt to determine what biographical factors may be related to airline pilots' perceptions of automation, the responses of the various pilot groups were compared to one another and correlated with their scores on the different factors. The current perceptions of the research group regarding advanced automation were determined by comparing the proportions of the sample with 'positive' scores versus 'negative' scores regarding flight deck automation.

6.3 RESEARCH METHODOLOGY

In order to meet the research objectives, a literature review and an empirical study were conducted. The literature review focused on the two parts of the human-machine system. The first part was discussed in Chapter 2, which looked at the development of and issues surrounding automation of the flight deck (the machine). Chapter 3 focused more on the human facets of the human-machine system. The literature review also identified human factor issues related to automated flight deck behaviour. Once the literature review had been completed, a measuring instrument, namely the Automation Attitude Questionnaire (AAQ), was constructed. The purpose of the questionnaire was to collect information on respondents' biographical details, their perceptions of and attitudes toward flight deck automation.

A list of all licensed pilots employed at a South African airline was received, and the AAQ, accompanied by a covering letter, was distributed to the entire population of pilots at this specific airline. Of the 800 questionnaires originally sent out, 262 usable data sets were returned. This represented a response rate of 33%. Of the 262 responses, 93.5% were obtained from male pilots and 6.5% from female pilots. The two major commercial aircraft manufacturers were represented: 35.5% of the respondents had flown Boeing and 63.4% had flown Airbus aircraft. In terms of the initial or *ab initio* flying training received by each airline pilot in the sample, 50% had been military-trained, 8% had been trained on cadet (company) sponsorships and 42% were self-sponsored.

6.4 RESEARCH FINDINGS

6.4.1 Core factors related to perceptions of advanced automation

In this study, the original 85 items of the AAQ were extensively analysed by means of a series of exploratory factor analyses (EFAs). The purpose was to identify the latent variables responsible for an airline pilot's perceptions of advanced flight deck automation. Principal factor analysis with promax rotation indicated that 32 items of the AAQ were related to airline pilots' perceptions of advanced flight deck automation. These items presented five core factors, namely *comprehension, training, trust, workload* and *design.*

- *Comprehension:* Understanding and interpretation of the flight management system are the main issues related to this factor. How pilots interpret the flight mode annunciator (FMA) determine their ability to grasp the consequences of their actions and inputs. A thorough theoretical grounding during the initial phases of learning how to use the system contributes to a pilot's positive perception of automation. The focus of this factor is primarily on how a person understands the computer's logic in executing specific flight path tasks. This understanding is directly proportional to the pilot's 'knowledge loop' or information base.

- *Training:* This factor refers to the training and learning required to get the pilot to an adequate standard or to the level needed to operate the automation system. An efficient, thorough learning experience by the pilot is needed to provide the basis for a positive perception of advanced flight deck automation. This is not to say that *more* training is required. The *quality* of an airline's training programmes plays a pivotal role in pilots' perceptions of advanced automation. Negative or destructive training methodologies may be detrimental to line operations.
- *Trust:* This factor refers to the level of confidence a pilot has when operating a highly automated or glass-cockpit aircraft. The aspects of the *trust* factor focus on stress levels due to a sense of increased exposure to perceived risk factors in automation. This factor is a measure of the lack of identification that the pilot may experience with the automation system. When a pilot feels that the aircraft is ahead of him or her, this will increase stress levels and detach the human being from the human-machine loop. Specific facets of this factor also refer to the impedance in crew co-ordination due to system trust issues.
- *Workload:* The primary issues covered in this factor are the efficiency and ability of the pilot to programme the necessary commands into the flight management system. The more experience a pilot has with the aircraft's flight management system (in other words, with programming in various functions), the lower the cockpit workload. Elements of the workload factor include the amount of time spent instructing the automation computer via the flight management system (heads-down time) and thereafter having it accomplish a specific task correctly. Other elements also include the *procedures* required for safely operating the aircraft and the ability to maintain adequate situational awareness.
- *Design:* The presentation of automation systems as created by the engineers is the basic issue related to this factor. Ergonomic features are important; and pertinent flight information is presented to the pilots through the design of the automation system. An improper or inappropriate system design affects the pilot's perception of

automation, raising human factor issues. Elements of the design factor thus include adequate use of colour in displays, ergonomic design and ease of use, as well as comfort. A well-rounded flight deck design has the added advantage of creating a positive perception of automation.

6.4.2 Relationship between pilots' characteristics and their perceptions of advanced automation

In order to determine what biographical factors influence airline pilots' perceptions of automation, the ranked scores of various groups were compared and correlated. (Only the biographical factors that displayed a meaningful relationship with the pilots' perceptions of automation are discussed below.)

- The overall results indicated that the airline pilots' involved in this study perceived advanced automation on the flight deck positively. This result was significant at a 99% level of confidence. Although the pilots' general perceptions of advanced automation were positive, there were differences in opinion between various groupings.
- The results indicated that pilots who operated the Airbus type aircraft had a statistically significant more positive perception of the *design* of the automated system than their Boeing counterparts ($p < 0.001$, with a small to medium effect size, $r = -0.28$).
- Co-pilots operating long-range aircraft held significantly more positive perceptions of automation *training* than line captains dedicated to long-range flying ($p = 0.001$, with a medium effect size, $r = 0.32$). Likewise, the mean ranks of captains flying short-range aircraft and captains flying long-range aircraft differed significantly on the training aspect of automation. Captains flying short-range aircraft were, on average, more positive ($p = 0.019$, with a small effect size, $r = 0.23$).
- The biographical variables (age, years of flying experience and total flying hours) appeared to be negatively related ($r = -0.133$ to $r = -0.174$) to both the *comprehension* and *training* dimensions of automation. Opportunity to operate automated aircraft correlated positively with the *training, trust* and *design* factors of

advanced automation. However, the effect sizes of the correlations were considered too small ($r < 0.30$) to have any practical significance. Nevertheless, the mere opportunity to fly these advanced automated aircraft seemed to have a positive impact on airline pilots' perceptions of the core factors related to flight deck automation.

6.5 MANAGERIAL IMPLICATIONS AND RECOMMENDATIONS

Successful organisations that make increasing use of modern commercial jets hope not only to minimise the number of incidents or aircraft accidents, but also to create mechanisms to correct and respond to adverse human factor issues.

With regard to the differences between the various pilot groups in respect of their perceptions of automation, there are only two biographical factors that create a statistically significant difference: aircraft type and the pilot's flight deck position (i.e. captain or co-pilot or in-flight relief etcetera). If airline managers want to train professional, safe and competent advanced aircraft pilots, the following recommendations are suggested in order to enhance the transition from analogue to digital flight decks:

- Initial training from the 'grass-roots' level should incorporate aspects of the modern glass cockpit. Defining and understanding basic automation concepts will help to make the transition to an automated flight deck easier. It is clear that understanding and mastering the systems takes time; therefore starting early allows trainees an adequate time frame to master these systems. In order to maintain homogeneity in pilot skills, knowledge and attitude, management must pay a lot of attention to recruiting trainees who all meet the same level of intellect.
- Prior to actual hands-on simulator flying, more time should be spent mastering the use of the flight management computer and input system (the heart of automation). Computer-based training is very helpful in allowing trainees sufficient time to practice programming the automation system. The primary interface between the pilot and aircraft is the FMS and flight control unit. Thus, a thorough knowledge of its workings is essential to a smooth transition to automated flight decks. Candidates recruited to

operate advanced aircraft should not be technology-averse. They must display a keen enthusiasm for technology.

- Comprehension of the system was identified by this study to be a core factor in portraying a positive perception of automation. Learning through computer software and media is already a fundamental part of most airline pilots' training, in turn demonstrating the progressiveness of many large carriers. Significant cost savings have already been gained from using such interactive computer-based training (CBT) media. Maximizing opportunities to work through computer-based training to discuss subject areas prior to actual flight training will also help to ensure an easier and more complete transition. This will reduce the study workload of trainees and enable a greater comprehension of the aircraft system.
- Training should emphasise the use of new flight instrument displays, such as vertical speed tapes or integrated primary and navigational flight displays.
- The design of the automated flight deck was identified as a core factor affecting pilots' perceptions of automation. The Airbus philosophy of flight deck design appeared to be received more positively. Thus management should look into the basic differences between Boeing and Airbus cockpits in order to latch onto positive aspects. New scanning techniques, such as interpreting the velocity trend vector on a speed tape, should be emphasised. At certain levels, there are vast differences between the traditional T-type scan taught on analogue flight decks and the new glass cockpit representations. The ability to eliminate clutter during instrument scanning when too much information is displayed can improve flying skills and judgement. In other words, pilots should know where to find pertinent information and how to interpret it and use it at the correct times.
- Complacency was identified as an important concern in advanced automated aircraft. More emphasis must be placed on pilots' being situationally aware and their cross-referencing with raw data instruments must be habitual. Regular training using raw or basic data instruments will enable pilots to maintain an adequate level of skill. Trust issues were identified as a core factor affecting perception in the study. By understanding elementary flight principles, pilots can easily identify false information

from an automated system. If they can do so, this helps them to regain trust in the system, as confidence is boosted by a thorough knowledge of flight principles. Training must emphasise the fact that incorrect data input will result in a false sense of comfort and confidence in the system. These errors can only be mitigated if the fundamental principles are applied. For example, if a pilot remembers (as a rule of thumb) that an aircraft requires three nautical miles to lose 1 000 feet on a three degree glide slope, the pilot can easily determine that computer predictions are incorrect when the aircraft is at 5 000 feet ten nautical miles from the airport during automated flight, yet indicates a correct profile.

- Advanced jet pilots (especially on long-range aircraft) should be given more opportunities simply to hand-fly the aircraft (for example, during bi-yearly simulator training), without apprehension on being evaluated on their performance. Management should encourage the practice of allowing pilots to turn off the automation and regularly practising hand-flying the aircraft during periods of low workload and good weather conditions to promote pilots' confidence levels.
- Training and simulator reports should include a question to enquire whether the candidate feels that he or she has received enough information to understand the system adequately. The results of this study show that pilots at the most junior level in the airline (in-flight relief pilots) appear to be more apprehensive about automation technology. Hence, they should be encouraged to speak up during training sessions. These simulator sessions should be seen as a learning environment where it is the norm to make mistakes. A non-punitive atmosphere is absolutely fundamental in order to foster a positive perception of advanced automation. This learning environment is a basic requirement for building a trainee's knowledge base. Comprehension was identified in this study as a core factor in automation perception – therefore any opportunity to improve knowledge loops is strongly encouraged.

6.6 LIMITATIONS AND SUGGESTIONS FOR FUTURE RESEARCH

Overall, the results suggest that the AAQ is a sufficiently reliable and valid measure to capture airline pilots' perceptions of flight deck automation. However, elements that influence overall perceptions of automation may also include the type of airline, leadership style, training programmes, experience level of participants, and other aspects. Any further research should thus endeavour to select measures that incorporate elements relevant to specific contexts or cultures. Caution should be exercised in generalising the results of advanced automation research across organisational and cultural contexts. Not limiting the sample to a single airline could solve some of the problems related to the context sensitivity of advanced automation perceptions. It is suggested that a cross-cultural or globalised analysis, using a similar instrument, be conducted to determine the validity of generalisations.

The scope of this study only permitted a brief overview of airline pilots' perceptions regarding important variables in their particular working environment. The sample was small and was drawn from only one specific organisation, which means that the data are not comprehensive enough to be used as a foundation for deductions regarding inter-cultural global operations. A larger sample which is more representative of the world airline pilot population should be used in future studies. Companies operating a large fleet of modern jets and employing pilots from a multitude of nationalities may yield an ideal sample for comprehensive research and analysis.

Although items from other studies were used to compile the questionnaire, better items could have been selected, using more positive statements. The inclusion of many negatively worded statements may explain why the distribution of scores of the factors was not normal and did not yield very significant results. The impact of these skewed distributions is also reflected in the low practical significance values (effect sizes) in some of the comparative statistics. To prevent the problem of response bias, both positively and negatively worded statements relating to advanced automation should be included in future questionnaires.

6.7 CONCLUSION

The findings of this study strongly support the results of research conducted by the Royal Aeronautical Society (James *et al.*, 1991), which suggested that there are specific factors which affect pilots' perceptions of automated flight decks. If organisations want to foster safe flying operations, they must be open to the shifts in training methodologies that may be necessary in a changing and dynamic aviation environment. A key antecedent to performance and safety appears to be an airline pilot's positive perceptions of automation, which implies that airline managements must promote such positive perceptions by providing a suitable environment.

Because of the nature and complexity of the modern advanced automated flight deck, this study recommends that the pilots of aircraft with such glass cockpits must exercise an internal locus of control principle. In other words, it is up to each and every pilot to take positive control of the learning environment, to study and understand his or her aircraft voluntarily, without being prompted to do so and on a regular basis. Such a rich enthusiasm for knowledge is the basic building block of safety and the competence of an advanced automated aircraft pilot. By taking responsibility for their own learning, pilots can mitigate latent flaws in training methods, aircraft design and the operational environment.

This study represents a very important step towards a better understanding of the dimensionality of automation perception. Examining the relationships between pilots' perceptions of advanced automation and various biographical differences using a questionnaire such as the AAQ should ultimately contribute to more effective training for pilots converting to aircraft with advanced automation.

REFERENCES

Aaker, D.A., Kumar, V. & Day, G.S. 1995. *Marketing Research.* 5th edition. New York: John Wiley.

Accident Statistics. Available at *http://www.airdisaster.com/statistics/.* Accessed 25 March 2007.

Airbus A380 Cockpit. Available at *http://www. gillesvidal.com/blogpano/cockpit1.htm.* Accessed 29 March 2007.

Airbus FCTM. 2002. *A330/A340. Flight Crew Training Manual.* Johannesburg: South African Airways.

Allport, G. 1954. *The Nature of Prejudice.* Reading, MA: Addison-Wesley.

Alter, W.K. & Powell, D. 1999. An Investigation into Flight Display Symbologies for Precision Instrument Approaches. *Proceedings of the 10th International Aviation Psychology Symposium Conference* (pp.140- 150). Columbus, OH: Ohio State University.

Bagshaw, D. 1996. *Complexities of the Airline Pilot Interface.* http://www.rvs.uni-bielefeld.de/publications/incidents. Accessed: 1 April 2007.

Beauden, E. 1989. Modern Flight Deck. *Canadian Aviation*, November: 45-46. Belson, W.A. 1986. *Validity in Survey Research*. Aldershot: Gower.

Billings, C.E. 1997. *Aviation Automation*. Mahwah, NJ: Lawrence Erlbaum.

Blalock, H.M. Jr. 1979. *Social Statistics.* Revised 2nd edition. New York: McGraw-Hill.

Cascio, F.W. & Aguinis, H. 2005. *Applied Psychology in Human Resource Management.* 6th edition. Hillsdale, NJ: Pearson/Prentice Hall.

Clark, J.M. & Paivio, A. 1990. Dual Coding Theory and Education. *The Educational Psychology Review,* 3(3):149-170.

Clark, L.A. & Watson, D. 1995. Constructing Validity: Basic Issues in Objective Scale Development. *Psychological Assessment,* 7(3):309-319.

Clausen, S.E. 1998. *Applied Correspondence Analysis.* Thousand Oaks, CA: Sage.

Cohen, J. 1988. *Statistical Methods for the Behavioural Sciences*. 2nd edition. Hillsdale, NJ: Erlbaum.

Cohen, J., Cohen P., West, S.G. & Aiken, L.S. 2003. *Applied Multiple Regression/Correlation Analysis for the Behavioural Sciences.* 3rd edition. Hillsdale, NJ: Lawrence Erlbaum.

Cooper, D.R. & Schindler, P.S. 2003. *Business Research Methods.* 8th edition. New York: McGraw-Hill/Irwin.

Cortina, J.M. 1993. What is coefficient Alpha? An examination of theory and applications. *Journal of Applied Psychology,* 78:98-104.

Crouch, T. D. 2003. *The Bishop's Boys: A Life of Wilbur and Orville Wright*. New York: W. W. Norton & Company.

Damos, D.L., John, R.S. & Lyall, A.E. 2005. The Effect of Level of Automation on Time Spent Looking Out of the Cockpit. *The International Journal of Aviation Psychology,* 9(3):303-314.

Davidson, I. 2007. *Knowledge Discovery and Data Mining: Challenges and Realities*. New York: Hershey.

Degani, A. & Heymann, M. 1999. Pilot-Autopilot Interaction: A Formal Perspective. *Proceedings of the 10th International Aviation Psychology Symposium Conference* (pp.110 - 145). Columbus, OH: Ohio State University.

DeVellis, R.F. 2003. *Scale Development: Theory and Applications.* Thousand Oaks, CA: Sage.

Edwards, E. 1988. Introductory Overview. *Human Factors in Aviation.* London: Academic Press.

Field, A. 2005. *Discovering Statistics using SPSS*. 2nd edition. London: Sage.

Fishbein, M. & Ajzen, I. 2001. *Belief, Attitude, Intention and Behaviour: An Introduction to Theory and Research.* Reading, MA: Addison-Wesley.

Flight Deck Pictures. Available at *http://www.airliners.net/search/photo.* Accessed 25 March 2007.

Flight Operations Manual (FOM). 2007. *South African Airways FOM.* Johannesburg: Jeppesen Sanderson.

Frankel, S.M. & Siang, S. 1999. *Ethical and Legal Aspects of Human Subjects Research on the Internet.* Washington, DC: American Association for the Advancement of Science. http://www.aaas.org/spp/dspp/projects. Accessed: 31 May 2007.

Fredricks, A.J. & Dossett, D.L. 1983. Attitude-behaviour relations: A comparison of the Fishbein-Ajzen and the Bentler-Speckart models. *Journal of Personality and Social Psychology*, 45:501-512.

Funk, K., Lyall, B., Wilson, J., Vint, R., Niemczyk, M., Surotegu, H.C. & Owen, G. 2000. Flight Deck Automation Issues. *The International Journal of Aviation Psychology,* 9(2):109-123.

Funk, K. & Lyall, B. 2000. A Comparative Analysis of Flight Decks with Varying Levels of Automation. *Final Report prepared for the FAA Chief Scientific and Technical Advisor for Human Factors.* Washington DC: Federal Aviation Administration.

Funk, K., Lyall, B., & Riley, V. 1995. *Perceived Human Factors Problems of Flight Deck Automation*. Corvallis, OR: Oregon State University, Department of Industrial and Manufacturing Engineering.

Gollwitzer, P.M. 1999. Implementation intentions: Strong effects of simple plans. *American Psychologist*, 54:493-503.

Gravetter, J.F. & Wallnau, L.B. 2002. *Essential Statistics for the Behavioural Sciences.* 4th edition. Pacific Grove, CA: Wadsworth.

Helmreich, R.L. 1997. Managing Human Error in Aviation. *New Scientific American,* (3)3: 62-67.

Hopkin, V.D. 1988. Air Traffic Control. *Human Factors in Aviation.* London: Academic Press.

Ishibashi, A., Kanda, N. & Ishida, T. 1999. Analysis of Aircraft Accidents by Means of Variation Tree. *Proceedings of the 10th International Aviation Psychology Symposium Conference* (pp.55-76). Columbus, OH: Ohio State University.

James, M., McClumpha, A., Green, R., Wilson, P. & Belyavin, A. 1991. Pilot Attitudes to Flight Deck Automation. *Proceedings of The Royal Aeronautical Society Conference on Human Factors on Advanced Flight Decks.* (pp. 130 – 158). London, UK: Human Factors Society.

Kabay, M.E. 1996. *Advanced Automated Flight Deck Issues.* http://www.ncsa.com/articles/incidents. Accessed: 1 April 2007.

Kantardzic, M. 2003. *Data Mining: Concepts, Models, Methods, and Algorithms*. San Francisco, CA: John Wiley and Sons.

Kantowitz, H. & Casper, P.A. 1988. Human Workload in Aviation. *Human Factors in Aviation.* London: Academic Press.

Kingsley. M. 2006. Airbus Rethinks Plan to put Winglets on A320. *Flight International. Magazine*. October: (pp.15-19).

Lankenau, A. 2001. *Avoiding Mode Confusion in Service-robots*. Evry: IOS Press.

Lawshe, C.H. & Baker, P.C. 1950. *Three Aids in the Evaluation of the Significance of the Difference between Percentages.* West Lafayette, IN: Purdue University, Sage.

Little, G.R. 1999. *A Theory of Perception.* San Francisco: Freeman.

Mattei, D. 2001. Paradigms in the Social Sciences. *International Encyclopaedia of the Social and Behavioural Sciences, Volume 16*, (pp. 56-75). St. Louis, MO: Elsevier.

Michael, S. & Lewis, B. 1995. *Data Analysis: an Introduction*. New York: Sage.

Mosier, K.L., Skitka, L.J., Heers, S. & Burdick, M. 1998. Automation Bias: Decision Making and Performance in High Tech Cockpits. *The International Journal of Aviation Psychology,* 8(1):47-63.

Morgan, G.A., Leech, N.L., Gloeckner, G.W. & Barrett, K.C. 2007. *SPSS for Introductory Statistics: Use and Interpretation.* 3rd edition. London: Lawrence Erlbaum.

Mouton, J. 2001. *How to Succeed in your Master's and Doctoral Studies. A South African Guide and Resource Book.* Pretoria: Van Schaik.

Myers, J.L. & Well, A.D. 2003. *Research Design and Statistical Analysis*. London: Lawrence Erlbaum.

Nunnally, J.C. & Bernstein, I.H. 1994. *Psychometric Theory.* 3rd edition. New York: McGraw-Hill.

Palmer, E. 1995. 'Oops, it didn't arm': Automation Surprises. *The International Journal of Aviation Psychology,* 2:5-43.

Paolo, R. 2001. *The Birth of Modern Science*. London: Blackwell.

Parasuraman, R., Molloy, R. & Singh, I. 1993. Performance Consequences of Automation Induced Complacency. *The International Journal of Aviation Psychology,* 3:1-23.

Parasuraman, R. & Riley, V. 1997. Humans and Automation: Use, Misuse, Disuse, Abuse. *The International Journal of Aviation Psychology,* 39(2):230-253.

Perrow, C. 2000. *Normal Accidents: Living with High-risk Technologies.* New York: Basic Books.

Pett, M.A., Lackey N.R. & Sullivan, J.J. 2003. *Making Sense of Factor Analysis.* Thousand Oaks, CA: Sage.

Phoenix Simulation Software, Systems Manual for the Airbus A330/A340. Available at: *http://www.phoenix-simulation.co.uk/.* Accessed 20 March 2007.

Ramtin, R. 1991. *Capitalism and Automation – Revolution in Technology and Capitalist Breakdown*. London, Concord, MA: Pluto.

Reyment, R.A. & Joreskog, K.G. 1993. *Applied Factor Analysis in the Natural Sciences.* Cambridge: Cambridge University Press.

Rigner, J. & Dekker, S. 2000. Sharing the Burden of Flight Deck Automation Training. *The International Journal of Aviation Psychology,* 10(4):317-326.

Risukhin, V. 2001. *Controlling Pilot Error. Automation.* New York: McGraw-Hill.

Rosenthal, R., Rosnow, R.L. & Rubin, D.B. 2000. *Contrasts and Effect Size in Behavioural Research.* Cambridge: Cambridge University Press.

Rudisill, M. 1991. *Line Pilots' Attitudes and Experience with Flight Deck Automation: Results of an International Survey and Proposed Guidelines.* Hampton, VA: NASA Langley Research Centre.

SACAA. 2007. [Statistics per licence on gender. XLS] According to C. Lakay, (e-mail communication, July 2007; LakayC@caa.co.za)

Sarter, N.B., & Woods, D.D. 1992. Pilot interaction with cockpit automation: operational experiences with the flight management system. *International Journal of Aviation Psychology*, 2 (4):303-321.

Scheck, W. 2007. The Development of the Autopilot. *Aviation History Magazine. http://www.century-of-flight.freeola.com/Aviation/autopilot.htm*. Accessed 5 June 2007.

Schepers, J.M. 1992. *Toetskonstruksie: Teorie en Praktyk.* Johannesburg: RAU Press.

Shepherd, B. 1998. *Statistical Analyses in Excel, Made Easy*. 2nd edition. London: McGraw-Hill.

Skitka, L.J., Mosier, K.L., Burdick, M. & Rosenblatt, B. 2000. Automation Bias and Errors: Are Crews Better than Individuals? *The International Journal of Aviation Psychology,* 10(1):85-97.

Stengel, R.F. 1993. Toward Intelligent Flight Control. *IEEE Trans. Systems, Man, and Cybernetics,* 23(6):1699-1717.

Stokes, J. 2007. *Inside the Machine: An Illustrated Introduction to Microprocessors and Computer Architecture*. San Francisco, CA: No Starch Press.

Stuart, A., Ord, K. & Arnold, S. 1999. *Kendall's Advanced Theory of Statistics*. London: Arnold.

Tabachnick, B.G. & Fidell, L.S. 2007. *Using Multivariate Statistics.* 5th edition. Boston, MA: Allyn & Bacon.

Taylor, J.W.R. 1998. *The Lore of Flight.* London: Universal.

Thom, T. 1988. *The Air Pilot's Manual 4-The Aeroplane-Technical*. Shrewsbury: Airlife.

Tucker, L.R. & MacCallum, R.C. 1997. *Exploratory Factor Analysis.* Ohio: Ohio State University. http://www.unc.edu/rcm/book/factornew.htm. Accessed: 30 March 2007.

Vermeulen, L. P., & Mitchell, J. I. 2007. Development and validation of a measure to assess perceptions regarding gender-related behavior. *The International Journal of Aviation Psychology*, 17(2), 75-96.

Vermeulen, L.P., Wilson, J., & Mitchell, J.I. 2004. The Measurement of Perceptions Regarding Gender-Related Pilot Behaviour: An Exploratory Study. *Proceedings of the 26th Conference of the European Association for Aviation Psychology* (pp. 205-210). Pretoria: University of Pretoria.

Wallace, J. 2000. *Unlike Airbus, Boeing Lets Aviator Override Fly-By-Wire Technology.* Miami, FL: Seattle Post Intelligencer Reporter.

Walters, S.J.C. 2002. *Crew Resource Management.* Pretoria: University of Pretoria Press.

Wickens, C.D. & Hollands, J.G. 2000. *Engineering Psychology and Human Performance.* 3rd edition. New York, NJ: Prentice Hall.

Wiener, E.L. 1989. *Human Factors of Advanced Technology ("Glass Cockpit") Transport Aircraft* (NASA CR 177528). Moffet Field, CA: NASA Ames Research Center.

Wiener, E.L. 1993. Crew Coordination and Training in the Advanced Cockpit. *Cockpit Resource Management.* San Diego, CA: Academic Press.

Winks S.D.A. 2008. Available at http://www.texasoft.com/winkmann.html. Accessed: 7 October 2008.

APPENDICES

APPENDIX A: Letter requesting permission

The Chief Pilot
Captain J. Woods

FO Preven Naidoo
Flight Ops (A319)
Box 33F
preven@discoverymail.co.za

3 April 2007

Dear Captain,

RE: Permission to use pilots for a Master's Degree research study.

- I am currently a First Officer flying the A319, and have been employed with the company for just over four years.
- I am also a Master's student at the University of Pretoria.
- As a student in Aviation Management and under the supervision of Professor L.P. Vermeulen (tel.: 012-420-3074), I am conducting research for the completion of a Master of Philosophy Degree (MPhil).
- Basically, my research entails constructing a valid and reliable instrument to measure flight crews' perceptions of highly advanced aircraft and, in particular, behavioural issues affecting the operation of automation. The results of this research will add to the body of knowledge regarding human factors and crew selection.
- The research design requires the distribution of a self-administered survey to all flight deck crew employed at the company. Thereafter, using a statistical technique called exploratory factor analysis, I hope to determine the underlying core factors responsible for the variation in flight crew perceptions, attitudes and behaviour.
- As part of the ethical considerations in the completion of this dissertation, it is required that I obtain permission from the company to disseminate all results, conclusions, recommendations, etc. into the public domain.
- All research will be used for academic purposes only, and all respondents will be kept totally anonymous.
- I thank you for your time and consideration. A response regarding this matter will be greatly appreciated.

Kind regards,

Preven Naidoo.

Tel.: 084 701 7794

Flight Ops Box number: 33F

APPENDIX B: Permission from the Royal Aeronautical Society

ROYAL
AIR FORCE

Wg Cdr Matthew E Lewis MSc MD DAvMed RAF
RAF Centre of Aviation Medicine

RAF Henlow
Bedfordshire
SG16 6DN
Tel: 01462 851515 Ext 8035
Mil: 95381 8035
Fax: 01462 857688
Email: hlw-cam-aioc@henlow.raf.mod.uk

Mr. P. Naidoo
The University of Pretoria
South Africa

Reference: CAM/181/AI
Date: 26 Mar 08

Dear Mr Naidoo,

Re: **Permission to use published material from the RAF archive for research purposes.**

- The Royal Air Force Centre for Aviation Medicine has no objection for the use of its published paper entitled:

  'Pilot Attitudes to Flight Deck Automation' published in **Human Factors on Advanced Flight Decks: Proceedings of a One Day Conference, 14 March 1991** (Royal Aeronautical Society, London).

- This permission is granted subject to the reasonable acknowledgement of the source in the dissertation.

Kindest regards.

Matt Lewis

Wg Cdr Matthew Lewis
OC Human Factors and Biomechanics Section

APPENDIX C: Covering Letter

University of Pretoria
Pretoria 0002 Republic of South Africa Tel (012)4204111

http://www.up.ac.za

Faculty of Economic and Management Sciences
DEPARTMENT OF HUMAN RESOURCES MANAGEMENT
TELEPHONE: 420-3074

Dear Sir/Madam

You are invited to participate in a study on **the perceptions and experiences of pilots operating advanced automated aircraft**. This study is being conducted by the Unit of Aviation Management at the University of Pretoria.

The purpose of the study is to explore the concepts of advanced automation, aircraft computerisation and their impact on human operators. The information obtained from this research project will add to the body of knowledge of human factors and automation, as well as the structuring of training programmes related to automation.

Procedures: If you agree to participate in this study, we request you to complete the attached survey. In the survey we will ask you about your opinions and experiences of operating glass-cockpit aircraft. The questionnaire has been designed to take as little of your valuable time as possible (in most cases all you have to do is to tick the answer you prefer). It should not take more than 30 minutes to complete the questionnaire.

Confidentiality: Please be assured that your responses will be treated as strictly confidential. Numerical codes will be used instead of names to prevent any possible identification of the answers with you. Participation in this study is voluntary, but the chief pilot of your company strongly encourages you to take part in the study, and the chief pilot endorses this study.

IT IS VERY IMPORTANT THAT YOU PARTICPATE IN THIS STUDY SO THAT THE SURVEY CAN BE FULLY REPRESENTATIVE AND THAT THE FINDINGS WILL BE VALID.

Ethical considerations: If you participate in this survey, it means that you give permission for any data gathered in the survey to be used for academic research purposes. The main risk associated with the questionnaire is that you might feel uncomfortable about answering some of the questions that are a little more personal.

The overall results will be published in scientific journals and might be used in the development of applicable training programmes. Your company will not be associated with any research reports or publications that use the results of the questionnaires.

We would greatly appreciate it if you will complete the survey within two weeks and return it to Box 37A in the flight operations passage.

Thank you for your cooperation.

Yours sincerely

Prof. Leo Vermeulen
HEAD: DEPARTMENT OF HUMAN RESOURCES MANAGEMENT
UNIT OF AVIATION MANAGEMENT
Telephone: 012 420 3074

If you have any questions about the study, you can contact
Preven Naidoo
Box 33F
Cell: 084 701 7794
preven.naidoo@hotmail.com

APPENDIX D: Questionnaire

AUTOMATION ATTITUDE QUESTIONNAIRE (AAQ)

The following questionnaire has been constructed to survey the perceptions and experiences of pilots operating advanced automated aircraft. Your cooperation in completing the questionnaire is a valuable input to the overall success of the study.

1. The questionnaire contains a number of questions/statements where you are requested to express your opinion and experiences of glass-cockpit aircraft.
2. No person will or can be identified and you may freely express your opinions.
3. Answer each question/statement as honestly as possible and **do not omit any**.
4. By completing the questionnaire, you give your consent to take part in this research.
5. Participation is voluntary.
5. Data gathered will be confidential and only the researcher(s) involved in the project has (have) access to the data.
6. The researcher(s) can be approached in order to clarify any issue, should doubts arise.

Instructions

Read each statement and choose the one number that best expresses your view. There are no right or wrong answers. It is your *frank, expressed* view which is important. Often the first answer that comes to mind is the best. Use the following scale markers:

KEY:

1	2	3	4	5	6	7

STRONGLY AGREE **STRONGLY DISAGREE**

Thank you in advance for your time and being prepared to participate in the survey.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Automation Attitude Questionnaire (AAQ)

SECTION I

Biographical Data

Please indicate the appropriate answer with a cross (X)

1. Gender:

Male	1	Female	2

2. Age:

	Years

3. Highest Educational Qualification:

High School	1	Diploma	2	Bachelor's Degree	3
Post Graduate Degree	4				

4. If you have tertiary education, please state your major field/s of study:

	N/A

5. Indicate your total level of experience as a pilot: ___________ years.

6. Indicate your total flying time: __________________ hours.

7. Indicate your total flying time in modern digital flight decks: __________________ hours.

8. Which of the following best describes your primary status and function at the company:

Dedicated In-Flight Relief Pilot	1	Co-Pilot (Short Range)	2	Co-Pilot (Long Range)	3
Co-Pilot and PI (Short Range)	4	Co-Pilot and PI (Long Range)	5	Captain (Short Range)	6
Captain (Long Range)	7	Training Captain (Short Range)	8		
Training Captain (Long Range)	9	Other:	10		

9. Indicate an aircraft manufacturer type that you currently operate:

Boeing	Airbus	Other/Specify
1	2	3

10. What is your current level of computer literacy?

Poor	Average	Above average	Excellent
1	2	3	4

11. Indicate where you received initial (*ab initio*) flying training:

Military	Cadet	Self-sponsored (part-time)	Self-sponsored (full-time)
1	2	3	4

SECTION II

Please complete this section if you have any experience operating in a 'glass-cockpit' environment. The questions refer to the aircraft you operated on your most recent flight.

On a scale from 1 to 7, please cross a number corresponding to whether you strongly agree or strongly disagree with the preceding statement.

KEY:

1	2	3	4	5	6	7

STRONGLY AGREE **STRONGLY DISAGREE**

1. **Pilots who fly advanced automated aircraft have enhanced flying skills.**

1	2	3	4	5	6	7

2. **Younger pilots are better able to cope with advanced automated aircraft.**

1	2	3	4	5	6	7

3. **Extensive flying experience (hours) is an advantage in coping with automated aircraft.**

1	2	3	4	5	6	7

4. **More automation is required on advanced flight decks.**

1	2	3	4	5	6	7

5. **I believe that pilots who fly automated aircraft rely too much on the automation system.**

1	2	3	4	5	6	7

6. **Highly advanced automated aircraft definitely require a minimum of two crew.**

1	2	3	4	5	6	7

7. **If/when there are more than two crew members I feel more confident working in an automated aircraft.**

1	2	3	4	5	6	7

KEY:

1	2	3	4	5	6	7

STRONGLY AGREE **STRONGLY DISAGREE**

8. Pilots flying automated aircraft are the ‘controllers’ and not just ‘monitors’.

1	2	3	4	5	6	7

9. I enjoy flying advanced automated aircraft.

1	2	3	4	5	6	7

10. In general, advanced automation on the flight deck is an extremely good thing.

1	2	3	4	5	6	7

11. Generally the automated flight deck is poorly thought out and poorly designed.

1	2	3	4	5	6	7

12. The electronic displays (EFIS) is more difficult to read than traditional flight instruments.

1	2	3	4	5	6	7

13. The displays in my aircraft make very poor use of colour.

1	2	3	4	5	6	7

14. I’m extremely unhappy with the set-up of the displays in my aircraft.

1	2	3	4	5	6	7

15. I feel that there’s no real difference between traditional aircraft and ‘glass-cockpit’ aircraft when it comes to me being ‘in the loop’.

1	2	3	4	5	6	7

KEY:

1	2	3	4	5	6	7

STRONGLY AGREE **STRONGLY DISAGREE**

16. **I find that the aircraft automatics are extremely unreliable.**

1	2	3	4	5	6	7

17. **The level of reliability and redundancy of the automatics is insufficient to conduct extended range operations.**

1	2	3	4	5	6	7

18. **If the automatics fail, it is very noticeable.**

1	2	3	4	5	6	7

19. **If the automatics fail, generally I don’t understand why.**

1	2	3	4	5	6	7

20. **If the automatics fail, I understand the nature of the failure almost immediately.**

1	2	3	4	5	6	7

21. **If the automatics fail, most of the time I don’t try to restore the system.**

1	2	3	4	5	6	7

22. **In the event of automation failure, the transition to manual flight is extremely difficult.**

1	2	3	4	5	6	7

23. **In the event of a partial system failure, it is never obvious which part of the automatic system remains serviceable.**

KEY:

1	2	3	4	5	6	7

KEY:

1	2	3	4	5	6	7

STRONGLY AGREE **STRONGLY DISAGREE**

24. **After failure of the automatics, I find it extremely difficult to hand fly this aircraft.**

1	2	3	4	5	6	7

25. **I am always making keying-in errors.**

1	2	3	4	5	6	7

26. **Once I've made a keying-in error, I never notice it immediately.**

1	2	3	4	5	6	7

27. **After a long leave, I usually forget how to programme the FMS.**

1	2	3	4	5	6	7

28. **The procedures used for programming the FMS, make errors inevitable.**

1	2	3	4	5	6	7

29. **Programming this aircraft's FMS is difficult.**

1	2	3	4	5	6	7

30. **Programming this aircraft's FMS is time consuming.**

1	2	3	4	5	6	7

31. **I find myself frequently manipulating the automatics by deliberately keying-in spurious data, to get the aircraft to do what I want it to.**

1	2	3	4	5	6	7

KEY:

1	2	3	4	5	6	7

STRONGLY AGREE **STRONGLY DISAGREE**

32. When my inputs are not accepted by the computer, I usually don't know why.

1	2	3	4	5	6	7

33. Even after an input produces an error message, I always repeat the procedure.

1	2	3	4	5	6	7

34. I don't use all the modes and features of this aircraft's automatic system.

1	2	3	4	5	6	7

35. I find myself struggling to understand or remember all the modes and features of this aircraft's automatic system.

1	2	3	4	5	6	7

36. I am often surprised by the aircraft's response to my FMS inputs.

1	2	3	4	5	6	7

37. I feel that the amount of feedback I get from the automatics is excessive.

1	2	3	4	5	6	7

38. I'm often confused about why the aircraft's automatics respond in the way it does.

1	2	3	4	5	6	7

39. Even after receiving adequate feedback from the system, I still won't correct my fault.

1	2	3	4	5	6	7

KEY:

1	2	3	4	5	6	7

STRONGLY AGREE **STRONGLY DISAGREE**

40. I often tend to question the output from the automation system.

1	2	3	4	5	6	7

41. I find myself trying to guess what this aircraft is going to do next.

1	2	3	4	5	6	7

42. The feedback I get in response to my inputs is usually too slow.

1	2	3	4	5	6	7

43. I'm of the opinion that the system generally displays incorrect information.

1	2	3	4	5	6	7

44. I will frequently disregard displayed information.

1	2	3	4	5	6	7

45. The information that this aircraft gives me is generally inappropriate for the task at hand.

1	2	3	4	5	6	7

46. The quantity of information that this aircraft displays is excessive.

1	2	3	4	5	6	7

47. My company strongly discourages me from dispensing with the automatics for an extended period of time.

1	2	3	4	5	6	7

KEY:

1	2	3	4	5	6	7

STRONGLY AGREE **STRONGLY DISAGREE**

48. I've found that my handling skills have slowly deteriorated over time due to the use of automation.

1	2	3	4	5	6	7

49. It is necessary to hand-fly part of every trip to keep my flying skills up.

1	2	3	4	5	6	7

50. I don't trust the system, therefore I find it necessary to always keep a mental picture of the real world, rather than relying on the aircrafts navigational display.

1	2	3	4	5	6	7

51. The automation is usually a distraction for me, preventing me from concentrating on important problems.

1	2	3	4	5	6	7

52. I feel that an individual who participates in general aviation during his or her spare time, will make better pilots.

1	2	3	4	5	6	7

53. My overall airmanship skills have been drastically reduced by automation.

1	2	3	4	5	6	7

54. I think that there should have been a lot more classroom training for the conversion onto this aeroplane.

1	2	3	4	5	6	7

KEY:

1	2	3	4	5	6	7

STRONGLY AGREE **STRONGLY DISAGREE**

55. **The computer based-training was insufficient for me to fully understand this aircraft.**

1	2	3	4	5	6	7

56. **I think that there should be more simulator training for the conversion onto this aircraft.**

1	2	3	4	5	6	7

57. **I feel that a lot more hours can be devoted to route training on this aircraft.**

1	2	3	4	5	6	7

58. **There is insufficient recurrent training on this aircraft.**

1	2	3	4	5	6	7

59. **The training I received was inappropriate to line operations.**

1	2	3	4	5	6	7

60. **My transition onto this aircraft was extremely difficult.**

1	2	3	4	5	6	7

61. **If the other crew member had become incapacitated during my first flight, I don't think that I would have been able to cope.**

1	2	3	4	5	6	7

KEY:

1	2	3	4	5	6	7

STRONGLY AGREE STRONGLY DISAGREE

62. Automation makes it very difficult for just one crew member to manage the flight during incapacitation.

1	2	3	4	5	6	7

63. Automation greatly decreases the quantity of crew communication.

1	2	3	4	5	6	7

64. Automation impedes crew co-ordination.

1	2	3	4	5	6	7

65. It is not important to follow the other crew member's inputs and selections.

1	2	3	4	5	6	7

66. It is usually impossible to follow the other crew member's inputs and selections.

1	2	3	4	5	6	7

67. I'm often frustrated by the other crew member's inputs and selections into the automation system.

1	2	3	4	5	6	7

68. The operation of this aircraft requires extremely good crew co-ordination.

1	2	3	4	5	6	7

69. I've noticed that there is much more 'heads-down' time in this cockpit.

1	2	3	4	5	6	7

KEY:

1	2	3	4	5	6	7

STRONGLY AGREE **STRONGLY DISAGREE**

70. **The procedures used to operate this aircraft don't suit it at all.**

1	2	3	4	5	6	7

71. **It is very difficult for the crew to maintain a good look out when flying this aircraft.**

1	2	3	4	5	6	7

72. **In the event of a flight plan change, the 'heads-down' time required is much more than conventional non-automated aircraft.**

1	2	3	4	5	6	7

73. **The automation actually increases workload during critical phases of flight.**

1	2	3	4	5	6	7

74. **In general the overall workload on this flight deck is much more than on non-automated aircraft.**

1	2	3	4	5	6	7

75. **The automation system greatly decreases my confidence as a pilot.**

1	2	3	4	5	6	7

76. **I feel constrained by the automation on my aircraft.**

1	2	3	4	5	6	7

77. **The aircraft is always ahead of me.**

1	2	3	4	5	6	7

KEY:

1	2	3	4	5	6	7

STRONGLY AGREE **STRONGLY DISAGREE**

78. I feel detached from the aircraft.

1	2	3	4	5	6	7

79. I feel exposed to risk by the automation.

1	2	3	4	5	6	7

80. Whenever I fly this aircraft, I feel a lot more stress then when I flew traditional aircraft.

1	2	3	4	5	6	7

81. The aircraft doesn't need me.

1	2	3	4	5	6	7

82. In marginal weather it's always better to disconnect the autopilot.

1	2	3	4	5	6	7

83. On average I tend to disconnect the auto-flight system by more than 10 nm from destination.

1	2	3	4	5	6	7

84. I prefer manual visual approaches.

1	2	3	4	5	6	7

85. The automation on this aircraft induces fatigue.

1	2	3	4	5	6	7

Please list the various aircraft types (e.g. 737-200, 737-800, A319, etc) which you have flown in your current airline.

Please include any comment(s) you may have regarding the operation of glass-cockpit aircraft (either positive or negative).

Thank you for taking the time to complete this questionnaire. Your participation is greatly appreciated.

APPENDIX E: Sample t-test

One sample t-test: Comparison of the percentage of negative versus the percentage of positive responses on the items of the AAQ (n = 262).				
AAQ Factors	**Percentage of sample**		**Test statistics**	
Factor 1: Comprehension	**% Low to extremely negative**	**% High to extremely Positive**	**t-value**	**p-value**
Q38. I'm often confused about why the aircraft's automatics respond in the way it does.	6.1	90.8	27.333	0.001
Q36. I am often surprised by the aircraft's response to my FMS inputs.	5.7	89.3	27.004	0.001
Q40. I often tend to question the output from the automation system.	11.8	80.5	16.558	0.001
Q41. I find myself trying to guess what this aircraft is going to do next.	11.1	86.3	19.045	0.001
Q23 In the event of a partial system failure, it is never obvious which part of the automatic system has failed.	24.0	69.8	8.687	0.001
Q37 I feel that the amount of feedback I get from the automatics is excessive.	2.7	92.0	37.377	0.001
Q42 The feedback I get in response to my inputs is usually too slow.	12.6	80.9	16.151	0.001
Q39 Even after receiving adequate feedback from the system, I still won't correct my fault.	3.1	95.4	40.955	0.001

Factor 2: Training	**% Low to extremely negative**	**% High to extremely Positive**	**t-value**	**p-value**
Q56. I think that there should be more simulator training for the conversion onto this aircraft.	12.2	79.4	15.961	0.001
Q55. The computer based-training was insufficient for me to fully understand this aircraft.	35.9	55.7	3.423	0.001
Q57. I feel that a lot more hours can be devoted to route training on this aircraft.	8.8	87.0	21.504	0.001
Q54. I think that there should have been a lot more classroom training for the conversion onto this aircraft.	16.0	78.6	13.162	0.001
Q58. There is insufficient recurrent training on this aircraft.	12.2	80.2	16.200	0.001
Q59. The training I received was inappropriate to line operations.	6.5	2.0	27.461	0.001
Q60. My transition onto this aircraft was extremely difficult.	13.4	82.1	16.000	0.001

Factor 3: Trust	**% Low to extremely negative**	**% High to extremely Positive**	**t-value**	**p-value**
Q78. I feel detached from the aircraft.	5.0	93.9	32.283	0.001
Q79. I feel exposed to risk by the automation.	4.6	92.4	31.849	0.001
Q77. The aircraft is always ahead of me.	1.1	98.5	72.422	0.001
Q80. Whenever I fly this aircraft, I feel a lot more stress then when I flew traditional aircraft.	3.1	96.2	42.413	0.001

Q75. The automation system greatly decreases my confidence as a pilot.	8.0	86.6	22.208	0.001
Q64. Automation impedes crew co-ordination.	2.3	94.3	43.060	0.001
Factor 4: Workload	**% Low to extremely negative**	**% High to extremely Positive**	**t-value**	**p-value**
Q73. The automation actually increases workload during critical phases of flight.	19.8	73.3	10.785	0.001
Q72. In the event of a flight plan change, the ‘heads-down’ time required is much more than in traditional flight decks.	31.7	62.6	5.433	0.001
Q69. I've noticed that there is much more ‘heads-down’ time in this cockpit.	59.2	30.5	-5.147	0.001
Q71. It is very difficult for the crew to maintain a good look out when flying this aircraft.	9.9	84.7	19.475	0.001
Q74. In general the overall workload on this flight deck is much more than on non-automated aircraft.	4.6	91.2	30.732	0.001
Q70. The procedures used to operate this aircraft don't suit it at all.	3.4	93.1	36.254	0.001
Factor 5: Design	**% Low to extremely negative**	**High to extremely Positive**	**t-value**	**p-value**
Q16. I find that the aircraft automatics are extremely unreliable.	3.4	95.0	38.944	0.001
Q13. The displays in my aircraft make very poor use of colour.	5.3	91.6	29.499	0.001

Q17. The level of reliability and redundancy of the automatics is insufficient to conduct extended range operations.	4.6	94.7	34.261	0.001
Q14. I'm extremely unhappy with the set-up of the displays in my aircraft.	6.9	91.2	26.234	0.001
Q21. If the automatics fail, most of the time I don't try to restore the system.	5.3	92.0	29.831	0.001