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Overcoming bottlenecks with the implementation of new technologies
African aviation safety system

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Executive summary

Currently, the majority of technical assistance projects in Africa involve the transfer of knowledge and technology from a donor institution to a receiving institution. Unfortunately, there are many examples of past cooperation projects that have only partly succeeded and even more examples that have failed.

Trying to maximize the effectiveness and efficiency of technical assistance to-, and cooperation with African States, this research tries to identify problems that can be expected when transferring and implementing technologies from western, developed countries to developing countries by means of technical assistance and cooperation.

Trough a study on past attempts to implement the Reduced Vertical Separation Minimum (RVSM) and a prospective study on a possible implementation of Automatic Dependent Surveillance Broadcast (ADS-B) in Africa, the aim is to identify the obstacles to an effective introduction of new technologies into the African aviation system. These case studies are complemented by numerous interviews with people from both within as well as outside the African aviation sector. A final data collection tool that is used in this research is an online survey distributed among specific parts of the worldwide aviation expert community. Finally, this research attempts to link existing scientific theories about innovation and technology transfer with daily practice. New insights may be drawn from this linkage aiming to facilitate the introduction of new technologies into the African aviation system.

The results from this study indicate that there are many areas in the field of technical assistance and cooperation that are eligible for improvement. One of the most important conclusions that results from this research is that even before implementation planning for new technologies is undertaken, basic and essential problems should be solved with priority. It is only when the basics are in place that one can embark on the implementation of advanced technologies.

Furthermore, the creation of a twinning program (based on the principle of city twinning) should be considered, establishing co-operative and durable links between European and African Civil Aviation Authorities. Through such a system of small scale and pragmatic cooperative agreements between European and African Civil Aviation Authorities at an operational level, Europe would have a lot to offer to many African States. Long term cooperation/ twinning would enable to go beyond the limited benefits that result from the current practice of mainly using consultancy services to address a specific ad-hoc safety challenge.

Finally, from the discrepancy between causes for accidents in Tanzania and the benefits that may be derived from ADS-B it can be concluded that ADS-B is not the answer to many of today's problems (causes for incidents and accidents). ADS-B should thus not receive priority over other measures such as improvement of maintenance schedules, pilot capability and capacity and the improvement of ground infrastructure such as runways and taxi tracks. However, with the expected growth in air traffic, ADS-B may become increasingly important in coping with the problems that may arise as the African skies become increasingly congested.

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List of abbreviations

ACAS	Airborne Collision Avoidance System
ADS-B	Automatic Dependent Surveillance Broadcast
AFI	Africa and Indian Ocean
AIC	Aeronautical Information Circular
AIP	Aeronautical Information Publications
ANC	Air Navigation Commission
APIRG	AFI Planning and Implementation Regional Group
ARMA	AFI RVSM Monitoring Agency
ASECNA	Agency for Air navigation Safety in Africa & Madagascar
ASN	Air Safety Network
ASTRA	Australian Strategic Air Traffic Management Group
ATAG	Air Transport Action Group
ATC	Air Traffic Control
ATM	Air Traffic Management
ATM	Air Traffic Management
ATNS	Air Traffic and Navigation Services Company
ATS	Air Traffic Services
CAA	Civil Aviation Authority
CASA	Australian Civil Aviation Safety Authority
CAST	Commercial Aviation Safety Team
CBA	Cost Benefit Analysis
CFIT	Controlled Flight Into Terrain
CNS	Communication, Navigation, Surveillance
COSTECH	Commission for Science and Technology
CRA	Collision Risk Assessment
DGCA	Director General Civil Aviation
DGTL	Directorate General of Civil Aviation & Freight Transport
DME	Distance Measurement Equipment
EASTO	European Aviation Safety Training Organisation
ES	Extended Squitter
ESAF	Eastern and Southern African
EU	European Union
FDI	Foreign Direct Investment
FHA	Functional Hazard Analysis
FIR	Flight Information Region
FIS-B	Flight Information Service - Broadcast
FL	Flight Level
FMS	Flight Management System
GDP	Gross Domestic Product
GPWS	Ground Proximity Warning System
HF	High Frequency
IATA	International Air Transport Association
ICAO	International Civil Aviation Organisation
ICT	Information and Communication Technology
IFALPA	International Federation of Air Line Pilots' Associations
IFBP	In-Flight Broadcast Procedure
IFR	Instrument Flight Rules
IVW	Transport and Water Management Inspectorate
JAA	Joint Aviation Authorities
KLM	Royal Dutch Airlines
M.Sc.	Master of Science
MTBF	Mean Time Between Failure

NDB	Non Directional Beacon
NLR	National Aerospace Laboratory
NOTAM	Notice To Airman
NSP	National Safety Plan
NSPVP	National Safety Plan Validation Panel
PISC	Pre-implementation Safety Case
RNAV	Area Navigation
RNP	Required Navigation Performance
RTCA	Radio Technical Commission for Aeronautics
RVSM	Reduced Vertical Separation Minimum
SMS	Safety Management System
SSR	Secondary Surveillance Radar
TAA	Tanzania Airport Authority
TANESCO	Tanzania Electric Supply Company Ltd.
$TanT^2$	Tanzania Transportation Technology Transfer Centre
TCAA	Tanzania Civil aviation Authority
TCAS	Traffic Collision Avoidance System
TDOA	Time Difference Of Arrival
TF	Task Force
THIO	Technoware, Humanware, Infoware, Orgaware
TIS-B	Traffic Information Service - Broadcast
TLS	Target Level of Safety
TTCL	Tanzania Telecommunications Company Ltd.
UAT	Universal Access Transceiver
US	United States
USOAP	Universal Safety Oversight Audit Programme
VDL-4	VHF Data Link 4
VHF	Very High Frequency
VOR	VHF Omni-directional Range
WTO	World Tourism Organization
WTO	World Trade Organization

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Hans van Dijkhuizen

Chapter 1 Introduction

Safe and reliable air transport is vital to the strengthening of many African economies. While national surface transport is the prime mode of transport in African economies, national and international air transportation play an important role and is considered an indispensable complement to other modes of transport. This applies in particular to those parts of the African continent where surface transportation is unreliable due to i.e. seasonal weather elements, lack of maintenance and security issues. In spite of its importance, most of the African air transport sector remains saddled with major problems, which are no longer a (major) concern in other regions of the world. Problems encountered in Africa may also have a detrimental effect of aviation safety outside the African continent and may jeopardize the safety of foreign aircraft operating within African airspace.

In its 2005 Civil Aviation Safety Agenda, the Dutch government acknowledges that it has an interest in ensuring that destinations flown to by Dutch airlines are sufficiently safe, especially when the level of flight safety is not as high as in western countries. Through its Aviassist program, the Netherlands Directorate General of Civil Aviation & Freight Transport provides technical assistance to aviation authorities in developing countries. The objective of these projects is to help keep aviation safety in line with the minimum standard as defined by the International Civil Aviation Organisation.

For this research the author was attached to DGTL/ Aviassist for a period of eight months to study the obstacles to the introduction of new safety related technologies into the African Air Traffic Management (ATM) system. The research has been carried out as a thesis project for the M.Sc. programme in Technology, Innovation and Policy for Developing Economies at the Eindhoven University of Technology in the Netherlands. Ultimately, the aim was to develop a deeper understanding of the bottlenecks for introducing new technologies and technical standards into the African Air Traffic Management system.

Substandard levels of safety

As will be shown in later parts of this report, in some areas of Africa the current level of flight safety does not comply with the requirements and standards of the International Civil Aviation Organization (ICAO). Across the whole continent there are areas with substandard levels of flight safety. The quality of Air Traffic Services (ATS) is often below global standards. Basic and essential services like Very High Frequency (VHF) coverage are not guaranteed and communication is sometimes impossible. Aircraft may even cross entire Flight Information Regions (FIR's) without any radio contact with Air Traffic Control (ATC). En-route surveillance with Secondary Surveillance Radar (SSR) is limited at best, and non-existent over many parts of the continent. There are many other problems with e.g. obsolete or unserviceable equipment and lowly motivated and poorly trained staff.

As a stopgap solution to some of the problems the International Air Transport Association (IATA) prescribes the use of In Flight Broadcasting Procedures (IFBP) in the African and Indian Ocean (AFI) region. These and other measures, like the use of the Airborne Collision Avoidance System (ACAS) and airline procedures have so far prevented the shortcomings of the African Air Traffic Management system from causing major accidents (involving European Airlines).

However, with the ever increasing complexity of new equipment and forecast growth of air traffic, the non-compliance with international requirements and standards is a situation that can no longer continue. Furthermore, a situation where special (company) arrangements and measures are needed to guarantee flight safety is not desirable.

Assistance and cooperation

There is a growing awareness in the international aviation community that technical assistance to aviation authorities in developing countries is an important part of the way forward. Based on pragmatic considerations, this cooperation and assistance may help in maintaining and improving a minimum level of flight safety. Several important documents acknowledge this need for technical assistance/ cooperation and provide a solid basis for coordinated action by the European Union (EU) Civil Aviation Authorities (CAA's).

First, on the basis of the 1947 Chicago convention and its annexes, each sovereign contracting State is responsible for ensuring adequate civil aviation safety in- and over its territory. Today, it is however acknowledged that some States may not have the legal framework, institutional set-up, financial resources or technical capabilities to comply with the minimum requirements contained in the convention (African Development Fund, 2004).

Second, it was concluded at the ICAO Directors General for Civil Aviation (DGCA) Conference on a Global Strategy for Aviation Safety in March 2006, that 'safety is a shared responsibility, and advances in global safety can only be possible through (…) cooperative, collaborative and coordinated effort among all stakeholders' and that 'further improvements in aviation safety within and among States require a cooperative and proactive approach in which safety risks are identified and managed' (ICAO, 2006d).

In addition to the conclusions of the ICAO 2006 Directors General for Civil Aviation Conference on a Global Strategy for Aviation Safety , the EU Communication 390 (2001) on a European Community contribution to World Aviation Safety Improvement provides a solid basis for coordinated action by the EU Civil Aviation Authorities. This communication defined the means to address the aviation safety problems from a EU point of view by further development of technical assistance to States to fulfil their ICAO/ Convention obligations (European Commission, 2006).

Finally, in the 2005 civil aviation safety policy agenda the Dutch government acknowledges that it has an interest in assuring that destinations flown to by Dutch airlines are sufficiently safe, especially when the level of flight safety is not as high as in western countries (Beleidsagenda Luchtvaartveiligheid, 2005).

Summarizing; the ICAO Directors General for Civil Aviation conference on a global strategy for aviation safety, the EU Communication 390 on a European Community contribution to World Aviation Safety Improvement as well as the Netherlands 2005 policy agenda concerning civil aviation safety acknowledge the inability of some countries to assure a minimum level of flight safety and confirm the importance of strengthening international technical cooperation for the further improvement of aviation safety. The question now remains how to maximize the effectiveness and efficiency of such air safety technical co-operation.

Focus of the research project

Currently, the majority of technical assistance projects involve the transfer of knowledge and technology from a donor institution to a receiving institution. Unfortunately, there are many examples of past cooperation projects that have only partly succeeded and even more examples that have failed. In most cases, it is hard to nail down the exact causes for the failure of the projects, but the lack of understanding of the characteristic features of the technology and its relations with the operational environment may well have played an important role.

Trying to maximize the effectiveness and efficiency of technical assistance and cooperation, this research tries to identify problems that can be expected when transferring and implementing technologies from western, developed countries to developing countries by means of technical cooperation. Based on the identification of problems and bottlenecks, a number of recommendations will be given allowing for more efficient and effective assistance and cooperation between countries.

This research studies the current process of implementing the Reduced Vertical Separation Minimum (RVSM) in Africa. Next, it looks at the chances and threats for a possible future introduction of Automatic Dependent Surveillance Broadcast (ADS-B) in Africa. Based on a review of the scientific literature, an analysis of past attempts to implement RVSM and a prospective study on ADS-B, the aim is to identify the obstacles to an effective introduction of new technologies (like RVSM, ADS-B and many others) into the African ATM system. Finally, this research attempts to link existing scientific theories about innovation and technology transfer with daily practice. New insights may be drawn from this linkage aiming to facilitate the introduction of new technologies into the African ATM system.

Chapter 2 Problem definition

2.1 Problem definition

The ICAO DGCA conference on a global strategy for aviation safety, the EU communication (2001) 390 on a European Community contribution to World Aviation Safety Improvement as well as the Netherlands 2005 policy agenda concerning civil aviation safety acknowledge the inability of some countries to assure a minimum level of flight safety and confirm the (increasing) importance of international technical cooperation for the further improvement of aviation safety. Unfortunately, there are many examples of past cooperation projects that have only partly succeeded and even more examples that have failed. The question now remains how to maximize the effectiveness and efficiency of such air safety technical co-operation.

2.2 Research questions

This research has two main goals:

1. Develop a deeper understanding of the bottlenecks for introducing new technologies and technical standards into the African ATM system.
2. Develop recommendations for more adequate and efficient (technical) assistance and cooperation projects, aimed to facilitate the introduction of new technologies and technical standards into the African ATM system.

2.3 Research goals

The research will focus on one central research question which can be divided into five sub-questions:

General Research question
Keeping in mind the lessons learned from theory and practice, how may new technologies be implemented more adequately & efficiently into the African ATM system?

Sub-question 1
What are currently the most important bottlenecks for introducing new technologies and technical standards into the African ATM system?

Sub-question 2
What are the underlying causes for the bottlenecks that prevent an efficient introduction of new technologies and standards into the African ATM system?

Sub-question 3
How may future technologies and technical standards be implemented more adequately and efficiently into the African ATM system?

Sub-question 4
A What problems are likely to arise when it is decided to implement ADS-B in the AFI region in the near future?
B How can these problems be alleviated allowing for a more efficient introduction of ADS-B in the AFI region?

Sub-question 5
How can the effectiveness and efficiency of (technical) assistance and cooperation projects be maximized? All answers should be based on the literature study and the lessons learned from the implementation of RVSM in the AFI region, the case study on ADS-B in Tanzania and the online survey.

Chapter 3 Literature review

An in-depth review of the scientific literature has been performed with the aim to:

1. Identify the key elements that affect the transfer and diffusion of (new) technology and,
2. Identify the key elements that affect the ability of developing countries to generate improved technological capabilities through the transfer of technology and,
3. See how technological capabilities facilitate the transfer of technology.

Topics included in the review are:

- The nature of technology
- Standards
- Technology transfer
- Diffusion of technology
- Technological capabilities
- Technological capability building

The literature review aims to link scientific knowledge with daily practice. The topics discussed in this literature review are not directly related to the issue of implementing new technologies like RVSM and ADS-B in Africa (see appendices 2 and 3 for more information on both technologies). However, general insights derived from academic theory can be valuable for understanding the problems that may arise when implementing specific new technologies in Africa.

Since most new technologies that are implemented in Africa are imported from industrialized countries, it is important for the importing countries to posses the capacity and capabilities to select, absorb, maintain and adapt the technology to the local environment and to facilitate its diffusion of the technology into the aviation industry.

Furthermore, a clear understanding of the relationship between technology transfer, diffusion of technology, technological capabilities, technological capability building and the variables that affect their effectiveness is of significant importance for the success of technical co-operation and assistance programmes.

In this review it is assumed that the indigenous capabilities, the conditions under which the technology is transferred as well as the characteristics of the technology itself influence the transfer and diffusion of the technology into the wider operating environment.

Furthermore, it is assumed that some basic technological capabilities are a prerequisite for successful technology transfer. In turn, this transfer of technology can lead, under certain conditions, to improved technological capabilities. The degree to which the technology transfer contributes to the development of technological capabilities of the receiving country ultimately determines the success of technology transfer.

The fact that this literature review studies technology transfer first before looking at technological capabilities and technological capability building, in no way implies that technology transfer is the only route to- or necessarily precedes the development of improved capabilities.

This chapter starts with an analysis of the role of technology in (economic) development in paragraph 3.1. A definition of technology is given in paragraph 3.2, followed by an in depth literature study on standards (3.3), the technology acquisition process (3.4) and technological capabilities and capability building (3.5). Based on the foregoing, paragraph 3.6 presents a model containing the most essential variables that influence the success of technology transfer and the development of (improved) technological capabilities.

3.1 Role of technology in development

In classical economic theories, economic growth is considered to be determined by two factors; labour and capital.

In the 1950's Robert Solow developed an extension to the Harrod-Domar model, which became known as the Solow growth model. In this model a third factor, technology, is added to the production factors capital and labour. The Solow growth model, which is also known as the Neo-Classical model or Exogenous growth model, takes technology as an exogenous factor by assuming that capital is subject to diminishing returns and growth is determined by technological progress and growth of the labour force. The Neo-classical theory also introduced the notion of total factor input which was the weighted sum of the growth rates of the factor inputs (labour and capital) and the concept of total factor productivity which was the difference between the growth rate of output and that of total factor input. Still, growth of capital could only explain a small part of the labour productivity growth and approximately 90% was due to the advance in total factor productivity which became known as the residual (Abramovitz, 1989). While the Neo Classical model was an improvement to the classical economic thinking, it did however not explain why technological change took place since technology was generally seen as the cause of the residual growth that could not be explained by the growth of factor inputs (Benda, 2005; 19).

This shortcoming in the Solow growth model led to the development of the Endogenous growth or new growth theory, which endogenizes technological change. Various models have been developed by various authors of whom Arrow (1962) tried to endogenise technological change by introducing the concept of learning by doing. Lucas (1988) focussed at technological development through human resources and Romer (1990) tried to endogenise technological change by knowledge accumulation. He suggested that knowledge is a product of investments that firms undertake in order to develop new products and services. The more a county invests in the development of products and services, the more spillover of knowledge it creates. Romer suggested that poor countries stay poor because they lack physical capital, human capital and ideas to generate new knowledge and hence they lack spillover effects. In conclusion, Romer predicts divergence between developed and developing countries and a widening of the knowledge gap between these countries.

On the other side of the spectrum we find Gerschenkron who states that "the opportunities inherent in industrialization may be said to vary directly with the backwardness of the country. Industrialization always seems the more promising the greater the backlog of technological innovations with which the backward country could take over from the more advanced country" (Gerschenkron, 1962; 8). However the theory of Gerschenkron does not hold since the idea- or knowledge gap between e.g. Africa and Europe has widened and there are no signs that Africa is narrowing the gap. This may be explained by the fact that conditions for the catch-up of backward countries and convergence of the knowledge gap should be favourable and sufficient absorptive capacities should be present at the side of the backward countries. In other words, catch-up could only be realized when certain conditions are met.

Abramovitz (1989) concludes with the observation that the opportunity for rapid growth afforded by technological backwardness may be offset by social backwardness. On the other hand Abramovitz states that growth and catch-up themselves can contribute to improving social capabilities in a virtuous circle, which can result in very rapid growth (Szirmai, 2005; 125).

From this brief and by no means exhaustive overview of the role of technology in (economic) development, it becomes clear that there is no consensus on what exactly explains economic growth not attributable to an increase in labour and capital input. Also, the question whether technology provides opportunities for narrowing the gap or that it causes countries to diverge cannot always be answered. It depends a.o. on the size of the technology gap, the absorptive capacity of the technology receiver and numerous other factors. However, it becomes evident from this literature review that all scholars acknowledge the prime importance of technology in socio-economic development.

3.2 What is technology?

Despite the amount of research undertaken, much of the literature aimed at defining the concept of technology remains fragmented. There is still no generally accepted definition of technology. This section examines what different scholars wrote on the subject and defines the concept of technology as it will be used throughout this research.
Kumar et al. (1999; 82) distinguish between two technology components:

- A *physical* component which comprises items such as products, tooling, equipment etc. and,
- An *informational* component which consists of knowledge and know-how in management, production, quality control, skilled labour etc.

Radosevic (1999; 14-17) distinguishes between two types of technological knowledge;

- Technology as *disembodied and codified information*. In this guise technology is seen as information that has been articulated and stored in certain media such as documents and manuals. This type of information (technology) is also referred to as explicit or ‘know-what’ and ‘know-why’ knowledge.
- Technology as *locally specific and embodied knowledge*. The locally specific and embodied knowledge, also referred to as tacit or ‘know-how’ and ‘know-why’ knowledge, cannot be codified but can only be transmitted via training or gained through personal experience (Lundvall and Johnson, 2004).

As Pavitt (1985) and Radosevic (1999) point out, most technical knowledge is tacit, cumulative and embodied within firms. This makes technological knowledge intangible, firm specific and not easily transferable. However, Radosevic states that when technology is only information, it becomes generic and easily transferable and as a result it has the characteristics of a public good.

Van Egmond (2001) makes another distinction and states that ‘’in the context of transformation of resources, technology may be regarded as a combination of both the physical tool and the related know-how either to make or use that tool’’. She decomposes technology into four embodiments that are used as inputs in production processes namely:

- *Technoware*: physical facilities (embodied in objects; machinery, equipment, tools).
- *Humanware*: human abilities (embodied in persons; skills, knowledge which makes it tacit).
- *Infoware*: documented facts (procedures, specifications and evaluations documented in documents such as publications, blue prints, patents etc which makes it codified).
- *Orgaware*: organizational framework (embodied in institutions, management, organizational structures, logistical systems). These four components are also known as the THIO components.

The assumption is that there will always be a minimum of all technology components (THIO) present in any type of technology. Reflecting on what has been written by the different scholars, the definition of technology that will be used in this research is as follows:

Technology: the tools, machines, processes and products that help to solve problems combined with the current State of our tacit and codified knowledge of how to combine resources to produce a desired product, to solve a problem, to fulfil a need or to satisfy a want.

The definition above implies that ADS-B can be seen as product technology with a well defined function, performance and physical appearance. Less obvious but equally interesting however, are the knowledge elements that come with the product technology. The capabilities needed to select, acquire, install, operate, maintain, improve and develop the product technology make use of both tacit and codified knowledge and information concerning the characteristics and performance properties of the product.

3.2.1 Relating theory to practice

When implementing new technologies into the African ATM system, it must be recognized that technology consists of both physical and knowledge components. Usually, the physical components can be acquired off-the-shelf from a number of suppliers without much difficulty.

The crux of the problem when transferring technology, however, is the knowledge component. Although much of the knowledge is articulated in documents, manuals and specifications (and hence quite easy to transfer), a substantial part of the knowledge needed to actually implement and operate the technology is tacit and embodied within the technology suppliers and a relatively small group of experts. This makes the (tacit or embodied) knowledge intangible and not easily transferable. It can only be done via well designed training in which theory is combined with on the job training and through personal experience.

3.3 Standards

The study of technology and technological processes will inevitably be linked to technological standards. Especially in the aviation sector, standards are omnipresent. The study of standards is a relatively young discipline and the literature is not as diverse as the literature on technology transfer or technological capabilities. Nevertheless it has gained a great deal of attention over the last years and promises to become increasingly important. This paragraph introduces and defines the concept of standards and standardization and reviews the literature on the topic.

Today, most standards aim to facilitate technological or economic development. Feng (2003) reviews the standardization literature in which he provides an oversight of the different meanings that standards may have. Blind (2004) discusses the most important theoretical aspects of standards and their economic impact. Combining the works of Feng and Blind, the following standards can be distinguished:

- *Standards as uniformity/ variety reducing standards* aim at uniformity allowing for economies of scale in (mass) production. This type of standards often shapes future technological trajectories by achieving focus and cohesion among pioneering companies.
- *Compatibility and interface standards* ensure compatibility between technologies and aim to foster network externalities (which are benefits that follow from being part of a large network of users)
- *Minimum quality and safety standards* aim to protect third parties from negative externalities, may solve the problem of adverse selection and reduce transaction- and search cost.
- *Standards as objectivity/ information and measurement standards* are the opposite of subjectivity. This type of standard aims to produce comparability of activities over time and place.
- *Performance standards* are closely related to minimum quality standards and require a minimum level of operational performance.
- *Standards as justice. A*pplying the same standard to all people has often been taken as a sign of fairness and has a sense of justice about it.
- *Standards as hegemony*. Rather than being symbols of justice, standards can become symbols of hegemony in which uniformity in society is promoted at the expense of diversity.

The work of Egyedi (1996) and Egyedi and Dahanayake (2003) explores into the types of- and causes for the problems that may arise while implementing standards.

Highly relevant and directly related to the problems encountered with standard implementations, the authors distinguish between consensus decisions and implementation independence decisions. *Consensus decisions* are democratic, consensus-oriented decisions that may prove difficult to implement because of their political compromises and intentional vagueness allowing opposing parties to rally behind it. *Implementation independence* decisions are based on the premise that the standard should not favour any company, firm or market and as a result may as well pose problems with implementability (interoperability).

By contrast, de facto standards are usually defined by a company and often aim at a specific application and are, as a result of this, implementation dependent.

In addition to the consensus- and implementation independence decisions, Egyedi and Dahanayake distinguish between three types of standardization:

– Formal standardization
– Grey standardization
– De facto standardization

Differences between the three types are the degree to which they are consensus based and the degree of implementation independence. Formal standardization being the most implementation independent, de facto standardization being implementation dependent while grey standardization lies in between.

Figure 1 Characteristics of three styles of standardization

Style of stand. / *Aspect in stand.*	*Formal standardization*	*Grey standardization*	*De facto standardization*
Implementation independence	High	Medium	Low

Source: Adapted from Egyedi and Dahanayake, 2003

Furthermore, Egyedi and Dahanayake propose three different states of a standard: a conceptual idea, standard specification and standard implementation. Between these states two translation processes are identified; the standard process and the implementation process. ''If the standard process leads to ambiguous specifications, no matter how well thought-out the implementation process, interoperability problems may still arise. That is, together the two processes determine whether or not standards implementation will be interoperable'' (Egyedi and Dahanayake, 2003).

Figure 2 Different States of a standard

Source: Egyedi and Dahanayake, 2003

Many other scholars among whom Baskin et al (1998), Söderström (2003), Slob and de Vries (2002) and de Vries (1999) look into the roles played by different parties involved in the standardization process. They distinguish between:

- Standard development organizations
- Standard user organizations
- Standard software organizations
- Standard adaptation organizations
- Standard service providers
- Standard researchers

Most effort seems to focus on the creation of standards and almost all of the other roles are discussed in relation to the development of standards (Söderström, 2003; 253). For reasons of relevance with this research topic only the standard development- and user organizations will be discussed in greater detail hereafter.

Standardization is the process by which the form or function of a particular product or process comes to be specified. The specifications that result are called standards.

Some well known examples of standard development organizations are the European Organization for Civil Aviation Equipment (EUROCAE), the Federal Aviation Administration (FAA), the Radio Technical Commission for Aeronautics (RTCA). Probably the best known of all is the International Civil Aviation Organization (ICAO) that develops and issues a.o. the following standards:

- Standards and Recommended Practices (SARP's)
- Procedures for Air Navigation Services (PANS)
- Regional Supplementary Procedures (SUPP's)

In contrast to these formal organizations come industry initiatives and consortia, so called grey standardization organizations like the Airlines Electronic Engineering Committee. At the end of the spectrum individual firms and organizations that develop de facto standards can be found.

Notwithstanding the importance of standard development organizations, standard user organizations like the Radio Technical Commission for Aeronautics (RTCA) are the ones that ultimately decide on the success of a standard - by using it or not using it (Söderström, 2003; 255). This means that user participation in the standards development process is essential for the standards to become a success (Jakobs et al, 1996). 'By involving the user in the development of standards, experience and practical knowledge flow into the standards. Even more important is that their knowledge about using standards can help to make the standards user-friendlier' (Slob and de Vries, 2002; 15).

As can be seen from the literature review and the examples, the topic of standardization holds many relationships with ADS-B and RVSM.

However, the conclusion that can be derived from the review of the standardization literature is that most of the theories on standards and standardization are about the way standards are developed and how they affect economic and technological performance. There is little literature on the problems that may negatively influence the standard implementation process and there is virtually nothing to be found on standardization and its effects on technology transfer and the development of (improved) technological capabilities of developing countries.

Notwithstanding the fact that the topic of standardization is very interesting and increasingly important most of the existing literature on standards has little to do with the focus of this research: problems that may arise when introducing and implementing advanced technologies such as RVSM and ADS-B to lesser developed countries.

To learn more about the implementation process of standards and new technologies, the following paragraphs study the theory on TT, diffusion of technology and TCB.

3.3.1 Relating theory to practice

Because of the dynamic and complex nature of the aviation industry, new technologies are subject to an abundance of standards.

The decisions made by several organizations like ICAO and IATA in favour of the 1090 Extended Squitter (ES) ADS-B data link technology over VHF Data Link mode 4 (VDL-4) and the Universal Access Transceiver (UAT) technology can be seen as a *variety reducing standard*. For more information on the preferred choice of Mode S, see IATA Technical Operations Policy Manual, part B resolutions, 13-01-10 and the ICAO Eleventh Air Navigation Conference held in Montreal, 2003.

Compatibility and interface standards are commonly used to achieve 'form fit' equivalence so that avionics boxes made by different manufacturers can be interchanged between airframes and aircraft types.

Objectivity or information standards as well as measurement standards are needed to monitor the integrity and comparability of data derived from different systems (e.g. onboard transponders).

Finally, the ICAO determined Target Level of Safety (TLS) for the application of RVSM in AFI airspace of 5 x 10-9 fatal accidents per aircraft flight hour due to all causes of risk in the vertical dimension is an example of a *safety standard*.

The choice for a uniform data link technology for carrying the ADS-B signal should preferably be a consensus decision in which all ICAO member States rally behind the choice. However, reality is not so perfect and each State is free to choose their preferred data link (Mode S, VDL-4 or UAT,)

It must also be recognized that many different standards may affect the same technology and there is great need for aligning these standards as this may allow for an effective introduction of the new technology into the African ATM system.

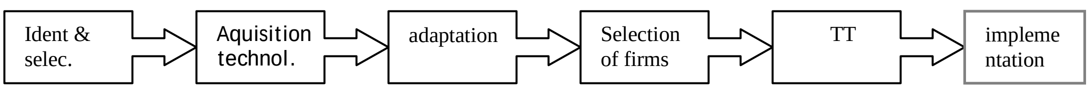
Furthermore, the standards should be unambiguous and free from political compromises and intentional vagueness.

Finally, (African) user participation in the (standards) development process is essential for the success of the technology and users should be involved in the technology implementation process from an early stage on. However, user participation alone is not enough as an example may exemplify. Currently, African user participation does take place in developing standards (e.g. Tanzania in the ICAO Air Navigation Commission (ANC)). Unfortunately, this doesn't necessarily mean that the standards that are developed are appropriate for African circumstances. As the Air Navigation Commission is charged with the development of worldwide (uniform) standards, these standards are not necessarily appropriate for the African environment.

3.4 Technology acquisition process

Bongenaar and Szirmai (1999; 2) present a simplified model that represents the different phases in the technology-development process of an African R&D institute. The model depicts the successive steps in the adaptation and transfer of technology from the R&D institute to industrial organisations.

Figure 3 Phases in the technology-development process



Source: Bongenaar and Szirmai, 1999; 2

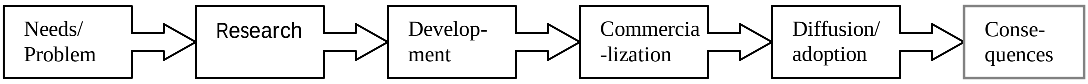
The model in figure 3 shows how an R&D institute may try to influence firms' adoption decisions, and the effectiveness of such efforts. The model mainly looks at the process preceding the actual implementation of the technology acquired by the industrial firm.

However, this research into the bottlenecks for introducing new technologies and standards into the African ATM system pays special attention to the transfer and implementation of new technologies and standards. The way a research institute may influence the decision process of industrial organisations is thus of lesser importance.

Nevertheless, some steps in the technology-development process as described above can be regarded similar to the process of implementing new technologies and standards into the African ATM system, being: identification & selection, technology transfer and implementation.

In his book ''Diffusion of innovations'', Rogers (2003; 136-163) describes the innovation-development process in which he distinguishes the following steps:

Figure 4 Innovation-development process



Source: Rogers 2003; 138

Rogers assumes that the identification of a need and the development of e.g. a product to fulfil that need take place within one and the same organisation.

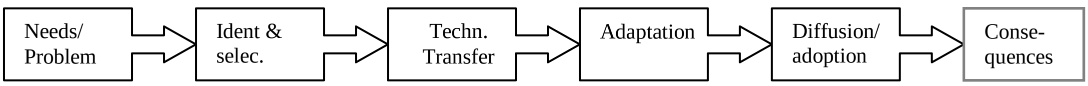
This is, however, not the case with the fulfilment of the need for e.g. enhanced surveillance capacity or an increased level of flight safety. This may particularly be the case for developing countries as they acquire most of their technologies from abroad.

As with the technology-development process developed by Bongenaar and Szirmai, the innovation-development process developed by Rogers is quite different from the process of introducing new technologies into the African ATM system and only parts can be used to describe it. When the development of the need-fulfilment is outsourced, the innovation-development process is reduced to three steps: need/ problem identification, diffusion/ adoption and consequences.

When the models for the technology-development process by Bongenaar and Szirmai and the innovation-development process by Rogers are combined and stripped from the steps that are irrelevant to the acquisition and implementation of technology, it is possible to create a new model that represents the technology-acquisition process.

Figure 5 presents a simplified scheme of the six main steps in the technology acquisition process as seen from the perspective of the technology users (e.g. Air Traffic Control, airlines, general aviation and Civil Aviation Authorities). The scheme shows that technology transfer and -diffusion are part of a larger process through which a new technology goes from the decision to start searching for the solution to a problem or fulfilment of a need to the consequences of the implementation (Rogers, 2003). Ultimately, this process aims to meet the need to comply with international (safety) standards.

Figure 5 Technology acquisition process



The phases are mentioned in a chronological order but this does not necessarily imply the absence of relationships of interdependency between phases not in chronologically order. In the following subparagraphs each step in the technology acquisition process is looked at in closer detail (3.4.1 to 3.4.3).

3.4.1 Step 1 and 2: Identification and selection

The technology acquisition process usually starts with the identification of a need for- or problem with something. For this research, there is a need for an increase in airspace capacity and compliance with worldwide standards (RVSM) or a need for enhanced surveillance capabilities (ADS-B). Usually, it is the user that identifies a need initiates the search for the fulfilment of this need. However, it is also possible for a producer to create a need by introducing a new product that addresses latent needs that customers were not aware of up to the point of introduction of this new product.

Four factors the effectiveness of the identification and selection process:

- *Appropriateness* refers to the technology that meets in most respects the objectives for it and should be appropriate in terms of local resources, quality of the work force, local infrastructure, environmental and geographic conditions etc. (Bongenaar and Szirmai, 1999, van Egmond, 2001).
- *Technological distance* refers to the difference between the level of technological advancedness of a technology supplier and a technology receiver (in both the informational as well as physical components of technology). The larger the distance, the more limited the opportunities for the receiving end to benefit from the newly acquired technology.
- *Adaptability* refers to the ability of organisations to fit changed circumstances as well as for the technology to be adapted to changing needs.
- *Prevailing standard* or the range of standards that a new technology must meet acts as a constraint to the range of choices one has for a new technology.

3.4.2 Step 3: (International) Technology Transfer

As with the literature on the concept of technology, much of the literature on (international) technology transfer is fragmented and there is still no generally accepted paradigm. However, the definition of technology transfer to be used in this research is based on the work of Fransman (1986) and van Egmond (2001; 77).

(International) technology transfer can be defined as the transmission of both physical products and knowledge across borders, between institutions or within the same institution.

Two important aspects of technology transfer that will be looked at in closer detail are:

1. Cost of technology transfer
2. Mode of transfer

Ad 1 Cost of technology transfer

Although a technology importer saves time and money by acquiring the technology from abroad instead of developing the technology itself, the cost of technology transfer can still be considerable.

Van Egmond (2001) distinguishes both direct and indirect costs. Direct or explicit costs include license fees, royalties and technical assistance payments. Indirect costs include those imposed by restrictive clauses for purchasing accessory equipment and those imposed by tie-in clauses for subsequent purchase of (spare) parts or material for continuous operation (Wei, 1995).

Furthermore, costs can be influenced by conditions set by the supplying party, government policy and the importer's bargaining power (which is related to the importer's indigenous technical capabilities). According to van Egmond (2001) conditions set by supplying parties can differ from limited ones to a full and complex set of controls including:

- Restrictive use of the technology

– Markets where the technology may (not) used
– Specific suppliers from which the necessary inputs have to be purchased
– Restrictive use of licenses and know-how

Ad 2 Mode of transfer

The mode by which the technology is transferred is of great importance for the success of the technology acquisition process. The mode of transfer is even more important for the technological capability building that must precede and, the other way around, may result from this transfer. Transfer modes come in many guises but the most well-known are:

– Process package deals (turn-key projects, technical assistance, licensing etc.)
– Project package deals (foreign direct investment, joint ventures and subsidiaries)
– Direct sale (direct transfer of the product or service to the ultimate consumer,)
– Alliances and co-operation
– Contracting and agreements

The advantages and disadvantages of technology transfer for the receiving country are closely related to the specific mode of transfer. To discuss all the pros and cons of each transfer mode will require a study on its own. However, regardless of a specific mode of transfer the most important advantages and disadvantages of technology transfer for the receiving end are displayed in the graph below (van Egmond, 2001):

Advantages of technology transfer:	**Disadvantages of technology transfer:**
-Development of new products and processes	-Dependency on supplier
-Reduction of costs	-No technical capability building
-Development of technical capabilities	-Poor terms and conditions of contracts
-Stimulus for foreign investment	-Burden of foreign debts
-Improvement of industrial base and infrastructure	-Net outflow of capital and profits
-Economic growth and development	

Central to the choice for any particular mode of transfer is the concept of packing and unpacking. Unpacking involves the knocking down of the technology into separate components (van Egmond, 2001). When a technology receiver is capable of unpacking the technology, it can exercise stronger bargaining power since the separate components can be acquired from different suppliers or produced locally. Bongenaar and Szirmai distinguish two aspects of unpacking:

– *Unpacking capabilities* of the technology receiver ‘’involve the capability to understand, divide and combine the technology. Furthermore, an unpacking strategy requires sufficient knowledge of the technology market to source the different elements from suppliers, and the ability to pick the transfer mechanism that is most advantageous, based upon criteria of interest’’ Bongenaar and Szirmai (1991, 5).
– *Unpacking possibilities* of the technology itself are determined by many factors such as age of the technology, embodiedness and level of advancedness.

Unpacking requires notable effort and can be rather time consuming. Most of the technology that can be unpacked involves older, widely studied, publicly available technologies that can be acquired through simple direct transactions. Total costs are, however, usually lower than compared with modes of transfer that involve packaging (Bongenaar and Szirmai (1991).

Once it has been decided to start with implementation of ADS-B in Africa, the specific mode of transfer and the possibilities for unpacking co-determine the success of the technology acquisition and implementation process.

3.4.3 Step 4 and 5: Adaptation, diffusion and consequences

Adaptation, or re-invention, serves the purpose of making the technology more appropriate to local conditions. It can be defined as the degree to which an innovation is changed or modified by a user in the process of its adoption and implementation (Rogers, 2003). Ultimately, adaptation aims to compensate for the differences between the environmental conditions before and after the technology transfer and to achieve a higher degree of sustainability. Therefore, the adaptation process depends on the characteristics of the originating environment as well as on the characteristics of the target environment in which the technology has to function (Bongenaar and Szirmai, 1999; 6). The accuracy of the technology selection process and the appropriateness of the transferred technology determine the degree of adaptation required. The more effort is put in the selection of appropriate technologies, the less effort will be needed in the adaptation phase (Bongenaar, 1997). However, even carefully selected technologies are not always fully appropriate and some degree of adaptation or re-invention may be needed.

Once the technology has been unpacked (if possible), transferred and successfully adapted, it still remains unsure whether the technology will diffuse effectively throughout the technology receiving side (organization, company or society) and develop into a functional system. Wissema and Euser (1988; 55) and Bongenaar and Szirmai (1999; 10) distinguish internal and external problems that may arise during the implementation and diffusion of new technologies.

- *Internal problems* involve resistance to change due to a lack of knowledge about the usefulness and functions of the new technology at lower levels in the organization. Generally, this is caused by incomprehension rather than unwillingness (Bongenaar and Szirmai, 1999; 11).
- *External problems* are the result of changes in the environment such as exchange rate fluctuations, political instability etc.

Apart from the internal- and external problems, several attributes belonging to the innovation or the new technology itself might influence the diffusion process or, more specifically, its rate of adoption. Rogers (2003; 223-259) distinguishes the following attributes that explain about half of the variance in the rate of adoption of innovations:

- *Relative Advantage;* the degree to which an innovation is perceived as being better than the technology it supersedes is called relative advantage and can be expressed in terms of economic profitability, increased efficiency, improved technical performance, social prestige etc.
- *Compatibility.* From a sociological perspective, a new technology can be compatible with socio-cultural values and believes, previously introduced ideas and/ or the need for the innovation. From a technological perspective, new technologies should be compatible and interoperable with existing techniques and processes.
- *Complexity* refers to the degree to which an innovation is perceived as relatively difficult to understand and use.
- *Trialability.* New technologies that can be tried and experimented with are generally adopted more rapidly.
- *Observability* refers to the degree to which the (positive) results of an implementation can be observed by others. It facilitates it is the rate of adoption. This explains why preventive innovations are hard to implement; the result cannot be observed since they are prevented from happening in the first place. In relation to this Rogers (2003; 223) concludes that perceptions count in the innovation diffusion process: ‘’The individuals’ perceptions of the attributes of an innovation, not the attributes as classified objectively by experts, affect its rate of adoption’’.

Note that these five attributes are not requirements for a successful implementation process but their presence or absence could greatly affect the rate at which it gets adopted (Atkinson, 1991).

3.4.4 Relating theory to practice

Transferring a technology like ADS-B from advanced economies to developing countries involves bridging the technological distance between the two. This technological distance mainly affects the ‘’technology transfer’’ phase in the technology acquisition process (see figure 5, paragraph 3.4). This may cause additional problems with the appropriateness of the transferred technology and it should be realized that in many cases it is impossible to make a one-on-one transfer of the technology for use in different environments.

Next to this, the direct cost of acquiring the (physical) technology may be obvious, but the indirect costs may be substantial as well. Because of the limited bargaining power of many developing countries (due to a lack of knowledge, capacity and capabilities) they may not be able to negotiate the best contract terms and the most beneficial mode of transfer. Agreement should be reached on supply of spare-parts, technical assistance, maintenance, training etc. When choosing the mode of transfer its important to make sure that there will not only be a transfer of physical equipment but also a transfer of information, knowledge and capabilities.

Very important but often ignored are internal problems that may arise. Incomprehension and a lack of knowledge with personnel (at lower levels in the organization) about the usefulness and functionality of the new technology may pose a significant threat to any implementation process. Many of these internal problems may be prevented or overcome by:

- Demonstrating the relative advantage of the new- over the old technology to all levels of the organisation involved
- Reducing the (perceived) complexity of the technology for all levels of the organisation involved
- Demonstrating the technology and explaining the positive consequences of the technology in concrete terms to all levels of the organisation involved

Observability of positive consequences may be especially difficult with preventive technologies since the direct results of an implementation cannot be observed directly. They can only be observed through statistical or economical analysis. This certainly applies to technologies relating to aviation safety.

Last but certainly not least: it is the perception of the technology users that counts in the acceptance of any new technology and not the objective facts and expert opinion. This means that great care and effort should be devoted to information, persuasion and confirmation to the people that have to work with the technology.

3.5 Technological capabilities and technological capability building

Technology transfer enables the development of indigenous technological capabilities but at the same time a certain level of capability is required to absorb the transferred technology and knowledge.

Unfortunately, many countries in Africa are presently handicapped by low levels of technological capabilities. Worldwide most technical change is generated in advanced economies and many African developing countries still import most of their technologies from abroad (Szirmai, 2005). Therefore, transferring an advanced technology is actually transferring a discontinuity into the technology environment of the African importing countries (Wei, 1995). This discontinuity is caused by the fact that the technology importer finds itself suddenly operating at a higher technological level without going through a corresponding learning process.

Because of this technological dependence of developing countries, it is important for them to create a technological self-reliant situation in which they have the ability to exercise choice and control over areas of partial technological dependence over their relations with other nations (van Egmond, 2001). One of the ways to achieve such a self-reliant situation is by the development and improvement of indigenous technological capabilities.

In this research, technological capabilities are defined as (Szirmai, 2005; Romijn, 1999; Madanmohan et al, 2004; van Egmond, 2001):

> Technological capabilities include skills, experiences, attitudes and schooling required to select, acquire, install, operate, maintain, improve and develop the imported technologies further.

Rosenberg and Frischtak (1985) summarize this by defining technological capabilities as a process of accumulating technical knowledge or a process of organizational learning.

3.5.1 Classification of technological capabilities

The literature describing technological capabilities is built around three main pillars:

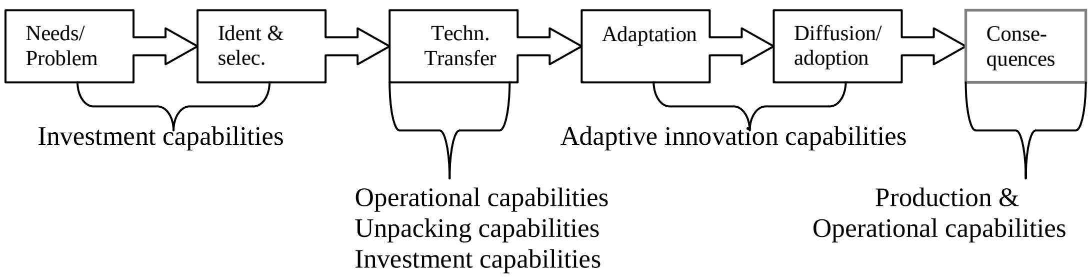
- *Investment capabilities* are the skills and knowledge needed to identify feasible investments projects, locate and purchase suitable technologies and manage the construction, commissioning and start-up of these newly acquired technologies and processes (Bell, 1987; Lall, 1982; Wei, 1995).
- *Production and operational capabilities* are the skills, knowledge, equipment and organizational methods and systems needed to operate and maintain the acquired technology (Bell, 1987; Platt, 1999).
- *Adaptive innovation capabilities* refer to the skills and information needed to design new or significantly improved products and processes or to implement new or improved organizational structures (Romijn, 1999).

Another approach to the classification of technological capabilities is the model with three levels of technical development and related capabilities as proposed by Lee et al. (1988) and Lall (1990; 1992).

At the first level the authors distinguish assimilation and improvement of mature technologies accompanied by simple and experience based capabilities. At the intermediate level; assimilation and improvement of new technologies are linked with research based adaptive and duplicative capabilities and at the third level generation of emerging technologies is accompanied by innovative capabilities.

The figure below shows the relation between the different types of capabilities and the various steps in the technology acquisition process (see figure5). It should be reminded that different capabilities may affect more then one step in the technology-acquisition process. However, to keep a clear view only the strongest connections are displayed.

Figure 6 Capabilities in the technology acquisition process



3.5.2 Technological capability building

Technological capability building refers to the efforts to increase the quantity and quality of the skills, experiences, attitudes and schooling required to select, acquire, install, operate, maintain, improve and develop the imported technologies further.

In order to develop the different capabilities, human capital, learning and technological effort are essential prerequisites.

- The *human capital* theory states that as people become more educated, they develop and improve their skills and increase their productivity. With increased skills and improved productivity, existing capabilities may be enhanced and new capabilities may be developed this way facilitating the introduction or transfer of new technologies.
- *Learning* refers to the skills and information needed to generate technical and organizational changes and to manage these changes (Bell, 1987; Bell and Pavitt, 1993; Wei, 1995). Learning does not take place overnight but is a gradual process that depends on a unique interplay of a host of factors within the firm or organization itself and its environment, which combine to generate a unique growth path (Katz, 1987; Romijn, 1999).
- *Effort* can be described as the 'purposive use of technological knowledge and allocation of other resources to assimilate, adapt and improve technology' (Romijn, 1999). The term affirms the intuitive feeling that capability building is not a trivial activity but needs to be accompanied by a purposive allocation of resources.

As mentioned before, technology transfer can lead to technological development and ultimately to improved technological capabilities. However, this does not mean that simply providing equipment, operating instructions and designs ensures that the transferred technology will be properly used and hence, contributes to the development of technological capabilities. Problem is that technology transfer does not automatically trigger the development of technological capabilities. It is necessary that these embodied elements (e.g. equipment, instructions and designs), have to be accompanied by tacit elements (knowledge and skills), which have to be taught and learned (Lall, 1993; Platt and Wilson, 1999; Radosevic, 1999). Otherwise, the technology importer will find itself operating at a higher level of technological capacity without going through the corresponding process of learning and capability development.

3.5.3 Improved capabilities as a result of technology transfer?

The degree through which technology transfer contributes to the development of (improved) technological capabilities of the receiving country determines the success of the transfer. Problem, however, is that technology transfer does not automatically trigger the development of improved technological capabilities but it needs to be accompanied by effort and learning (Radosevic, 1999). Some examples that follow will show that capabilities are not always developed in spite of technology transfer taking place.

Wei (1995; 108) examples how technology transfer doest not necessarily contribute to technological capability building by looking at the process of replacing parts of the imported technology by locally manufactured parts: ''localization of the simple parts and localization of the complicated parts may impose different levels of difficulty and, thus, require different levels of technical capabilities. Therefore, it follows that a high level of localization (as a result of technology transfer) measured in terms of money or weight may not necessarily indicate a corresponding level of technological capability''.

Radosevic (1999; 19) stresses the importance of firm specific and generic knowledge when looking at the relationship between technology transfer and technological capability building. ''When a technology is firm specific rather then generic, technology transfer is an investment process, with capabilities as objects of transfer. The tacit knowledge embodied in capabilities makes them inherently difficult transfer without local investments in learning. This makes the acquisition process irreducible to explicitly traded elements in technology transfer ''. Differences in technology status between sellers and recipients not only determine the size of costs and payments, but make technology acquisition a localized and path-dependent learning process in which the effect of technology transfer on the development of (improved) technological capabilities is not always clear.

Finally, Yin (1992) illustrates how growth strategies influence the development of technological capabilities. An extensive growth strategy that focuses on acquiring foreign machinery to expand production capacity has often little to do with absorption and adaptation. An intensive growth strategy, by contrast, focuses on productivity and efficiency and, thus, development of technological capability (Yin, 1992; 26).

From the examples above it becomes clear that for technology transfer to be effective and as a result of this the development of technological capabilities to take place, a great variety of variables interact with each other.

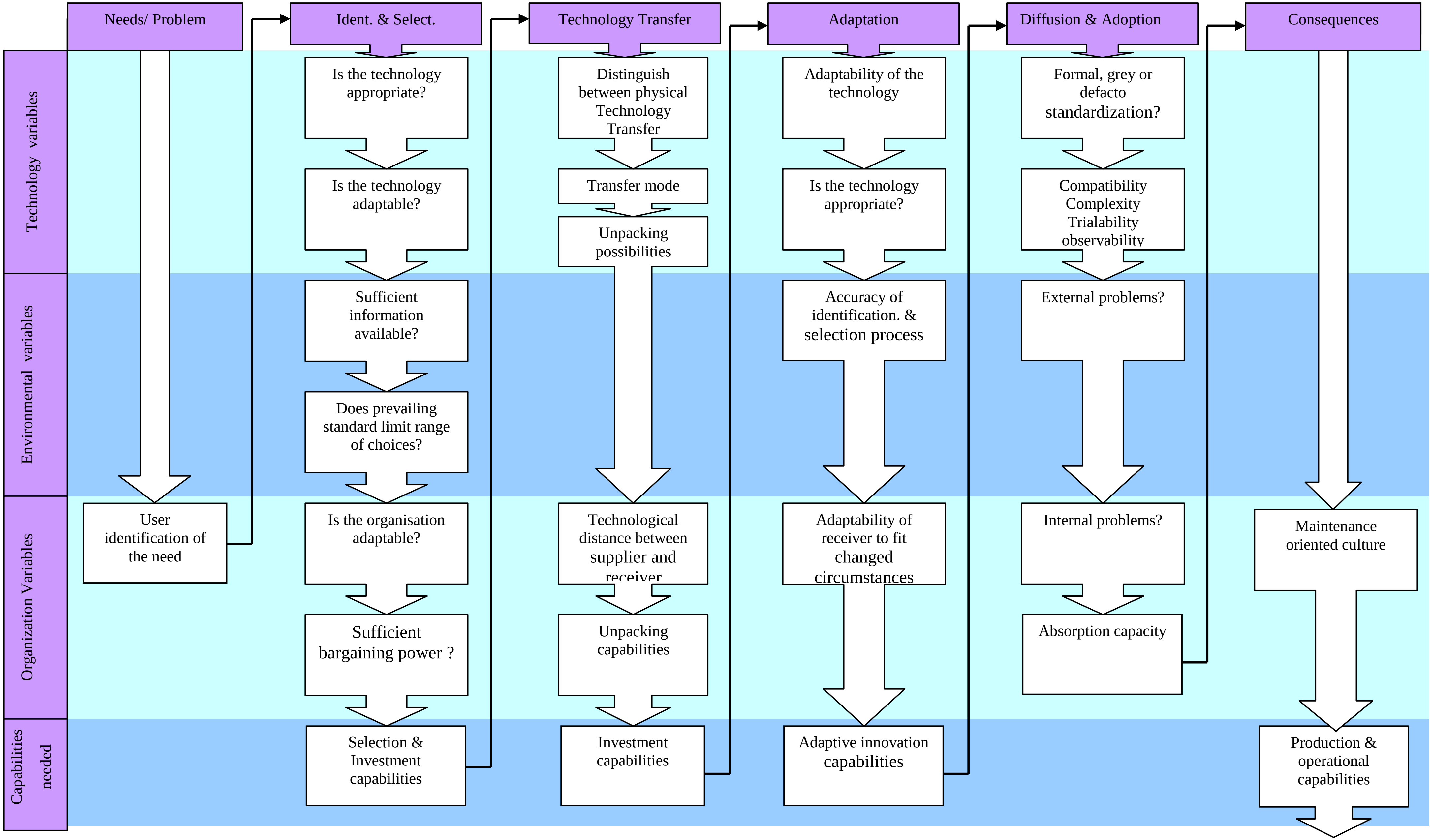
3.5.4 Relating theory to practice

Because of the low levels of (unpacking and investment) capabilities, many African countries are unable to bargain for good contractual terms. To prevent these countries from selecting the wrong technology (too expensive, non compatible, less effective etc.) they are in need of independent, non-commercial consultation and advice allowing them to grasp a completer picture of what is available and most beneficial to their needs. Next to investment capabilities, many African countries lack (basic) operational capabilities needed operate and maintain the acquired technology. To improve these capabilities, human capital should be increased by offering training that is adjusted to the specific need, time, place and circumstances of the receiving country. Finally, new technologies should be adapted in such a way they become more appropriate, sustainable and effective. Many developing countries lack the capabilities to adapt new technologies to their needs and are in need for assistance and advice.

3.6 Theoretical Model

Summarizing the theory on TT and TCB, Szirmai (2005; 125) concludes: 'an important lesson to be derived from the technological capability literature is that acquisition of technology is neither easy nor free of costs, as suggested by older neoclassical theories of growth. Acquisition of existing technology requires skills, efforts and capabilities in order to absorb the transferred technologies. The adaptation of international technology to local conditions requires effort and capabilities. These capabilities themselves have to develop or to be developed through education, training, experience and investment in human capital'.

The model on the next page summarizes the theory discussed in this chapter and provides an overview how different variables and capabilities (displayed on the vertical side) may affect the steps in the technology acquisition process (displayed on the horizontal side). Every step in the process represents a variable that may have a direct influence on the course of the technology acquisition process and hence each step may co-determine the success of the introduction of the technology.



Needs/ Problem
Ident. & Select.
Technology Transfer
Adaptation
Diffusion & Adoption
Consequences
Technology variables
Environmental variables
Organization Variables
Capabilities needed
Is the technology appropriate?
Is the technology adaptable?
Sufficient information available?
Does prevailing standard limit range of choices?
Is the organisation adaptable?
Sufficient bargaining power ?
Selection & Investment capabilities
Distinguish between physical Technology Transfer
Transfer mode
Unpacking possibilities
Technological distance between supplier and receiver
Unpacking capabilities
Investment capabilities
Adaptability of the technology
Is the technology appropriate?
Accuracy of identification. & selection process
Adaptability of receiver to fit changed circumstances
Adaptive innovation capabilities
Formal, grey or defacto standardization?
Compatibility
Complexity
Trialability
observability
External problems?
Internal problems?
Absorption capacity
User identification of the need
Maintenance oriented culture
Production & operational capabilities

Chapter 4 African aviation environment

What are the main aviation safety problems in Africa and how important is it to invest in improved safety? This chapter tries to answer these and many other questions that may arise when we address the need for the implementation of new technologies, technical cooperation and the necessity to raise the level of aviation safety on the African continent.

4.1 Some initial facts

- In 2005, Africa was again the most unsafe continent with 37% of all fatal airliner accidents happening in Africa, while the continent only accounts for less then 4% percent of all world airline departures (ASN, 2006).
- A small sample of just nine European airlines (Virgin Atlantic, Alitalia, British Airways, Air France/ KLM, Iberia, Lufthansa, SN Brussels and TAP air Portugal) serve over 70 destinations in 46 African countries.
- In the summer 2006 flight schedule, the KLM/ Air France alliance alone operates 161 (57 and 104 respectively) weekly flights into Africa. This may add up to over 8000(!) flights annually (Air France, 2006).
- African air traffic is forecast to double or even triple over the next twenty years.
- The fatal accident rate per million departures in Africa is 8.3 times higher then the fatal accident rate for Europe. The rate of accidents with total loss of the aircraft for a million departures in Africa is 33.3 times higher than that of Europe.
- 90% of Africa’s export value is transported by air, which accounts for 10% of the export volume (African Development Fund, 2004).
- Air transport accounted for 51% of total international passenger arrivals in Africa in 2000 while road transport accounted for 37% (World Tourism Organization, 2002b).
- The EU is the main market for Africa, accounting for 42.8% of total exports in 2004 (World Trade Organization, 2005).
- Airservices are very concentrated within Africa: the ten biggest national markets account for 70% of the total number of passengers and 90% of cargo flights.
- The average age of the African airliner fleet is nineteen years against twelve years in North America and nine years in Europe (African Development Fund, 2004).
- 54% of the western built passenger jets (> 100 seats) and freighters flying in Africa belong to the older generation, 19% to the middle generation and 27% to the new generation whilst these figures for Europe are 7%, 40% and 53% respectively (Airbus, 2004).

4.2 Transport modalities

While most African countries have the basic building blocks of the transport infrastructure in place, this infrastructure is far from efficient and not very safe to say the least (Odero, 2004).

However, great differences exist between the problems and limitations of the different transport modalities. The following paragraphs take a brief look at the limitations of- and the differences between the most important transport modalities. They will show the relative importance of air transport and the advantage it has over other modes of transport.

4.2.1 Road transport

The road transport system in Africa carries 80 to 90 percent of the continent’s internal passengers and freight. In many cases, it is the only way of reaching remote area’s (Heggie, 1994).

In spite of their importance, the African roads suffer from many problems. For political reasons, road building has traditionally received more priority than road maintenance. Therefore most roads in Africa are poorly managed and badly maintained while almost three quarters of them is unsealed (United nations, 2002). Overloaded trucks and old, inefficient vehicles populate the roads and the traffic is in many cases close to anarchy. Many countries lack a highway system and secondary roads range from good to nearly impassable depending on the season, being the worst during the rainy season.

Looking at the African road transport from a global perspective it can be seen that with only 4% of the world’s motor vehicles, the African road transport is responsible for 10% of the global road deaths. When this is compared with the combined figure for Europe, the United States, Australia and Japan which contain 60% of all the vehicles but are responsible for only 14% of all road traffic deaths, it can be concluded that the road safety situation throughout the African continent is one of the worst in the world (Jacobs, 2000).

Add to this corruption of traffic police, delays at international borders and a lack of uniform infrastructure standards between countries. The conclusion can be drawn that road transport, despite the fact it is the largest and in many cases only available mode of transport, may not always be the safest and most efficient mode of transport.

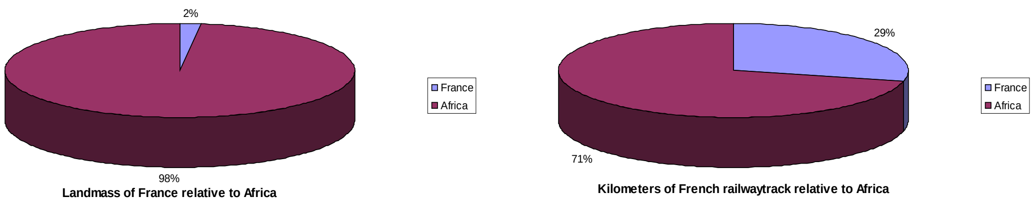
4.2.2 Railway Transport

The aggregate network of African railways is estimated at 73,000 kilometres, of which South Africa alone accounts for some 22,500 km while eleven countries have no railway system at all (Jerome, 1999). By comparison: France, which is over fifty times smaller than Africa in area size, has over 30,000 kilometres of railway track. This means that with less than 2% of the African land area, France has approximately 40% of the total African length of railway track.

With the exception of North Africa, railways in Africa generally have a low level of traffic and most lines are unsuited for fast and heavy traffic (Jerome, 1999). As with many things, there is a general deterioration of the railway system due to maintenance problems and usage of ageing equipment.

Links between countries are weak and don’t connect with each other in any meaningful way since the railway system has been laid down by colonial rulers for transport from the interior to seaports with barely any connections between countries and metropolitan areas.

Figure 7 Comparison of French and African landmass and railway length



4.2.3 Maritime Transport

Maritime transport is the most important mode of transport for intercontinental trade with over 90% of the export volume transported by sea. (It may be recalled that 90% of the African export value is transported by air).

The containerization has reached African ports as well but the cost of passage and ship holding are still very high, mostly due to slow turn around of ships at ports, high tariffs, shallow waters and time-consuming customs procedures (African Development Fund, 2004).

Furthermore, Africa has 15 landlocked countries that have no direct access to seaports. The transportation needs to the sea of these countries are dependent on slow administrative procedures and poor transport facilities within transit countries.

The role of inland waterways is still very limited in most of the African countries. This is mainly caused by a lack of navigable waterways with only the Congo, Nile and the Zambezi rivers being classified as international waterways. Most other rivers are still in their natural State, with seasonally variable and unpredictable water depths (United Nations, 2002).

4.2.4 Air Transport

As with the other modes of transport, the African air transport sector has its fair share of problems which will be discussed in greater detail later on in this report.

However, looking at the limitations and problems of the road-, rail- and maritime transport sectors, there is an enormous potential for the air transport sector.

Given the speed of transport by air, the weakly developed rail transport network, the absence of navigable inland waterways, bad access to- and shape of many of the seaports and the bad shape of the road infrastructure, the air transport sector is crucial in opening up many African States. This applies especially to those countries faced with natural obstacles such as the equatorial forest, the Sahara desert and countries that are landlocked.

However, with the partial exception of Nigeria, South Africa is the only African country with a real domestic air transport market. Elsewhere there is a very limited degree of inter–modal competition. Road transport enjoys a virtual monopoly for passenger and cargo transport (Boeing, 2003).

Still, air transport may provide the only transportation means for remote areas, it may boost the export of perishables such as fruit and vegetables, fresh flowers, meat and fish and it may foster the development of tourism for which Africa has a huge potential (African Development Fund, 2004; Goldstein, 1999).

In the following paragraphs the economic importance of the air transport for Africa is briefly discussed and it will be argued that the aviation sector has a vital role to play in the future (economic) development of the continent.

4.3 Aviation for development

A safe and efficient transport infrastructure (system) is one of the necessary conditions for economic growth. It may offer firms greater access to a more efficient supplier base, new production techniques and knowledge and greater accessibility may attract inward investment/ Foreign Direct Investment (FDI). While it must be recognized that rural transport is the main mode of transport and should receive priority for improvement, the potential of air transport to the continent's economic and social development should not be underestimated (ATAG, 2003). There are three ways in which the air transport sector can contribute to economic development:

- Linking communities within a country
- Promoting export of perishables and high value goods
- Development and promotion of tourism

4.3.1 Linking communities

In many African countries travelling can be difficult and time consuming due to long distances and difficult geography. Notwithstanding the fact that road transport will continue to be the most available and affordable mode of transport, it is here that air transport may offer a supplementary and effective way of linking people and communities.

By making flying more available to the general public by e.g. the creation of low cost carriers it can reduce the cost- and increase the efficiency of trade and movement, supporting the creation of businesses where a rapid movement of goods and people is crucial (just in time) (ATAG, 2003).

4.3.2 Export promotion

The EU is the main market for African exporters, accounting for 42.8% of total exports in 2004, followed by the US with 18.7%. The EU is also the largest source of imports into Africa, accounting for more than 47.7% of the total in 2004 whereas Asia is second with 21.9% of total imports (WTO, 2005).

Together with the construction of cold storage houses, the development of a more efficient road transport system, a safe and reliable air transport system may open up new- and improved opportunities for the export of perishables and high value goods. Approximately 15% of worldwide air cargo flows are perishables with a further expected growth of 7.1%

annually to 2008. In the case of Africa, up to 80% of air freight consists of perishables. It is not uncommon that fruits and vegetables are harvested some 1000 kilometres away from the airport from where they are shipped (Lufthansa consulting, 2006). Up to 35% of the total production of perishables is lost after harvest. A tremendous efficiency increase could be realized with a safer and more efficient air transport system.

4.3.3 Development and promotion of tourism

With the right policies in place, tourism can be a major stimulant for development. Unfortunately, the tourism sector in Africa is still small compared to other parts of the world. In 2004, tourism represented on average only 5% of Gross Domestic Product (GDP) in Africa while the world average was 10.4% and some Asian countries even generated over 40% of their GDP through tourism. In terms of international tourist arrivals Africa only had a 4.5% share of the world total in 2003 while Europe and Asia accounted for 54.9% and 19.3% respectively in 2005 (WTO, 2006).

Despite this backlog, Africa has an enormous potential for growth in (nature-based) tourism. The continent contains over a third of the word's biodiversity and more then 1200 protected area's which add up to 7% of the continent's landmass and 15% of the world's total protected area's (Good, 2003). With over half of all international tourists travelling to Africa by air (WTO, 2002b), air transport provides the foundation for further development of international tourism and for many African countries air travel is the only viable link between their product (tourism) and their market in the industrialized world (Lipmann, 2004).

In order to attract increasing numbers of international visitors, Africa needs to create easy access to tourist destinations by setting up an extended domestic and inter-State air transport system and frequent flight schedules. Above all a minimum level of flight safety should be guaranteed. Unfortunately, most of these prerequisites are not (yet) met and many problems exist that hamper the development of an efficient, reliable and safe air transport system.

4.4 Problems encountered in African aviation

Most of the African air transport sector remains saddled with major challenges, which may no longer be a (major) concern in other regions of the world. Some parts of Africa have well developed airports and air traffic management systems but at many airports and in Flight Information Regions numerous problems exist and it is not uncommon that international safety standards are not met. Problem areas are (IATA, 2005a; ICAO, 2005; IFALPA, 2001):

- Degradation of runway, taxitrack and platform pavement
- Degradation of, and/or inadequate airfield, taxitrack and runway lighting
- Unreliable power supply
- Unreliable/ outdated weather information services
- Unserviceable/ unreliable Communication, Navigation and Surveillance aids
- Absence of, or inadequate emergency plans
- Avian hazard
- Inadequate Search & Rescue and fire fighting capacity
- Absence of, or degrading aerodrome fencing
- Poor reinvestment of taxes and charges into the industry
- Poor maintenance of aircraft
- Insufficient crew proficiency
- Unreliable/ outdated notice to airman (NOTAM's)

It is unlikely, however, to attain an acceptable level of safety in air transport by only looking after these rather physical/practical problems. Policy and regulatory support functions also require equal attention (ICAO, 2006a). Findings of the ICAO Universal Safety Oversight Audit Programme (USOAP) reveal that a number of African States lack the necessary resources and institutional set-up to fulfil their safety oversight responsibilities under the Chicago Convention. Deficiencies identified as major problems include (ICAO, 2002):

- A lack of appropriate legislative and regulatory frameworks

- A lack of appropriately established, empowered and well funded Civil Aviation Authorities
- A lack of adequate, appropriately qualified and experienced (technical) personnel
- A lack of a system for the control and supervision of licensed and certificated bodies
- A lack of a system for the resolution of safety issues, reporting of errors and incidents and investigation of incident & accidents
- A lack of commitment by governments to support their Civil Aviation Authorities.

Furthermore:

- Unreliable legal documents since they are issued administratively, without control or follow-up
- Improper and insufficient inspections prior to the certification or licensing of air operators, maintenance organizations and aviation training institutes

Looking at the problems that specifically hamper the African ATM/ATS/CNS sector the following deficiencies and problems can be seen:

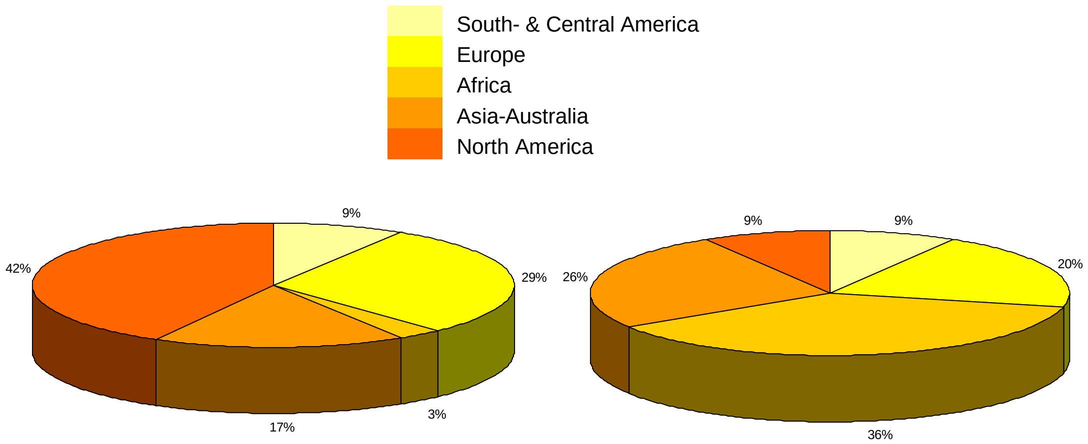
- Poor quality of Air Traffic Services
- Insufficient/ inadequate controller language, skills and attitude
- A lack of adequate and dependable (VHF) radio communications in some Flight Information Regions
- A lack of Air Traffic Control in certain areas
- Acts of vandalism
- Inappropriate control towers and few radar systems

The bottom line is that a number of African States are experiencing serious problems in meeting their aviation safety and security obligations. They lack adequate resources to resolve deficiencies or effectively meet safety and security challenges. Resources required for establishing and maintaining an effective and sustainable aviation system proof to be beyond the reach of most of its States (Belai, 2006).

4.5 Africa's safety record

All the deficiencies and problems that affect many African airports, Flight Information Regions, policy & regulatory support functions and the ATM/ATS/CNS system, obviously have a direct bearing on the (comparatively) high accident rate in Africa. While global aviation accident and incident rates have significantly decreased over the past few years, accident and incident rates in Africa did not reflect this trend and grew! According to the Aviation Safety Network (ASN), in 2005 Africa was again the most unsafe continent with 37% of all fatal airliner accidents happening in Africa, while the continent only accounts for less then 4% percent of all world aircraft departures (ASN, 2006). Figure 8 shows the relation between world accidents to world departures for each region.

Figure 8 World departures and world accidents in 2004



% of world departures (total number unknown) % of world accidents (35 total)

Source: adapted from ASN, 2005

Most of the accidents in Africa take place in a limited number of States, mostly involve African carriers and the causes tend to be different from those that prevail in the rest of the world.

For example, due to a lack of high terrain and generally good weather conditions, Controlled Flight Into Terrain (CFIT) that used to be "the most wanted killer" in other regions has never been a significant factor in Africa. However, poor maintenance, insufficient crew proficiency and a lack of safety oversight by several African States play an important role in the accidents in AFI region. The infrastructure deficiencies mentioned in the foregoing paragraph and the substandard quality of Air Traffic Services so far, have not caused serious accidents but with the forecast growth in air traffic and the ongoing degradation of the ground infrastructure they are likely to become major factors in the years to come. Therefore continuation of this situation will inevitably lead to serious accidents in the (near?) future (ICAO, 2006b).

4.5.1 The statistics

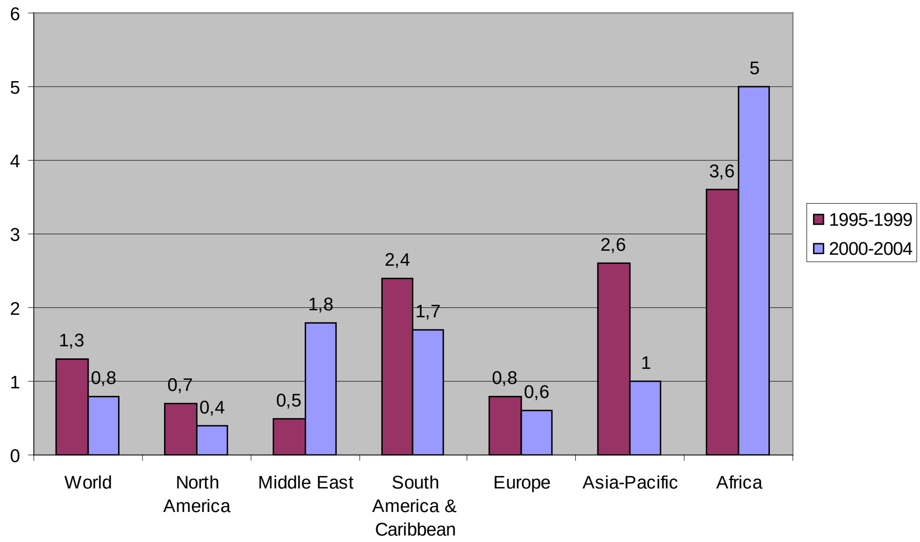
In general, accident rates are reported as a measure of accidents per million departures (or flight cycles) since there is a stronger statistical correlation between accidents and departures than there is between other measures like accidents and flight hours, accidents and the number of airplanes in service or accidents and passenger miles (Boeing, 2005) This section highlights:

1. The African fatal accident rate per million departures
2. The accident rate with total loss of the aircraft per million departures

Ad 1 Fatal accident rate per million departures

In the last five years the fatal accident rate per million departures on scheduled flights is higher in Africa than any other region in the world (see figure 9).

Figure 9 Fatal accidents per million departures, 1995-1999 and 2000-2004



Source: according to ICAO data

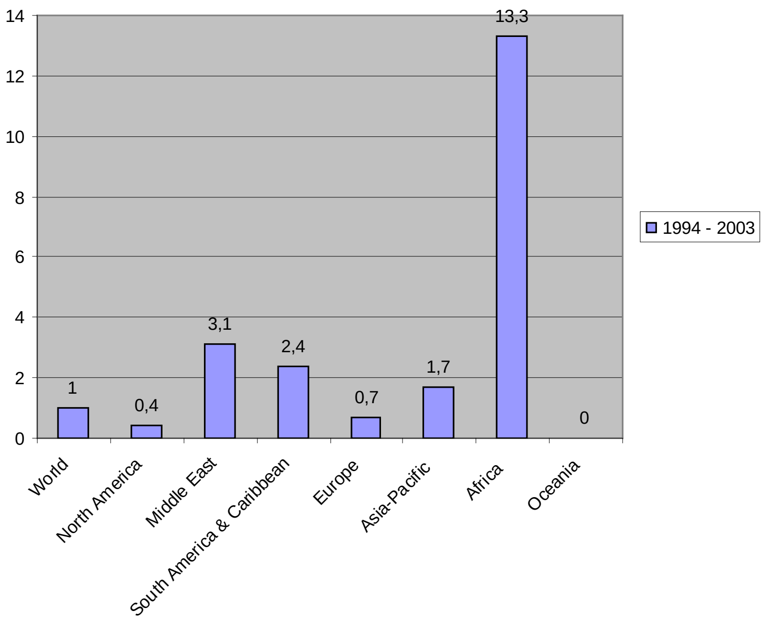
From the figure above it can be seen that the fatal accident rate per million departures in Africa is 6.3 times higher then the world average and even *8.3 times higher* then the fatal accident rate for Europe.

It is unfortunate to see that the fatal accident rate per million departures of 5.0 over the period 2000-2004 is an increase over the 1995-1999 rate of 3.6, especially when the fatal accident rate per million de departures for all other regions (except the Middle East) decreased over the same period (ICAO, 2006c).

Ad 2 Rate of accidents with total loss of the aircraft per million departures

The last decade, the rate of accidents with total loss of the aircraft (total hull losses) per million departures is, again, higher in Africa than any other region of the world (see figure 10).

Figure 10 Number of accidents with total loss of the aircraft per million departures, 1994 to 2003



Source: according to ICAO (2006c)

From the figure above it can be seen that the rate of accidents with total loss of the aircraft per million departures in Africa is 13.3 times higher then the world average and even *33.3 times higher* than that of Europe. Accident rates calculated by IATA for 2005 alone show almost the same picture: the worldwide average of accidents with total loss of the aircraft per million departures reached 0.76 whilst Africa had the highest rate of all regions with 9.8 hull losses per million departures, which is 12.9 times the world average (ICAO, 2006b). And this on a continent that can financially least afford the loss of expensive aircraft.

4.6 Tanzania accident data analysis

The top six causes for fatal accidents for the worldwide jet fleet from 1987 through 2004 is (Boeing, 2005a):

1. Controlled Flight Into Terrain
2. Loss Of Control – In-flight
3. System/ Component Failure or malfunction (non power plant)
4. Fire/smoke (Non-Impact)
5. System/ Component Failure or malfunction (power plant)
6. Runway Excursion

When the same analysis is performed on Tanzania air accident/ incident data from 01-01-1997 through 13-04-2006, provided by the Tanzania Civil Aviation Authority (TCAA) accident investigation branch, using the ICAO/ Commercial Aviation Safety Team (CAST) aviation occurrence category definitions the top six causes for fatal accidents is:

1. Controlled Flight Into Terrain
2. Loss Of Control – In-flight
3. Overload of the aircraft
4. System/ Component Failure or malfunction (power plant)
5. Runway Incursion – Vehicle, Aircraft or person
6. -No fatalities in another category-

For the analysis of the Tanzania air accident/ incident data, the ICAO/CAST aviation occurrence categories have been supplemented with two categories; ‘overload’ and ‘birdstrike’.

When the worldwide and Tanzanian causes for fatal accidents are compared it can be seen that Controlled Flight Into Terrain, Loss Of Control – In-flight and System/ Component Failure or malfunction (power plant) are almost equally important. Overload and Runway incursion are dangers more specific for the Tanzanian environment.

The fact that Controlled Flight Into Terrain is also the number one cause for fatal accidents in Tanzania is in direct conflict with paragraph 3.5 in which it is stated that Controlled Flight Into Terrain used to be “the most wanted killer” in other regions but has never been a significant factor in Africa. Reason for Controlled Flight Into Terrain being at the number one position in the Tanzanian analysis is because of one extreme value (the crash of Cessna 406 5H-NAT on the southern slope of Mt. Meru on 01-09-1999). In this accident all twelve onboard were killed. Out of a total of 15 fatalities due to Controlled Flight Into Terrain over the 1997-2006 period this single accident produces a so called ‘’outlier’’ that greatly influences the overall analysis.

In numbers, Controlled Flight Into Terrain is not an important factor for causes of accidents in Tanzania. When the extreme value of twelve killed in the single accident is omitted, Controlled Flight Into Terrain will be the fourth ranking cause for accidents in Tanzania, making the difference with the top six causes for fatal accidents for the worldwide jet fleet from 1987 through 2004 more apparent.

The relative importance of the factor ‘’overload’’ (third place) may be explained by the fact that some Tanzanian operators may fly their aircraft at the economic margin. Trying to make as much profit as possible they push their operations to the outer boundary of the safety envelope by taking as much passengers and freight as possible on each flight. This occurrence category is not used by the Commercial Aviation Safety Team so prudence is called for comparing the worldwide and Tanzanian accident data.

The importance of the factor Runway Incursion (fifth place) is caused by numerous accidents involving game and other wild animals.

Airport fencing is often deficient or not present at all, which is a hazard not only due to security breaches but also due to wildlife wandering within the airport perimeter. The only solution to these problems is proper fencing. However, even with fencing in place runway incursions cannot be ruled out completely. E.g. elephants are not easily stopped by regular fencing and there are instances known in which fencing has been stolen.

It should be noted that the comparison between worldwide and Tanzanian causes for fatal air accidents should be made with great care since;

- The data of worldwide accidents only cover jet airplanes that are heavier than 60,000 pounds maximum gross weight while the Tanzanian data cover all aircraft, including jet aircraft lighter than 60,000 pounds, helicopters, general aviation etc.
- The type of operations performed with and the flight envelope of jet aircraft are significantly different from those of general aviation aircraft. This means that the level of risk may be rather different, making it difficult to compare the categories.
- The number of fatal accidents in Tanzania in the period 01-01-1997 through 13-04-2006 only includes 7 fatal accidents with 39 casualties in 5 categories, making the data extremely sensitive to chance and extreme values (outliers).
- The data provided by the Tanzania Civil Aviation Authority may not have been as detailed as the data used for the determination of causes for fatal accidents for the worldwide jet fleet from 1987 through 2004. For example, in many cases it proved to be difficult to trace back from the available data whether e.g. a landing gear failure was attributable to pilot error, runway conditions or to system component failure.
- The author used his own knowledge and judgement in the classification of causes for fatal accidents in Tanzania. These judgements may be slightly different from the systematics used for the determination and classification of causes for fatal accidents for the worldwide jet fleet.

A better way to get some insight into the areas of greatest risk in Tanzanian air transport is by looking at the causes for both fatal and non-fatal accidents/ incidents (139 total).
When the ICAO/CAST aviation occurrence categories (including ’overload’ and ‘bird strike’) are applied to the Tanzanian air accident/ incident data, the top six causes of air accident/ incidents is (see also figure 11):

1. System/ Component Failure or malfunction (non power plant)
2. System/ Component Failure or malfunction (power plant)
3. Abnormal Runway Contact
4. Runway Incursion - Animal
5. Undershoot/ Overshoot
6. Aerodrome

Figure 11 Number of accidents and incidents in Tanzania in the period 01-01-1997 through 13-04-2006

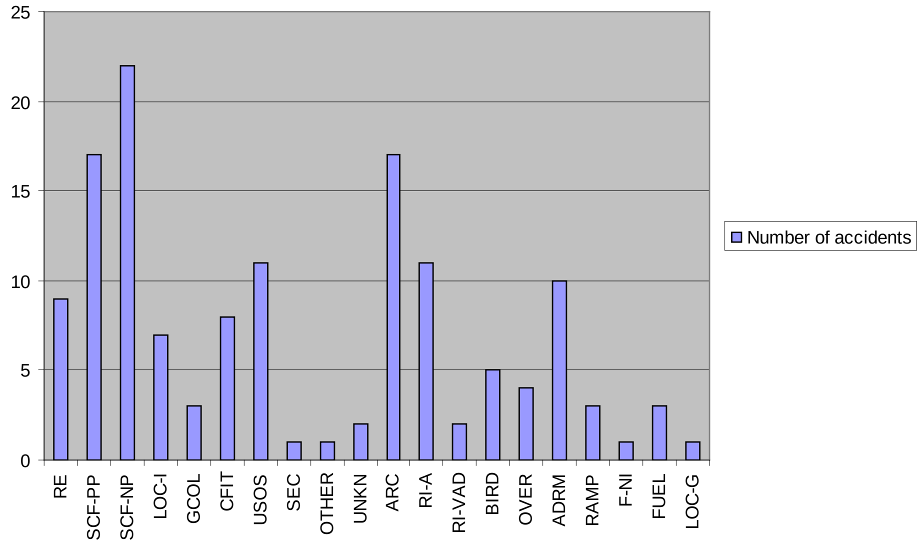
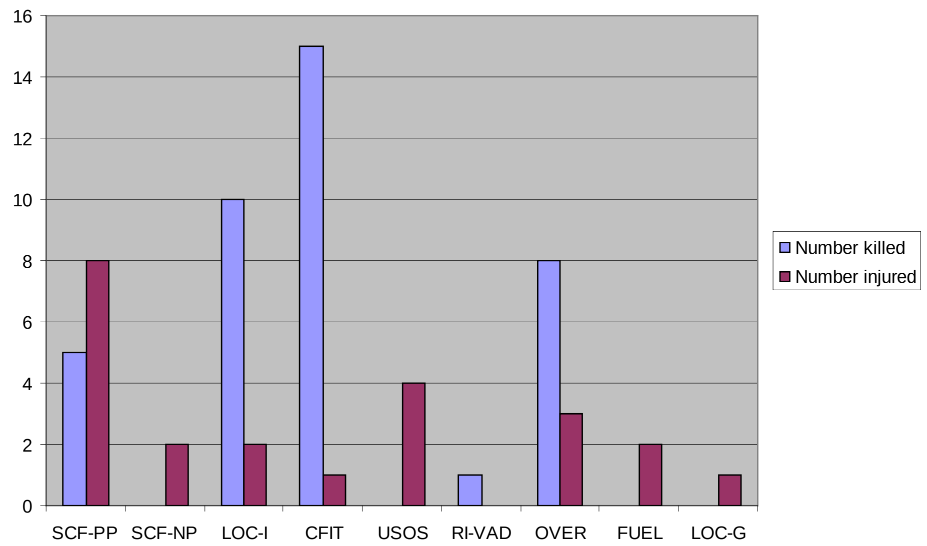


Figure 12 Number of fatalities and injured in Tanzania in the period 01-01-1997 through 13-04-2006



Legend for figures 11 and 12

RE	Runway Excursion	SEC	Security related	OVER	Overload
SCF-PP	System/ Component Failure or malfunction (powerplant)	OTHER	Other	ADRM	Aerodrome
SCF-NP	System/ Component Failure or malfunction (non powerplant)	UNKN	Unknown or undertermined	RAMP	Ground Handling
LOC-I	Loss Of Control - Inflight	ARC	Abnormal Runway Contact	F-NI	Fire/smoke (Non-Impact)
GCOL	Ground Collision	RI-A	Runway Incursion - Animal	FUEL	Fuel related
CFIT	Controlled Flight Into Terrain	RI-VAD	Runway Incursion - Vehicle, Aircraft or Person	LOC-G	Loss of Control - Ground
USOS	Undershoot/ Overshoot	BIRD	Birdstrike		

Despite the fact that it is difficult to compare statistics on worldwide fatal jet aircraft accidents with both fatal and non-fatal accidents with aircraft in Tanzania as noted before, some remarkable differences can be seen.

– Controlled Flight Into Terrain and loss of control in flight, which are the most frequent causes for accidents in other parts of the world, are not in the top six causes for accidents in Tanzania with only eight Controlled Flight Into Terrain accidents/ incidents and seven Loss of control during flight accidents/ incidents over the past decade.
– Runway excursion and fire or smoke in the aircraft which are in the top six causes for fatal accidents worldwide are not in the top six causes for accidents in Tanzania.
– System component failure both power plant and non-power plant (mainly landing gear failures) are higher on the list of most probable causes for accidents/ incidents in Tanzania than they are for the rest of the world.
– Abnormal runway contact (mostly hard landings and belly landings), runway incursion by animals that wander across the runway (mostly giraffes, zebra's and antelopes), undershoot and overshoot of the runway and 'aerodrome' (mostly damage to landing gear by pot holes, foreign object damage caused by loose stones, ingestion of stones by engines etc) are unique for Tanzania compared to the rest of the world.

As said before, great care should be given to the interpretation of the data; however, it is relatively safe to conclude which accidents could have been prevented by the usage of ADS-B and which could not.

As can be seen in appendix 2 and from the outcomes of the survey in paragraph 4.4.1, ADS-B will mainly benefit the aviation community by:

– Improving pilot and Air Traffic Control information and situational awareness
– Reducing the risk for mid-air collisions
– Improving Air Traffic Control efficiency and capacity
– Improving Search and Rescue capabilities.

However, from the analysis of the main causes for accidents and incidents in Tanzania in the period 01-01-1997 through 13-04-2006 it can be seen that none of the five main causes for these incidents and accidents could have been reduced by the usage of ADS-B as most of the incidents and accidents in Tanzania are caused by:

– System/ Component Failure or malfunction (both power plant and non power plant)
– Abnormal Runway Contact, Runway Incursion and runway Undershoot/ Overshoot
– Aerodrome deficiencies such as degrading runways and taxi tracks.

From the discrepancy between causes for accidents in Tanzania and the benefits that may be derived from ADS-B it can be concluded that ADS-B is not the answer to many of today's problems (causes for incidents and accidents). ADS-B should thus not receive priority over other measures such as improvement of maintenance schedules, pilot capability and capacity and the improvement of ground infrastructure such as runways and taxi tracks. However, as paragraph 4.8 will show, with the expected growth in air traffic ADS-B may become increasingly important in coping with the problems that may arise as the African skies become increasingly congested.

4.7 How African safety influences western safety

It can be stated that the situation existing in most parts of Africa and its worse comparative safety record represent a serious threat to the overall safety of air transport throughout the world. To see how the African safety record directly affects air transport safety in Europe, it is important to see how the international traffic flows to and from Africa are composed.

The composition of traffic flows to and from Africa is rather skewed, with routes to/from Europe accounting for roughly two thirds of the total. The share of intra-African traffic is limited and the remainder of the flights are mainly to Asia (with India and China becoming increasingly important), North- and South America (Boeing, 2005).

To gain an understanding of the traffic volume and (economical) importance of the African routes, appendix 4 shows the African destinations of nine major European carriers (KLM-Air France, British Airways, Iberia, TAP Air Portugal, Virgin Atlantic, Swiss, Lufthansa, Alitalia and SN Brussels). Note that due to the availability of data (holiday) charters, freight flights and many of the smaller airlines and low-cost carriers etc are not included.

The example in appendix 4 learns that just nine (out of hundreds of) European airlines serve over 70 destinations in 46 African countries. Next to the many flights performed by European airlines, there are African carriers like Ethiopian Airlines, Kenya Airways, South African Airways, Royal Air Maroc, EgyptAir, Air Mauritius etc. that serve many destinations throughout Europe. This means that thousands of European citizens fly to and over Africa each day and that many African aircraft enter European airspace, not to mention the vast amount of cargo transported to and from European destinations (it may be recalled that Europe accounts for 42.8% of total African exports).

However, the real worries do not go out to these large and well established airlines but to the many smaller (African) airlines operating in the margin of safety while the safety oversight on the air operations may be minimal and the infrastructure on the ground may be hardly adequate. As aviation is a truly global industry, safety deficiencies in any part of Africa may have a wide impact on Europe and beyond:

- African registered aircraft enter European airspace and fly to/ from European airports
- European airlines enter African airspace and fly to/from African airports
- European citizens use African aircraft and African airports for local transport in Africa

With the majority of Africa’s air cargo heading to Europe and with most tourists arriving from Europe it is apparent that African air transport safety has a direct bearing the safety of European citizens and aircraft. Therefore, a direct public interest exists for Europe to help African nations in ever increasing their safety performance.

4.8 Forecast growth

The African air transport market has grown considerably since the mid–1980s. However, the market share of Africa in world air traffic has declined over the last decades, from more than 4% in 1985 to 3% in 2003 (Airbus, 2004). These figures show that Africa is only a small player in the worldwide revenue passenger kilometres arena (Airbus, 2004).

Over the 2004-2023 period, Airbus (2004) forecasts world passenger traffic to increase by 5.3% per annum and world freight traffic is expected to grow at 5.9% annually, resulting in an increase of 281% and 315% until 2023 and 2024 respectively. The forecast made by Boeing is only slightly different; world passenger traffic is forecast to increase by 4.8% per annum and world freight traffic is expected to grow at 6.2% annually over the 2005-2025 period, resulting in an increase of 255% and 333% respectively.

When the focus is on Africa, it is forecast that the passenger- and freight traffic growth will be between 4.5% (Airbus, 2004) and 5.7% (Boeing, 2005) over a twenty year period. This means that African traffic will double (241%) or even triple (303%) over the next twenty years. Part of this growth is accomplished by increasing the number of seats per aircraft but for a large part this growth will be achieved by increasing the number of flights.

Looking at the recent growth figures and the forecast for the next twenty years, it doesn’t need much explanation that the already limited and, in many cases, inadequate capacity of many of Africa’s Flight Information Regions and Air Traffic Services organizations will be overtaxed.

The drastic growth figures may cause congestion of the airspace to become increasingly important. Improvement of pilot and Air Traffic Control information and situational awareness, reduction of the risk for mid-air collisions and improvement of Air Traffic Control efficiency and capacity may become priority issues, were these are not very urgent today.

4.9 Summary

While global aviation accident and incident rates have significantly decreased over the past few years, accident and incident rates in Africa did not reflect this trend and remained unacceptably high (IVW Jaarbericht 2001, 2003). In 2005 Africa was again the most unsafe continent with 37% of all fatal airliner accidents happening in Africa, while the continent only accounts for less then 4% percent of all world airline departures (ASN, 2006). It is evident that most of the African air transport sector remains saddled with major challenges, which may no more be a (major) concern in other regions of the world. Most of the accidents in Africa take place in a limited number of countries, mostly involve African carriers and the causes tend to be different from those that prevail in the rest of the world.

When the worldwide and causes for fatal accidents in Tanzania are compared it can be seen that Controlled Flight Into Terrain, Loss Of Control – In-flight and System/ Component Failure or malfunction (power plant) are almost equally important. Overload and Runway incursion are dangers more specific for the Tanzanian environment.

The bottom line is that a number of African States are experiencing serious problems in meeting their aviation safety and security obligations. They lack adequate resources to resolve deficiencies or effectively meet safety and security challenges simply because resources required for establishing and maintaining an effective and sustainable aviation system proves to be beyond the reach of most of its States (Belai, 2006). It is unlikely, however, to attain an acceptable level of safety in air transport by only looking after the physical and practical problems. Policy and regulatory support functions also require equal attention.

Furthermore, as aviation is a truly global industry, safety deficiencies in any part of Africa may have a wide impact on Europe and beyond since:

- African registered aircraft enter European airspace and fly to/ from European airports
- European airlines enter African airspace and fly to/from African airports
- European citizens use African aircraft and African airports for local transport in Africa

However, looking at the limitations and problems of the road-, rail- and maritime transport sectors, there is an enormous potential for the air transport sector, even despite its bad comparative safety record. The development of a safer and more efficient air transport system may link communities to foster economic development, it may stimulate export and it is vital for the growth ad development of tourism on the continent.

Current growth figures predict that African air traffic will double (241%) or even triple (303%) over the next twenty years. The strong growth figures may cause congestion of the African airspace to become increasingly important. Improvement of pilot and Air Traffic Control information and situational awareness, reduction of the risk for mid-air collisions and improvement of Air Traffic Control efficiency and capacity may become priority issues, were these are not yet very urgent today.

With a view to future bottlenecks caused by the expected increase in air traffic new projects are underway to prevent these bottlenecks to cause serious problems. Two of these projects concern the implementation of the Reduced Vertical Separation Minimum and the possible introduction of ADS-B in Africa.

With regard to the research questions mentioned in chapter two the following questions now arise:

- What are currently the most important bottlenecks for introducing RVSM and ADS-B into the African ATM system?
- What are the underlying causes for the bottlenecks that prevent an efficient introduction of RVSM and ADS-B into the African ATM system?
- How may future technologies and technical standards like RVSM and ADS-B be implemented more efficiently into the African ATM system?

The next chapter highlights these questions and tries to come up with the answers to these important questions.

Chapter 5 Empirics

5.1 RVSM (desk) research

The first case study is on the ongoing -and already many times delayed- implementation process of the Reduced Vertical Separation Minimum in AFI. This case study tries to find an answer to two questions. Firstly, why has this implementation process been delayed so many times? Secondly, what can be learned from these delays with respect to the second case study, the possible implementation of ADS-B (or any other new technology) in Africa?

5.1.1 The data

The RVSM case study is mainly executed by performing desk research in which several sources of information were used:

- AFI Planning and Implementation Regional Group (APIRG) RVSM/RNAV/RNP task force meeting publications
- RVSM seminars
- Reference material which is publicly available on the ICAO website.
- The Altran AFI RVSM Functional Hazard Analysis (FHA) (Altran, 2005)
- Several documents provided by Eurocontrol.

Furthermore, a number of meetings with officials from Eurocontrol, the National Aerospace Laboratory NLR, KLM Royal Dutch Airlines and the Transport and Water Management Inspectorate (IVW) offered some interesting and valuable insights (see appendix 1).

Finally, one of the surveys contained a specific question on the RVSM implementation process in Africa. This survey question provided 30 responses.

This RVSM analysis is based on official documents and is mainly descriptive in nature.

5.1.2 AFI RVSM history

To gain initial insight into the matter, a brief historical description is presented of the major hurdles and milestones in the AFI RVSM programme. This historical AFI RVSM analysis may then allow us to find out what problems are hampering the introduction of RVSM in Africa. Based on this analysis, in paragraph 4.1.3 the question is asked what the underlying causes for the problems are and whether these problems could be expected to play a role for a possible future introduction of ADS-B (or any other technology) in Africa.

First steps

The original starting point of RVSM implementation was the North Atlantic followed by European Airspace and other regions with Africa lagging behind. The AFI RVSM program will provide six additional flight levels between FL 290 and FL 410 inclusive in the airspace of 53 African States through a 1 000 ft reduced vertical separation minimum. This should result in additional airspace capacity, reduction in flight delays and fuel economies for the users.

First efforts to launch RVSM in Africa date back to the mid-nineties of the past century while the first RVSM/RNAV/RNP Task Force meeting was held in Dakar, Senegal in June 2002. At this meeting all African States committed themselves to set up procedures for reporting of data necessary for performing the RVSM safety assessments. These data should be send to the AFI RVSM Monitoring Agency (ARMA) which is hosted by the Air Traffic and Navigation Services Company (ATNS) from South Africa and is responsible for coordinating the implementation and continued safe use of RVSM.

Data sent to the AFI RVSM Monitoring Agency should include information on (ICAO, 2002a):

- Height deviations of 300 ft or more
- Total number of Instrument Flight Rules (IFR) movements for each month

– Average time per movement spent between Flight Level (FL) 290 and Flight Level 410
– Air Traffic Control coordination failures
– Turbulence
– Traffic data

Furthermore, with regard to the enforcement of RVSM in national legislation, States should (ICAO, 2002a):

– Publish an Aeronautical Information Circular (AIC) informing the users of their intention to implement RVSM.
– Include the necessary provisions in their national legislation (Aeronautical Information Publications, AIP’s).
– Receive sample Aeronautical Information Circulars and sample national legislation on RVSM from the ICAO Regional Office for East and Southern Africa (ESAF) in Nairobi.

At the time of the first AFI RVSM/RNAV/RNP Task Force meeting the date for the RVSM implementation was set for 20 January 2005.

As Stated before (paragraph 2.2.1), in the framework of RVSM, ’safe’ has a quantitative meaning: the technical Target Level of safety (TLS) attributable to aircraft height-keeping performance is defined as $2.5x10^{-9}$ fatal accidents per aircraft flight hour. The overall Target Level of Safety for risk due to all causes in connection with RVSM is left to regional agreement; however in practice this should be consistent with $5x10^{-9}$ fatal accidents per aircraft flight hour (ICAO, 2004).

Steps in the RVSM implementation process

In June 2004 the ICAO Eastern and Southern African office issued the following overview of the steps in the AFI RVSM implementation process (ICAO, 2004a).

1. Implementation for State RVSM approval process for aircraft and operators
2. Nomination of national RVSM program managers
3. Implementation of national RVSM plans
4. Implementation of national Air Traffic Services manuals
5. Training of Air Traffic Controllers
6. Implementation of national safety plan
7. Execution of an operator RVSM readiness assessment survey
8. Publication of national Aeronautical Information Circulars to advice airspace users of RVSM implementation date
9. Action plan for implementation of RVSM in the AFI region

At the fourth RVSM/RNAV/RNP Task Force meeting the slow progress of States ‘’in responding to the AFI action plan required for RVSM implementation in the region was noted. The meeting was also concerned with the lack of the West African Agency for Air Navigation Safety in Africa & Madagascar (ASECNA) involvement in the RVSM Task Force activities’’ (ICAO, 2004b). Involvement of ASECNA is particularly important as the provide Air Traffic Services for seventeen West African countries and Madagascar covered by six Flight Information Regions.

RVSM safety assessment

In addition to the steps as given by the ICAO Eastern and Southern African office, a safety assessment has to be conducted before any actual implementation of RVSM can even be considered. The AFI RVSM Monitoring Agency is responsible for this safety assessment. Main elements of the safety assessment are the Functional Hazard Analysis (FHA) being conducted by Altran Technologies of France, the Collision Risk Assessment (CRA) performed by the Netherlands National Aerospace Laboratory (NLR) and the National Safety

Plan to be developed by individual States. Together, these three deliverables are necessary to develop the Pre-implementation Safety Case (PISC) (ICAO, 2005a). Summarizing, the main elements of the RVSM safety assessment are:

- RVSM Functional Hazard Analysis
- Collision Risk Assessment
- National Safety Plans
- AFI RVSM Pre-Implementation Safety Case
- AFI RVSM Post-Implementation Safety Case

One of the AFI RVSM Safety Policy conditions is that 90% of the aircraft operating in AFI RVSM airspace must be certified for RVSM operations. Therefore, countries were asked to provide sufficient information concerning their aircraft readiness for RVSM operations as well as information on their RVSM safety assessment (ICAO, 2004c). In October 2004, States were once again asked by the AFI RVSM Monitoring Agency to send in sufficient information in order to determine the level of readiness to implement RVSM for the Go/ No go decision which was due in November 2004 (ICAO, 2004d). Unfortunately to this day, a number of States show little willingness to send in information in a timely manner.

Slow progress

At the RVSM/RNAV/RNP Task Force 5 (November 2004) meeting a lack of response from-, and slow progress being made by many States was noted. It was agreed that there was a need for ICAO to intensify its campaign and missions to assist States with the RVSM Implementation process. Furthermore, the Task Force meeting noted that there were several issues still pending. Among the most important pending items were (ICAO, 2004e).

- A lack of data collection to prepare the safety assessment case and more specifically the Collision Risk Assessment and Functional Hazard Assessment.
- The slow progress in the publication of States national RVSM safety policies, in the publication of their national safety plans and in the provision of State RVSM readiness assessments.

Given the above it was decided to postpone the AFI RVSM implementation date by one year to 19 January 2006.

Results of the Functional Hazard Analysis and Collision Risk Assessment

At the RVSM/RNAV/RNP Task Force 6 meeting held in May 2005, the meeting was presented with the results from the Functional Hazard Analysis performed by Altran technologies. The Functional Hazard Analysis identified two risks as being critical/ not tolerable and presented the meeting with some recommendations of which the following two related to the AFI RVSM Core Airspace (ICAO, 2005a):

- "Air/Ground Communication system shall be designed to ensure a total coverage of the RVSM Airspace with a minimum MTBF (Mean Time Between Failure) of two months for a given FIR"
- "Aircraft shall be equipped with ACAS II version 7.00"

At the August 2005 RVSM/RNAV/RNP Task Force 7 meeting, the tentative results from the Collision Risk Assessment were presented. It was concluded that RVSM could not be implemented at the date envisaged (19 January 2006) as the overall Target Level of Safety has so far had not been met (ICAO, 2005b). The Technical Target Level of Safety of $2.5x10^{-9}$ fatal accidents per flight hour was satisfied but the overall Target Level of Safety of 5 x 10-9 fatal accidents per flight hour was not met and is exceeded with a factor 13 (ICAO, 2006g). This meant it was technically feasible to implement RVSM in the AFI region. However, when other factors such as Air Traffic Control, monitoring, organizational issues etc. were included in the analysis the Target Level of Safety was (and still is) not met.

It became also clear from the NLR presentation that incident reporting should be improved, especially with regard to vertical displacement incidents.

Taken all of the above into account it was decided to set the new target date for implementation of RVSM in the AFI region at 28 September 2006.

Current status

To assist States with their National Safety Plans (NSP) the NSP Validation Panel (NSPVP) was set up in September 2005. At the second meeting of the NSP Validation Panel it was concluded that there are 27 States that submitted a National Safety Plan as did ASECNA on behalf of fourteen States. Furthermore it was concluded that (ICAO, 2006f):

– Fourteen States whose National Safety Plan is nearly complete
– Ten States need significant additional work on their National Safety Plans
– Four States require special attention
– One State issued a wrong format
– Four States did not submit a National Safety Plan at all as did the fourteen States that fall under the National Safety Plan submitted by ASECNA while two States delegated their obligations to other States.

Please note that the total number of States in Africa is 53 while the above overview only concerns 49 States, meaning that there seems to be no information on four States.

Finally, there is still a large percentage of AFI registered aircraft that are not RVSM compliant and approved either due to the age of the fleet or that there is currently no necessity (as will be discussed in the next paragraph) (ICAO, 2005c). At the most recent RVSM/RNAV/RNP Task Force meetings (9 and 10) the AFI RVSM Monitoring Agency reported that 51% of AFI aircraft are RVSM approved. It may be recalled that one of the requirements of the AFI RVSM Safety Policy is to have at least 90% of all aircraft operating in AFI airspace RVSM approved.

Summarizing the AFI RVSM implementation history it can be concluded that after ten RVSM Task Force meetings and several postponements of the implementation deadline RVSM has still not been implemented in Africa. Looking at other regions like e.g. Asia-Pacific that already needed 29 task Force meetings before and after RVSM was implemented and the current problems that affect the African RVSM implementation process, the fear arises that the actual implementation date may lie head in the distant future. In fact, at the tenth and most recent Task Force meeting it was decided that the new implementation date would be determined after completion of a second Collision Risk Assessment.

5.1.3 Problems and underlying causes

From the brief AFI RVSM historical analysis it becomes clear that the project is plagued by many problems delaying the actual implementation. The original implementation date of 20 January 2005 has already been postponed a number of times and currently no firm implementation date has been set.

From the above historical analysis, the theoretical model from chapter three, conversations with people closely associated with the AFI RVSM project and the results of the online survey three major and several minor causes for the problems and delays that affect the AFI RVSM implementation can be identified:

1. A Lack of involvement from African States
2. A Lack of technological capabilities in African States
3. Limited need for RVSM in Africa
4. Other

Ad 1 Lack of involvement from African States

One of the main problems associated with the African RVSM implementation process is a lack of involvement from many African States. For example during the APIRG/15 meeting, it was reported that no single State had fully completed the Functional Hazard Analysis and mitigation in their national safety plans. A large number of States had not submitted complete and accurate information to help in the collision risk and readiness assessments. Even then, from the incomplete data, it was possible to determine that the overall Target Level of Safety had not been achieved. From these experiences, it is clear that there are major weaknesses in the appreciation of the importance of data collection and documentation.

Quite understandably, on a continent where a number of countries are plagued by war, famine, corruption, disease, political instability, lack of leadership and many other problems, aviation may not be high on the priority list of politicians and governments. Furthermore, due to many basic problems (see paragraph 3.4) such as degrading runway-, taxi track- and platform pavement and lighting, poor maintenance or aircraft and a lack of adequate, appropriately qualified and experienced (technical) personnel many African Civil Aviation Authorities may not (be able to) devote enough resources to the implementation of RVSM.

However, the lack of involvement, competence and will from many African States and Civil Aviation Authorities is not only a cause in itself but can also be seen as a result of more fundamental problems. The model in chapter three contains several important variables that may explain these more fundamental problems. These variables and their relationship to the RVSM implementation are discussed below.

Ad 2 Lack of capabilities in African States

Many African States lack appropriate legislative and regulatory frameworks; lack appropriately established, empowered and well funded Civil Aviation Authorities and lack adequate, appropriately qualified and experienced (technical) personnel.

Looking at the AFI RVSM implementation process, the African Civil Aviation Authorities had to train themselves before they were able to guide the industry. As one respondent to the survey noted: ‘’ICAO has not provided enough guidance and information to the Civil Aviation Authorities and States had to seek themselves for info in RVSM implementation’’
Furthermore, training of staff, necessary for the Civil Aviation Authorities to own the RVSM project, has been slow.

With the passage of time, it was recognized that a cooperative approach for achieving African aircraft to become certified for RVSM should be given a high priority by States. Furthermore it was acknowledged that ‘’States having difficulties with the implementation of operational airworthiness certification on the RVSM implementation should seek assistance from other States having this expertise’’ (ICAO, 2005b).

Unfortunately, too late in the implementation process this need for cooperation was acknowledged and too late it was acknowledged that many States did not have the capability to perform detailed analysis themselves. As one respondent noted: ‘’ICAO and IATA were not conscious about the backwardness of some parts of AFI airspace’’.

It may be concluded that most African CAA’s did not posses the capabilities needed for the implementation of RVSM. As can be seen from figure 6; capabilities in the technology acquisition process (page 16) different capabilities influence all steps in the technology acquisition process. The lack of capabilities thus negatively influences the whole acquisition and implementation process and may also explain the lack of involvement of many African CAA’s.

Ad 3 Limited need for RVSM in Africa

As said before, the AFI RVSM Program will provide six additional flight levels between FL 290 and FL 410 inclusive in the airspace of 53 African States. This should result in a significant en-route airspace capacity increase, reduction in flight delays and fuel economies for the users. The question that now arises is whether this airspace capacity increase is needed in Africa.

The benefit of the Reduced Vertical Separation Minimum by adding extra flight levels for sure was beneficial to e.g. the North Atlantic and European airspace. However, could the same principle (extra flight levels and financial benefits to operators from taking long routes) be justified for African airspace?

In most parts of the African airspace the original 2000 ft separation between flight levels is not used to its maximum and the problem of airspace congestion is not (yet) seriously felt in the African airspace, except for possibly a number of specific spots. Since there is (at present) no real need for RVSM congestion wise, many African airlines who are already operating in the economical margin have no incentive to invest in RVSM as a long term promise as they are struggling to keep afloat in the short term.

Furthermore, the introduction of RVSM in Africa is not an African initiative but required by the international aviation community (a.o. ICAO and IATA) for the extension of RVSM airspace where the globe could be in a single order. Except for a few northern States -the interface States with Europe- and South Africa there is no real demand for RVSM other then for the homogeneity of the continent. The benefits from such a global single standard would mainly be of the benefit to operators that fly on intercontinental routes, this way avoiding transition areas between non-RVSM and RVSM airspace. Unfortunately, most of the carriers flying in and out of Africa are western carriers and thus most of the benefits resulting from the introduction of RVSM in Africa will flow to non-African airlines.

From the model in chapter three it became clear that for any successful introduction of a new technology user identification of a problem or need is crucial. With no pressing need for an increase in airspace capacity from the side of many African States and with RVSM in Africa being mainly pushed by the international aviation community there is no such thing as user identification of the need. This observation may be one of the main reasons for the slow progress being made with the introduction of RVSM in Africa.

However, with the expected growth of air traffic in Africa (see paragraph 3.8) RVSM may become increasingly important. However, with many African operators looking at short term profits, the long term promise that RVSM offers may not be convincing enough to pursue African operators, Civil Aviation Authorities and governments to intensify their efforts for the implementation of RVSM in Africa.

Ad 4 Other

Other problems affecting the feasibility of the AFI RVSM project are:

– Many African operators and Civil Aviation Authorities are in need for detailed Cost Benefit Analysis (CBA) but lack the capability and data to perform the analysis themselves.
– Equipage of aircraft operating in AFI airspace proves to be a problem. The fleet is rather old and problems with certification exist (compatibility problems). Furthermore, many operators may not be able to upgrade their fleet due to the high cost involved.
– Lack of agreement and cooperation between neighbouring Flight Information Regions, insufficient Air Traffic Controller training, degradation of Communication Navigation and Surveillance equipment and financial constraints may hamper the introduction of RVSM in Africa.
– Most of the aviation authorities are still not autonomous, which makes the development of enabling legislation take too long.

5.1.4 Conclusions

The first question raised at the start of this chapter was “why has the RVSM implementation process been delayed so many times?” With respect to that question, the following can be concluded:

One of the main problems associated with the African RVSM implementation process is a lack of involvement from many African States.

However, the lack of involvement from many African States may, in turn, be caused by several other factors:

– There are major weaknesses in the appreciation of the importance of data collection and documentation.
– Due to many, perhaps more basic problems such as degrading runway-, taxitrack- and platform pavement and lighting and poor maintenance or aircraft many, African Civil

Aviation Authorities may not (be able to) devote enough resources to the implementation of RVSM

- Many African States lack appropriate legislative and regulatory frameworks; lack appropriately established, empowered and well funded Civil Aviation Authorities and lack adequate, appropriately qualified and experienced (technical) personnel.
- The need for interstate cooperation was acknowledged too late in the implementation process. Also, the fact that many States did/do not have the capability to perform detailed analysis themselves was recognised too late in the process.

The second question raised at the start of this chapter was: ”what can be learned from the RVSM implementation related problems with respect to the possible implementation of ADS-B?’’ With respect to that question the following can be concluded:

- Even before implementation planning is undertaken, a full awareness campaign should be launched with the emphasis on the benefits that may result from the implementation. Such an awareness campaign should reach well beyond only the relevant managers in Civil Aviation Authorities. It should target all levels and, very importantly, should involve all operators (not just the major airlines).
- User involvement and participation should receive priority in any implementation process. (This can only be realized if information is provided through a thorough information campaign as mentioned above).
- African airlines and authorities should enter into strategic partnerships with those from other (developed) countries.
- The backwardness of some countries, the problems that exist with basic services and the capacity & resources that these problems demand from aviation authorities, should not be underestimated.
- It should be appreciated that many problems are not caused by unwillingness or ignorance but many States lack the resources and capabilities to actively participate in any new technology implementation process.

5.2 ADS-B and other innovations in Tanzania: Interviews

Part of this research is to conduct qualitative research in which respondents are asked for their opinion concerning the problems that might be encountered while introducing any new technology into the African Air Traffic Management system. To keep a clear focus, two case studies are performed.

Firstly a case study on RVSM in the AFI region through desk research, the results of which have already been discussed in the preceding paragraph.

Secondly, a case study on a possible future introduction of ADS-B in Africa with a geographical focus on Tanzania. The case study on ADS-B consist of interviews with people from within as well as from outside the Tanzanian aviation sector, supplemented with an online questionnaire distributed among (a part of) the worldwide ADS-B and African aviation expert community (see 4.3). The interviews that were conducted were unstructured, meaning that there were no prepared questionnaires or interview schedules. Rather the interviews were guided by a number of themes and issues that had been determined in advance.

5.2.1 Respondents

In order to obtain the necessary credibility and to increase the likelihood a respondent was willing to participate in the research, official TCAA invitations were sent to each respondent in Tanzania. The total number of respondents was kept relatively small, with a minimum required number of twenty respondents. The choice for a minimum of twenty respondents guaranteed that sufficient data would be available for analysis, even when some interviews would not yield enough or any meaningful data. Furthermore, small respondent sizes allow keeping a clear view of the details, something which is one of the important contributions of qualitative research (Ritchie and Lewis, 2003).

The choice for respondents was not random but based on certain selection criteria.

First, information needed for the research was of specific nature, causing the need for respondents to be knowledgeable of the problems within their sector and being representative for their sector. Interviews mainly took place with higher level management officials and senior engineers since they may be expected to have a complete overview of ongoing operations and problems encountered.

A second selection criterion was that the respondents originated from both the aviation sector as well as other technologically advanced sectors. Reason for also including sectors other then the aviation sector was to find out whether there are similar problems affecting the Tanzanian aviation sector as well as other technologically advanced sectors such as telecommunications, energy transmission & supply and banking & financial services. If it would be possible to identify (causes for) problems that span across sector borders, it may be possible to learn from this and, ideally, apply this knowledge to facilitate for a more efficient and effective introduction new technologies into the African aviation environment.

Last but certainly not least, the third criterion related to the accessibility of the respondents. Since the research had to be performed in a limited timeframe and under basic conditions in terms of transportation and communication, it was important that the Tanzanian respondents were located near Dar es Salaam.

Based on the selection criteria above, 37 respondents from 21 different organizations were invited to take part in the research. Of these 37 respondents, 31 people responded positively and welcomed the author at their offices. The organizations that took part in the interview round were:

- Air Tanzania Ltd.
- Celtel Tanzania Ltd.
- Coastal Aviation
- Eurocontrol
- Flightlink Ltd.
- KLM Royal Dutch Airlines
- Martinair
- National Aerospace Laboratory NLR
- Precision Air Ltd.
- Sky Aviation Ltd.
- Standard Chartered Bank
- Tanzania Airport Authority (TAA)
- Tanzania Civil Aviation Authority (TCAA)
- Tanzania Commission for Science and Technology (COSTECH)
- Tanzania Electric Supply Company Ltd. (TANESCO)
- Tanzania Transportation Technology Transfer Center
- Tanzanian Airservices Ltd.
- Transport and Water Management Inspectorate (IVW)

A detailed overview of all the interviewees can be found in appendix 1. From the overview it becomes clear that this qualitative research is characterized by its wide scope. A mix of governmental institutions, commercial companies, research institutes and universities from the Netherlands, Belgium and Tanzania were included.

5.2.2 Interview results

From the interviews it can be concluded that the Tanzanian aviation sector suffers from many problems that are similar to those of other sectors. Most of the problems originate outside the aviation sector and have to do with basic problems that are characteristic for many developing countries. Examples are financial constraints, lack of dedication, lack of education, poor infrastructure etc. The aviation sector has to deal with these kinds of problems just as any other business.

The topics that were most recurrent during the interviews are listed below and will be discussed individually:

1. Maintenance and availability of spare parts
2. Knowledge, training and personnel
3. Communication, access to- and dissemination of information
4. Monitoring of compliance
5. Type of ADS-B data link
6. Other

Ad 1 Maintenance and availability of spare-parts

Perhaps one of the most challenging tasks that lies ahead when implementing new technologies is finding ways to keep them running. This means that great care should be devoted to make sure that new technologies are sustainable. Currently, in some countries it is rather rule than exception for new technologies to become (and stay) unserviceable shortly after commissioning them. The level of practical knowledge within most organisations is not sufficient to operate and maintain (advanced) technologies. In the theoretical model in chapter three (page 29) this can be seen as a lack of production- and operational capabilities.
Furthermore the sometimes harsh environmental conditions and basic problems as vermin, leaking shelters and electricity outages contribute to the rapid deterioration of equipment.

Next to these problems, two of the biggest causes for new technologies to become unserviceable are a lacking (preventive) maintenance culture and a lack of spare parts.

Being displayed in the last phase of the theoretical model in chapter three, a maintenance oriented organisation culture may facilitate a successful implementation of any new technology. However, a culture of preventive maintenance is largely absent in many countries. When maintenance is carried out it is mainly ad hoc maintenance only after a problem appeared. This may be caused by a lack of appreciation and, perhaps more important, a lack of available (financial) resources. Time and effort should thus be devoted to sensitizing people of the need for preventive maintenance and, were needed, the necessary resources should be provided. The increased appreciation of the need for preventive maintenance may also lead to workers recording equipment deterioration so they know to replace or repair worn parts before they cause a system failure.

For example, many problems exist with NDB’s and HF/VHF communications infrastructure and technology. The equipment is rather old (in some cases dates back to the 1960’s) causing problems with the availability of spare parts, which are sometimes not available at all. This means that technicians have to locate the malfunctioning part precisely and repair it instead of replacing the complete unit containing the malfunctioning part. It is here that adaptation of the technology occurs; original parts are replaced with modified parts. However, these parts are often of inferior quality and reliability.

The problem with the (non)availability of spare parts is, like the ad hoc maintenance culture, not a problem that is restricted only to the aviation sector but effects all parts of the African economies and societies.

In conclusion, the problems with spare parts come down to the fact that:

- In many cases the financial means are not available to stock up spare-parts and to carry out preventive maintenance
- Due to a lack of information and (operational) knowledge it may sometimes not be known which parts may be expected to wear out rapidly.
- Parts that do not fail very often may be difficult to order
- Parts have to be imported from outside Africa, resulting in long delivery times (sometimes even weeks)
- Problems may exist in ordering as suppliers will be reluctant to send things off to developing countries without advance payment

However, there are also some positive developments. A visit to Celtel, the leading mobile telephone service provider in Tanzania, learned that maintenance and spare-parts related problems are on the decline. The equipment in present day mobile telecommunications is off the shelf and doesn't need much maintenance. The new technologies are less prone to wear (mainly due to the absence of mechanical parts) and resetting of the software usually will do the trick. With new Communication, Navigation and Surveillance technologies becoming more and more digitalised, optimized for easy replacement and self-diagnostics this may promise an improvement for the future.

In the scientific literature (and in the model) there is little mentioned about maintenance and its relationship to a successful introduction of new technologies. This may be explained by the fact that maintenance can only follow after the actual introduction of a technology. In the longer term however, maintenance significantly affects the successfulness of a technology and in this way the successfulness of an introduction. From the field research it can be concluded that, certainly in developing countries, maintenance issues are no to bee underestimated when trying to introduce any new technology.

Ad 2 Knowledge, training and personnel

Another issue raised in many of the interviews was the lack of operational and hands-on knowledge and the (knowledge and organisational) gap between the (higher level) management and the operational divisions.

At a local- or technical level it proves to be difficult to obtain personnel with sufficient technical skills and hands-on knowledge. In the case of TCAA it proves difficult to attract new employees with sufficient operational and technical knowledge, especially operations- and air worthiness inspectors.

At a regional- or organizational level the problem seems to be less severe. There are fewer shortfalls of highly trained personnel with sufficient theoretical knowledge in the higher levels of most organizations (i.e. Bachelors and Masters level). Problem however is that only training and theoretical knowledge are not enough. Problems exist with technically well qualified managers because education and training does not make someone automatically a good manager as other factors such as personality, leadership and motivation and are equally important.

A visit to the Tanzania Electric Supply Company Ltd. learned that some level of basic knowledge for analysis and applied research (i.e. fault diagnostics, basic design skills) is present within most large organizations. However, for more advanced analyses and measurement procedures they still rely on foreign partners. In other words; the know-what is there but the know-how of reasons behind things is lacking.

Furthermore, in many organisations problem solving capacity is almost non existent and hierarchic structures and lack of responsibilities with the workers stand in the way of pragmatic and efficient operations.

Education and training prove to be serious problems as well. People are sent on a regular basis to workshops, seminars and trainings organized by a.o. ICAO and IATA but there are several problems:

– In many cases it is just one person who receives training.
– This one person is responsible for transferring the knowledge to its colleagues. However, attending a training does not make one an instructor.
– Knowledge is power and sharing knowledge may mean that a person looses some of its power and status, making some individuals reluctant to spread the knowledge.
– The increased knowledge makes this person eligible for promotion. When promoted, the person may loose connection with the matters he received training for to begin with and in many cases the knowledge and skills are lost.
– Finally, nothing is permanent when it comes to holding positions. Many organizations not go in for career planning and the sometimes fierce competition for prestigious

positions causes too much time being wasted claiming and preserving personal interests instead of looking after what is best for the community.

The issue of training and education is not depicted in the theoretical model in chapter three. The literature study did not explicitly reveal that knowledge, training and education are vital variables for the transfer of new technologies. Again, like with the issue of maintenance, training and education may not directly affect the actual transfer of the new technology but they become increasingly important once the technology has to function in its target environment. Education and training do however, greatly affect the effectiveness and sustainability of the technology as it enables people to operate the technology is the most effective and efficient way. So, in the long term, education and training are vital elements in ensuring that an initial successful technology transfer remains successful.

Ad 3 Communication and information

One of the most important problems according to several interviewees is access to- and dissemination of information and knowledge. It is very important to first inform people on a new technology, what it is and what it has to offer. The benefits that may be derived from- as well as the need for the new technology should be made clear. It is only then that the real implementation of the new technology can be started.

Communication, access to- and the dissemination of information are thus a vital component in any technology implementation process. Unfortunately, this can be rather difficult in many African countries. Obviously, this may be attributed to a lack of physical communications infrastructure and a lack of maintenance but equally important are the following causes that several interviewees mentioned.

- There is a lack of (accessible) information on new technologies causing people to not know what technologies are available and preventing them from making well considered decisions.
- People do not know where to search for information and lack the skills to use/ apply proper search techniques.
- People do not know which selection criteria to use for the selection of alternative technologies; choices for a particular technology may be based on the wrong criteria.
- Technologies that are available at least effort are selected. This means that technologies that people have been exposed to and those that are relatively easy available are more likely to be selected. However these straightforward choices may not necessarily be the most appropriate and cost effective options.

An example of the difficulties with access to- and dissemination of information is presented by one of the leading Tanzanian airlines. This airline houses (part of) their engineering department in container-like sheds with just one computer that is connected to the internet. The quality of the internet connection is so bad that very useful documents from e.g. the ICAO website cannot be accessed due to the low download speed and frequent interruptions. This example is illustrative for many African airlines (and other companies) and shows that, in spite of the vast amount of freely available information at the internet (e.g. at the ICAO and IATA websites), the access to- and dissemination of information still remains a large hurdle.

Finally, some interesting discussions with officials from the Tanzania Transportation Technology Transfer Center ($TanT^2$) learned that there is currently a lack of interaction and effective communication between R&D institutes, the government and the industry. This lack of communication manifests itself through a lack of consultation and input in each other's processes and a lack of an effective and efficient system for interaction.

All these shortfalls affect several points in the chain depicted in the model in chapter three as information and communication are an integral part of any implementation process. These items are particularly important in the adoption and diffusion process as internal and external problems may arise here.

Ad 4 Monitoring

Monitoring can be divided into three separate components:

- Monitoring of compliance with standards and regulations
- Monitoring of equipment
- Certification

The monitoring, or better; the lack of monitoring of compliance with standards, regulations and maintenance requirements is often one of the main reasons for the delay or, worse, failure of implementation projects. Program management and traceability are highly important but lacking in many African countries. Furthermore tracking the progress and state of readiness of each individual aircraft (operator) has proven to be difficult with past innovations, as can be seen with the RVSM case study in which slow progress was (and still is) made with the readiness assessments.

Causes for the lack of monitoring are numerous, ranging from a lack of (sufficiently qualified) staff, a lack of expertise, a lack of leadership, competence and awareness to factors such as bribery and vast geographical distances that have to be travelled.

Ad 5 ADS-B data link technology options

Another issue raised in several interviews was the concern that Tanzania might adopt an isolated or unique solution with an ADS-B system based on both Mode S and UAT data link technology.

According to current plans (July 2006) two Mode S base stations might be installed in Tanzania, providing services to aircraft operating into and within Tanzania that are already 1090 MHz ES equipped while the UAT (ten ground stations) is planned to cater for the general aviation.

The choice for an ADS-B system based on two data links however, may not be the most preferable choice since:

- The two systems (Mode S and UAT) use different frequencies and are not interoperable. Considerable investment in additional ground infrastructure is required to translate and re-broadcast UAT and Mode S signals to provide air-to-air visibility (ADS-B in).
- At the ICAO 11th Air Navigation Conference the Mode S Extended Squitter data link was endorsed as being the preferred ADS-B technology for international harmonization. However, it seems as if ICAO has left open opportunities to work with other ADS-B technologies as well.
- Most transport and passenger aircraft are already mandated to carry a Mode S transponder in most airspaces.
- Amongst others, all new Airbus and Boeing aircraft are being forward fitted with the capability to transmit ADS-B out messages using Mode S.
- Mode S transponders on many aircraft are (currently being) upgraded to meet the European elementary- and enhanced surveillance mandate. This means that the addition of ADS-B only comprises a software update in the same transponder.
- From ADS-B trails held in Australia the Australian Strategic Air Traffic Management Group concluded that UAT is more expensive compared to Mode S (ASTRA, 2005).

One of the nice features of the UAT is the ability to uplink traffic and weather services (Traffic Information Service - Broadcast (TIS-B) and Flight Information Service - Broadcast (FIS-B)). However, it is to be seen whether these services will be available in Tanzania since TIS-B services require that the aircraft receiving the uplink data is in the coverage of radar, something which is not available in most parts of the country (like most parts of the African continent). Furthermore, other types of data link (other then ADS-B data link) which may be deployed in the future could also be used to offer these services.

More information on the system and possible data link options can be found in appendix 2. Please note that the information in the appendix (taken from a World Bank publication) is written from a viewpoint that UAT may be the preferred data link for ADS-B implementation in Africa. This view does not necessarily reflect the author's opinion but may serve as an example of the ongoing discussion on which type of data link (combination) should be used.

The model at page 19 in chapter three shows that these compatibility and standardization problems may have a negative influence on the implementation of technologies and, more specifically, on the adaptation, adoption and diffusion of the new technology.

Ad 6 Other

Some interviewees mentioned that for any new technology to be successful, the technology should be cost effective. (Assistance with) Cost benefit Analysis (CBA) calculations relating to any new technology (a.o. ADS-B) should be provided to all operators.

Since most organizations are not in the position that they can afford failure of any new technology, cutting edge technology may be too risky and some organizations prefer proven technologies for their operations. This can be exemplified by the policy of the Tanzania Electric Supply Company Ltd. to only acquire and implement proven technologies. This policy choice has been made because TANESCO, like many other organizations, does not posses the in-house capabilities to adapt (their internal processes), operate and maintain cutting edge technology which may be prone to teething troubles and unforeseen setbacks.

Next issue is the lacking capacity and capability of many Air Traffic Controllers/ control centres throughout the continent. In many Flight Information Regions problems exist with unserviceable equipment, poor controller skills and proficiency and lack of State regulation and oversight. Even in Flight Information Regions that do possess up to date equipment, many Air Traffic Controllers (ATCO's) lack the capacity to operate the equipment in an effective way.

Another issue mentioned concerned the installation of a ground network linking possible ADS-B stations together. At present the Tanzania Telecommunications Company Ltd. (TTCL) has a government approved monopoly on the fixed grid in Tanzania. Companies not active in the field of communications but owning a fiber(optic) network for their own operations are thus not allowed to lease some of their excess capacity for use by third parties to offer other services. The absence of competition makes TTCL indifferent to the wishes of consumers and not really inclined to improve the services they offer or to be innovative. This has resulted in an unreliable, ageing and badly maintained network and poor services. Furthermore, a failsafe and redundant system is not possible with one supplier and this may also stress the need for more competition between different service providers.

However, three mobile, private, telephone networks operate on the entire Tanzanian national territory and these could be contracted to support the system in terms of power supply, communication and data transfer. Nevertheless, the national aviation authorities may be reluctant to actually involve private parties.

As said before, a large part of the African fleet consists of rather old aircraft. Supplemental type certificates developed in western countries are mainly based on the new generation of aircraft such as the A320 family, A330, B737NG family, B747-400 etc. Question now remains who is going to develop these supplemental type certificates for older aircraft generations such as the DC-8, 707, An-12, Il-76, Y-8 etc. operating in large quantities in many African countries? Who is going to certify these type certificates and who is going to perform the maintenance? It is clear that many African countries do not posses these capabilities while western nations have no interest in providing these capabilities as they do not operate these types anymore. Furthermore, it may prove too costly for many African operators to modify their old aircraft with new technologies that are mainly designed for installation in the new generation of aircraft.

Finally, a number of interviewees mentioned the need for a culture change within both African and western organizations. Summarizing, African organizations should:

- Change the prevailing culture and attitude from a passive and hierarchic attitude to a pro-active attitude that is less controlled top down but with room for own initiative and bottom up approaches.
- Open up for assistance and become more communicative to the outside world.
- Fight corruption

At the same time western organizations should:

- Focus less on short term profits but instead aim at long term development
- Besides transfer of technology, western companies should also transfer knowledge and capabilities.
- Acknowledge and take advantage of local expertise
- Respect local traditions and customs

5.2.3 Interview conclusions

From the interviews it can be concluded that the African/ Tanzanian aviation sector suffers from many problems that are similar to those of other sectors in Africa/ Tanzania. The aviation sector has to deal with these kinds of problems just as any other sector. However, several problems areas have been identified that play an important role in the African aviation sector:

Ad 1 Maintenance and availability of spare parts

The level of practical knowledge at all levels of most organisations and countries is not sufficient to operate and maintain (advanced) technologies. A culture of preventive maintenance is still largely absent in many countries (quite often for understandable reasons) and numerous problems exist with the availability of spare parts.

Time and effort should be devoted to sensitizing people of the need for preventive maintenance and, were needed, assistance with implementing preventive maintenance systems should be provided.

Ad 2 Knowledge, training and personnel

Many problems exist with the availability of knowledge (mainly operational and hands-on knowledge), training capacity and the availability of well qualified personnel.

Despite the many problems, several solutions can be proposed that may help to solve or, at least, to reduce some of the problems:

- Training and retraining others by the ones that received initial training.
- Assist staff with transferring their skills into a training module of some sort, depending on the type of training that is needed. For Tanzania this could be done at the Civil Aviation Training Centre.
- Build more training capacity in the region so as to avoid that large numbers of relevant staff cannot be trained since training them all abroad is financially not viable.
- Provide more training at up country facilities.
- More attention is needed for knowledge management, career path planning and assuring that knowledge and skills will not be lost when positions move around.
- More priority should be given to technology-, knowledge- and capability transfer by western companies & countries.

Ad 3 Communication, access to- and dissemination of information

Communication, access to- and the dissemination of information are vital components in any technology implementation process. Unfortunately, communication, access to- and the dissemination of information can be rather difficult in many African countries. However, several solutions that may help alleviate the problems are:

- Even before implementation planning is undertaken, a full awareness campaign should be launched with the emphasis on the benefits that may result from the new technology.
- Make information available (DGTL, ICAO, IATA) in form of easily accessible leaflets that also allow low skilled but operationally very relevant staff members of aviation authorities and industry to appreciate the contents.
- Encourage people to actively search for best methods and technologies instead of choosing what's available at least effort. Create awareness to be more critical in selecting new and sustainable technologies.
- Focus on special interest groups and provide them with tailored information.
- Promote and build durable relationships between tactical partners.
- Provision of independent and non-commercial advisory services and assistance by western counterparts
- Create and facilitate transfer of technology-, knowledge- and capabilities between research institutes, commercial companies and society.

Ad 4 Monitoring of compliance

Monitoring can be divided into three separate components: monitoring of compliance with standards and regulations, monitoring of equipment and, third, certification. The monitoring, or better, the lack of monitoring of compliance with standards, regulations and maintenance requirements is often one of the main reasons for the delay or failure of implementation projects. Furthermore, program management and traceability are highly important but lacking in many African States. Based on the interviews the following recommendations can be made:

- Develop a (regional) system for the control and supervision of licensed and certified bodies.
- Develop a (regional system for the resolution of safety issues, reporting of errors and incidents and investigation of incident and accidents.
- Train (regional) inspectors and oversight personnel.
- Increase the capacity of Civil Aviation Authorities and sensitize for the importance of data collection and documentation.
- Sensitize for the need of program management and traceability.

Ad 5 ADS-B data link technology

In conclusion, with an ADS-B system based on both UAT and Mode S problems may be expected additional to the problems that may arise when implementing ADS-B based on a single data link (interoperable, non-conformity with global standard, additional ground infrastructure, different standards etc). All the interviewees that mentioned this issue preferred the Mode S data link over UAT.

5.3 ADS-B and other innovations in Tanzania: Survey

Next to the desk research on RVSM and the interviews held in The Netherlands and Tanzania, an online survey was conducted among (part of) the worldwide ADS-B and AFI expert community. The choice for the online survey format was mainly based on time, cost and efficiency considerations.

In this research project the online survey consisted of a mixture of multiple choice- and open ended questions. It is recognized that the list of questions to a great extend determines the results of the survey. When certain concepts/ topics are overlooked during the construction of the survey, this will directly affect the outcome of the research. By adding ''other'' categories and adding open questions in which the respondent is invited to add topics that the respondent considers important but are not included in the survey, this validity issue is safeguarded.

Furthermore, it should be recognized that only people who are able to access the internet can participate in an online research, causing problems with representivity as well. This may especially be the case with the survey on the introduction of new technologies in Africa as many of the (potential) respondents are from Africa, a continent that is well known for its weak ICT infrastructure. For this research only professionals and organisations have been approached by e-mail so it may be safe to assume that most are computer knowledgeable and able to fill in an online survey.

Two slightly different surveys were send to different groups. First, a survey on the chances and threats for ADS-B in AFI was sent to the worldwide ADS-B expert community. This group of ADS-B experts was identified using ICAO Asia-Pacific ADS-B Task Force meeting documents, documents provided by the Australian Strategic Air Traffic Management Group (ASTRA), publications of the Australian Civil Aviation Safety Authority (CASA) as well as personal contacts and several international websites dedicated to ADS-B. This means that the experts involved may be expected to be knowledgeable on ADS-B but it cannot be assumed these experts are familiar with the African aviation environment.

To compensate for this deficiency, another survey was send to a control group (the AFI expert group) that may be expected to be very knowledgeable of the African aviation environment but not particularly on ADS-B. This group of experts was identified using documents from ICAO AFI Planning and Implementation Regional Group RVSM/RNAV/RNP Task Force meetings and the conference of African ministers responsible for air transport, held in Libreville, Gabon on 15-19 May, 2006.

The worldwide ADS-B expert group was asked questions directly related to a possible implementation of ADS-B in Africa while the AFI control group was asked the same questions however not directly related to ADS-B but to new technologies in general. By comparing the answers from both groups it is possible to see whether a (possible) lack of knowledge of the African aviation environment with the ADS-B expert group and a (possible) lack of knowledge of ADS-B with the AFI expert group may have influenced their answers and thus negatively affect the reliability of the measure.

To increase the response rate, a personalized pre-notification e-mail was send to all respondents introducing the research and inviting them to take part once the survey went online. This was followed by an official invitation e-mail containing the link to the survey website five days later. Finally, those who not responded within ten days after the official invitation email received a reminder/ follow-up email to bring the research to the notice once again.

5.3.1 Survey results

Combined, both surveys yielded 103 responses. After close examination thirteen surveys were dropped, because they were incomplete or did not reveal any useful information. Of the 90 remaining surveys, 30 were from the AFI expert group and 60 from the worldwide ADS-B expert group. Out of a total of 446 people that were invited to participate in the research (240 for the AFI expert group and 206 for the ADS-B expert group), these 90 effective responses make up for a combined response rate of 20% (13% for the AFI expert group and 29% for the ADS-B expert group).

With the main focus of this research on a possible future introduction of ADS-B in Africa, the survey on the chances and threats for ADS-B in Africa was regarded as the main source of information while the survey on Introducing new technologies in African aviation served as a control group to which the results of the ADS-B survey could be compared.

Most respondents from the ADS-B expert group originate from western, developed countries while most of the respondents from the AFI expert group originate from African countries as can be seen from figure 13 and 14. The average level of education is for both groups approximately the same with the majority having had bachelor or master level education.

Figure 13 Origin of ADS-B expert group respondents

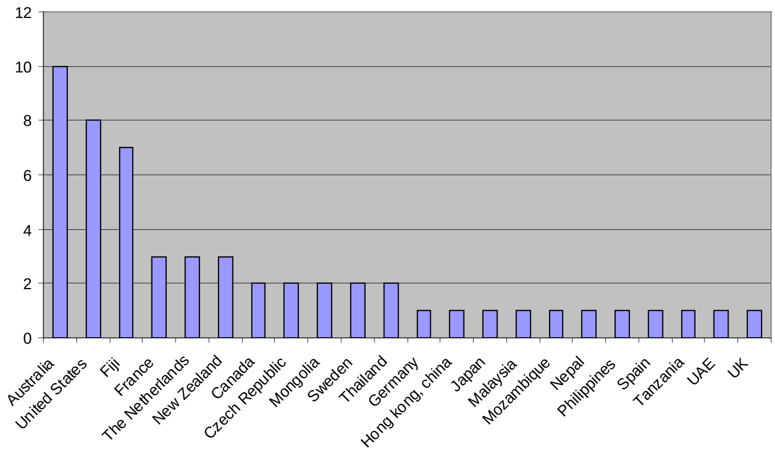
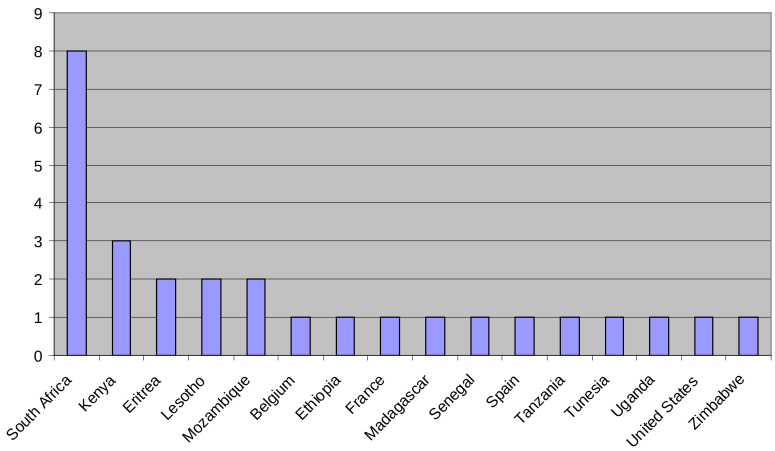


Figure 14 Origin of AFI expert group respondents



Question no. 1: ‘’Please indicate the level of importance you attach to the supposed benefits that the introduction of ADS-B in Africa might offer’’.

This first question yielded the following top four of most important benefits as indicated by the worldwide ADS-B expert group (Appendix 5a)

1 Improved pilot and ATC traffic information and situational awareness
2 Reduction in the risk of mid-air collisions
3/4 Improved ATC efficiency and capacity
3/4 Improved Search and Rescue (SAR)

The AFI expert group was asked to ‘’please indicate the level of importance you attach to the items listed below that aim to solve or reduce problems and hazards that may affect aviation safety and operating efficiency in Africa’’. The results of this question were exactly the same as the outcome with the worldwide ADS-B expert group that can be seen above (appendix 5b)

These outcomes may lead to the conclusion that areas most open to improvement (according to the AFI expert group) are exactly those areas where ADS-B may prove its greatest value (according to the ADS-B expert group).

However, it should be recognized that it is hard (maybe nearly impossible) to value the possible benefits derived from any introduction when the focus is on Africa as a whole.

Due to its vastness and diversity, cost and availability of skilled labour, existing communication infrastructure, nature and density of air traffic etc. may have a large impact on the benefits that can be expected for any specific time and place. These results therefore mainly serve as an indication of the possible benefits that may be derived from the introduction of ADS-B.

Question no. 2: ''Please indicate the level of importance you attach to the following problems that may possibly pose a threat to- or may form an obstacle for an effective and efficient introduction of new communication, navigation and surveillance (CNS) technologies like ADS-B into the African aviation environment''.

This question to the worldwide ADS-B expert group produced the following top four (appendix 5c):

1 Lack of financial resources with both African operators and authorities to purchase, implement and maintain new technologies.
2 Lack of standardization, regulation and guidance from and amongst African CAA's
3 Compatibility problems with installation of ADS-B equipment in African aircraft fleet
4 Lack of CNS infrastructure

The AFI expert group was asked the same question, but not limited to CNS technologies. It focussed on the implementation of new technologies into the African ATM system in general: ''Please indicate the level of importance you attach to the following problems that may possibly pose a threat to- or may form an obstacle for an effective and efficient introduction of new technologies into the African aviation environment ''.

The top four of problems and threats rated as being most important by the AFI expert group is as follows (appendix 5d):

1 Lack of financial resources with both African operators and authorities to purchase, implement and maintain new technologies.
2 Lack of specialized knowledge
3 Compatibility problems with installation of ADS-B equipment in African aircraft fleet
4 Lack of standardization, regulation and guidance from African CAA's

The results of these two questions may lead to the conclusion that the ADS-B expert group and the AFI expert group agree on three out of five possible problems and threats, namely:

1 Lack of financial resources with both African operators and authorities to purchase, implement and maintain new technologies.
2 Lack of standardization, regulation and guidance from African CAA's
3 Compatibility problems with installation of ADS-B equipment in African aircraft fleet

For most respondents the most important benefit is undoubtedly the low cost of the system compared to conventional CNS technologies. One respondent argued that when the system would be provided (by western nations) at no initial cost for users, ADS-B will create a business case for its own and that this possibility should be studied. Others mentioned that the development of a system like ADS-B can be done most efficient by teaming up with commercial/third parties or with a commercial Air Navigation Service provider. However, the will to proceed and the communication between specialists and higher authorities (Civil Aviation Authorities and governments) needs to be established. Another respondent emphasized the need to work together with other sectors like telecommunications for provision of sites and services. Finally, numerous respondents stressed the importance to work on maintenance issues and to assure the security of the physical sites.

Question no. 3: ''For the improvement of flight safety, should African CAA's and airlines (both African and non-African) continue to use and improve conventional surveillance technologies like primary and secondary radar, or should they focus on newly developed and low cost alternative surveillance aids such as ADS-B?''

To this question both the ADS-B (appendix 5e) and the AFI expert group (appendix 5f) agreed that the focus should be on newly developed technologies.

However, both expert groups also mentioned that there should be a gradual shift from conventional technologies to new and more advanced technologies and that great care should be given to such a transition period.

Furthermore, numerous respondents from both groups advised to also explore the concept of multilateration[1] as a first step towards full scale ADS-B implementation.

Question no. 4: The ADS-B expert group was asked: **''If ADS-B were implemented in the AFI region, for which purpose(s) could it prove its greatest value?''**

The AFI expert group was asked the same, however not only related towards ADS-B specifically but towards new and enhanced surveillance technologies in general: ''If it is decided to introduce new and enhanced surveillance technologies for Air Traffic Control/ Air Traffic Management, then it should be aimed at:…''
Both the ADS-B- as well as the AFI expert group agreed that ADS-B or any new CNS technology would mainly be beneficial for the en-route phase (appendices 5g and 5h).

Question no. 5: ''Do you think the introduction of ADS-B into the African aviation environment will be feasible in the near future (5 to 8 years)?''

To this question the vast majority (87%) of the ADS-B expert group answered that this would be possible.

5.3.2 Survey summary

The expectation of the results I had before I send out the questionnaire to both groups was that the ADS-B expert group would be very much in favor of implementing ADS-B (and other advanced technologies) in Africa while the AFI expert group would be more conservative on this issue and more inclined to tackle basic problems first. However, this turned out be wrong.

The most important benefits that may arise from a possible introduction of ADS-B in Africa are (according to most survey respondents):

- Improved pilot and ATC traffic information and situational awareness
- Reduction in the risk of mid-air collisions
- Improved ATC efficiency and capacity
- Improved Search and Rescue opportunities (SAR)

From the survey it became also clear that these four areas are also the areas that are in need for improvement the most. This means that, according to the majority of the survey respondents, ADS-B may provide the benefits right were they are needed.

[1] Multilateration uses Time Difference Of Arrival (TDOA) to triangulate or multilaterate the aircraft's position. The aircraft's position is determined by accurately calculating the Time Difference Of Arrival of a signal transmitted by e.g. a Mode S transponder to three or more receivers. Multilateration offers an accuracy of less than five meters and is said to be more accurate than primary and secondary radar

Both the ADS-B and the AFI expert group agreed also on the following three problems as being the most important ones that may hamper the efficient and effective introduction of ADS-B or any other new technology into the African ATM system:

- Lack of financial resources with both African operators and authorities to purchase, implement and maintain new technologies.
- Lack of standardization, regulation and guidance from African Civil Aviation Authorities
- Compatibility problems with installation of ADS-B equipment in African aircraft fleet

Furthermore, both expert groups agreed that the focus for future development should be on newly developed Communication, Navigation and Surveillance technologies. These technologies would then mainly be beneficial for the en-route phases of flight.

Finally, the vast majority (87%) of the ADS-B expert group answered that the introduction of ADS-B into the African ATM system would be possible within five to eight years. Unfortunately however, the experiences with the AFI RVSM project may indicate that this might be a bit too optimistic.

Contrary to my expectations to find rather strong differences between both expert groups I concluded that both groups agree on most issues. This may mean that the conclusions drawn from the survey are rather reliable as they are based on the answers of two different groups. Furthermore it is a positive sign to see that most of the experts from the aviation community agree, even though the questions were rather general. On the downside it can be concluded that the AFI expert group is in favor of implementing new and advanced technologies. This is contrary to my conclusions (based in the interviews and case studies) to tackle basic problems first before proceeding with advanced technologies like ADS-B.

Conclusions and recommendations

Reflection on theory

The literature study performed at the beginning of the research proved to be very useful for understanding the complex nature of technology itself and technology implementation processes. Especially the distinction between a physical and informational component as well as the distinction between embodied and disembodied information proved to be valuable. Finally, the theory on technology transfer, technological capability building as well as the interrelationship between these two maintains strong ties with every day reality.

During the research, existing theory was validated by practice on many occasions. Especially during the RVSM case study it was concluded that user identification -or at least user recognition- of a need is essential for the smooth and successful implementation of any new technology.

However, because of the rather focused and practice-based nature of this research no new theories or implications have been found in addition to already existing theories. This may mean that, from an academic point of view, no new insights into the theoretical background of technology implementation processes have been developed.

Finally, every day practice in many African States (though not all!) makes it impossible to capture processes in a theoretical framework or some scheme.
Science and academic theories are based on reason, logic and order. However, because of the rather complex relationships between history, culture, poverty, corruption etc in many African countries it may be hard to find any reason, logic or order in many decisions made by African government officials and leaders. This may mean that, notwithstanding the importance of scientific knowledge, working in Africa requires a lot more then just theoretical knowledge.

Sub-question 1 and 2

‘’What are currently the most important bottlenecks and their causes for introducing new technologies and technical standards into the African ATM system?’’

Financial restrictions

The first bottleneck may be obvious and an overworked subject but one of the main bottlenecks (and cause for the vast majority of the problems that will follow) is still a chronic lack of funds with many developing countries. In an attempt to meet the (high) international (safety) standards, many developing countries and operators are forced to operate and maintain expensive equipment they can hardly afford to acquire and install to begin with. Authorities and operators have no financial capacity, cannot afford grounding planes for upgrading and may not be able to sufficiently train their personnel.

In spite of financial restrictions probably being the most obvious and important bottleneck for the introduction of new technologies, just providing funds will not solve the problems and a comprehensive approach is required addressing the overall air transport system.

Basic- and regulatory problems

Quite understandably, on a continent where a number of countries are plagued by war, famine, corruption, disease, political instability, lack of leadership and many other problems, aviation may not be high on the priority list of politicians and governments. Furthermore, due to many basic problems such as degrading runway-, taxi track- and platform pavement, poor lighting and poor maintenance of aircraft, many African Civil Aviation Authorities may not be able or willing to devote enough resources to the implementation advanced technologies such as RVSM and ADS-B.

Furthermore, many African States lack appropriate legislative and regulatory frameworks; lack appropriately established, empowered and well funded Civil Aviation Authorities, lack policy- and regulatory support functions and lack adequate, appropriately qualified and experienced (technical) personnel.

Monitoring of compliance with standards, regulations and maintenance requirements is often in default and one of the main reasons for the delay or failure of implementation projects.

Information and communication

Communication, access to- and the dissemination of information can be rather difficult in many African countries. Accessibility and dissemination of information through the internet many not be enough in a region where many may have no or limited access to the internet. This results in people across the industry not being familiar with the latest developments, new and improved technologies and best practices.

Very important -but often ignored- are internal problems that may arise as a result of a lack of information and communication. Incomprehension and a lack of knowledge with personnel (at lower levels in the organization) about the usefulness and functionality of any new technology may pose a significant threat to the technology implementation process. Many of these internal problems may be prevented or overcome by:

- Showing the relative advantage of the new- over the old technology
- Reducing the (perceived) complexity of the technology
- Demonstrating the technology and explaining the positive consequences of the technology in concrete terms

Observability of positive consequences may be especially difficult with preventive technologies since the results of an implementation cannot be observed directly. This certainly applies to technologies that aim to improve aviation safety (as they prevent incidents and accidents from happening).

Currently, there is a lack of communication between many of the African Civil Aviation Authorities and operators and their western counterparts and technology suppliers. This makes it more difficult to tailor assistance to the specific needs and to adapt technologies to make them more appropriate and sustainable for the African environment.

Knowledge and education

Problems exist with the availability of operational and technical knowledge, training capacity and the availability of well qualified personnel (e.g. operations- and air worthiness inspectors). More resources, facilities and capabilities are needed to offer in-house training programmes.

Furthermore, much of the information and knowledge needed to actually transfer, implement and operate new technologies is tacit and embodied within (western) technology suppliers and a relatively small group of (western) experts. Depending on the willingness of the technology supplier to share and transfer its knowledge and capabilities, this knowledge may not be easily transferable.

Technological problems

The composition and age of the African aircraft fleet may cause compatibility problems when installing advanced technologies such as ADS-B into older airframes. Furthermore, compatibility problems may arise when trying to integrate ADS-B into the existing (CNS) infrastructure.

Furthermore there may be the problem of maintenance and certification as there are few maintenance organisations in Africa that are capable of installing advanced technologies into existing airframes and infrastructure and maintaining them.

Appropriate and sustainable

Much too often new technologies become unserviceable only after a short period of time. Besides environmental problems and maintenance difficulties, many of the problems are caused by new technologies not being appropriate and sustainable.

Transferring an advanced technology like ADS-B from western economies to developing countries involves bridging the technological distance between the two. This may cause additional problems with the appropriateness and sustainability of the transferred technology. It should be realized that in many cases it is impossible to make a one-on-one transfer of the technology for use in different environments.

Sub-question 3

‘’How may future technologies and technical standards be implemented more efficiently into the African ATM system?’’

The problems identified in this report that hold back Africa from reaching its potential are not new. They have been identified before and several attempts have been made to resolve them. However, to date, the results do not reflect the effort made (Belai, 2006).

This paragraph offers solutions that may assist in solving some of the problems and facilitate for a more adequate and effective introduction of new technologies.

Basic- and regulatory problems first

Even before implementation planning for advanced technologies is undertaken, basic and essential problems should be solved with priority.
Some of these solutions are listed below (this list is only indicative and not exhaustive):

- More maintenance facilities (in particular in avionics)
- More engineers and (maintenance)technicians trained
- More Civil Aviation Authority surveyors, inspectors and air traffic controllers
- More appropriately established, empowered, well funded and -very important- autonomized Civil Aviation Authorities
- Improvement of airport infrastructure (improved runways, taxiways, fencing and lighting)
- A more pro-active and maintenance based safety management culture/ mindset (which may be achieved by offering a.o. Safety Management System (SMS) courses)

It is only when the basics are in place that the implementation of advanced technologies can be supported.

Knowledge and education

From the preceding chapter it became clear that there is a lack of operational and hands-on knowledge. Below are some recommendations on how to possibly improve the education and training to members of the African aviation community.

- Priority should be given to the training of inspectors and oversight personnel.
- Western Civil Aviation Authorities could assist staff from African Civil Aviation Authorities and industry with transferring their skills into a training module of some sort, depending on the type of training that is needed. For Tanzania this could be done at the Civil Aviation Training Centre (CATC).
- Training and retraining others by the ones that received initial training is a cost effective option.
- Set up of programs for experienced (western) engineers and experts to come and work with African personnel. E.g. western fire fighting experts or airport security experts that come and assist/ advise their African counterparts on how to improve their fire fighting capabilities and how to improve airport security.
- More training should be provided on location, close to where the knowledge is needed.

- More attention is needed for program management and traceability, knowledge management, career path planning and assuring that knowledge and skills will not be lost when people move to another position.
- More reflection on past training to see if the training is still relevant or maybe open for improvement.
- Research into the possibility to annually train a number of African experts at the European Aviation Safety Training Organisation (EASTO) in Hoofddorp, the Netherlands. As EASTO is a consortium of the Joint Aviation Authorities (JAA), the International Institute of Air and Space law of the University of Leiden, the Dutch National Aerospace Laboratory (NLR) and the Netherlands Aviation College (NLC) it may offer a wide range of courses that may be beneficial for many African Civil Aviation Authorities.

Create awareness of the need

First and foremost the technology should address the actual need. Every new project should begin with an audit to identify the actual need of the sector (industry, authority and operators). Following this audit and even before implantation planning is undertaken; a full awareness campaign should be launched with the emphasis on the need for- and the benefits that may result from the new technology. Only when full support is received from the sector, successive steps can be taken. It may be reminded that it is the perception of the technology users that counts in the acceptance of any new technology and not the objective facts and expert opinion.

Furthermore, users should be involved in the technology implementation process from an early stage on.

Tactical partnerships

The creation of a twinning program (based on the principle of city twinning) could be considered, establishing co-operative and durable links between European and African Civil Aviation Authorities. Through such a system of small scale and pragmatic cooperative agreements between European and African Civil Aviation Authorities at an operational level, Europe would have a lot to offer to many African States. Long term cooperation/ twinning would enable to go beyond the limited benefits that result from the current practice of mainly using consultancy services to address a specific ad-hoc safety challenge.

Building on this idea, it may be interesting to investigate into a possible partnership between Airservices Australia or the Alaska Capstone project and African/ Tanzanian authorities and operators that may consider ADS-B implementation.

Another possibility for international cooperation may be between newly joined, ex-communist EU members and African countries as they may partially operate the same aircraft types. This way the former Warsaw pact countries can assist African countries in upgrading their fleet.

Furthermore, interstate cooperation and partnerships between African authorities and operators may also facilitate for a more effective introduction of new technologies as economies of scale may be achieved and knowledge shared.

Sub-question 4

A ‘’What problems are likely to arise when it is decided to implement ADS-B in the AFI region in the near future?’’

Next to the problems already mentioned with research question 1 and 2 (financial restrictions, basic infrastructure and regulatory problems, information and communication deficiencies, knowledge and educational shortcomings, technological (compatibility) problems and appropriateness and sustainability issues), some ADS-B specific problems can be seen.

From the analysis of the main causes for accidents and incidents in Tanzania in the period 01-01-1997 through 13-04-2006 it can be seen that none of the five main causes for these incidents and accidents could have been reduced by the usage of ADS-B.

From the discrepancy between causes for accidents in Tanzania and the benefits that may be derived from ADS-B it can be concluded that ADS-B is not the answer to many of today's problems (causes for incidents and accidents). ADS-B should thus not receive priority over other measures such as improvement of maintenance schedules, pilot capability and capacity and the improvement of ground infrastructure such as runways and taxi tracks.

However, when it is decided to introduce ADS-B into the African ATM system it should be reminded that the system does not address the greatest need, i.e it does not prevent the majority of accidents from happening. Furthermore, great care should be given to inform operators and authorities of the need for increased surveillance and the benefits that may be derived from the technology even before implementation planning has started.

B ''How can these problems be alleviated allowing for a more efficient introduction of ADS-B in the AFI region?''

See suggestions made with research question 3

Sub-question 5

''How can the effectiveness and efficiency of (technical) assistance and cooperation projects be maximized?''

Coordination and pragmatic, comprehensive assistance

Currently, air safety technical co-operation is too fragmented, influenced by personal or export preferences and not sufficiently standardized. Cooperation and assistance projects are not coordinated and economies of scale are not achieved. Cooperation partners should proceed more pragmatically and the focus should be on safety enhancement instead of export promotion.

Furthermore it is important to remind that a piece-meal approach to many of the problems will not be sufficient. Instead, a comprehensive approach is required addressing the overall air transport system.

It should also be assured that the assistance provided will remain effective, even after the support mechanism or project is terminated.

The drafting of an ECAC (European Civil Aviation Conference) Agenda to Support Aviation Safety in Africa (ASASA) is a first step in the right direction. Furthermore the DGTL- Flight Safety Foundation (FSF) think-tank may offer new and improved insights into the possibility to coordinate new projects aimed at increased flight safety in Africa.

Information provision

International partners like DGTL, ICAO and IATA may try to make information available in form of easily accessible leaflets that also allow low skilled but operationally very relevant staff members of aviation authorities and industry to appreciate the contents.

Partnerships

The creation of a twinning program (based on the principle of city twinning) could be considered, establishing co-operative and durable links between European and African Civil Aviation Authorities. Such a system of twinned aviation authorities may provide opportunities for officials to be immersed in aviation safety environments of various complexities through long-term partnerships.

Summary of findings and recommendations

When the answers to the research questions at the previous pages are combined with the research data that has been discussed throughout the thesis the following can be concluded and recommended:

The problem

1.1 Most African countries have the basic building blocks of an air transport infrastructure in place. Quite often, this infrastructure is utilised far from efficiently and is not always up to international standards. While national surface transport is the prime transport mode in African economies, national and intenational air transportation play an important role. It is considered an indispensable complement to other modes of transport. This applies especially to those countries faced with natural obstacles such as the equatorial forest, the Sahara desert and countries that are landlocked.

1.2 In 2005, Africa was once again the most unsafe continent with 37% of all fatal airliner accidents occuring in Africa. At the same time, the continent accounts for less than 4% percent of all world airline departures (Aviation Safety Network, 2006). One may conclude that most of the African air transport sector remains saddled with major problems, which are no longer a (major) concern in other regions of the world.

1.3 It is worth noting that some African States may not have the legal framework, institutional set-up, financial resources and/ or technical capabilities to comply with the minimum safety requirements. This highlights the importance of international technical cooperation as well as a need for a global framework for the coordination of safety policies and initiatives. Furthermore, the operational benefits and moral imperative for coordinated action that may be derived from increased safety are compelling motives themselves.

1.4 Unfortunately, there are many examples of past cooperation projects that have only partly succeeded and even more examples of projects that have failed. *The key question is how to maximize the effectiveness and efficiency of technical co-operation in the field of aviation safety.*

1.5 In spite of the importance of financial constraints, just providing additional funds will not solve the problems. A comprehensive approach is required addressing the overall air transport system that looks beyond the well known problems (e.g. lack of maintenance, financial restrictions etc).

1.6 Quite understandably, on a continent where a number of countries are plagued by war, famine, corruption, disease, political instability, lack of leadership and many other problems, aviation may not be high on the priority list of politicians and governments.

Furthermore, due to many basic problems (such as degrading runway-, taxitrack- and platform pavement, poor lighting and poor maintenance of aircraft, lack of appropriate legislative and regulatory frameworks and a lack of autonomous & assertive Civil Aviation Authorities), many African States may not be able or willing to devote the resources that are needed for the implementation of advanced technologies.

1.7 Communication, access to- and the dissemination of information can be rather difficult in many African countries. Accessibility and dissemination of information through the internet many not be enough in a region where many have no or limited access to the internet.

Very important -but often ignored- are internal problems that may arise as a result of a lack of information and communication. Incomprehension and a lack of knowledge by personnel about the usefulness and functionality of any new technology may pose a significant threat to the technology implementation process.

1.8 The case study on RVSM shows that there is presently a mismatch between needs and technology supply. Furthermore we conclude that most African Civil Aviation Authorities did not posses the capabilities needed for the implementation of RVSM. The Case study on ADS-B shows that a possible future implementation of ADS-B in Africa may also result in a mismatch between (highly advanced) technology and (basic) needs. From the discrepancy between causes of accidents in Tanzania and the benefits that may be derived from ADS-B it can be concluded that ADS-B is not the answer to many of today's problems (causes for incidents and accidents). ADS-B should thus not receive priority over other measures such as improvement of maintenance schedules, pilot capability and capacity and the improvement of ground infrastructure such as runways and taxi tracks.

1.9 Problems sometimes also exist with the availability of operational and basic technical knowledge, training capacity and the availability of well qualified personnel.

2 Contributing to solutions

2.1 Even before implementation planning for new technologies is undertaken, basic and essential problems should be solved with priority. It is only when the basics are in place that one can embark on the implementation of advanced technologies. Some of these priority items are:

- Education and training
- More maintenance facilities
- More engineers and technicians trained
- More Civil Aviation Authority surveyors, inspectors, air traffic controllers, etc.
- More appropriately established, empowered and well funded Civil Aviation Authorities
- Improvement of airport infrastructure
- A more pro-active and maintenance based safety management culture/ mindset

2.2 The research highlights that in many cases, it is impossible to make a one-on-one transfer of western technology for use in different (African) environments. Great care should be given to the specific circumstances in which the technology has to operate as well as the people that operate the equipment.

2.4 Every new technology project should start with an audit to assess the actual need for the technology. Following this audit, a full awareness campaign should be launched with the emphasis on the benefits that may result from the implementation of the new technology. Furthermore, users should be involved in the technology implementation process from an early stage on since it is the perception of the technology users that matters most in the acceptance of any new technology rather than objective facts and expert opinion.

2.5 The creation of a twinning program (based on the principle of city twinning) could be considered, establishing co-operative and durable links between European and African Civil Aviation Authorities. Through such a system of small scale and pragmatic cooperative agreements between European and African Civil Aviation Authorities at an operational level, Europe would have a lot to offer to many African States. Long term cooperation/ twinning would enable to go beyond the limited benefits that result from the current practice of mainly using consultancy services to address a specific ad-hoc safety challenge.

Furthermore, interstate cooperation and partnerships between African authorities and operators may also facilitate a more effective introduction of new technologies as economies of scale may be achieved and knowledge shared.

2.6 Currently, air safety technical co-operation is too fragmented, influenced by personal or export preferences and not sufficiently standardized. Cooperation and assistance projects are not coordinated and economies of scale are not achieved. Cooperation partners should proceed more pragmatically and the focus should be on safety enhancement instead of export promotion. It should also be assured that the assistance provided will remain effective, even after the support mechanism or project is terminated.

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Appendices

Appendix 1 Interviewees

Name	position	organisation	date	place
Mr. Abdullah	Director Corporate Planning and Research	TANESCO	20-04-2006	Dar-es-salaam
Mr. M.R. Alloo,	Director Air Navigation Services	TCAA	03-04-06	Dar-es-salaam
Mr. A. Angelo		Standard Chartered Bank	13-04-2006	Dar-es-salaam
Mr. A. Bairektar	Operations Director	Celtel Tanzania	21-04-2006	Dar-es-salaam
Mr. H. K. S. Bishanga	Manager	Technology Transfer Centre	12-04-2006	Dar-es-salaam
Mr. Bokango	Chief of Compliance Unit	TAA	18-04-2006	Dar-es-salaam
Mr. C. Bouman	Former Eurocontrol RVSM Programme Deputy Manager	Eurocontrol	20-03-2006	Brussels
Mrs. L. A.K. Chobya	Programme Engineer	Technology Transfer Centre	12-04-2006	Dar-es-salaam
Mr. M. Dhirani	Managing Partner and Pilot	Flightlink Ltd	27-04-2006	Dar-es-Salaam
Mr. D. Finke	Director	Sky aviation ltd	27-04-2006	Dar-es-salaam
Mr. A. Hallgren	Senior ATM Expert	Eurocontrol	20-03-2006	Brussels
Mr. G. S. Hemdoe		COSTECH	04-04-2006	Dar-es-Salaam
Mr. J. Hermens	Navigation & Communication Expert	IVW	31-01-2006	Hoofddorp
Mr. Killindo	Development Engineer	Precision Air	18-04-2006	Dar-es-Salaam
Mr. A.A. Kiroge	Senior Airworthiness Surveyor/ Inspector of Air Accidents	TCAA	30-03-06	Dar-es-salaam
Mr. M. Manji	Operations Manager	Air Tanzania	18-04-2006	Dar-es-Salaam

Mr. L. Matindi	CNS Engineer	TCAA	30-03-2006	Dar-es-Salaam
Mr. Maugo	Director of Safety Regulation, Inspector of Air Accidents	TCAA	24-04-2006	Dar-es-Salaam
Mr. A.S.I. Mbamba	Manager Information Technology	TAA	18-04-2006	Dar-es-Salaam
Mr. T. Minja	Chief Inspector	Coastal Aviation	18-04-2006	Dar-es-Salaam
Mr. G. Moek	Researcher	NLR	24-01-2006	Amsterdam
Mrs. C. Mpili	Principal CNS regulations	TCAA	27-03-2006	Dar-es-Salaam
Mr G. Mpili	Manager Telecom Engineering	TCAA	06-04-2006	Dar-es-Salaam
Mr. Prof. J. S. Nkoma	Director General	TCRA	27-04-2006	Dar-es-Salaam
Mr. J. Nyamwihura	Airworthiness Surveyor Dep. Chief Inspector Air Accidents	TCAA	24-04-2006	Dar-es-Salaam
Mr. L. Paul.	Civil Aviation Commandant	TCAA	06-04-06	Dar-es-Salaam
Mr. G. Plaisier	Member of IATA AFI Regional Coordination Group	KLM	11-01-2006	Schiphol
Mr. Dr. M. L. Raphael	Director	COSTECH	04-04-2006	Dar-es-Salaam
Mr. D. Rwehumbiza	Chief Inspector	Tanzanian Air Services Ltd.	28-04-2006	Dar-es-Salaam
Mr H. Tuluhungwa	Head Product Management	Standard Chartered Bank	13-04-2006	Dar-es-salaam
Mr. A. Young	Flight Safety Programme Manager	Martinair	10-01-2006	Schiphol

Appendix 2 What is ADS-B?

The contents of this appendix are a literal citation (or copied*)* from the Worldbank Air Transport Infrastructure Review, United Republic of Tanzania, 2006. By Charles E. Schlumberger and Heinrich C. Bofinger. This appendix does not necessarily reflect the author's opinion but merely serves as background information on the ADS-B system.

''Introduction

Traditional air traffic control depends on radar sweeps to detect aircraft in the air. In addition, the aircraft sends a signal to radar via a transponder providing identifying information and vital numbers such as altitude (mode "C" transponder). Radar coverage depends on six second "sweeps" – i.e. every 12 seconds the location of the aircraft is determined by the reception of an echo that was emitted about six seconds earlier. The course of the aircraft is extrapolated from the echoes collected every twelve seconds. The accuracy of the echo location is negatively related to distance, and is affected by weather.

The advent of satellite navigation systems is rewriting the fundamental paradigm by which the location of an airplane is determined. With GPS technology, an aircraft is able to instantly determine its location anywhere on the earth with an accuracy of 30 meters.

By broadcasting this information to interlinked collection stations on the ground, a computerized network can assemble the location of every reporting aircraft over the entire surveyed airspace. The technology does not face the physical constraints of radar, i.e. it is accurate even at its outmost ranges, and is independent of weather. In addition, since the basic infrastructure requires satellites already in existence, the cost of GPS based air traffic control technology is a fraction of that of traditional radar.

ADS-B Described

The acronym "ADS-B" stands for

- **Automatic:** As soon as the electric system of the aircraft is turned on, the reporting mechanism for the aircraft is activated, and the aircraft is visible to the control network, and to other aircraft if so equipped
- **Dependent**: The system depends on GPS satellites to determine each aircraft's position.
- **Surveillance**: The system provides radar-like position awareness to ground controllers and, depending on the system type, other aircraft.
- **Broadcast:** The aircraft, instead of being "interrogated" by radar, broadcasts its position continuously.

The figure below (1) shows the basic features of an ADS-B system. The system requires only six core components:

1. A satellite navigation system (typically GPS)
2. GPS equipment aboard the aircraft
3. Transmitter aboard the aircraft
4. Ground-based transceiver to receive data broadcast by aircraft
5. A data link to the air traffic control center
6. An air traffic control center, if not already in place

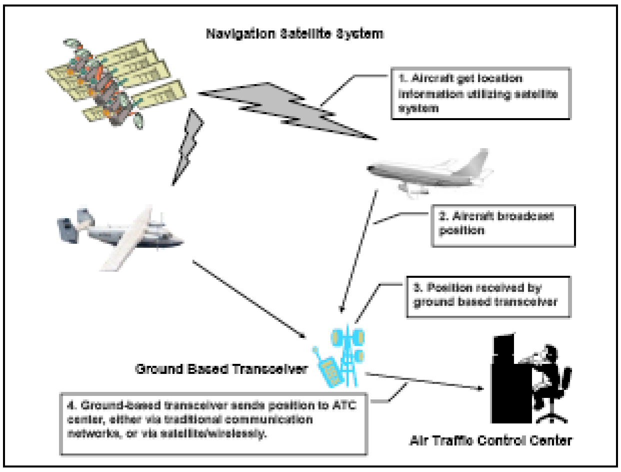


Figure 1. Generic layout of ADS-B. The aircraft receive their position data from the global satellite navigation system (GPS) and transmit their data to ground based transceivers, which then relay the positions to either via traditional networks or wirelessly to air traffic control centers.

Two Flavours of ADS-B

Two approved standards of ADS-B have emerged. Their core difference lies in their ability to share information between the ground and aircraft in the air, and amongst aircraft themselves. Operationally, their difference lies in the equipment found aboard aircraft and in the ground-based transmitter.

Extended Squitter

Transport category aircraft are now equipped with a standard “Mode S” transponder, which, if equipped with an “extended squitter” box, is able to broadcast a digital message providing basic aircraft information, such as the longitude, latitude, airspeed, and barometric altitude, transmitted at 1090 MHz. Mode S does not require geographic information be derived from a satellite navigation system - data can come from anywhere in the flight management system, and in aircraft not equipped with satellite navigation the data may well come from inertia -based equipment. However, the information transmitted via the Mode S transponder is highly limited, and the capacity of the 1090 MHz bandwidth is stretched. More importantly, the standards of Mode S extended squitter ADS-B only allow for digital data to be broadcast, but allow for no reception of digital data. Though the more common standard today in transport class aircraft, only 25% of aircraft now being equipped with Mode S transponders will also be equipped with the extended squitter capability.

UAT

The newer ADS-B standard operates on 978 MHz and is called Universal Access Transceiver. UAT operates with a different transceiver box in the aircraft than the Mode S transponder, and is able to not only send data but also to receive data from the ground and from other aircraft (see Figure 2). This has significant advantages - if equipped with a standard multifunction display the pilot is able to see all other traffic in the vicinity and perhaps up-to-date weather information, all superimposed on a terrain map for the current location (see Figure 3). The safety implications of seeing other traffic, especially in uncontrolled environments, regardless of weather, are significant (all of this is also possible with a Mode S system – author). In addition, because ADS-B Extended Squitter’s bandwidth is somewhat limited in terms of bi-directional capability and growth, most experts agree that 978 MHz has better long range potential for growth and additional cooperation for uplink services.

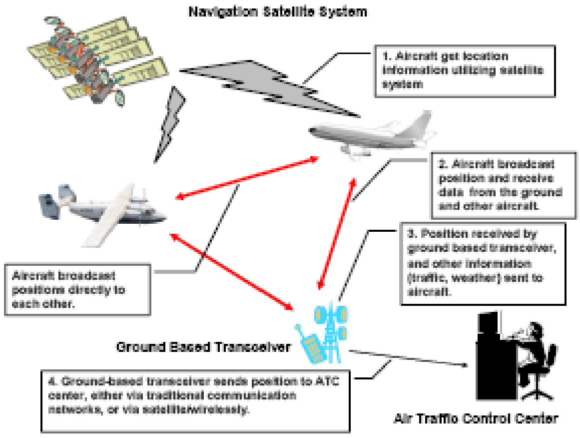


Figure 2. In contrast to ADS-B following the extended squitter standard, ADS-B UAT allows for bi-directional communications, giving the aircraft the possibility to receive information from the ground (weather, other aircraft in the area) and from other traffic in the air.

Figure 3. In this display, traffic can be seen superimposed on the surrounding terrain. The information is received live from other transmitting aircraft and from the ground-based transceiver.

ADS-B as the choice for developing countries

ADS-B today presents the best fit choice for bringing airspace control to countries lacking such infrastructure. The technology presents itself as optimal because of its low cost of introduction, its much lower maintenance cost, its accuracy compared to traditional radar, and its independence from most other infrastructure networks, such as the power grid.

Costs of Introduction

Complete coverage of a country such as, for example, Tanzania (945,087 km2) would require the installation of about ten ground based transceivers. With the cost per transceiver, including site preparation, estimated at about US$ 165,000, excellent coverage could be achieved for under US$ 2 million. By contrast, a single radar installation toady costs about U.S. $ 6 million. A requirement in introduction, however, is that aircraft be equipped with the transceivers and GPS equipment necessary to participate in the system. Assuming no GPS devices previously installed, the basic cost per unit would be US$ 20,000 (GPS US$ 7,000, UAT US$ 9,000, installation US$ 4,000). In Tanzania, with 210 aircraft registered, this would add US$ 4.2 million to the introduction. Even if half of the aircraft were registered for light commercial use, and it would be deemed necessary to add the cost of multifunction displays to the cockpits of those aircraft, the cost would still only increase by about US$ 2.1 million, brining the total installation/equipping, including management fees, training, and interfacing with the current radar system, to about US$ 9.7 million.

Costs and Ease of Maintenance

A radar installation requires budgeting of about 15% of the purchase costs each year to maintenance. On a US$ 6 million installation, this implies about US$ 900,000 be spent each year in keeping the equipment functional for each installation. ADS-B ground-based transceivers, though, rarely need actual visits (once a year is the standard for the most remote units placed in Alaska under the trial “Capstone” program), and are easily administered remotely. With an estimated maintenance cost of US$ 600,000, the overall costs of keeping the system running would be a third less of than that of one radar site.

Accuracy of ADS-B

One of the core differences with satellite-based technologies is the timeliness and accuracy of determining one’s position. Radar technology depends on the timing of the scanning “sweep”, and produces a single point of location per aircraft every 12 seconds. Depending on the distance, the accuracy of the point is compromised by as much as 1.5 nm in each direction, with weather playing an important role in the location error. The course of the traffic observed needs to be extrapolated from the observations, and, since there is the possibility of considerable error in the resulting plot, separation with other traffic needs to be given a wider envelope. With ADS-B, the aircraft transmits its position every second, with a possible error of only roughly 30 meters in each direction. The result is a smooth line describing the aircraft’s - 74 – path, with much tighter tolerances and much higher accuracy. In addition, radar coverage acts as a cone, and as the aircraft lowers in altitude, coverage terminates. With ADS-B, coverage terminates if and only if the aircraft falls out of line of sight with all groundbased transceivers. The implications are significant in terms of search and rescue should an accident occur – in general, coverage terminates where the aircraft strikes the ground, and there is an accurate record as to where to commence rescue efforts, with very little searching needed. This has saved, and will save, lives.

Low Power Consumption

A traditional radar installation is dependent on the power grid or extensive backup capabilities, with power requirements being in the scope of 440 Volts and 20 Amperes. ADS-B ground-based transceivers, however, require only 24 Volts at about 3 Amperes, and could be made self-sufficient with their own solar power. The implications are not just lower power consumption costs, but also higher independence and reliability. The Added Safety of UAT The highest risk aircraft operations are those not involving large jets flying over the country in the upper airspace, but lighter commercial operations flying at lower altitudes, often in terrain that is hostile in bad weather or in case of serious technical malfunctions. These are the same operations that occur in airspace not having much, if any, surveillance, and where up-to-date weather information is not readily available. Having surveillance capabilities on the ground is of obvious help in avoiding obstructions and other traffic. However, the capability of seeing, on one display in the cockpit, all surrounding terrain, the weather conditions en-route, and all other traffic, significantly lowers the risks that are most commonly leading to accidents with lighter aircraft. In the United State, the Federal Aviation Administration launched a test program in the state of Alaska where operators using the ADS-B UAT system reduced their fatal accident rate by over 50%. If one compares the cost of the system for an entire country such as Tanzania to the loss of one Cessna Caravan fully loaded with passengers, the benefits become apparent immediately’’.

Appendix 3 What is RVSM?

The information in this appendix is *copied* and edited from www.rvsm.com (http://www.rvsm.com/what_rvsm.html) accessed at 05-08-2006.

‘’RVSM stands for Reduced Vertical Separation Minimum and comprises a newer set of rules & regulations that has been recommended by the ICAO and will be enforced by the FAA the JAA and other civil aviation authorities around the world. The purpose of RVSM is to free up airspace between FL290 and FL410 (inclusive) by decreasing the minimum vertical separation from 2,000 feet to 1,000 feet.

Before RVSM, a limited number of flight paths were allocated between these altitudes to ensure that aircraft would not pass one another vertically too closely. The 2000 feet minimum vertical separation was used between FL290 and FL410 inclusive and necessary because the instruments used to display, report, and control aircraft altitude had poor accuracy compared to today’s standards. As altimeters have become more accurate and autopilots more effective in maintaining a set level it became apparent that the 2000 feet separation minimum was too cautious.

Furthermore, because these altitudes between FL290 and FL410 are the most fuel-efficient, they are the most desirable and, consequently, the busiest. As air travel has become more prevalent, the problem of congestion and flight safety at these popular altitudes has worsened. Flight path planning became a major issue for operators wanting to utilize these altitudes. Recognizing the problem early on, the ICAO and other organizations began to do studies looking for viable solutions. Of all the possibilities examined, RVSM was selected by the ICAO as the one to recommend to their member states and various other organizations.

Only aircraft with certified altimeters and autopilots are allowed to fly in RVSM airspace. Non certified aircraft must fly lower or higher than the RVSM airspace, or need special exemption from the requirements.

Safe reduction of the vertical separation minimums is a complex project, and its implementation is a major undertaking that affects not only government agencies and airlines, but also every owner and operator of aircraft capable of operating at these flight levels. Many steps to implement RVSM have already taken place, but many others are still required’’.

Appendix 4 African destinations of major European carriers

Alitalia

Algiers
Tripoli
Casablanca
Tunis

Lufthansa

Algiers
Egypt s.a.
Asmara
Adis Abeba
Nairobi
Casablanca
Windhoek
South Africa s.a.
Khartoum
Harare

Swiss

Tripoli
Benghazi
Cairo
Douala
Malabo
Youande
Nairobi
Dar es salaam
Johannesburg

Virgin Atlantic

Lagos
South Africa s.a.
Port-Harcourt

British Airways

Egypt s.a.
Tunis
Hassi Messaoud
Algiers
Fez
Agadir
Tangier
Casablanca
Triploi
Khartoum
Adis Ababa
Borg el Arab
Abuja
Lagos
Accra
Entebbe
Nairobi
Luanda
Lusaka
Dar-es-salaam
Harare
Mauritius
South Africa s.a.

TAP air Portugal

Luanda
Mozambique s.a.
Dakar

Air France/ KLM

Algiers
Luanda
Cotonou
Gaborone
Ouagadougou
Bujumbura
Bangui
Ndjamena
Brazzaville
Lubumbashi
Kinshase
Djibout
Cairo
Addis Abeba
Libreville
Accra
Abijan
Douala
Kenya s.a.
Maseru
Tripoli
Bamako
Marocco s.a.
Mauritius
Maputo
Namibia
Niamey
Nigeria s.a.
Entebbe
Kigali
Dakar
Khartoum
Tanzania s.a.
Lomo
Tunis
Livingstone
Bulawayo
South Africa s.a.

Iberia

Agadir
Cairo
South Africa s.a.
Casablanca
Dakar
Durban
Fez
Harare
Laayoune
Lagos
Malabo
Marrakech
Port Elizabeth
Tangier
Victoria Falls

SN Brussels

Abidjan
Banjul
Casablanca
Conraky
Dakar
Douala
Entebbe
Free Town
Kigali
Kinshasa
Luanda
Monrovia
Nairobi
Yaounde

s.a. = several airports within the country

Abijan - Ivory Coast
Abuja - Nigeria
Accra - Togo
Adis Abeba - Ethiopia
Agadir - Morocco
Algiers - Algeria
Asmara - Eritrea
Bamako - Malawi
Bangui - Central African Republic
Banjul - Gambia
Benghazi - Libya
Borg el Arab - Egypt
Brazzaville - Congo
Bujumbura - Burundi
Bulawayo - Zimbabwe

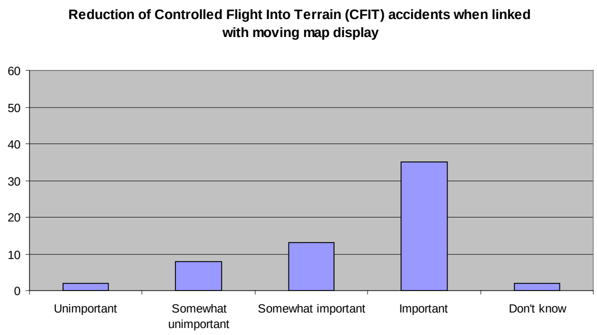
Cairo - Egypt
Casablanca - Morocco
Conraky - Guinea
Cotonou - Benin
Dakar - Senegal
Dar es salaam - Tanzania
Djibouti - Djibouti
Douala - Cameroon
Durban - South Africa
Entebbe - Uganda
Fez - Morocco
Free Town - Sierra Leone
Gaborone - Botswana
Harare - Zimbabwe
Hassi Messaoud - Algeria

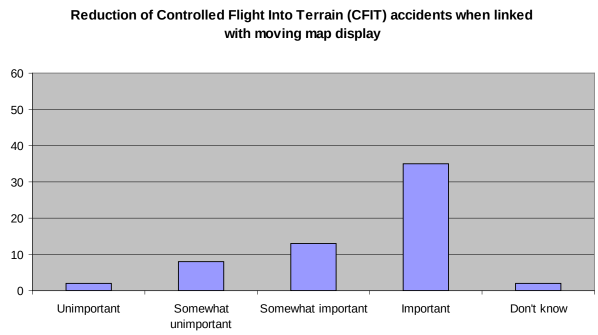
Johannesburg – S.A.
Khartoum - Sudan
Kigali - Rwanda
Kinshasa - DRC
Laayoune -Morocco
Lagos - Nigeria
Libreville - Gabon
Livingstone - Zimbabwe
Lomo
Luanda - Angola
Lubumbashi - DRC
Lusaka - Zambia
Malabo - Equatirial Guinea
Maputo - Mozambique
Marrakech - Morocco

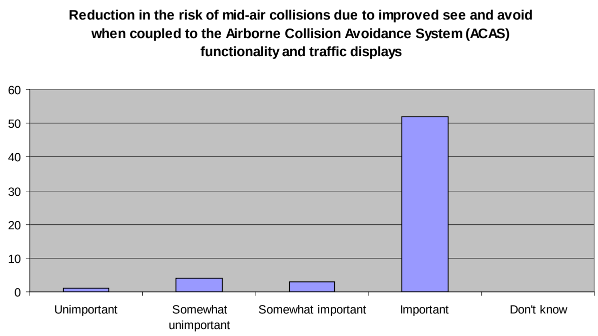
Maseru - Leshoto
Mauritius
Monrovia - Liberia
Nairobi - Kenya
Namibia
Ndjamena - Chad
Niamey - Niger
Ouagadougou - Burkina Faso
Port-Harcourt - Nigeria
Tangier - Morocco
Tripoli - Libya
Tunis - Tunisia
Victoria Falls - Zambia
Windhoek - Namibia
Youande - Cameroon

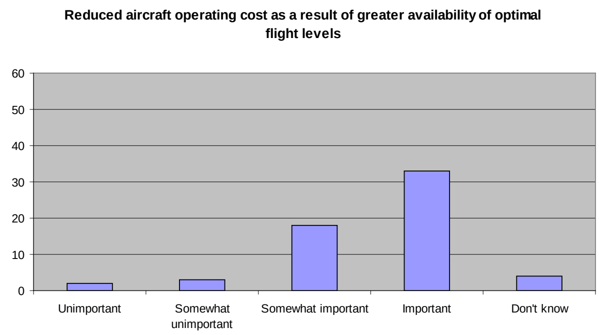
Appendix 5a Survey results

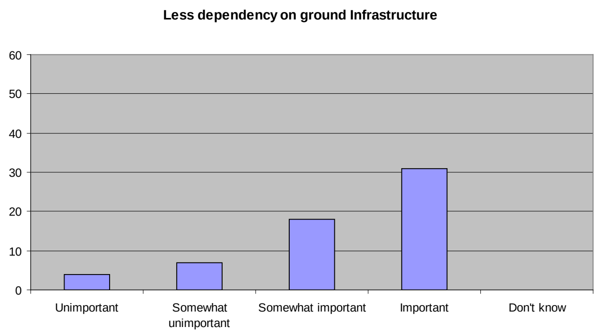
ADS-B expert group question no. 1: ‘’Please indicate the level of importance you attach to the supposed benefits that the introduction of ADS-B in Africa might offer’’.

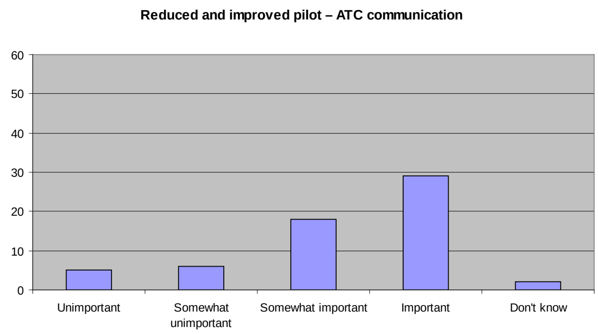




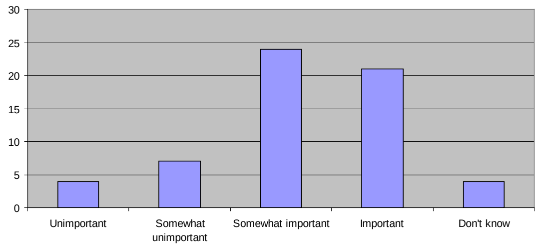




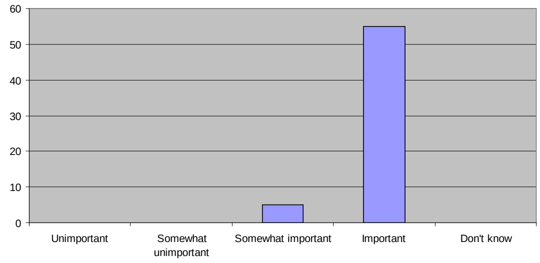




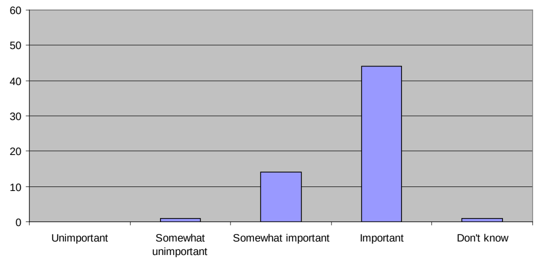
Reduced aircraft operating cost and improved on-time performance as a result of tighter flight monitoring



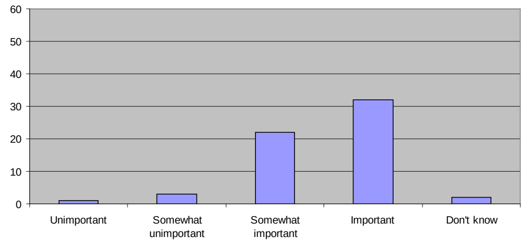
Improved pilot and ATC traffic information and situational awareness



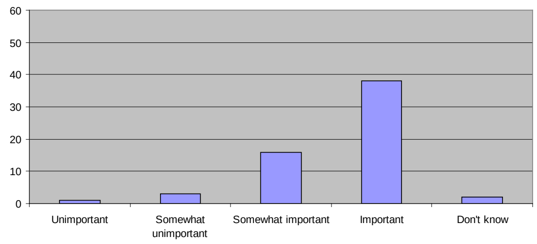
Improved ATC efficiency and capacity



Improved accident investigation capabilities due to expanded surveillance

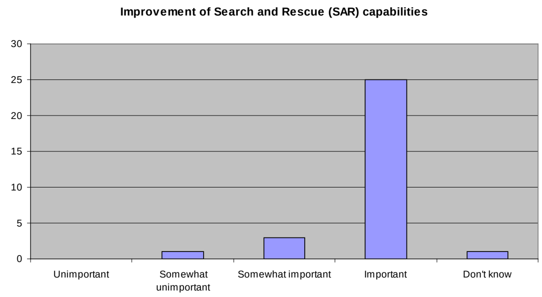


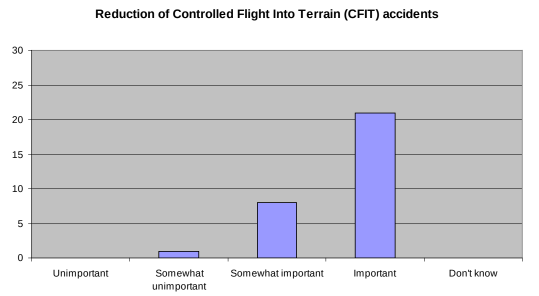
Reduced risk of runway incursions where ADS-B is used for surface movement surveillance

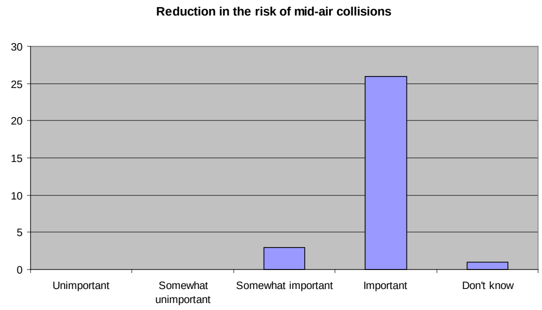


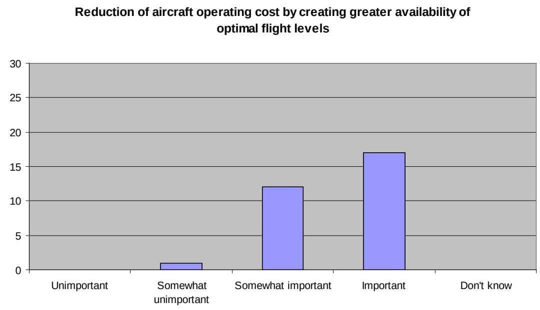
Appendix 5b Survey results

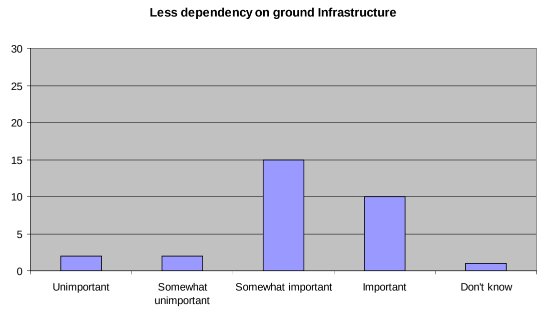
AFI expert group question no.1 ‘’please indicate the level of importance you attach to the items listed below that aim to solve or reduce problems and hazards that may affect aviation safety and operating efficiency in Africa’’

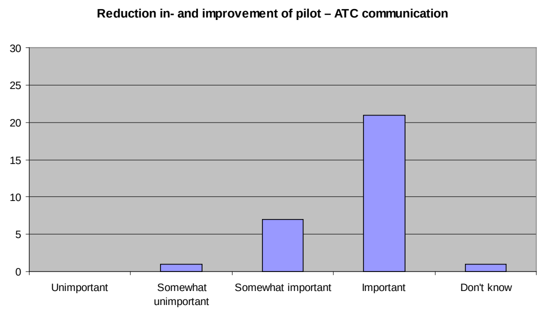




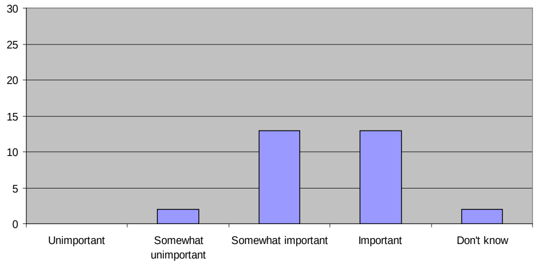




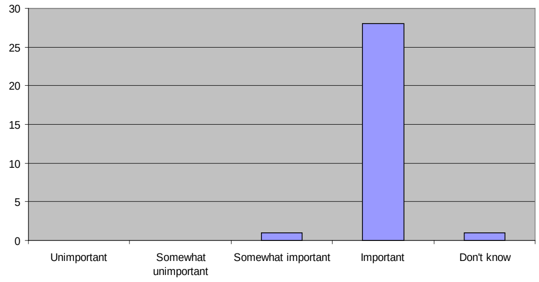




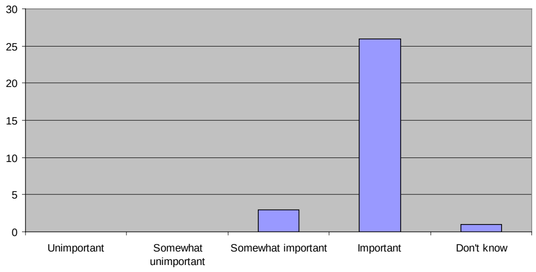
Reduction of aircraft operating cost and improved on-time performance by tighter flight monitoring



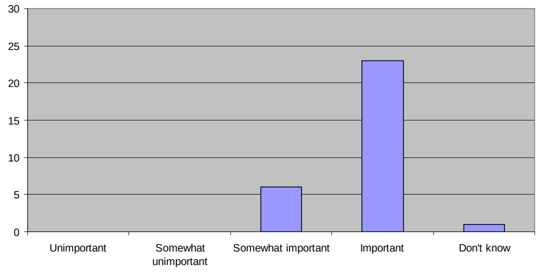
Improvement of pilot and ATC traffic information and situational awareness



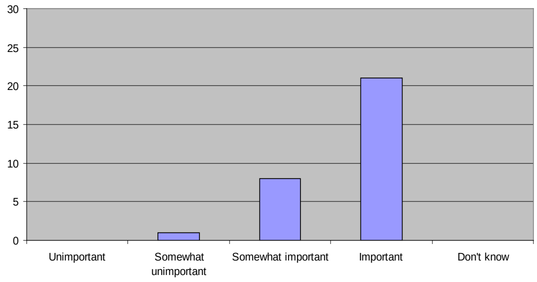
Improvement of ATC efficiency and capacity



Improvement of accident investigation capabilities

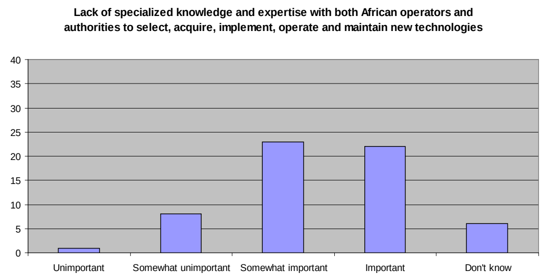


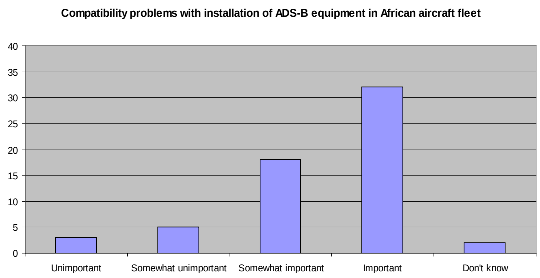
Reducedtion of the risk for runway incursions

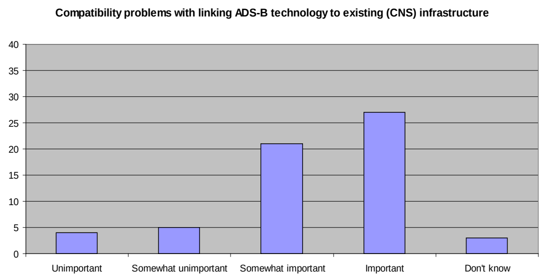


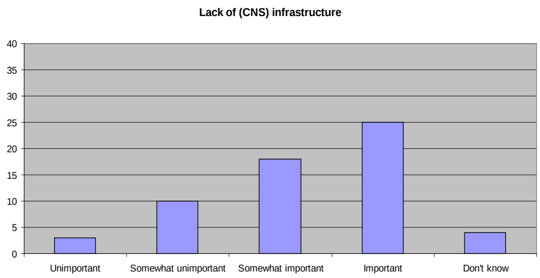
Appendix 5c Survey results

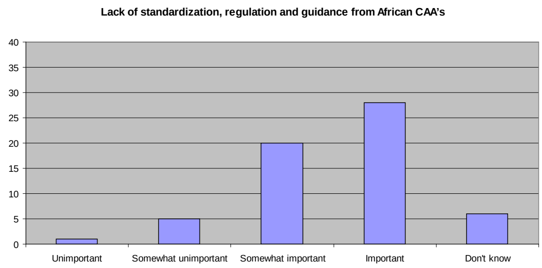
ADS-B expert group question no. 2 ‘’Please indicate the level of importance you attach to the following problems that may possibly pose a threat to- or may form an obstacle for an effective and efficient introduction of new communication, navigation and surveillance (CNS) technologies like ADS-B into the African aviation environment’’

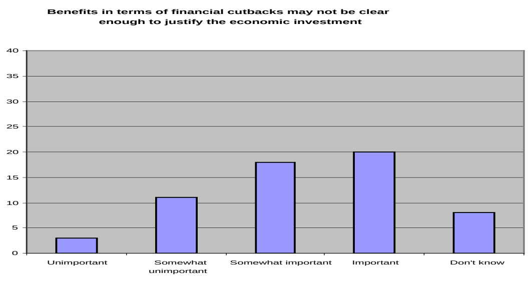


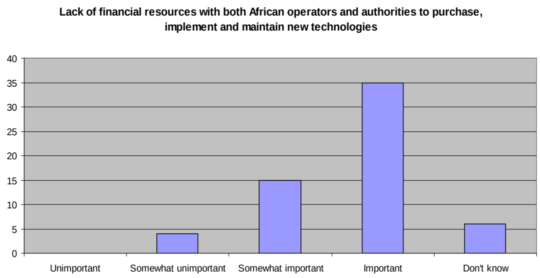






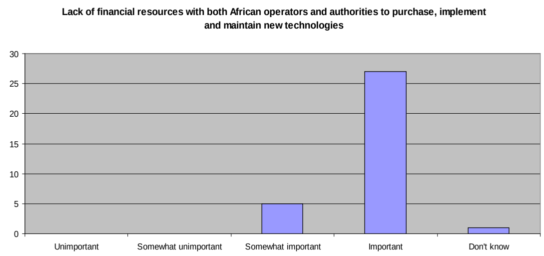


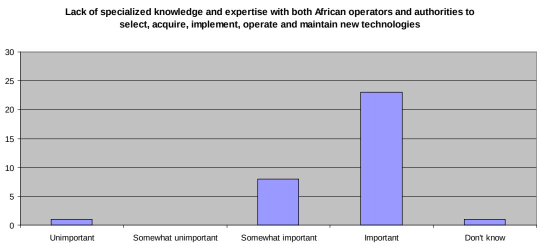


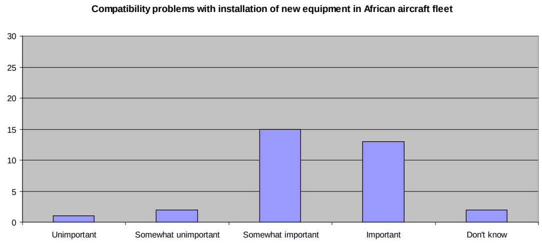


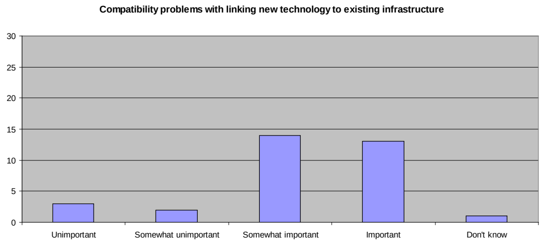
Appendix 5d Survey results

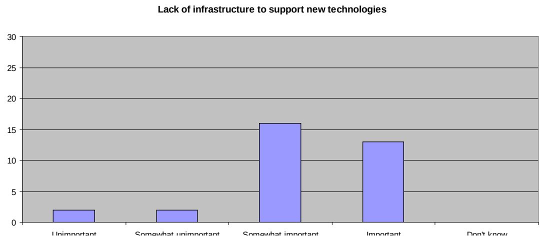
AFI expert group question no.2 ‘’Please indicate the level of importance you attach to the following problems that may possibly pose a threat to- or may form an obstacle for an effective and efficient introduction of new technologies into the African aviation environment‘’

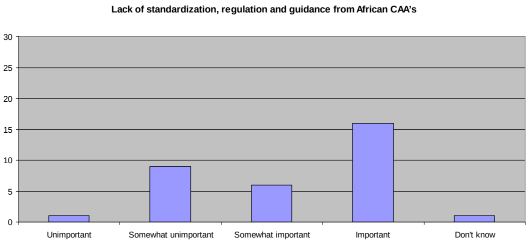


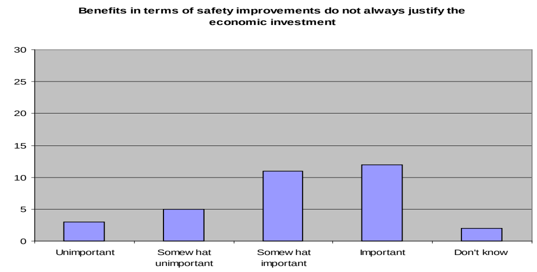


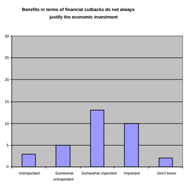






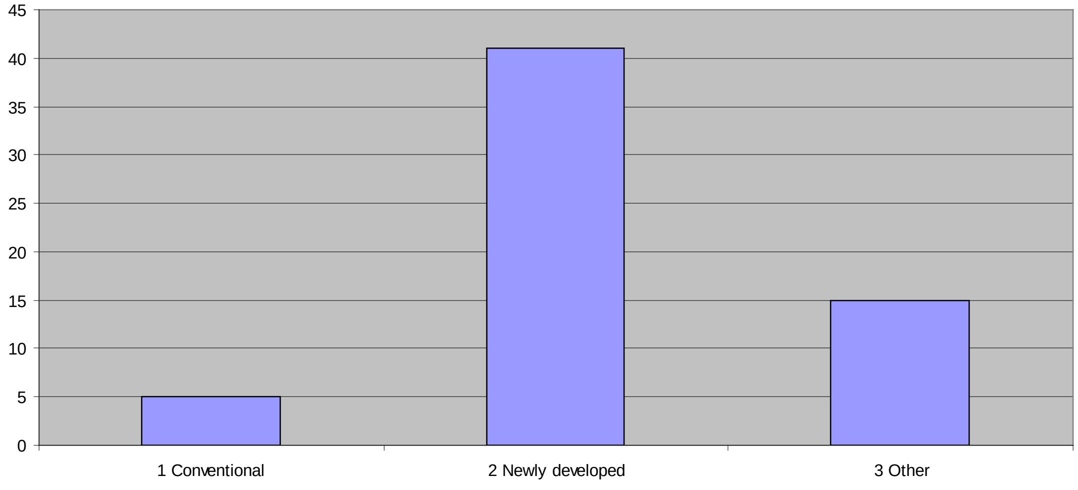






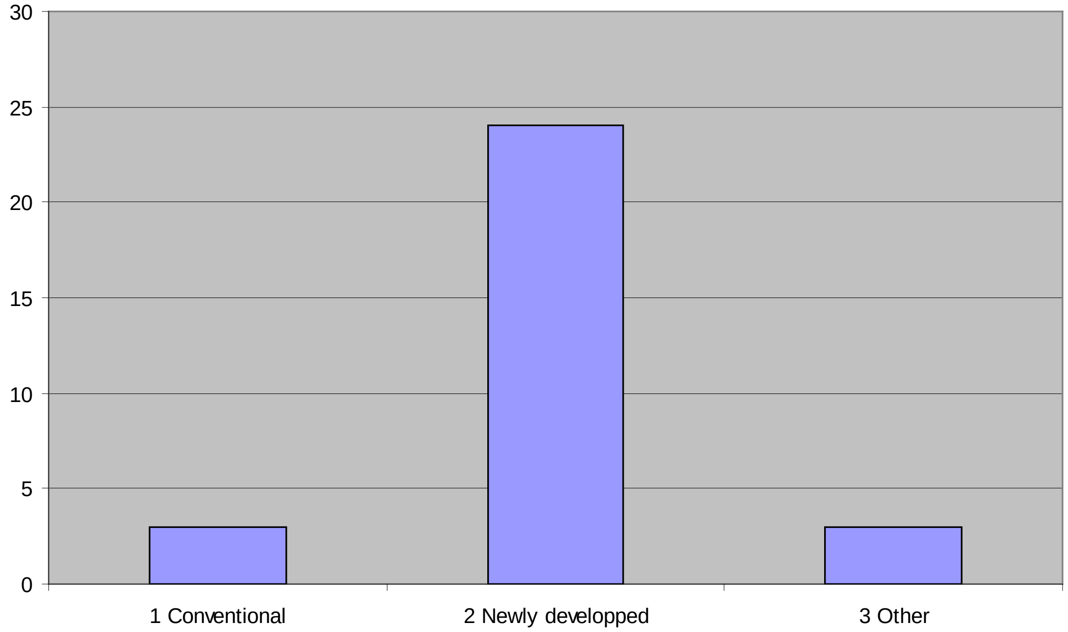
Appendix 5e Survey results

ADS-B expert group question no. 3 ‘’For the improvement of flight safety, should African CAA’s and airlines (both African and non-African) continue to use and improve conventional surveillance technologies like primary and secondary radar, or should they focus on newly developed and low cost alternative surveillance aids such as ADS-B?’’



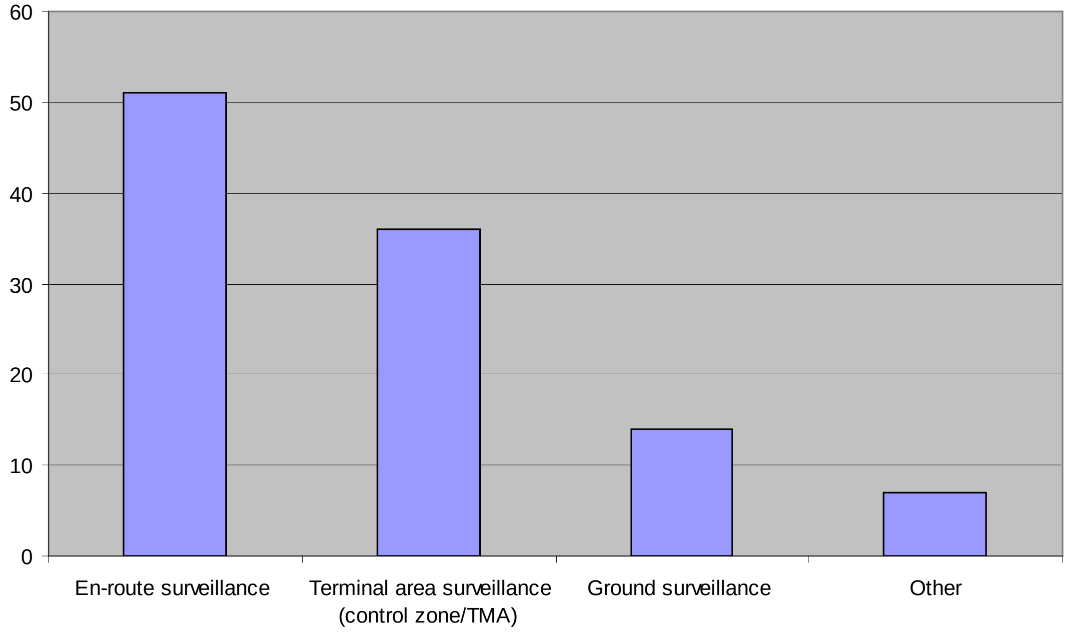
Appendix 5f Survey results

AFI expert group question no. 3 ‘’For the improvement of flight safety, should African CAA’s and airlines (both African and non-African) continue to use and improve conventional surveillance technologies like primary and secondary radar, or should they focus on newly developed and low cost alternative surveillance aids?’’



Appendix 5g Survey results

ADS-B expert group question no. 4 ‘’If ADS-B were implemented in the AFI region, for which purpose(s) could it prove its greatest value?’’



Appendix 5h Survey results

AFI expert group question no. 4 ''If it is decided to introduce new and enhanced surveillance technologies for Air Traffic Control/ Air Traffic Management, then it should be aimed at:…''