# Journal of Air Transportation

**VOLUME 12, NUMBER 3 – 2007**

ISSN: 1544-6980

Journal of Air Transportation Volume 12, Number 3– 2007

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Published by:
Aviation Institute
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World Wide Web: http://jat.unomaha.edu

Printed by: University of Nebraska Medical Center Printing Services

Published as a not-for-profit service of the Aviation Institute.

# About the Journal of Air Transportation

The mission of the *Journal of Air Transportation (JAT)* is to provide the global community immediate key resource information in all areas of air transportation. The goal of the Journal is to be recognized as the preeminent scholarly journal in the aeronautical aspects of transportation. As an international and interdisciplinary journal, the *JAT* will provide a forum for peer-reviewed articles in all areas of aviation and space transportation research, policy, theory, case study, practice, and issues. While maintaining a broad scope, a focal point of the journal will be in the area of aviation administration and policy.

**Development:**

The *JAT* was conceptualized to fulfill an international void of scholarly publications in this area as identified by the primary organizers. It is envisioned that aviation leaders will utilize the *JAT* as a key decision-making tool. Scholarly rigor and standards will be uncompromised with regular evaluation by the Editorial Board and Panel of Reviewers.

**Scope:**

The *JAT* accepts manuscripts on all topics that relate to air transportation, both technical and non-technical. The Panel of Reviewers represents the interdisciplinary nature of air transportation to ensure review by recognized experts. Broad categories of appropriate topics include, but are not limited to:

**Aviation Administration:** Management, Economics, Policy, Fixed Based Operations, Employment & Internships, Marketing; **Airport Planning, Design & Development:** Capacity & Delay, Small Aircraft Transportation System (SATS), Air Transportation Systems—Domestic & International; **Aviation Law:** Air Traffic Control, Regulation Process, Privatization; **Airlines & Cargo:** Logistics, Transport Operations, Air Carrier Training, Low Cost Airlines, Intermodal Transportation; **Education & Training:** Aviation Education, Cognitive Factors & Learning Styles, Instructional Techniques, Distance Learning, Research Methods for Aviation, Aviation/Aerospace Psychology & Safety, Human Factors & Crew Resource Management; **Technology:** Engineering, Aerospace Structures, Propulsion & Performance, Avionics, Geographic Information Systems, Simulation, Electronic Signal Processing, Electronic Markets & Internet, Meteorology & Weather Services; **Future Advancements:** Space Transportation & Flight, General Aviation, Forecasting.

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*The *JAT* is available on-line at the National Transportation Library at the Bureau of Transportation Statistics, U.S. Department of Transportation.

addition, the *JAT* is available through inter-library loan at the University of Nebraska at Omaha and the Transport and Telecommunications Institute in Latvia via accessing the global OCLC inter-library loan network. A permanent archive is maintained at the University of Nebraska at Omaha. Annual subscriptions are available on CD-ROM for $35 for individuals and $99 for institutions. Hard copies may be available pending special request. Add $20 for subscriptions outside the U.S.A. Payments may be made by credit card, check or purchase order to the UNO Aviation Institute.

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# Panel of Reviewers

Reviewers are appointed by the Editor to represent all elements of aviation and space transportation scholarship and practice. An appointment to the Panel of Reviewers recognizes professional and academic achievement. Appointments are for a three-year term with the option of renewal. For membership consideration, submit a curriculum vita or industry résumé to Dr. Brent Bowen, Executive Editor.

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# The Editors

### BRENT D. BOWEN

Dr. Brent Bowen serves as Distinguished Professor at the Aviation Institute, School of Public Administration; University of Nebraska at Omaha Bowen attained his doctorate in Higher Education and Aviation from Oklahoma State University and a Master of Business Administration degree from Oklahoma City University. His Federal Aviation Administration certifications include Airline Transport Pilot, Certified Flight Instructor (Gold Seal), Advanced Instrument Ground Instructor, Aviation Safety Counselor, and Aerospace Education Counselor. Dr. Bowen's research on the development of the national Airline Quality Rating is regularly featured in numerous national and international media, as well as refereed academic publications. Dr. Bowen has in excess of 300 publications, papers, and program appearances to his credit. His research interests focus on aviation applications of public productivity enhancement and marketing in the areas of service quality evaluation, forecasting, and student recruitment/retention in collegiate aviation programs. He is also well published in areas related to effective teaching and has pioneered new pedagogical techniques. Dr. Bowen has been recognized with awards of achievement and commendation from the American Marketing Association, American Institute of Aeronautics and Astronautics, Federal Aviation Administration, Embry-Riddle Aeronautical University, W. Frank Barton School of Business, Travel and Transportation Research Association, World Aerospace Education Association and others.

### IGOR KABASHKIN

Dr. Igor Kabashkin is Vice Rector of the Transport and Telecommunications Institute, Latvia and a Professor in the Aviation Department of the European Commission for Cooperation in the Field of Scientific and Technical Research. Kabashkin received his Doctor Degree in Aviation from Moscow Civil Engineering Institute, a High Doctor Degree in Aviation from Moscow Aviation Institute, and a Doctor Habilitus Degree in Engineering from Riga Aviation University and Latvian Academy of Science. His research interests include analysis and modeling of complex technical systems, information technology applications, reliability of technical systems, radio and telecommunication systems, and information and quality control systems. Dr. Kabashkin has published over 274 scientific papers, 19 scientific and teaching books, and holds 67 patents and certificates of invention.

# Introduction

The *Journal of Air Transportation* concludes its twelfth year of publication with Volume 12, Number 3. This edition contains five manuscripts from scholars worldwide, as well as a review of a new aviation safety book. Air transportation is an ever-changing industry. As such, the *Journal* continues to serve as a medium for non-engineering based aviation research to be published. Contained in this issue are articles which address contemporary issues from air traffic avoidance systems to air traveler preferences; low cost carriers to airline human resource management, to RFID technology. Also featured is a review of a new book on pilot error and airline accidents. Each article contributes greatly and uniquely to the knowledge base of the global aviation community.

Sorenson award-winning authors Avitabile, Northam, Peacock and Tank of Embry Riddle Aeronautical University analyze air traffic control tapes to evaluate Automatic Dependent Surveillance-Broadcast effectiveness.

Wittmer, Laesser and Bieger research Swiss air traveler preferences on transatlantic flights. Data from a survey of 514 passengers was utilized. Discrete choice analysis measured preferences in the process of identifying travel choices

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Nine US airlines were invited to participate in a human resources survey by Ramlall. Policies and practices were examined in this study.

Jones and Silveray relate Radio Frequency Identification technology to operations on the International Space Station. Also presented is a Design for Six Sigma methodology. Study results are compared to NASA requirements.

This edition of the *Journal* concludes with a review of the new aviation safety book, *The Limits of Expertise: Rethinking Pilot Error and the Causes of Airline Accidents* by Daley.

We hope that you enjoy this copy of the *Journal of Air Transportation.* We encourage all air transportation researchers and scholars to consider submission of their research to the *Journal*. Manuscript submission guidelines are provided at the back of this publication.

Best regards,

Brent D. Bowen, Executive Editor

# Sorenson Best Paper Award

The *Journal of Air Transportation* is proud to present the Sorenson Best Paper Award, named in honor of Dr. Frank E. Sorenson. This award gives recognition to the author(s) with the best literary and scholarly contributions to the field of air transportation. The Editor, on the basis of reviewer rankings during the review process, grants the Sorenson Award. The manuscript with the highest overall score is awarded the Sorenson Best Paper Award. This consideration is considered a high recognition in the aviation community.

Dr. Frank E. Sorenson was a pioneer in the field of aviation education since its early beginnings in the 1940s. A renowned educator and prolific writer, Sorenson contributed not only educational texts to the field, but also served as a consultant and innovator throughout the expanding realm of aviation education and research.

Dr. Sorenson's aviation impact and potential were recognized early on by the National Aeronautics Association when he received the Frank G. Brewer Trophy in 1946 for the most outstanding contribution to the development of youth in the field of education and training. In 1958, the University Aviation Association honored him with the William A. Wheatley Award in recognition of outstanding contributions to aviation education. These were the first of many awards and citations he would earn on a local and national level as he continued his active involvement in the field of aerospace education up until his death in 1977.

Through his involvement with the University of Nebraska-Lincoln Teachers College, Dr. Sorenson generated some of the earliest teaching materials for aviation education and textbooks for military aviators during World War II. Throughout the course of his career, he contributed over forty articles and publications related to the field of aviation education. His efforts guided the way for extensive aerospace research and scholarship from the grassroots to the global level through his participation in Civil Aeronautics Association, the World Congress on Air Age Education, and UNESCO. He has served as chairman of the Air Force Association's Aerospace Council, the Aerospace Education Forum at the First World Congress of Flight, the U.S. Air Force Air Training Command, the Men in Space book series, and NASA's Aerospace Education Advisory Committee. As a result of his visionary involvement and development of the Link Foundation, the organization has gone on to provide grants now totaling over a half million dollars a year to support and advance aerospace education and training in aeronautics.

Dr. Sorenson's continuous involvement in aviation education and research laid the groundwork for many of the advancements currently taking place in the industry. His ceaseless research and educational outreach demonstrated how one person can make a difference not just today but well into the future. Currently, several awards exist that are representative of his achievements in aerospace education and research. These include the Frank E. Sorenson Award for Excellence in Aviation Scholarship, representing the highest scholarly honor in aviation education, presented annually by the University Aviation Association; the Frank E. Sorenson Pioneers in Nebraska Aviation Education Award presented annually by the University of Nebraska at Omaha Aviation Institute, as well as a memorial lecture fund and scholarship fund.

## Past Recipients of the SORENSON BEST PAPER AWARD

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2001 James C. Taylor and Manoj S. Patankar, *Four Generations of Maintenance Resource Management Programs in the United States: An Analysis of the Past, Present, and Future*, Volume 6, Number 2.

2002 Lawrence F. Cunningham, Clifford E. Young, and Moonkyu Lee, *Cross-Cultural Perspectives of Service Quality and Risk in Air Transportation*, Volume 7, Number 1.

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# AUTOMATIC DEPENDENT SURVEILLANCE-BROADCAST UTILITY FOR AIR TRAFFIC AVOIDANCE

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**Prescott, AZ**

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**Juergen Tank**
**Embry Riddle Aeronautical University**
**Prescott, AZ**

**ABSTRACT**

Sixteen hours of air traffic control (ATC) tapes from the busy Prescott, Arizona, airport were analyzed to evaluate the effectiveness of Automatic Dependent Surveillance-Broadcast (ADS-B) in reducing the time taken for a pilot/instructor to sight another airplane following an ATC call. The results of the investigation indicated that 82.9 percent ADS-B-equipped aircraft and 65.9 percent of non-ADS-B-equipped aircraft reported immediate sightings. Comparison of the times to sight the second aircraft following an ATC call indicates that the average ADS-B response time (6.57 seconds) was significantly less than the average non-ADS-B response time (14.17 seconds). It is concluded that ADS-B offers a considerable advantage in the avoidance of near mid air collisions through improved situation awareness.

**Jeffrey Avitabile** is a flight instructor at Embry Riddle Aeronautical University (ERAU). He is his team safety manager and specializes in aerobatics instruction. He recently graduated with a Masters degree in Safety Science. This work on ADS-B is mainly the result of his Graduate Research Project, which was sponsored by a grant from the Federal Aviation Administration.

## INTRODUCTION

The threat of midair collisions (MAC) has been present since the advent of widespread general and commercial aviation. From the MAC between a Lockheed Super Constellation and a Douglas DC-7 over the Grand Canyon in 1953 to the loss of a Pacific Southwest Airlines 727 over San Diego, California, in 1978 to hundreds of near or actual collisions today, MACs are an ever-present threat to every person in the air. These accidents spurred efforts of airspace managers and technology developers to greater efforts in the anticipation of greater air traffic density. Successful use of available collision avoidance techniques and technologies are vital to the survival of all pilots and air travelers.

In June of 2004, a new collision avoidance technology, Automatic Dependent Surveillance-Broadcast (ADS-B), was implemented at the Prescott Campus of Embry-Riddle Aeronautical University (ERAU). The system, designed to provide pilots and flight instructors with information never before found in the cockpit of small aircraft, sought to reduce the occurrence of near and actual MACs, as well as provide enhanced situational awareness regarding the activities of other pilots in this busy local airspace. Relying on cutting edge technologies such as global positioning systems (GPS), satellite weather uplinks, and terrain mapping, the system gives unprecedented amounts of information in a user-friendly format (Scott, 2006).

In one particularly safety-critical industry, aviation, many new technologies are explored and meet with considerable optimism, but few ever result in revolutionary changes. One of the most important safety-related tasks of the aviation mission is collision avoidance, which is traditionally carried out primarily by separation services such as traffic lanes and patterns, radar and visual sequencing provided by air traffic controllers, and supplemented by sense and avoid technology. However, the modern computer age has allowed the development of exciting new systems to further improve the identification of and lead time to avoid collision threats.

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**Gary Northam** is chair of the Department of Safety Science at ERAU. He has a long history of educational contributions in the area of aviation. He was chair of the Department of Aviation at St. Louis University before moving to Prescott. He is also very active in accreditation of university departments of aviation.

**Brian Peacock** is professor of safety science at ERAU. He spent 15 years in academia where he taught various industrial engineering topics; he then moved to General Motors for 15 years followed by 4 years with the National Space Biomedical Research Institute/NASA. He has published widely on human factors topics.

**Juergen Tank** is director of flight safety at ERAU. He recently obtained his Masters degree in Safety Science. Before coming to Embry Riddle he had a long military aviation career.

The Federal Aviation Administration (FAA) and the aviation industry have placed their faith ADS-B. This equipment, although technologically promising and drawing high praise from its users needs more testing to assure its utility. The FAA, along with many other aviation institutions, has invested considerable time and large sums of money in the development and implementation of the ADS-B system. While technologically promising, the system's net effect on transportation safety is uncertain. Nowhere is this truer than in general aviation, where little or no experience with cockpit displays of traffic information (CDTI) has been gained. Until now, no CDTIs have been available and viable for the general aviation market. The implementation of ADS-B has the potential to revolutionize the way that traffic is seen and avoided, but can only do so if the system is accurate, precise, reliable and, perhaps most importantly, easy to use.

## BACKGROUND

In the early days of aviation, few airplanes traveled in domestic skies, and no established routes existed. Because of the sparse distribution of air traffic, few MACs occurred. The lack of modern technologies and limited use of radio meant the main method of maintaining separation between aircraft was visual sighting, which occurred largely by chance. Shortly after the end of World War II, however, domestic civil air travel experienced an explosion in popularity. In fact, in the years between 1940 and 1950, air travel increased from 3 million passengers annually to over 55 million. Considering that this occurred in a country with a population of merely 150 million, this growth parallels the meteoric expansion of newer technologies such as cellular telephones and personal computers (Kruggel, 2003). With this increased traffic density, along with the tendency of air carriers to travel similar routes, the possibility of a MAC increased dramatically.

In response to the explosive growth of air travel and the resulting congestion, a technological solution was needed. In 1946, the Civil Aeronautics Administration began testing an experimental ATC tower equipped with radar for the tracking of aircraft movement. By 1952, radar was in use for approach and departure control at select airports. In the mid-1950s, a famous MAC occurred between two airliners over Arizona's Grand Canyon, taking the lives of all on board. In response, the U.S. Congress investigated and demanded changes to the air traffic system. To prevent the accident's recurrence, United States (US) aviation regulatory bodies pushed forward with nationwide implementation of radar tracking for aircraft en route between major cities. This system allowed air traffic controllers to perform, on various levels, separation and sequencing of air traffic. Provided that both aircraft were visible on radar, aircraft could safely operate in relatively close proximity to each other with improved safety. By 1958, the presence of radar control reached 85 airports and many common routes in the form of enroute control (U.S. Centennial of Flight Commission, 2003).

By the late 1970s and early 1980s, air traffic density had again increased to levels which would greatly compromise the safety of flights, especially in busy areas where many types of aircraft performed many different types of operations (such as near large urban centers). Fortunately, technological advances offered at least a partial solution, the Traffic Collision Avoidance System (TCAS) that, when coupled with the newly created Mode-S transponder, broadcast position and flight-path information among TCAS-equipped aircraft. Anytime two aircraft equipped with TCAS get too close to each other, the system calculates an escape maneuver for each aircraft and aurally announces it (such as, “climb, climb”).

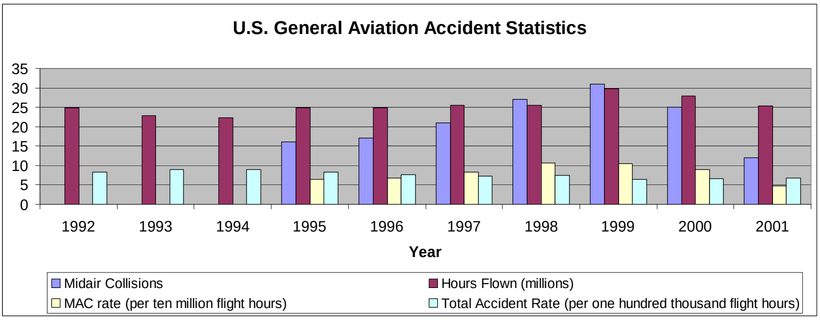
Today, TCAS is required equipment for all 14 CFR part 121 air carrier operators and select other operators, generally of large aircraft. The introduction of TCAS offered considerable advantage in sighting and avoiding traffic, with little impact on the crew’s duties or ATC functions (Tillotson, 1988). Unfortunately for many pilots, TCAS is a prohibitively expensive system, making it impractical for the operators of smaller commercial and general aviation aircraft.

## The current problem

The danger of MACs is ever-present and possibly increasing as air travel continues its march toward greater popularity. As noted by the National Transportation Safety Board's Annual Reviews of Accident Data for general aviation, between 1997 and 2001, 110 MACs between aircraft occurred, with more than 48% resulting in at least one fatality (NTSB, 2000, 2003, 2004, 2006). This is a relatively small fraction of total aviation accidents, but represents a subsection of hazards that has had little recent attention paid to it. Further, the number of actual MACs is only a poor reflection of the number of dangerous encounters (near misses) with other aircraft that are experienced every year (see Figure 1).

Since MACs are such rare events (when viewed as a function of the number of hours or total flights flown), they are difficult to use as a statistical measure of aviation collision risk. Instead, many analyses use the near midair collision (NMAC) to evaluate air traffic system safety.

**Figure 1. U.S. General Aviation Accident Statistics, 1992-2001**




*Note*. The data are from A*nnual reviews of aircraft accident data: U.S. general aviation, 2000-2006, Washington, DC, National Transportation Safety Board.*

To determine how many NMACs occur each year, Schuch (1993) devised a probabilistic analysis of existing NMAC data compiled by the National Aeronautics and Space Administration (NASA) through the non-punitive Aviation Safety Reporting System (ASRS). Schuch's analysis resulted in a 95% confidence that the actual number of NMACs occurring in the US as of 1993 lies between 12,903 and 27,733. This wide margin is largely a result of various assumptions about pilot reporting rate. These assumptions include the number of aircraft sighted by chance (assumed at 10%) and the probability of a NMAC being reported by the pilot experiencing it (also assumed to be 10%). However, these analyses all resulted in estimates with the same order of magnitude, lending at least some credibility to the numbers. Despite the large uncertainty in the exact numbers of NMACs in the US, it is evident that the general aviation environment does expose a large number of aircraft to the danger of a collision.

## Development of a solution

ADS-B is an airborne situation awareness system that can contribute greatly to collision avoidance, developed through the integration of GPS information and line-of-sight transmission directly from aircraft to other aircraft. The system consists of four main parts: an aviation-grade GPS navigation unit, a Universal Access Transponder (UAT), a reception antenna, and a cockpit display unit. In a typical scenario, an aircraft's identification, GPS position, altitude, and velocity vector are obtained from the onboard GPS unit and transmitted through the UAT approximately once every second. This information is received by the antennae of other aircraft within line-of-sight of the first aircraft, and a symbol depicting the pertinent information is portrayed on the cockpit display in the receiving aircraft. This enables the pilots of other aircraft equipped with ADS-B to note the location of adjacent aircraft quickly, attain visual contact earlier and more precisely, avoid misidentifying aircraft sighted visually, and adjust flight paths to avoid a conflict. Further even if the aircraft never actually sight each other, flight path adjustments can be made so that conflicts are resolved even earlier. There is no ground infrastructure required for the ADS-B information to be exchanged between equipped aircraft, so the system will work throughout the world (including areas with difficult separation requirements, such as over the North Atlantic) with nothing more than installation in the participating aircraft.

The ADS-B system is also tightly integrated with a Traffic Information System-Broadcast (TIS-B) system. This system allows the display of aircraft not equipped with ADS-B on the cockpit displays of aircraft that are ADS-B equipped. The TIS-B system operates via a Ground-Based Transmitter (GBT), which relays traffic position, altitude, and velocity information taken from existing ATC radar installations to the ADS-B-equipped aircraft via a radio uplink. With this system, pilots of ADS-B-equipped aircraft get the advantage of seeing the exact radar picture that the controlling agencies do. Ideally, this will enhance situational awareness, allow for even more self-directed collision avoidance in non-controlled environments, and decrease the chances of miscommunication when in controlled environments. This radar-based system is more limited than ADS-B, however. The uplink of ATC radar information is refreshed every 3-13 seconds, far less often than the approximately one second ADS-B interval (Garmin, 2005). Further, the TIS-B system relies on line-of-sight from the GBT to the receiving aircraft, limiting range. Also, ATC radar systems cannot be relied upon to detect all aircraft, especially at lower altitudes and in rugged terrain (where many general aviation operations occur).

As part of the long-term FAA plan for ADS-B, ATC radar facilities will be replaced with a direct link to ADS-B-equipped aircraft. With this, air traffic controllers will receive a more frequently updated, potentially more accurate display of aircraft position and movement. Furthermore, the ground infrastructure for such a system is far cheaper and less maintenance-intensive than large, costly radar installations. The ADS-B system also displays terrain and weather information. This system of weather broadcasting is known as Flight Information Service-Broadcast, and relies upon relayed weather radar and satellite weather information sent through the GBT. Also, many of the cockpit displays allow the depiction of terrain by reference of the aircraft's GPS position and altitude to an internal terrain database (see Figure 2). Combined, these systems provide a comprehensive situational awareness package that attempts to solve many of the longstanding problems experienced in general aviation, and provides enhancement to the technologies available to the crew of large aircraft.

**Figure 2. Typical MX-20 Traffic Display**


*Note.* From ADS-B Technologies Website.Retrieved on January, 30, 2008 from http://www.ads-b.com/gallery.htm. Copyright 2007 by ADS-B Technologies. Reprinted with permission.

FAA's Capstone Program initiated the use of ADS-B technologies in the aviation environment of Alaska. The Yukon-Kuskokwim Delta region of Alaska is a dangerous and challenging flying environment, and an ideal place to evaluate new safety and situational-awareness technologies (FAA, 2001a).

In the final report, titled The Impact of Capstone Phase 1 Program (FAA, 2005), it was concluded that pilot opinions were mixed, although mostly positive, throughout the study. Prior to using the equipment, 97 percent of pilots surveyed anticipated at least "some benefit" in terms of the risk of NMACs. Three percent of pilots anticipated "no benefit." Shortly after the system came online, pessimistic views indicating "very small" or "no" benefit jumped to 17 percent, while those seeing a "major benefit" dropped sharply from 70 percent to 22 percent of respondents in 2001 (FAA, 2001b). One year later, however, pilot opinions rebounded strongly toward the positive views seen in the baseline survey, although an increase in those reporting "very small" or "no" benefit remained at 8 percent, a number nearly triple that observed prior to implementation (FAA, 2005). In another set of surveys, an ongoing investigation of the traffic system usefulness, ease of use, and frequency of use looked at opinions solicited in 2003 and again in 2004, several years after the system went live. In all three areas, improvements in pilot opinion were noted (FAA, 2005).

As mentioned in the Capstone Phase 1 Program final report, "pilots consider traffic avoidance to be one of the more useful and frequently used capstone capabilities" (FAA, 2005, p. 28). In addition, the responses from surveyed Anchorage Air Route Traffic Control Center controllers indicated that no controllers disagreed with the assertion that "ADS-B targets are an improvement over radar," although 21 percent of respondents indicated neutral feelings on the matter. When asked about system preference, 82 percent preferred the use of ADS-B over radar as a primary controlling technology.

When capstone experimentation and implementation in the Yukon-Kuskokwim Delta was completed, the FAA sought the expansion of the system into wider areas of Alaska, as well as into the contiguous US (Scott, 2006). Fortunately, ERAU had the vision, the means, and the fleet to become the first installation customer in the contiguous US. ERAU-Prescott is a flight training university with over 100 flights per day, and Love Field is among the busiest airports in the US without radar approach control. The high density of traffic, combined with an unusually high density of training present the potential for frequent NMAC hazards. The installation of ADS-B equipment in ERAU airplanes and GBT antennae in the area was completed to an initially functional level by June 2004.

One of the shortcomings in the TIS-B/Radar System is the delay in the displayed image given to the pilot and controller. On average, the time it takes to collect radar information, build a picture, and distribute that information to the controller and the aircraft is on the order of 3-13 seconds. In most cases, especially those where a pilot or controller is attempting to alter a flight path well in advance of a dangerous conflict, this is more than acceptable. However, in closer quarters, such as a traffic pattern or busy VFR (Visual Flight Rules) corridor, those 3-13 seconds can lead to life threatening inaccuracy. For instance, if two aircraft approach a collision point a general aviation friendly groundspeed of 120 knots, a delay of 12 seconds means that, since the information was gathered, each aircraft moved four-tenths of a nautical mile (Garmin, 2005). By contrast, the full ASD-B system experiences an update approximately every one second. This, of course, makes the errors on the cockpit display much smaller (roughly 1/30 of a mile, or about 200 ft at 120 knots groundspeed). This distance is never an acceptable following distance, so, even in tight quarters, the ADS-B images are reliable for sequencing purposes.

Further compounding the issue of positional accuracy, a TIS-B target's trajectory, airspeed, and altitude are subject to these same delay errors. These problems are identical in nature to those faced by air traffic controllers every day (although the uplink time may increase the delay for cockpit users). However, air traffic controllers are often able to mitigate the danger and adapt to the idiosyncrasies of the system for several reasons:

1. The delay in the picture is not usually as long as in TIS-B cockpit displays because the ATC displays do not require as many steps from data acquisition to display.

2. The controller is free to focus more attention on the aircraft and their movement than the pilot who sees the display in the cockpit.
3. The controller has, in most cases, better information regarding an aircraft's intention than would the third-party pilot due to direct radio contact.

These advantages, along with a very conservative set of aircraft separation regulations, have allowed radar-equipped air traffic controllers to maintain a very good safety record.

These problems could potentially become a thing of the past under the emerging ADS-B-integrated airspace system. The decreased delays, decreased chances of missing or delayed aircraft identification tags on radar screens, more accurate position information, and real-time transmission of altitude and trajectory information could leave controllers with a vastly better picture of the airspace they control. This, combined with the potentially improved autonomy of pilots, promises to decrease workload and frustration for every involved party, allow tighter aircraft separation standards without increased danger, and improve overall airspace utilization. It seems, therefore, that the implementation of ADS-B could indeed score the elusive hat trick of low setup and operating cost, increased safety and improved efficiency.

Until now, the evaluation of the ADS-B system has been carried out by technological analysis and user-response surveys. The technological evaluations have proven the system capable of displaying information accurately and punctually, as well as established methods for independent, anti-spoofing evaluation. The user survey results have been overwhelmingly positive, indicating that, whether or not there is a real safety benefit, most users would prefer to have the system installed in the aircraft they fly, fleets they manage, or airspace they control. In the final report on the FAA's Capstone Program, survey results indicated generally favorable opinions about all ADS-B related services. When asked how useful, usable, and frequently used the traffic information is, over 90 percent of Yukon-Kuskokwim Delta pilots responded positively (FAA, 2005). Similarly, the ease of use of the avionics associated with the Capstone Program was reported by 84 percent of pilots to be similar to or easier than other avionics they had used.

Previous research on NMACs and ADS-B's effect on collision avoidance have been based in reports of NMACs maintained in either the NASA ASRS, or by analysis of various smaller NMAC databases. In either case, it is found that NMAC reporting data is ineffective at predicting changes in the actual number or severity of NMACs (Scott, 2006, Aviation Safety Commission, 1988). Fortunately, some indications suggest that CDTIs do positively influence the ability of the pilot to visually acquire or otherwise avoid traffic as compared to pilots using more traditional avoidance techniques. In 2004, Williams and Ball found that a multi-function traffic display system (including a Garmin MX-20™) was effective at improving the number of aircraft sighted in simulated cross-country flight. Interestingly, the use of the multi-function display lowered the amount of time the pilots spent scanning outside, despite the improved traffic acquisition performance.

This paradoxical situation, where pilots see more traffic while looking outside less, may be a result of how unlikely it actually is that a pilot would see other traffic by a chance look outside. A 2005 analysis of limiting considerations in the see-and-avoid method of collision avoidance included an empirical evaluation of the chances of seeing another aircraft. The results were profoundly low probabilities of detection, with real-world detection likely to be even worse. Also mentioned in the study were numerous MACs where the inherent limitations of the see-and-avoid technique were listed as probable causes. That is, the backbone of all aviation collision avoidance has fundamental flaws, including physiological limitations of the pilots and behavioral limitations due to workload and other demands of the flying environment. A poignant remark concludes the study:

> The see-and-avoid concept misleads pilots and controllers by encouraging overconfidence in visual scanning while neglecting its physical and behavioral limitations and mitigation strategies. While visual scanning is necessary to prevent midair collisions, especially of aircraft flying slowly in close proximity and not yet on collision courses, it is not sufficient. Potential mitigation strategies include…affordable and reliable collision avoidance technologies in all general aviation aircraft, as the NTSB recommended in 1987. (Morris, 2005)

## METHODS

Previous studies evaluating the effectiveness of ADS-B on reducing NMAC rates have proven inconclusive (Scott, 2006). Other studies have demonstrated the promise of ADS-B or similar systems, but not in the operational environment (Williams & Ball, 2004). This study seeks to bring together evaluation of the manner in which ADS-B influences the ability of pilots to see and avoid traffic before a NMAC situation develops with performance data on pilots' interaction with the system. The present study was limited to the Prescott area which has high volume student training traffic—both flight training and air traffic controller training.

The ERAU airplanes were equipped with ADS-B displayed on the MX-20TM display which was located on the right side of the instrument panel—

in front or to the right of the instructor. The majority of flights at this busy airport (more than 100 flights per day) are dual and the ADS-B display is principally accessed by the instructor. Other airplanes using the airport, such as those from two busy local flight schools, were not equipped with ADS-B.

The approach of this research involved observation of scanning behavior and performance through analysis of public domain records of ATC frequency proceedings. These recordings, maintained in an archive by LiveATC.net, include the primary flight control frequency (125.3) at Love Field, Prescott, Arizona. The flights involved were either in or approaching the flight pattern. The tapes were analyzed to determine the time required by aircrews to acquire other aircraft by timing from an ATC traffic advisory to the corresponding response from the aircrew. An example of this information would be when a phrase such as "you're number two," "follow traffic ahead," "traffic at…" or similar are given by the air traffic controller. The initiation of the response by the aircrew (e.g., "have traffic in sight") signaled the end of the timing.

This evaluation of archived recordings covered two one-hour periods of each day over eight consecutive days. The first period was from 0800-0900 local time and the second from 1400-1500 local time. This represents relatively busy times of the day. Some of the available data were not counted, however. For example, no traffic advisories issued to helicopters were evaluated. Also because of the low response rate, even when traffic is sighted, traffic advisories issued to aircraft taking the runway for departure were discarded. For the purposes of this investigation, only the most recent ATC traffic advisories were used in the analysis. If two or more traffic advisories were issued, the initial advisory was considered a failure of the aircrew to find traffic, and the aircrew's performance was measured from the last traffic advisory prior to affirmative response.

In order to supplement and expand the data gathered through audio analysis, in-flight observations were conducted with crews in both ADS-B-equipped and non-ADS-B-equipped aircraft to form a subjective evaluation of the usage of the ADS-B system and how that compared to traditional visual scanning and collision avoidance methods.

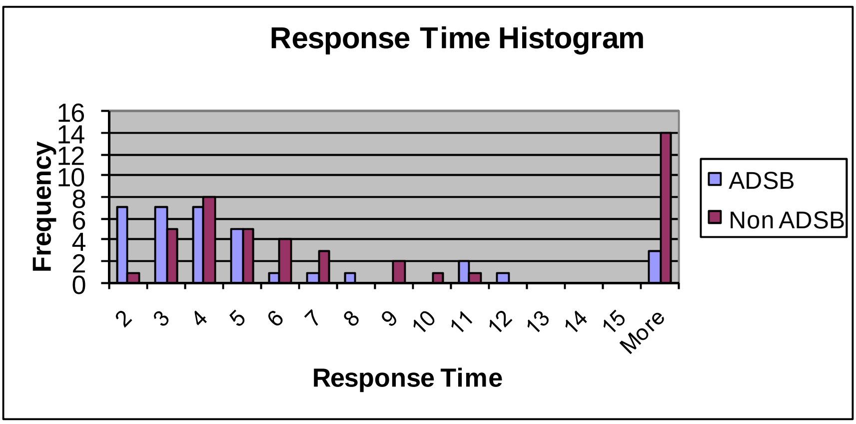
## RESULTS

The results from the analysis of sixteen hours of ATC recordings were evaluated with several statistical methods, including Excel and SAS. Table 1 shows some basic descriptive statistics and Figure 3 shows a distribution of the response times. Comparison of the means using the Students T test indicates that the average ADS-B response time (6.57 seconds) is significantly less than the average non-ADS-B response time (14.17 seconds, T0.05, 78 = 2.46 > tcrit = 1.99). However, it was observed that the data sets had different variances and skewness. Consequently the data were ranked and a Mann Whitney non parametric test was used to compare the two data sets. This test also indicated that the ADS-B response times were significantly less than the non-ADS-B times ($Z = 3.13 > Z_{.001} = 3.1$).

**Table 1. Descriptive Statistics of Evaluation of the Usage of the ADS-B System Compared to Traditional Visual Scanning and Collision Avoidance Methods**

| | ***non-ADS-B*** | ***ADS-B*** |
|---|---|---|
| Mean | 14.16 | 6.57 |
| Standard Error | 2.53 | 1.36 |
| Median | 6 | 4 |
| Mode | 4 | 4 |
| Standard Deviation | 16.77 | 8.02 |
| Sample Variance | 281.16 | 64.37 |
| Kurtosis | 6.59 | 12 |
| Skewness | 2.35 | 3.3 |
| Range | 83 | 40 |
| Minimum | 2 | 2 |
| Maximum | 85 | 42 |
| Sum | 623 | 230 |
| Count | 44 | 35 |

**Figure 3. Distributions of Response Times with and without ADS-B**



A large number of the traffic advisories, 82.9 percent for ADS-B-equipped aircraft and 65.9 percent for non-ADS-B-equipped aircraft, resulted in an immediate affirmative response from the aircrews. This may imply that either the aircrews sighted the other aircraft during the traffic advisory or that the traffic was already sighted prior to the traffic advisory. These proportions were compared and shown to be significantly different ($Z = 1.693 > Z_{.05} = 1.645$). Thus it can be concluded that the ADS-B-equipped crews performed better than non-ADS-B crews in immediately sighting or pre-sighting other traffic in the area.

## DISCUSSION

Avoiding MACs is an extremely important task for all pilots. Unfortunately, it is also a very difficult task to perform successfully. Nearly every pilot has endured at least one close call, if not more. For the first time since widespread implementation of ATC radar, a new technological solution to the endemic problem of collision avoidance is available. ADS-B is a low-cost, lightweight, easy-to-use system that is available and practical for the general aviation market.

The particular methods used by pilots to interact with and use the ADS-B system vary widely. On the one hand, during observations of flight crews who used ADS-B in the operating environment, some crews appeared comfortable taking the information given by ADS-B as true position, altitude, and velocity, and using that information to make decisions about when and how to change course, altitude, speed, or some combination thereof. On the other hand, different crews might use the ADS-B information to prompt a search for other aircraft in an attempt to obtain visual contact prior to any concrete decisions to alter flight parameters.

From the observations of aircrews in both ADS-B and non-ADS-B-equipped aircraft, it became apparent that two general behaviors for collision avoidance were used by pilots, regardless of their ADS-B status. For maneuvering in wide open areas with low traffic density (such as maneuvering or practice areas), pilots depended largely on relative position, as determined by evaluating position reports or ADS-B, to keep away from other traffic. For instance, if an aircraft in a practice area reports to be on the 315° radial from a VOR at 25 nautical miles range, the crew of the receiving aircraft might simply analyze their own current position and attempt to build a mental picture of the situation. This mental image then gives the crews an idea of what should be done to avoid close proximity to the other aircraft. In the case of non-ADS-B aircraft observed, as well as discussions with flight instructors who have flown without ADS-B, visual scanning for the other aircraft is not very intense unless the position report indicates close proximity. Another consideration with this situation is that many low-time pilots, such as solo students, are unable to form accurate mental pictures of the relative position of the two aircraft, implying that scanning performance is improved very little, if any, by the issuance of a position report, no matter how accurate.

Generally, this type of scanning and collision avoidance technique works well. However, there is little or no indication between position reports of the location, movement, or intentions of the aircraft issuing that report. With many aircrews providing position reports immediately prior to the initiation of a flight maneuver, a considerable time gap can develop during which aircraft may stray into close proximity of one another. For instance, one maneuver commonly practiced in multi-engine aircraft flight training, the Vmc demonstration (a demonstration of loss of directional control in simulated engine-inoperative flight), can take as much as 5 minutes to complete, cover close to 10 miles, and involve altitude changes of thousands of feet. It is not a large stretch of the imagination to conclude that the mental model formed by the aircrews at the initiation of the position report may be worthless after 5 minutes, yet no further prompt for vigorous visual scanning has been produced. Further, if an aircraft is sighted several minutes after a position report, the crew without ADS-B may be tempted to assume that the aircraft sighted is the same as that issuing the position report. However, many other aircraft may be present in and moving about the practice area, so no guarantee can be had.

Finally, the creation of a mental model (and its accurate retention) of the airspace and aircraft operating in it as well as the visual scanning prompts hinges upon position reports being issued by the aircraft utilizing the airspace. Unfortunately, not all traffic using the practice areas give position reports, nor even monitor the frequency on which the position reports are issued. Instead, many private aircraft, transient operations, and non-local training flights traverse the airspace without calls or frequency monitoring. While it can be assumed that every pilot operating there is aware of the collision danger present in any airspace, studies show that vigilance in see-and-avoid collision avoidance is nearly impossible to maintain at highly effective levels. Even worse, aircraft on an actual collision course are very difficult to sight due to a lack of apparent motion against the background (Morris, 2005)

Overall, this first mode of visual scanning and collision avoidance driven primarily by position reporting has some significant flaws when used in the traditional manner. However, the aircrews using ADS-B in the same practice areas may have considerable advantages which tackle the challenges presented by traditional methods. The first challenge, the creation of an accurate mental model, may be mitigated by the graphical depiction of the airspace available on the ADS-B display. For example, if the aircraft issuing a position report is five degrees different in azimuth and three more nautical miles from the VOR than the receiving aircraft, a significant amount of personal estimation bias is present in the resulting mental model. The common verbal response noted in observations is something like, "ok, they're over there (with a vague pointing motion), we'll be ok." However, a cockpit display of relative position (configurable with a 360° ring which can help with clock positioning—i.e., two o'clock high), cannot only help to create the mental picture for those who struggle with such spatial relationships, but also enhance the accuracy of those individuals with a well-honed skill for such things.

The implementation of ADS-B on a wide scale can also help with the issues in maintaining an accurate understanding of relative position between position reports. Instead of up to five minutes of silent motion while maneuvers are in progress, all changes in altitude, heading, and position are documented in real-time. In addition, the ADS-B display may provide more positive identification of aircraft giving position reports, meaning that an assumption that a sighted aircraft was indeed the aircraft the crew was concerned about can be more accurate.

Finally, the aircrafts that do not make and/or receive position reports may be much easier to see and avoid, as their position and movement will be well documented. As mentioned by Morris (2005), and in line with what many people intuitively suspect, a tiny object in a large and varied three-dimensional world with no relative motion against the background is difficult to spot, at best. A large cyan symbol on the black background of an ADS-B display is likely to be much easier to identify, track, and avoid. The human visual system is well adapted to sensing motion and contrast, attributes not available in the classic see-and-avoid collision avoidance model, but available in abundance on the ADS-B display. Further, the small area and short time required to scan the ADS-B display does not succumb to the vigilance decrement that a high-effort, low-return task such as scanning the sky for traffic may suffer from.

The other general model of collision avoidance observed in in-flight observation was that of intense scanning with generally good rates of capture seen in high-traffic-density, strictly controlled environments such as the traffic pattern and practice instrument approaches. Here, prompts by position reports or ATC traffic advisories often result in a visual acquisition, and reactive maneuvering often occurs only after that acquisition. The reason for this may be the close proximity of other traffic, and a resistance to hasty maneuvering due to concerns about maneuvering into the path of the other aircraft.

As shown by the results of the analysis of ATC recordings, the ADS-B-equipped aircraft have a distinctly better record of quickly visually acquiring the traffic that ATC advises them of. Further, the crews of ADS-B-equipped aircraft are more likely to either sight traffic before the traffic advisory or to immediately sight the traffic when prompted than are the crews using traditional visual scanning methods. These shorter acquisition times and higher likelihood of immediately sighting traffic imply that the crews of ADS-B-equipped aircraft have a much greater opportunity for effective collision avoidance, flight path adjustment, and self-sequencing.

Although not measured by the analysis of ATC recordings, the concepts of flight path, airspeed, and altitude adjustments seen in the practice area may also apply in the airport area, although any adjustments would be made within the confines of ATC instructions and restrictions. For instance, if two aircraft are maneuvering for a simulated radar vector entry to a practice instrument landing system approach, the ADS-B can be used either before or after visual sighting, to determine appropriate timing of inbound turns to maintain proper sequencing. Further, the system can be used to maintain adequate separation with less effort than continuously maintaining visual contact. Although the ADS-B system is not intended or adequately certified as a controlling system in the Prescott, Arizona, area, it can be functionally used to provide some sort of self-sequencing, regardless of visual contact status.

Finally, it has been argued that an ADS-B or similar cockpit display of traffic information may decrease heads-up time, or time spent actively searching the surrounding area for traffic. In traditional collision avoidance models, this is assumed to indicate a lessening of collision safety and an increase in MAC risk. Regrettably, the traditional model of visual scanning and collision avoidance is riddled with limitations and provides a profoundly low probability of actually sighting an aircraft by chance (Williams & Ball, 2004). With the ADS-B system, scanning performance is improved greatly, which may indicate that the quantity of time spent looking outside for traffic is less relevant with a CDTI than without. Instead, a concentrated search prompted by real-time, high contrast, easy-to-read, information-loaded displays is more important to a net decrease in MAC risk and an increase in overall collision safety.

## CONCLUSIONS

Although this research indicates a significant benefit from the use of ADS-B, it is limited in many ways, most notably by the homogeneity of the types of air operations conducted in the Prescott, Arizona, area. A large proportion of the aircraft using Prescott Love Field are conducting flight training, with two pilots on board. The specific workload requirements in flight training, compared with those in recreational or personal aviation, may sway the data. For instance, it is possible that single-pilot crews would rely upon the ADS-B more due to the possibility of decreased scanning workload; or they may rely less upon the ADS-B for collision avoidance due to the position and readability of the display (ADS-B installations in the ERAU Cessnas and Pipers occupy the far right side of the instrument panel). However, the transition to glass cockpits, with which a large number of newer general aviation aircraft are equipped, may change the way the traffic information is presented and therefore its effectiveness, regardless of the number of crewmembers.

For these reasons, replicating this research (the data are publicly available) in other areas, such as airports with more recreation or business aviation, along with continued evaluation of human behavior and performance with ADS-B is required. The addition of improved equipment and techniques, such as eye tracking equipment to evaluate time spent scanning outside the aircraft and the ADS-B display, measuring the number of aircraft sighted overall, or other metrics of human behavior and performance may more accurately evaluate the net safety increase. Further, data from the ASRS could be evaluated for a change in NMAC rate and/or reporting behavior once more widespread implementation of ADS-B and TIS-B is achieved.

Another consideration which should be followed closely as ADS-B gains popularity is the change in the behavior of pilots and controllers as a result of a change in information provided to each. The improvement in the traffic and sequencing picture offered to pilots may result in greater feelings of autonomy and therefore more instances of pilot deviation from ATC clearances or suggestions from pilots about how to sequence themselves. If these feelings are properly harnessed with altered rules and procedures (along with ADS-B equipage of ATC), customer service, safety and efficiency may be greatly improved. However, a lack of timely adjustments to regulations and procedures could lead to frustration and legal issues.

Similarly, the behavior of air traffic controllers may change with the assumption that pilots can see-and-avoid each other without ATC intervention. This may lead to a degradation of the benefit of ADS-B as a supplement, rather than a replacement for, existing collision avoidance safeguards. In any case, it is extremely important that, as ADS-B equipage expands, clear definitions of rules and responsibilities are maintained and altered to be as relevant and appropriate as possible.

The introduction of ADS-B has finally offered the traffic information that has been desired since the first time two aircraft flew close to each other. This technological solution has the potential to revolutionize the safety, efficiency, and ease of aviating. With the FAA planning to complete nationwide implementation and mandate ADS-B in decades to come, all pilots stand to benefit from the advantages ADS-B offers.

**REFERENCES**

Aviation Safety Commission. (1988). Final report and recommendations. Washington, DC.

Federal Aviation Administration - Alaska Region. (2001a). Air safety in Southwest Alaska. Anchorage, AK: University of Alaska.

Federal Aviation Administration - Alaska Region. (2001b). FAA capstone program: Baseline report. Anchorage, AK: University of Alaska.

Federal Aviation Administration – Alaska Region. (2005). The impact of Capstone Phase 1 Program. Anchorage, AK: University of Alaska.

Garmin MX20™ color multi-function display pilot's guide. (2005). Olathe, KS: Garmin International, Inc.

Kruggel, James C. (2003). Social history: Air travel: Its impact on the way we live and the way we see ourselves. Retrieved January 6, 2007, from http://www.centennialofflight.gov/essay/Social/impact/SH3.htm

Morris, Craig C. (2005) Midair collisions: Limitations of the see-and-avoid concept in civil aviation. Aviation, Space, and Environmental Medicine, 76(4), p 364.

National Transportation Safety Board. (2000). Annual reviews of aircraft accident data: U.S. general aviation, Calendar year 1997. Washington, DC.

National Transportation Safety Board. (2003). Annual reviews of aircraft accident data: U.S. general aviation, Calendar year 1998. Washington, DC.

National Transportation Safety Board. (2004). Annual reviews of aircraft accident data: U.S. general aviation, Calendar year 2000. Washington, DC.

National Transportation Safety Board. (2006). Annual reviews of aircraft accident data: U.S. general aviation, Calendar year 2001. Washington, DC.

Scott, Vincent D. (2006). Safety impact of automatic dependent surveillance-broadcast on Embry-Riddle flight operations. Unpublished Master's Thesis. Prescott, AZ: Embry Riddle Aeronautical University.

Schuch, Paul H. (1993). Near midair collisions: How many really occur? Retrieved February 23, 2007, from http://www.qsl.net/n6tx/prose/nmacrate.htm

Tillotson, Daniel H. (1988). Results of the in-service evaluation of the traffic alert and collision avoidance system industry prototype. AIAA/IEEE Digital Avionics Systems Conference, 8th (pp. 277-282). San Jose, CA: American Institute of Aeronautics and Astronautics.

U.S. Centennial of Flight Commission. (2003). Air traffic control. Retrieved January 6, 2007, http://www.centennialofflight.gov/essay/Government_Role/Air_traffic_control/POL15.htm

Williams, Kevin W., & Jerry D. Ball. (2004) Usability and effectiveness of advanced general aviation cockpit displays for visual flight procedures. Oklahoma City, OK: Civil Aerospace Medical Institute - Federal Aviation Administration.

# A CASE STUDY ON SWISS TRAVELERS AND THEIR AIR TRAVEL PREFERENCES ON TRANSATLANTIC FLIGHTS

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## ABSTRACT

This paper reports the results of research on Swiss air travelers on transatlantic flights, and presents explicit and implicit measurements of the attributes of air travel choices. Market research often identifies the preferences already known to the respondent, or preferences that the respondent desires to reveal, which could lead to erroneous marketing and investment decisions by companies and governmental agencies. The problem is especially relevant where the general or socially accepted behavior, rather than what actually happens, is communicated. Market research needs to develop methods and techniques to identify real preferences, as opposed to assumed ones. This paper contributes to the discussion about the differences between stated and hidden travel attributes by (a) offering a case in a specific context about differences between stated and hidden preferences, (b) conceptualizing stated and hidden preferences, and (c) drawing conclusions on marketing decisions, particularly in the aviation and travel industry. The study examines transatlantic, long-haul travel, which is often subsidized by companies. It draws on data from a survey of 514 passengers traveling from Switzerland. The discrete choice analysis is evaluated for the purpose of measuring hidden preferences, which identifies real travel choices made and compares them to stated travel preferences.

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## INTRODUCTION AND RESEARCH OBJECTIVE

Heated debate occurred after the Swissair bankruptcy in 2001 in Switzerland regarding the utility of direct intercontinental flights. With the introduction of larger planes such as the A380, and increasing pressures on costs—even on long-haul operations—network carriers' business models have undergone further transformation in two directions (Bieger, Bickhoff et al. 2001). Some major airlines rely on economies of scale by flying these large new planes and offering more indirect flights on long-haul routes. Other airlines, by relying on planes such as the Boeing 767, emphasize direct intercontinental flights between medium-sized centers.

This paper discusses the preferences that influence the buying behavior of Swiss travelers of transatlantic airline tickets. The study uses the origins and destinations Zurich (Switzerland) and selected transatlantic destinations, such as Chicago, Washington and Sao Paulo.

The study focuses on transatlantic flight connections, and identifies the hidden traveler preferences (Bieger, Laesser, & Wittmer, 2005; Crouch & Louviere, 2004; Louviere, Hensher, & Swait, 2000; Wittmer, 2005) of direct flights to American destinations based on four flight ticket purchasing criteria: price, direct versus indirect connection, number of connections per day, and airline brand. More criteria are included regarding direct connection flights, but not in the implicit questioning, due to the increasing complexity associated with more criteria in choice methods. Charter leisure travel out of Switzerland is excluded from the study.

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The study contributes to the discussion of business models and strategies in the long-haul flight supply sector by evaluating customer preferences for direct transatlantic flights in the case of Switzerland.

Specifically, the following questions are addressed in this paper:

1. What are the differences between stated and hidden preferences of consumers regarding direct transatlantic flights? (Crouch & Louviere, 2004; Louviere et al., 2000; Wittmer, 2005).
2. Do business travelers prefer direct connections?

The results of this study contribute to the identification of the opportunities for directly connected hubs out of Switzerland based on the identified customer preferences.

Two aspects are important for this study's analytical framework:

1. Motivating factors for customers' preferences on direct transatlantic flight connections; and
2. The method used to identify customers' preferences.

## ANALYTICAL FRAMEWORK

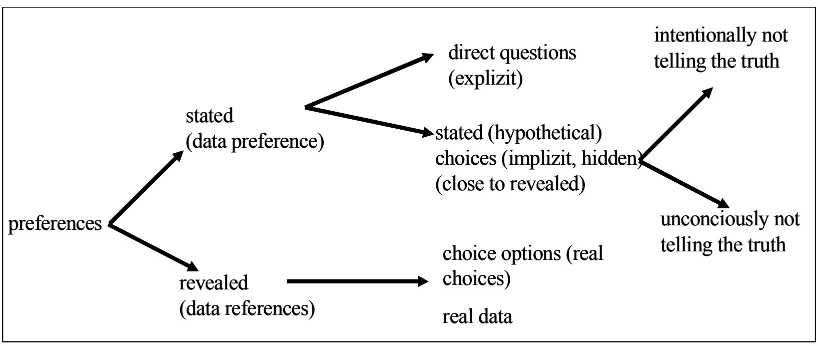
Respondents' demands are only apparent at the actual sales interaction. Research has difficultly creating real buying situations that influence the choice of a product or service. Demand for air transport can be defined as a derived demand, because users buy an airline ticket for a specific purpose, for example, they have a business obligation or want to consume tourist services in the destination. Thus airline ticket demand depends on the purpose of the trip and the demand in the destination.

One of the main difficulties in measuring travel preferences directly is the identification of the *true* preferences and the *real* perception of costs and benefits (Mazanec, Crouch, Brent Ritschie, & Woodside, 2001). Often respondents do not indicate their real preferences, attitudes, or evaluations, because they are not aware of them (hidden) or because they do not want to reveal them (see Figure 1). This is especially so regarding decisions about traffic modes and routes, because of different external influences that make these decisions very complex. Respondents often take situational decisions based on internal value systems which are hard to identify (Bieger, 2000; Bieger, Laesser, & Boksberger, 2003; Wittmer, 2005). Social pressures also influence travel decisions in many cultures. for example, the desirability of some modes of transportation might be influential. Hence stated answers to surveys might include subjective influences, and involve opinions influenced by actual occurrences as well as feelings. Revealed preferences are not influenced as strongly by different actual occurrences because results are evaluated across several criteria and respondents often do not know what is actually measured by these criteria.

Hidden preferences can be defined as implicit, unconscious preferences, which can be measured by hypothetical stated and real choices. The methods for determining these can be divided into three groups:

1. Methods that imply real decisions (Backhaus, Erichson, Plinke, & Weiber, 2003; Louviere et al., 2000; Verma, Plaschka, & Louviere, 2002; Wittmer, 2005);
2. Methods that identify the contribution of single dimensions to overall customer satisfaction (Backhaus et al., 2003; Wittmer, 2005; Zikmund, 1997); and
3. Methods with direct and indirect preference assessment (Sauerwein, Bailom, Matzler, & Hinterhuber, 1996).

**Figure 1. Stated versus Real Preferences**




## A METHOD FOR RECORDING HIDDEN PREFERENCES: DISCRETE CHOICE ANALYSIS AND RANDOM UTILITY THEORY

Several research methods can help to minimize the bias which can result from direct questioning, called implicit research methods. For the purpose of this study, the discrete choice analysis (DCA) was chosen.

The purpose of conjoint analysis is to determine the utilities (values) which respondents attach to different levels of different attributes (Elrod, Louviere, & Davey, 1992; Schweikl, 1985; Wittink & Catting, 1989). DCA is a kind of conjoint analysis, which places a respondent in simulated choice-making situations (Gustafsson, Herrmann, & Huber, 2003; Wittmer, 2005) derived from realistic variations of the product and service offerings that they might find on the market. DCA is used to identify the relative weights that customers put on product or service features and attributes. It is one of few modeling approaches based on a sound, well-tested, and relatively comprehensive behavioral theory known as random-utility theory (RUT), which leads to a wide variety of testable models of choice behavior (Verma et al., 2002; Wittmer, 2005). To evaluate the relative importance of several preference factors, a theory of how decisions are made, and the process by which these factors combine to drive decisions, is needed (Crouch & Louviere, 2004).

Random utility theory was originally proposed by Thurstone (1927), and further developed by (McFadden, 1973). According to RUT, preferences for airline services can be divided into a systematic and explainable component, and a random and unexplainable component (Louviere et al., 2000). The utility function is represented by the systematic component, which is the decision strategy of individuals, and the random component represents all possible unobserved influences on decisions (Crouch & Louviere, 2004). Different factors and associated properties of random components are specified and represent discrete choice models which underlie the choice generation process.

RUT-based models should be supplemented with a choice experiment or a data collection with additional preferences and choice reasoning (Crouch & Louviere, 2004). The usual objective of choice research is to predict how individuals' choices change, if attribute configurations change. In this case, attribute configurations represent possible airline service offerings. So choice-modeling research can predict which airline services are preferred and are more important for air travelers, and thus which choices motivate travelers to buy a specific air ticket.

Choice questionnaires include several choice option sets, and from each set respondents must choose one. This task of selecting a choice is repeated several times with a different set of product alternatives each time (in this case, airline tickets). After respondents choose one alternative from each of the sets, an aggregate logit model is fitted to the choice shares using the method of maximum likelihood. The choice sets and their compositions are determined according to the fractional factorial design (Louviere et al., 2000). The analysis is often performed using an aggregate binary or multinomial logit model.

A binary logistic regression only consists of binary variables as dependent variables. It is used to determine factors that affect the presence or absence of a characteristic when the dependent variable has two levels (0 and 1). It is a technique for predicting the mean value of a binary response variable as a function of one or more covariates.

Discrete choice models assume that people aim at maximizing the utility of their activities, and therefore choose the activity likely to offer them the highest utility. Although there are different types of choice models, all assume that from a set of alternatives each person expects a different utility, and each alternative can be described by different characteristics, whose values vary across different alternatives. Utilities depend on the different judgments of those characteristics (Simma, Schlich, & Axhausen, 2002).

## THE EMPIRICAL STUDY

### The experimental design

The choice experiments consist of four different attributes with three levels each, which results in a design of $3^4 = 81$ different factorial combinations.[1] In order to choose a maximum of 18 different combinations to be ranked by the respondents, an orthogonal fractional factorial design was used. The orthogonal design ensures that all combinations of levels are represented within the 18-combination design. This means 18 choice sets with two options each among which respondents choose, can be developed. The design is calculated the following way:

*(3 levels -1) * 2 options * 4 attributes + 2 degrees of freedom or error terms = 18 choice options*

Hence, the respondents were given 18 choice sets, where they had to choose one of the two options from each of the 18 sets.

### The questionnaire

The first part of the questionnaire asked demographic questions; the second part presented the 18 choice sets to the respondent.

The choice experiments presented respondents with several options, in which specified attributes were changed. According to the experimental design, choice sets were grouped and presented to the respondents. The survey was conducted with flight passengers before boarding the plane at Zurich airport.

Every choice set consisted of two specific flight offers (flight tickets). The respondents were asked to choose one option from two possible options per choice set. Table 1 shows the four attributes and their different levels (flight criteria). To keep the model simple, it was limited to four attributes, and was based on personal expert interviews with airline managers. However, there could be additional attributes in the model, which constitutes a limitation to this research. A more comprehensive number of attributes is included in the direct data collection presented in Table 4.

[1] Four factors with three levels each: $3^4 = 81$ possible combinations

**Table 1. Overview of Attributes and their Levels**

| Attributes | Levels |
|---|---|
| Airline | Swiss (direct connection) |
| | Home carrier of destination (direct connection) |
| | Airline with change of plane |
| Number of stops/change of plane | 0 |
| | 1 |
| | 2 |
| Number of daily connections | 1 to 2 |
| | 3 to 4 |
| | 5 + |
| Ticket price | Cheap |
| | Middle |
| | Expensive |

The DCA procedure allows researchers to isolate individual buying criteria and compare the relationship of attributes with one another by using the calculated -2nd log-likelihood value which is a measure of variance decomposition. The -2nd log-likelihood value per attribute explains the value proposition of each single attribute, and can be defined as the explained variance of each single attribute on the total -2nd log-likelihood value of all attributes together. This variance decomposition method indicates that the larger the -2nd log-likelihood value of a single attribute, the larger is its effect, meaning the more important that attribute is. Depending on the characteristic of the empirical observation ($y_k$), one specific case (choice set—in this case, two specific flight offers) in an equation presents either factor A (where A equals choice of flight offer 1 of the choice set) or factor B (where B equals choice of flight offer 2 of the choice set) equal to 1. For $y_k = 0$, factor A = 1, which results in $p_k(y = 0)$; while $y_k = 1$ for factor B $p_k(y = 1)$. The parameters of logistic regression models are estimated in a way that the likelihood is maximized (Backhaus et al., 2003; Louviere et al., 2000).

The difference of antilog beta values within a buying criterion based on several choice levels was used for the determination of the sensitivity (elasticity) of a buying criterion. The sensitivity values are based on the variables that reveal the largest difference within an attribute. The larger the difference, the more sensitive is the reaction of an attribute to changes.

## Data collection and sample

The data collection was carried out at Zurich airport during seven days during April 2005. The questionnaires were handed out to flight passengers at the gates and in different business lounges. Business and economy class passengers were included in the sample. Only passengers who could fill in the questionnaire in English or German, and who regularly used the Zurich hub, were considered. Questionnaires were collected from the travelers after completion at the airport, or they could complete them during their flight and send it back by international mail (an international prepaid envelope was provided). During the seven-day survey period 2,500 questionnaires were distributed at the airport, of which 1,000 were returned, a response rate of 40 percent. From these 1,000 questionnaires 514 were returned from passengers on transatlantic flights (Washington, 194; Chicago, 215; Sao Paulo, 105), which were used for the analyses in this paper.

The following tables summarize the demographic background, the voyage and the buying criteria of the respondents. Statements about the representativeness of the data are not possible, because information about the population of flight passengers is not available.

Nearly one-third of the respondents worked in Switzerland. The sample included Swiss and foreigners (for example, southern Germans) who used Zurich airport regularly. A large proportion of the foreigners in the sample who used Zurich airport regularly were assumed to come from southern Germany. They represented approximately one-third of the respondents. Approximately one-third of the respondents did not live in Switzerland, but in a neighboring country, or commuted regularly for occupational reasons to Zurich. Fifty-seven percent of the respondents worked in a Swiss company, and 43 percent in a foreign company.

**Table 2. Demographic Information about the Respondents**

| **Variables** | **Values** |
|---|---|
| Date of birth | Year of birth: 1923–1988 |
| Gender | Male: 71.5%<br>Female: 28.5% |
| Workplace | Switzerland: 58.1%<br>Other country: 41.9% |
| Place of residence | Switzerland: 59.2%<br>Other country: 40.8% |
| Employer | Local SME*: 25.8%<br>International SME*: 23.8%<br>Swiss large-scale enterprise: 27.2%<br>Foreign large-scale enterprise: 23.3% |

*SME = small and medium enterprises

**Table 3. Information Concerning Structure and Response Rate**

| Variables | Values |
|---|---|
| Destination | Chicago: 41.7%<br>Sao Paulo: 20.5%<br>Washington: 37.8% |
| Class | Economy: 63.9%<br>Business: 36.1% |
| Travel purpose | Business: 50.0%<br>Leisure: 50.0% |
| Payment | Paid myself: 49.2%<br>Company paid: 40.0%<br>Mileage credit: 5.9%<br>Somebody else paid: 4.9% |

The destinations that are included in the analysis represent some of the more relevant connections between Switzerland and the Americas for the purpose of this research, because they do not generally induce high seat load factors for airlines and are not the most profitable routes. Destinations like New York, which are overbooked anytime, are not providing the critical information needed. Approximately 64 percent of the respondents chose economy class and 36 percent chose to fly business class. Half traveled on business and the other half for leisure. Only approximately 14 percent of the leisure travelers chose to fly business class. Nearly half of all passengers paid for the flight ticket themselves. Companies/employers paid for 40 percent of the respondents' travel and approximately six percent realized a mileage credit. Five percent of the travelers received the flight ticket from somebody else who had paid for it.

## Analyses of direct transatlantic flight connections

Only two levels of each attribute are represented by the statistical reports. The third is the base case, which is calculated into the model and included in the result. Some variables in the model are not significant at a five percent significance level. These variables are usually not excluded from the model, because the significant variables in the model are only significant if the insignificant ones are included. This is because the variables in the model are dependent on each other.

Another important issue for the interpretation of the model is the extent to which the model can explain something, that is, its strengths. The strength of a model can be explained by the extent it can predict the choices made. The models of this research can significantly explain or predict the choices and combinations of choices and their levels, for example, 88.7 percent of the choices made by economy travelers, and 83.9 percent of the choices made by business travelers, can be predicted.

## RESULTS AND DISCUSSION

Tables 4, 5 and 6 highlight the importance of different quality criteria to the respondents regarding the decision to buy a flight ticket. The sample is split into two groups: business class and economy class passengers. The importance rating ranges between 1 (completely unimportant) and 6 (absolutely important).

**Table 4. Importance of Different Buying Criteria for Transatlantic Direct Flight Tickets**

| Descriptives | Business* | | | Economy** | | |
|---|---|---|---|---|---|---|
| | Mean | Std. Dev. | Variance | Mean | Std. Dev. | Variance |
| Total travel time | 5.011 | 0.785 | 0.615 | 4.818 | 1.033 | 1.066 |
| Time of departure/arrival | 4.788 | 0.974 | 0.950 | 4.506 | 1.022 | 1.045 |
| Punctuality | 5.000 | 0.944 | 0.890 | 4.818 | 0.896 | 0.803 |
| No. of daily connections | 3.888 | 1.123 | 1.262 | 3.445 | 1.232 | 1.518 |
| Total travel costs | 4.497 | 1.070 | 1.144 | 4.885 | 0.976 | 0.953 |
| Travel convenience | 4.906 | 0.985 | 0.969 | 4.817 | 0.969 | 0.939 |
| Direct connection | 5.238 | 0.882 | 0.778 | 4.917 | 1.055 | 1.114 |
| Security | 4.989 | 1.067 | 1.138 | 4.877 | 1.183 | 1.399 |
| Sympathy | 4.506 | 1.227 | 1.506 | 4.398 | 1.227 | 1.506 |
| Mileage program | 4.348 | 1.123 | 1.261 | 3.689 | 1.462 | 2.138 |

* Respondents who fly mostly for business reasons
** Respondents who fly mostly for leisure reasons

It is not surprising, that most buying criteria based on stated research are rated as very important. Compared to the other buying criteria, the number of daily connections and the mileage programs seem to be less important. The most important criteria are punctuality, direct connection, total travel time, and convenience. The total travel costs, security and the time of departure and arrival are also very important.

These results should be interpreted with care, because generally, respondents consider different criteria to be important if they do not have to be assessed in comparison with other criteria. Despite this disadvantage, the question provides insight into the ways consumers evaluate different buying criteria. The hypothesis that business travelers prefer direct connections because of their time requirements cannot be rejected at this point.

The following results are based on the choice-based conjoint analysis. The -2nd log-likelihood-analysis was undertaken separately for business and economy class passengers. This allows a comparison of the differences in the implicit buying criteria of the respondents in the respective classes.

**Table 5. -2nd Log-likelihood Analysis of Business Class**

| Excluded attributes (factors) | -2nd log likelihood | Change -2nd log likelihood based on total log value | Percent of sum of change in -2nd log likelihood | Rank (importance) |
|---|---|---|---|---|
| None (all attributes included) | 2297.030 | | | |
| Ticket price | 3644.965 | 1347.935 | 59.3% | 1 |
| Number of stops/change of plane | 3050.179 | 753.149 | 33.2% | 2 |
| Airline | 2135.467 | 161.563 | 7.1% | 3 |
| Number of daily connections | 2306.167 | 9.137 | 0.4 | 4 |
| Sum | | 2271.784 | 100.00% | |

**Table 6. -2nd Log-likelihood Analysis of Economy Class**

| Excluded attributes (factors) | -2nd log likelihood | Change -2nd log likelihood based on total log Value | Percent of sum of change in -2nd log likelihood | Rank (importance) |
|---|---|---|---|---|
| None (all attributes included) | 3246.271 | | | |
| Ticket price | 6903.694 | 3657.423 | 88.9% | 1 |
| Number of stops/change of plane | 3657.466 | 411.195 | 10.0% | 2 |
| Airline | 3286.667 | 40.396 | 1.0% | 3 |
| Number of daily connections | 3251.635 | 5.364 | 0.1% | 4 |
| Sum | | 4114.378 | 100.00% | |

The model fit (Nagelkerke R square) equals 627 for the business class data and 714 for the economy class data, which is satisfactory. This means that nearly two-thirds of the variance of the business class data and more than two-thirds of the variance of the economy class data can be explained by the four attributes in the model. However, this also indicates that approximately one-third of it is not explained. Further possible explanatory factors that might increase validity could be the time of departure and arrival, night versus day flight, hub (airport) of transfer, and others. The following outcomes result regarding the attributes that are included in the model.

1. Price is clearly the most important decision criterion in both classes (business and economy). The number of stops represents the second-most important factor; however, direct connection is far more important for business travelers than for economy travelers.

This may be because a large proportion of business class passengers travel for business purposes and are under time pressures. They prefer the convenience of direct connections; whereas this is less important for economy passengers, who mostly travel for leisure purposes.

2. The brand of airline is more important for business class travelers than for economy class travelers. This may be due to the mileage accounts with alliances. Business travelers are often frequent flyers, and prefer to fly with one of the alliance partner airlines, which increases the importance of the brand. Also, daily connections are slightly more important for business passengers than for economy passengers, although the importance of this attribute is very low for both traveler groups.

**Table 7. Sensitivity of Attributes**

| Variable | Beta (log) | Beta powered by e | Sensitivity (change) | Argument |
|---|---|---|---|---|
| Number of stops/change of plane = 0 | 1.324 | 3.758 | 2.508 | The fewer stops, the higher the positive influence on the model. |
| Number of stops/change of plane > 0 | 0.223 | 1.250 | | |
| Number of daily connections 1-2 | 0.166 | 1.181 | 0.643 | The fewer daily connections, the higher the positive influence on the model. |
| Number of daily connections > 2 | -0.62 | 0.538 | | |
| Price = low | 2.339 | 10.371 | 9.297 | The lower the price, the higher the positive influence on the model. |
| Price = high | 0.071 | 1.074 | | |
| Airline brand = Swiss International Airlines | -0.36 | 0.698 | 0.231 | The brand Swiss International Airlines has a negative influence on the model. |
| Airline brand ≠ Swiss International Airlines | -0.074 | 0.929 | | |

A positive effect of the model is conterminous with a positive influence on the decision behavior. The largest sensitivity is measured within the price attribute, which means that a change in price has the greatest impact on changes in decision behavior when buying a transatlantic flight ticket. The sensitivity of the number of stops is only half as large. The fewer stops, the more lucrative a flight is, and the more likely that the flight ticket will be bought. Yet price remains the dominant factor. The number of daily connections has only a small influence on the decision behavior. However, it is not essentially better to have more than one to two daily connections.

Airline brand does not play an important role for travelers taking off from Zurich. The brand of the home carrier Swiss International Airline has a slightly negative influence on the model, meaning that foreign airlines are often preferred. Rather, the decision behavior, when buying an intercontinental flight ticket, is more influenced by the price than the number of stops.

## SUMMARY AND CONCLUSIONS

This article identifies implicit and explicit air travel preferences when buying flight tickets for direct transatlantic flights. Stated preferences result from the descriptives, which are based on importance evaluation of different customer preferences. The most important stated criteria for long-haul travelers are: punctuality, travel convenience (including a direct connection) and travel costs.

Differences between business class and economy class travelers also emerged. For business class travelers, the total travel time, punctuality and a direct connection are the most important factors, followed by travel costs. Economy class travelers focus on punctuality, travel costs and travel convenience, followed by the total travel time or a direct connection. According to the stated answers, business class travelers focus on travel time, and economy class travelers on travel costs.

The evaluation of implicit research methods led to the use of discrete choice analysis for this research. Using this enabled the researchers to identify sensitivities towards different attributes, and the importance of preferences was quantified by performing a variance decomposition.

The availability of direct flights was an important factor. However, because of the analysis of hidden preferences based on the choice model, the most important criterion is price, followed by a direct connection. Direct flights represent a relevant factor if passengers are asked, but implicitly, the fact that a connection is provided at all is of higher importance than the presence of a direct connections.

Price strongly influences the decision making when choosing a transatlantic flight. Other criteria have a limited impact on the relevance of a direct connection. Based on the discrete choice analysis, it can be concluded that price is the most important hidden criterion for business and leisure travelers.

The implication of this research for the industry is that new airline business models for traditional long-haul network carriers should increase travel convenience, and thereby increase the acceptance of higher prices on direct connections.

The fact that that only four attributes are included in the model is a limitation of this research, so the model is based on limited factors that influence buying behavior.

Further research should extend the study by including further attributes into the discrete choice analysis, which should help to better evaluate the importance ratings of price and direct connection attributes.

## REFERENCES

Backhaus, K., Erichson, B., Plinke, W., & Weiber, R. (2003), Multivariate Analysemthoden [multivariate analysis methods]. Berlin: Springer.

Bieger, T., Bickhoff, N., Caspers, R., zu Knyphausen-Aufsess, D., Reding, K. (2001), Zukünftige Geschäftsmodelle: Konzepte und Anwednung in der Netzökonomie, Hamburg: Springer.

Bieger, T., Laesser, C., & Boksberger, P. E. (2003). Nachhaltiger Kundenwert bei Dienstleistungen zwischen L- und C-Nutzen [Sustainable customer value with services between L- and C-benefits]. In K. Matzler & B. Renzl (Ed.), Werte schaffen, (pp. 143-164). Wiesbaden: Gabler.

Bieger, T., Laesser, C., & Wittmer, A. (2005). Der volkswirtschaftliche Nutzen von direkten interkontinentalen Flugverbindungen ab und in die Schweiz [The conomic benefit of direct intercontinental flight connections from and to Switzerland]. St. Gallen: Institut für Öffentliche Dienstleistungen und Tourismus.

Bieger, T. (2000). Dienstleistungsmanagement [Servicemanagement] (2nd ed.). Bern: Haupt.

Crouch, G. I., & Louviere, J. J. (2004). The determinants of convention site selection: A logistic choice model form experimental data. Journal of Travel Research, 43(Nov. 04), 118–30.

Elrod, T., Louviere, J. J., & Davey, K. S. (1992). An empirical comparison of ratings-based and choice-based conjoint models. Journal of Marketing Research, 29(August), 368–77.

Gustafsson, A., Herrmann, A., & Huber, F. (2003), Conjoint analysis as an instrument of market research practice. Berlin: Springer.

Louviere, J. J., Hensher, D. A., & Swait, J. D. (2000). Stated choice methods. Cambridge: Cambridge University Press.

Mazanec, J. A., Crouch, G. I., Brent Ritschie, J. R., & Woodside, A. G. (2001). Consumer psychology of tourism, hospitality and leisure. New York: CABI Publishing.

McFadden, D. (1973). Conditional logit analysis of qualitative choice behaviour. In P. Zarembka (Ed.), Frontiers in econometrics (pp. 105-142). New York: Academic Press.

Sauerwein, E., Bailom, F., Matzler, K., & Hinterhuber, H. H. (1996). The Kano model: How to delight your customers. IX International Working Seminar on Production Economics,. Innsbruck: University of Innsbruck.

Schweikl, H. (1985). Computergestützte Präferenzanalyse mit individuell wichtigen Produktmerkmalen [Computer based preference analysis with individual importance characteristics]. Berlin: Dunker und Umbolt.

Simma, A., Schlich, R., & Axhausen, R. W. (2002). Destination choice modelling for different leisure activities. Zurich: Institut für Verkehrsplanung und Transportsystemen, Eigenössische Technische Hochschule.

Thurstone, L. (1927). A law of comparative judgement. Psychological Review, 34, 273-286.

Verma, R., Plaschka, G., & Louviere, J. J. (2002). Understanding customer choices: A key to successful management of hospitality services. Cornell Hotel and Restaurant Administrative Quarterly, 43(6), 15–24.

Wittink, D. R., Catting, P. (1989). Commercial use of conjoint analysis: An update. Journal of Marketing, 53(July), 91–96.

Wittmer, A. (2005). Internal service systems and cultural differences: An exploratory study of Switzerland, Australia and Singapore. Unpublished doctoral thesis, University of St. Gallen.

Zikmund, W. G. (1997). Business research method (5th ed.). Orlando: The Dryden Press.

# EUROPEAN TOUR OPERATORS AND LOW COST CARRIERS: STRATEGIC OPTIONS IN A CHANGING MARKETPLACE

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## ABSTRACT

This paper examines the threat posed by Low Cost Carriers (LCCs) to the traditional tour operators (TOs)/charter sector of the European tourism industry. The paper starts with an overview of European tourism travel trends and key developments in the tour operator (TO) sector. The growth of LCCs within the EU is then examined to understand the dynamics between LCCs and TOs. Traffic trends are reviewed for both groups as well as a survey distributed to key TOs in Europe on their perceptions of the LCC threat and how that threat is shaping their strategy regarding future product planning and product differentiation. Finally, the implications for TO strategy are explored.

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## INTRODUCTION

Air transport is the main mode of travel for Europe's international tourism industry. As a mature travel market with an estimated 444 million international tourist arrivals in 2005, Europe's market share accounts for almost 55% of international tourist arrivals worldwide (World Tourism Organization, 2006). An increase in demand for European short-haul destinations has been fuelled in part by the rapid expansion of Europe's regional low cost carriers (LCCs). This coincides with a recovery in the rate of growth in demand for long-haul travel (increase of 6% globally in 2005) after a period of uncertainty following 9/11 and the disease-related scares of SARS and Avian Flu. In 2006 European adults made 389 million trips abroad, of which 69% were holidays, 14% business and 17% visiting friends and relatives (IPK International 2007). In Europe, intra-regional traffic has been growing and short-haul travel to new destinations in Central and Eastern Europe continues to advance with improved air access from the leading EU source markets. Recent years have also witnessed an acceleration of previously identified travel trends including late bookings, shorter and more frequent trips, self-organised independent holidays, and on-line research and booking of travel (World Tourism Organisation, 2004). These latter trends have been facilitated by the possibilities offered by the Internet and LCCs (Buck & Lei, 2004).

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It is widely recognized that the Internet has revolutionized the tourism and travel industry, empowering (potential) travellers. Information communication technology (ICT) has become a driving force behind the personalisation and customisation of travel and tourism products with virtual market processes beginning to replace the real market. This trend is likely to continue with higher ICT skills in Europe's younger generation. The e-market has changed travel-booking behaviour to facilitate personally assembled travel products. Increasingly, Europeans also remain wired while travelling (for example, via mobile phones, e-mail, laptops and PDA devices). Tourism and travel suppliers have taken advantage of the new opportunities to develop eCommerce applications to allow users direct access to their reservation systems. On-line travel sales increased by a staggering 41% (2003-2004), valued at €18.4 billion in the European market in 2004. In terms of a breakdown by type of service, air travel accounted for 57.4% of these bookings. The UK and Germany accounted for 56% of the European online travel market (Marcussen, 2005). Internet portals (for example, Yahoo and Excite) and vertical portals have developed on-line travel distribution (Buhalis & Licata, 2002). Utilization of other ICTs for tourism and travel (including innovative value-added services, interactive digital television, multifunctional chip cards, vending and dispensing machines) continue to advance. The Internet has effectively leveled the playing field among competing destinations and travel sectors. Travel agents fear disintermediation in many market segments, although many travel agents are learning to embrace the Internet's possibilities. The UK has lost about 10% of its high-street agents during the past five years due to falling commissions from airlines. Tour operators (TOs) now sell flights and package holidays directly to consumers. The increased use of the new ICT in the tourist industry continues to have dramatic effects on market processes and structures in supply and demand in so far as it alters the tourist value-added chain and intensifies global competition for tourism. The changes brought about by ICT underlie many of the other changes within the travel and tourism distribution system.

At the same time, TOs are facing increasing pressure from rapidly expanding LCCs in the Single Sky EU market that came into effect on April 1, 1997. The European charter market historically served the leisure class traveler while the large traditional carriers focused on international, business-class passengers. In the early 1990s, more than 25 percent of the passenger miles in Europe were accounted for by charter service (Sinha, 2001). International liberalization and domestic deregulation have changed the market for air travel within and beyond Europe. LCCs now offer low fare travel to an expanding list of European destinations. Ryanair has indicated that its long term goal is to offer up to 30 percent of its seats for free, making its money on pay-for-use amenities. In further competition with TOs, Ryanair has pledged to turn their website into a one-stop travel site where customers can book hotels, cars, and other travel necessities (Creaton, 2004).

The purpose of this paper is to explore the changing dynamics of the EU marketplace, specifically the role of TOs and LCCs in European travel. Following an overview of the trends in EU travel, including the role of TOs and LCCs, we discuss the results of a survey of TOs intended to assess their understanding of the changing market and their response to LCC growth. Finally, we explore new strategic responses to the twin challenges of ICT and LCCs.

## TOUR OPERATORS AND CHARTERS IN EUROPE

The TO sector has been an integral part of the wider European tourism industry, catering to the more traditional mass tourism market and providing specialist niche products. The declining real costs associated with international travel and brand identity enabled TOs and travel agents to control a substantial share of European leisure travel arrangements. Most discussion of TOs and charter airlines go hand in hand given their historically close interdependent relationship.

### Historical development

The development of Europe's travel industry gives much insight into the changing structure of the TO/charter business. Traditionally the primary distinction between charter and scheduled airlines was that the former was contracted to operate the flight by a TO, a company, or an individual. This implied that a charter's distribution channel is not directly to the passenger, however, there were some exceptions to this rule, as some charters offered seat-only packages. The distinction however remained until the 1990s.

In the past, charters would have been regarded as the low-cost travel providers in Europe, particularly for leisure passengers. The 1960s saw the emergence of dedicated TOs and the development of hotel-based Inclusive Tour Packages and Inclusive Tour charters (ITCs). ITCs allowed passengers to purchase a complete holiday package from a travel agent or TO for a single price, combining accommodation, flights, ground transport, and other ancillary services. Between 1965-1973, ITC traffic grew annually by 25%, that is, more than double the rate for scheduled services. As charters were not members of the International Air Transport Association (IATA), a trade association of international airlines that in the past set fares on all international routes, they could offer lower fares than IATA members. This resulted in a significant cost advantage for charters. The fare setting of IATA was eventually challenged by the US government following the 1978 deregulation of the US airline industry and IATA eventually withdrew from this activity allowing market forces to establish fares (Rhoades, 2003; Toh, 1998).

Williams (2002) estimated that 80% of the EU charter traffic is comprised of ITC travelers. This raised some concern among southern European countries who adopted a less liberal policy towards charters, worried that charters would affect the sustainability of their own scheduled flag carriers (Papatheodorou, 2002). In the 1970s, scheduled carriers began to sell off blocks of seats to TOs who then packaged the seats into inclusive tour holidays. The advantage for the scheduled airline was that blocks of seats could be sold upfront at a guaranteed price. TOs could therefore service a destination without actually providing an aircraft. Part-charters were first introduced on the UK to Spain routes in 1971. The 1980s witnessed a growth of self-catering ITCs providing accommodation in houses and/or apartments. The concept of selling flight/seat-only also emerged and TOs began integrating vertically with elements in their supply chain. The 1990s saw considerable amount of consolidation within the industry including Pan European and international consolidation of TOs and charters, for example, the airlines Leisure and Air 2000. The travel agent and TO sectors were dominated by the strategies of five leading companies who attempted to increase market share through acquisition and organic growth. Historically, TOs and charters concentrated on developing the international leisure market and avoided the option of scheduled route development which would also include business passengers. By the beginning of 2000, the strategic focus of the main companies moved towards overseas expansion.

**Recent developments and current structure**

Liberalisation and deregulation in the EU has proceeded through a series of three packages designed to gradually introduce changes into the highly regulated airline industry. With the introduction of the Third Package, there no longer exists any regulatory distinction between scheduled airlines and charters; they can now compete more directly with each other. The deregulation process also altered controls on the ownership of EU carriers and enabled increased cross-border acquisitions of airlines by EU registered companies. Given the integral role that charters play in the overall service of the TO, it is not surprising that many TOs own or partly own air charter operations. While some independent charters do still exist in the market place, consolidation and competition have led to the disappearance of many medium-sized companies or their integration into a vertical TO (Williams, 2002). An examination of the economics of LCCs and charters by the Air Transport Group at Cranfield University, quoted in Williams (2000), revealed that charters, at the time of the study, had lower operating cost advantages achieved through a combination of cost differentials such as higher load factors, higher aircraft utilization, comparatively larger aircraft capacity, and longer flight sector advantages. It is not clear whether these advantages continue to exist between the TOs and the rapidly growing LCCs. Williams (2002) identified three areas where LCCs had made significant inroads into TO markets: intra-European business travel with short holiday potential routes, short and long break holiday markets, and, even, some traditional holiday routes. This seems to leave only the long haul (3.5 hours plus), non-EU markets primarily to the TOs.

The current TO industry in Europe is characterized by concentration, consolidation, and vertical integration. This change in the TO industry began first in the UK and then spread to Germany. Large TO groupings from both the UK and Germany now dominate the EU market. The five largest participants in 2004 are listed in Table 1 with their revenue, passengers, and market share listed. These numbers continue to change the industry integrates and consolidates.

The vertical integration of the top five is illustrated in Table 2. These TOs can sell directly through their travel agents and have greater control over the delivery of the tourist product, enhancing their market power (Theuvsen, 2004). According to Williams (2002), in-house charter airlines provide between 70% and 90% of their parent company flight requirements. As noted before, the two largest travel markets within Europe are located in the UK and Germany where demand remains very high for the typical package holiday provided by TOs. In the UK alone, four major TOs (TUI/Thomson, Thomas Cook, MyTravel and First Choice) accounted for about 75 percent of the mass-market package holidays sold (PricewaterhouseCoopers, 2006). However, the traditional TO is facing significant challenges into the future, not least of which have been the twin developments of scheduled LCCs who have been growing rapidly and ICT which has made it easier for customers to coordinate their own travel packages.

**Table 1. European Tour Operator Sector—The Big Five, 2004**

| | | **Revenue $ (billions)** | **Passengers (millions)** | **% EU Market Share** |
|---|---|---|---|---|
| 1. | TUI | 11.3 | 18.9 | 12.4 |
| 2. | C&N/Thomas Cook | 7 | 15.3 | 8.1 |
| 3. | My Travel | 7.3 | 10.0 | 7 |
| 4. | First Choice | 3.4 | 7 | 3.5 |
| 5. | Kuoni Reisen | 2.4 | n/a | 2.5 |

In 2007, Europe's big four TOs have continued their remarkable consolidation strategies. The merger of Europe's second largest TO, Thomas Cook AG and MyTravel Group Plc. to form Thomas Cook Group Plc. was approved by the European Commission in May 2007 (Europa, 2007a). This new group now forms the second-largest travel group in Europe, behind TUI AG and account for approximately, 35 percent share of the UK package holiday market alone. Both companies abandoned earlier plans to pursue a takeover of the British package holiday business rival, First Choice.

**Table 2. Vertical Integration in the Top 5**

| | Main Tour Operators | Main Travel Agents | Charters |
|---|---|---|---|
| TUI | Thomson<br>TUI Nordic<br>TUI Schone<br>Ferein | Lunn Poly<br>Nouvelles Frontieres<br>Hapag-Lloyd | Britannia<br>Hapag-Lloyd<br>Britannia AB |
| C&N/Thomas Cook | Neckermann<br>Kreutzer/ Terramar<br>Air Marin | Thomas Cook | Condor<br>JMC<br>Condor<br>Berlin |
| My Travel | Airtours Hol.<br>Going Places<br>Travel World | Going Places | My Travel<br>Airways<br>My Travel<br>AS |
| First Choice | First Choice | Bakers<br>Dolphin<br>Travel Choice<br>Hayes Travel | Air 2000 |
| Kuoni Reisen | Kuoni | Kuoni Helvetica | Edelweis<br>Novair |

Source: Compiled from various sources including company websites.

One month after the announcement of plans to merge MyTravel and Thomas Cook, Germany's TUI AG unveiled plans for a merger of its tourism unit (excluding hotel assets) with Britain's First Choice Holidays Plc., (Europe's first largest  and fourth largest TOs, respectively) to create TUI Travel Plc., in March 2007, with annual pro forma revenues of stg£12 billion. The link-up brings the number of major league European TOs down from four to two. While some consolidation in itself was not entirely unexpected, it is the speed at which four has become two that is so remarkable. In June 2007, conditional clearance by the European Commission was granted for acquisition of First Choice by TUI, subject to TUI's divesting itself of its Irish business, Budget Travel (Europa, 2007b).

## LOW COST CARRIERS IN EUROPE

The emergence of LCCs and the appeal of the Internet are widely regarded as having radically altered the purchasing patterns of European holiday consumers. While the Internet changed the traditional intermediary role of travel agents and TOs, it is the emergence of LCCs offering relatively low fare prices that has fuelled competition.

**The development and growth of LLCs**

As with charters, LCCs take advantage of dense seat configurations and regional, satellite airports to target price-elastic customers. Competition in the global airline industry has been transformed over the last 20 years by deregulation (USA) and liberalisation (EU) initiatives, leading to the emergence of new entrants into the airline industry (see Sinha, 2001, for additional information). Restrictions on the provision of low fares have been removed and legislation has fostered the proliferation of new entrant LCCs, fuelling competition. By the end of 2002, LCCs had captured 12% of all intra-EU air capacity. According to IATA and the Association of European Airlines (AEA) forecasts, the LCC market is expected to increase to 35% of European air traffic by 2010, thus intensifying air transport competition. The most successful of the new entrants include Ryanair, easyJet, German Wings, and BMI Baby. Table 3 presents a five year history of the changes in relative strength between the LCCs and the TOs. As Table 3 shows, most of the charter airlines have experienced a decline in passenger traffic over the period, although this passenger decline is not necessarily reflected in Available Seat Kilometers (ASKs) indicating that TOs may have shifted out of shorter haul intra-EU routes to longer haul trans-Atlantic routes. Some of the passenger decline is also attributable to a post-9/11 effect on trans-Atlantic routes. This effect is not seen on intra-EU traffic or the EU LCCs that have experienced significant growth over the same period. While the charters continue to have an advantage in load factor, it is not clear whether the cost differential noted by Williams (2000) continues to exist in the other areas noted (utilization, for example). According to the figures available from Air Transport Intelligence (ATI), the net margins for the charter operators (where such information is available) range over this period from 0.0% to almost 8.0%. The net margin for Ryanair averaged 22.22%. The net margin for easyJet was a more modest 5.13, more consistent with the margin for the charter group. As for productivity, Ryanair reported that 3,201 employees carried 33,308,000 passengers in 2005 resulting in a per employee productivity rate of 10,428 passengers per employee. The productivity of easyJet was somewhat lower at 7,639 passengers per employee (3,875 employees and 29,600,000 passengers). By comparison, the productivity for First Choice and Thomas Cook (UK) was 2,950 and 2,716 passengers per employee respectively. If productivity is viewed in terms of ASKs, then the TO do somewhat better. For 2005, Thomas Cook reported 2,826,000 ASKs for a rate of 13,900 kilometers per employee. First Choice reported 17,503,000 ASKs for a rate of 8,751 kilometers per employee. This compares to 11,437 for Ryanair and 8,295 for easyJet. Clearly, the leading

LCCs have not only surpassed the TOs in total passenger traffic, but are addressing the differences in costing and productivity as well. All of this has occurred despite of the fact that LCCs typically fly shorter haul flights than TOs, a fact that would normally be expected to raise the level of employees needed for departure and arrival activities (Gitell, 2003). With the proliferation of the single economy class, LCCs have tended to pursue a distinct competitive strategy summarized in Table 4, although easyJet has strayed from the model serving some major airports and offering a higher level of amenities.

The travel flexibility provided by LCCs and the Internet have attracted many Europeans seeking an alternative to the worst excesses of the traditional all-inclusive short-haul mass package market. A second change in the European market relates to destination. City tourism in Europe has traditionally been dominated by the established cultural capitals, however, the LAgroup and InterArts report (2005) has confirmed a trend towards smaller secondary city destinations and newer regions of Europe attracting tourists, partly fuelled by the availability of LCCs and the supply of innovative cultural products and travel services.

**Table 3. Changes in Passenger Traffic for Low Cost Carriers and Tour Operators, 2001-2005**

| | Passenger Traffic (millions) | | | | | | 2005 Statistics | | |
|---|---|---|---|---|---|---|---|---|---|
| **Air Carrier** | 2001 | 2002 | 2003 | 2004 | 2005 | %Change | Fleet | Load Factor | Destinations |
| **Tour Airlines** | | | | | | | | | |
| **TUI** | | | | | | | | | |
| Thomsonfly | | | | 8.660 | 9.550 | 10% | 48 | 88.62 | 25 |
| TUIfly | 1.570 | 1.240 | 1.080 | 1.150 | .9500 | (40%) | 5 | 93.01 | - |
| **C&N/Cook** | | | | | | | | | |
| Cook (UK) | 6.040 | 5.260 | 4.930 | 5.010 | 4.910 | (19%) | 22 | 88.14 | |
| Cook (BE) | | .660 | .880 | .970 | 1.000 | (48%) | 6 | 84.04 | |
| Condor Berlin | 1.680 | 1.700 | | | | 1% | 14 | | |
| Condor Flugdienst | 6.800 | 5.600 | 6.520 | 7.110 | 7.380 | 9% | 23 | 86.1 | 67 |
| **My Travel** | | | | | | | | | |
| Airways | 7.210 | 7.440 | 7.920 | 6.690 | 4.380 | (39%) | 21 | 91.62 | |
| Lite | | .090 | | | | | | | |
| **First Choice** | | | | | | | | | |
| Airways | 7.030 | 6.510 | 6.330 | 6.060 | 6.000 | (15%) | 32 | 89.86 | |
| **Kuoni Reisen** | | | | | | | | | |
| Edelweiss Air | | .660 | .590 | .590 | .490 | (26%) | 4 | | |
| Novair | .430 | .490 | .390 | .400 | .400 | ----- | 4 | 99.1 | |
| **Low Cost Carriers** | | | | | | | | | |
| **easyJet** | 7.120 | 11.350 | 21.070 | 25.720 | 29.600 | 415% | 108 | 85.4 | 75 |
| **Ryanair** | 11.100 | 15.740 | 23.130 | 26.580 | 33.380 | 300% | 111 | 85.0 | 128 |
| **German Wings** | 3.530 | 3.770 | 5.280 | 6.520 | 7.204 | 49% | 31 | 76.91 | 42 |
| **bmibaby** | | .700 | 3.000 | 3.250 | 3.490 | 20% | 19 | 79.46 | 22 |

Source: Air Transport Intelligence- Air Transport Intelligence. (Electronic database, available at The Hunt Library, Embry Riddle Aeronautical University) Reed Business Information, Quadrant House, Sutton, UK. Retrieved December 21, 2006, from www.rati.com/airlines

**Table 4. Competitive Strategy of the Low Cost Carriers**

| **Price Leadership Achieved by:** | |
|---|---|
| 1. | Simple pricing, low fares, conservative route development |
| 2. | Short haul point to point |
| 3. | Use of secondary airports |
| 4. | Direct distribution and sales |
| 5. | No frills operation and organizational structure |

Adapted from "Cleared Off for Take-off—Structure and Strategy in the Low Fair Airline Business," by T. Lawton (2002), Ashgate, London.

## LCC long term impact on TOs

The long-term growth potential of LCCs and their impact on the TO sector is still open to debate as charters, intermodal transport systems, and the limited number of secondary airports could impede further growth in the EU (see Rhoades, 2003). In contrast to the US, LCCs in the EU also have limited access to primary airports, thus reducing their appeal to business travellers who prefer airport destinations closer to central business districts. The charter market in the US has traditionally provided very limited competition to LCCs, unlike in the EU. Consolidation within the sector, particularly vertical integration within the leisure markets, adds to the competitive advantage of TO and charters. TOs have also tried to use new technology creatively in an attempt to counteract the threat from LCCs and the growing use of the Internet for independent holiday bookings. In 2002, both JMC and Airtours began offering a no-frills inclusive tour package. Thomson Holidays (part of TUI since 2001) began using its core package holiday brand to make its first serious inroad into the accommodation-only sector. Rivals Thomas Cook and First Choice launched accommodation-only sites through agents in 2005. This is viewed as an area with significant growth potential as the number of packages remains static. Thomas Cook AG has been the second largest European travel group with ownership of the UK's third biggest leisure airline. In December 2006, KarstadtQuelle AG (the German retailer that owns Thomas Cook since April 2001) agreed to buy out the scheduled carrier, Deutsche Lufthansa AG, its 50-50 partner in Thomas Cook, for €800 million. TUI/Thomson positioned its airline, ThomsonFly.com in direct competition to the LCCs, offering competitive short-haul flights from a wide range of UK airports. The launch followed TUI UK's decision to seek more business directly and become a dynamic packaging player. In 2004, Thomson acquired Coventry Airport (UK) to avoid LCCs duplicating its routes from that hub, a further example of vertical integration. (It later sold the airport in January 2006). In 2003, the travel agents and TOs' share of Europe's outbound market fell slightly, a trend that is likely to continue as low-cost air services grow, but the total growth in the market should sustain travel agent and TO revenues. There is some evidence to support the view that LCCs are gaining market share through growth and diversion from other modes of transport and not from incumbent scheduled airlines (Lawton, 2002). In the US, this has been called the Southwest Effect as low fares have made it cheaper to fly than use other modes of transportation (Gittell, 2003). However, despite these potential moderating variables, there can be no doubt that LCCs offer huge potential for customers wishing to travel independently (Williams, 2001). While the extent to which LCCs have induced new traffic instead of simply diverting passengers from incumbent carriers has not been established, the future strategies of TOs and charters are inextricably linked to that of the low-cost sector, which forms the basis of this paper's exploratory research question: To what extent do TOs perceive LCCs to be a threat and what actions are they taking to any perceived threat?

## TOUR OPERATOR SURVEY

Surveys were distributed to leading TO groups in the EU. The initial distribution included TOs with and without charter ownership. Responses were received from 12 TOs, including three of the top five TO companies who have dominated Europe's travel market in terms of passenger numbers and market share (refer to Table 1). A key distinction emerged between TOs who owned or partly owned a charter airline, over half of the respondents reported such links. Of the total responses, six were from Germany, four were from Britain and one each from France and Turkey. Table 5 presents the key findings of the survey separated by TOs with and without charter ownership.

**Table 5. European Tour Operators' Perceptions of Low Cost Carriers**

| | **TO with Charter Ownership** | | **TO with No Charter Ownership** | |
|---|---|---|---|---|
| Respondents | n=7 | 58.3% | n=5 | 41.6% |
| Has your business been affected by low cost carriers? | Yes<br>n=7, 100% | No<br>0 | Yes<br>n=2, 40% | No<br>n=3, 60% |
| Have you launched a strategic response? | Yes<br>n=7, 100% | No<br>0 | Yes<br>n=2, 40% | No<br>n=3, 60% |
| Nature of Response | | | | |
| 1. Change in pricing strategy | n=7 | 100% | 0 | 0 |
| 2. Launch of own low cost airline | n=1 | 8.3% | 0 | 0 |
| 3. Use of low cost airlines to book passengers | 0 | 0 | n=2, 40% | 0 |
| Long-term Future | | | | |
| Are LCCs a threat to your company? | Yes<br>n=7, 100% | No | Yes<br>0 | No<br>n=5, 100% |
| Expect LCCs to enter package holiday market? | Yes<br>n=7, 100% | No<br>0 | Yes<br>n=1 | No<br>n=4 |

One can see that TOs affiliated to a charter(s) perceive that they have been more affected by LCCs than their counterparts without such connections. A similar pattern emerges in relation to whether strategic responses have been initiated with all the linked TOs and some of the non-linked TOs indicating that they had responded in a strategic manner to the new competition from LCCs. Changes to the pricing strategy were used by 58.3% of respondents which is not altogether surprising given that LCCs compete on the basis of price. One respondent cited the establishment of a separate LCC, however, this was the largest TO in the sample. The respondents (three) not citing any strategic response were TOs without a linked charter. Most TOs believe that they will ultimately find LCCs competing directly with them and of the four TOs that do not think LCCs will compete directly with them, three are not linked with a charter. All of the TOs with charters view LCCs as a threat. Interestingly, seven indicated that LCCs are an opportunity for them. One can conclude that for TOs not affiliated to a charter, LCCs may be perceived as an opportunity to provide low cost air travel to a wider range of destinations. However, for the larger TOs with charter ownership, LCCs remain a significant threat because of their similar cost structures and recent moves into the package holiday market by LCCs. The large TOs appear to be very aware of their competitive operating environment.

## DISCUSSION

From the survey, one can see the differing perspectives on the extent to which LCCs should be viewed as a threat or an opportunity. TOs with charter links are more likely to consider LCCs as a threat, particularly if the seat-only element is a key part of their overall business. It is evident that TOs without their own charters are much more likely to view LCCs as an opportunity and actively seek them as a viable transport alternative for their package holiday clients. A TO's perception of LCCs as a threat or opportunity might also be influenced by the extent to which the TO relies on sales in the long haul versus the short haul market, (the latter being where LCCs can best compete at the present time). On long haul routes, charters have operated on dense, leisure routes leaving business travel to the scheduled carriers (Pompl, 2002). In relation to non-linked TOs who regard LCC expansion as an opportunity, this view might be based on the belief that a core customer market exists that will not bypass the TO in order to book their travel arrangements independently. A careful segmentation of the travel market might reveal one or more segments of the market that would continue to favor the integrating role of the TO such as older, less technologically savvy travelers or high-end, exclusive destination clients. While the entry of LCCs on proven charter routes is well documented (Williams, 2001), in the case of the family-holiday segment, LCCs might be regarded as less of a threat. Panorama have re-branded their image to a greater emphasis on the family holiday with more family-oriented products and structures in place such as kids clubs, etc. Families generally book holidays well in advance at full-brochure prices, (yielding higher margins in peak seasons). LCCs might also provide an opportunity for linked-TOs where the TO has excess accommodation capacity. Interestingly, as part of its diversification strategy, First Choice created a division called ODS (Online Destination Services) which provides in-destination services (including, airport transfers, accommodation and in-resort tours), which was offered via a click-through agreement on easyJet's website, that is, "essentially offering all the elements of a package holiday apart from the flight" (PricewaterhouseCoopers, 2006, p. 4). It has since expanded more into luxury holidays and activity trips to avoid direct competition from LCCs.

Many commentators recognize that LCCs in Europe have been in a state of flux with a shake-out phase that has seen several of these carriers disappear in recent years. It has also been argued that European travelers are not yet comfortable with the no-frills approach of carriers like Ryanair. Ryanair CEO Michael O'Leary has said,

> Our customer service is about the most well-defined in the world. We guarantee to give you the lowest airfare. You get a safe flight. You get a normally on-time flight. That's the package. We don't and won't give you anything more on top of that. (Creaton, 2004, p. 163)

Recent well-publicized media concerns have been raised about Ryanair's approach to safety and security (For more details see Tighe & Oakley, 2007). The European Commission has also ruled that incentives received by Ryanair (as part of a deal it negotiated at Charleroi Airport in 2001) amounted to illegal state aid. If Ryanair is forced to pay higher fees for landing, etc., then their cost of operation would rise (and presumably the prices). However, there is no evidence to date that these problems have slowed the growth of Ryanair which continues to post some of the fastest growth and highest profits in the industry.

There is some debate within the airline industry about the benefits of economies of scale which would be expected to lower the cost of operation and might further threaten the cost advantage of TOs. In some areas, size might offer clear advantages. Larger firms can benefit from lower costs of borrowing, greater ability to spread marketing and technology costs, and lower bulk purchasing rates (O'Connor, 2001; Rhoades, 2003). There are also advantages to increasing scope as airlines with larger networks can generate and flow greater volumes of traffic, create synergy in production, product development and distribution, and, in the case of airlines, increase aircraft utilization. If the LCCs are successful in lowering their costs vis-à-vis TOs as appears to be happening based on the rough look presented earlier on net margins and productivity, then a TO strategy of price competition would seem to be ill advised. Rather, TOs might be better served to focus on a differentiation or best value strategy. A key weakness of LCCs such as Ryanair is customer service. While "Doing a Ryanair" has become synonymous with a cheap weekend getaway to an out-of-the-way destination, it has also been used to describe a fraught and difficult experience in which luck may mean the difference between a relaxing trip and a nightmare (Creaton, 2004). Travelers willing to spend a little more money for amenities such as meals,; guaranteed refund' free wheelchairs' integrated, stress-free travel packages; and less remote arrival destinations might be a better target for TO marketing. In southern Europe, it must also be acknowledged that fast trains will increasingly compete with air carriers, in distances of up to approximately 400 miles in the next few years (Littorin, 2004).

The results of our survey support the argument that it is those TOs not affiliated with a charter who feel less or not threatened by LCCs. Williams believes that Europe's charters will not be replaced by LCCs if they "form part of large vertically integrated tour operating organizations" (2001, p. 2) and concentrate on their traditional core activities. Middleton (1991) has also suggested changing the image of package tourists, de-emphasizing the mass market, tour group aspects, but he questions whether or not TOs have the flexibility to attempt this re-imaging. The North American cruise industry has successfully re-imaged itself as an affordable, family vacation, appealing to a mass market that did not previously exist (Cudahy, 2001). TOs might try to reverse this strategy by re-imaging and repositioning themselves as either a best value, hassle-free travel experience or a higher-end, specialty travel provider. Like Panaroma, TOs might seek to appeal to different audiences focusing on families, high adventure (rock climbing, scuba diving, river rafting), cultural travelers (food tours, music festivals, historical sites), or other identifiable segments of the market. However, at the present time, TOs appear to be offering products such as seat-only and accommodation-only products in an effort not to lose market share to LCCs. A strategy of differentiation, enabling TOs to specialise and establish core competences in travel markets not served by LCCs while retaining the perceived price and quality advantages of traditional package holidays appears more likely to succeed.

Pompl (2002) sees the integration strategy of TOs as a source of difficulty for independent carriers, but he does not believe that a price only strategy is enough. He suggests the development of niches (new destinations with new departure airports or specialization on thin routes) can help charters and LCCs can compete effectively. However, charters offering seat-only scheduled services have incurred considerable sunk costs.[1] Since 2000, TOs have increasingly sought seat-only passengers, both to fill spare capacity and as a response to cheap flights offered to competing destinations of LCCs. In Ireland, Panorama (part of Airtours) launched Justflights in 2004, partially as a response to Budget Travel (part of TUI) who launched Budgetair. Falcon Holidays (part of First Choice) indicated that up to 60% of its flights from Ireland to Malaga are seat-only.[2] It is estimated that between Budget and Falcon/JWT, they control about 65 percent of the Irish sun holiday market.

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[1] Such costs include, yield management software, marketing expenditure, Computer Reservation System payments, travel agency commissions

[2] This offer also coincides with the surge in overseas property purchases by Irish seeking foreign holiday homes in traditional European coastal resorts.

## CONCLUSIONS

It is evident from the preceding discussion that different views and perspectives exist on the extent to which LCCs should be viewed as a threat or an opportunity by European TOs. TOs with charter links are more likely to consider LCCs as a threat as are TOs that consider the seat-only element a key part of their overall business. The competitive strategy and market segments of these TOs and the LCCs overlap more extensively than the non-linked TOs. For this group of TOs, the growth of LCCs is more likely to be seen as an opportunity, a transport alternative for their package holiday clients.

Linked TOs in our survey clearly saw a threat from LCC growth. The challenge before them now is to determine their response. TOs could opt, as appears to be happening, to consolidate themselves into ever larger vertical operations in the hope of achieving lower costs through economies of scale and higher profits through leveraging network scope economies or TOs might consider disaggregating themselves from the charter operations and outsourcing air travel to the LCCs. For any given firm, the decision to make or buy will depend on their answer to several questions. The first question has to do with whether the firm considers the activity part of their core competence. We would assume that if air transport were truly a core competency of the firm that it would be able to do it better and/or cheaper than an outside company. Cheaper is a matter of efficiency (inputs to outputs) and should consider the transaction costs of contracting with an outside firm and monitoring their performance. Better is a matter of effectiveness and raises the second question about the possible competitive advantage of in-house versus outsourcing. Performing an activity in-house not only reduces the cost of searching for outside firms and monitoring their performance, it also provides the firm with greater control over the quality of the output and the availability of the product or service. There are also no middle men whose profit margin must be worked into the final cost. On the other hand, if there is a reliable, cheaper source of the product or service available outside the firm that meets the quality requirement of that firm, then outsourcing is the better option, particularly if other firms in one's industry are availing themselves of this option. Some TOs may decide that their added-value lies not in providing in-house air travel but in some other aspect of the total package. As long as they are able to procure sufficient, reasonable air travel, they would be advised to avoid the high capital costs of starting their own airline. TOs who opt for a premium differentiation strategy might decide that an in-house charter provides them with greater control of the quality of the air travel product and is thus worth it to maintain their own charter carrier. TOs who can not, choose not to, or are not able to position themselves as a premium differentiator are likely to find in-house air travel a growing burden on their business.

European TOs are very aware of the encroachment by LCCs on traditional TO/charter routes. Given the survey's results, its seems reasonable to assume that the extent to which TOs perceive LCCs as a threat is shaped by their own company structures and commitments (for example, as a linked-TO), their own performance benchmarks, and the existence of a strategy regarding future product planning and product differentiation. Flexibility to meet the needs of a changing travel market combined with an ability to anticipate and respond to an increasingly competitive industry environment is key for the future of Europe's TOs.

## REFERENCES

Air Transport Intelligence. (Electronic database, available at The Hunt Library, Embry Riddle Aeronautical University) Reed Business Information, Quadrant House, Sutton, UK.. Retrieved December 21, 2006, from www.rati.com/airlines

Buck, S., & Lei, Z. (2004). Charter airlines: Have they a future? Tourism and Hospitality Research, 5(1), 72-78.

Buhalis, D., & Licata, M. C. (2002). The future etourism intermediaries. Tourism Management, 23(3): 207-220.

Creaton, S. (2004). Ryanair: How a small Irish airline conquered Europe. London: Aurum Press, Ltd.

Cudahy, B. J. (2001) The cruise ship phenomenon in North America. Centreville, MD: Cornell Maritime Press.

Europa. (2007a). Mergers: Commission approves proposed acquisition of MyTravel Group by KarstadtQuelle [Press Release]. Brussels. May 4. Retrieved June 22, 2007, from http://europa.eu/rapid/pressReleasesAction.do?reference=IP/07/614&format=HTML&aged=0&language=EN&guiLanguage=fr

Europa. (2007b). Mergers: Commission approves proposed acquisition of First Choice by TUI, subject to conditions [Press Release]. Brussels. June 4. Retrieved June 22, 2007 from http://europa.eu/rapid/pressReleasesAction.do?reference=IP/07/759&format=HTML&aged=0&language=EN&guiLanguage=en

Gittell, J. H. (2003). The Southwest Airlines way. New York: McGraw-Hill.

IPK International. (2007). Message from the Pisa Forum - 2007, A World Travel Trends Report, November, 1-29, Germany Retrieved February 11, 2008 from http://www1.messe-berlin.de/.../MesseBerlin/htdocs/www.fair.itb-berlin.de/de.Presseservice/Publikationen/WTTR.pdf.

LAgroup and InterArts. (2005). City tourism & culture: The European experience. European Travel Commission Research Report, Brussels, Retrieved February 11, 2008 from http://wwwsacr.sk/download.php?FNAME=1137670406.upl&ANAME=ETC_CityTourism%26Culture.pdf

Lawton, T. (2002). Cleared for take off—structure and strategy in the low fare airline business. London: Ashgate.

Littorin, H. (2004). Low-fare airlines are on their way to make a major breakthrough in the Swedish market. Journal of Air Transport Management, 10(5): 293-294.

Marcussen, C.H. (2005). "Trends in European internet Distribution of Travel and Tourism Services", Centre for Regional and Tourism Research, Denmark, November.

Middleton, V. T. (1991). Whither the package tour. Tourism Management, 12(3), 185-192

O'Connor, W. E. (2001). An introduction to airline economics, 6th ed. Westport, CT: Praeger.

Papatheodorou, A. (2002). Civil aviation regimes and leisure tourism in Europe. Journal of Air Transport Management, 8(6), 381-388.

Pompl, W. (2002). Structural changes in the airline industry and the consequences for tourism. Air Transport and Tourism, 44, 85-120.

PricewaterhouseCoopers. (2006). Hospitality Directions Europe Edition, 13(March).

Rhoades, D. (2003). Evolution of international aviation: Phoenix Rising. London: Ashgate.

Sinha, D. (2001). Deregulation and liberalization of the airline industry: Asia, Europe, North America, and Oceania. London: Ashgate.

Theuven, L. (2004). Vertical integration in the European package tour business. Annals of Tourism Research, 31(2), 475-478.

Tighe, M., & Oakely, R. (2007, February 11). Who's in hot water now Michael? Sunday Times. p. 15.

Toh, R. S. (1998) Towards an international open skies regime: Advances, impediments, and impacts. Journal of Air Transportation World Wide, 3(1), 61-70.

Williams, G. (2000). Charter versus no-frills scheduled European experience. Avmark Aviation Economist, 17(3), 13-16.

Williams, G. (2001). Will Europe's charter carriers be replaced by 'no frills' scheduled airlines? Journal of Air Transport Management, 7(5), 277-286.

Williams, G. (2002). Airline competition: Deregulation’s mixed legacy. London: Ashgate.

World Tourism Organisation. (2006, January 26). International tourism up by 5.5% to 808 million arrivals in 2005 [News Release].

World Tourism Organisation. (2004). World tourism barometer. 2(1).

**Journal of Air Transportation** **Vol. 12, No. 3 -2007**

# CURRENT HUMAN RESOURCE MANAGEMENT PRACTICES IN THE US AIRLINE INDUSTRY

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## ABSTRACT

This paper examines the impact of various trends on human resource (HR) policies and practices in the US airline industry; compares productivity, operational and financial performance measures at the major carriers; and explores future HR strategies to enhance organizational outcomes. The airlines invited to participate in the study were Alaska, American, Continental, Delta, JetBlue, Northwest, Southwest, United, and US Airways. The rationale for choosing these airlines was based on the fact that the selected airlines have the highest domestic market share according to the Bureau of Transportation Statistics (2005). For most of the airlines, the HR practices match to a significant level with the best practice reports in the scholarly literature. Most of the airlines have an integrated HR model where HR is a key part of the executive component of the company and function as business partners.

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## INTRODUCTION

Significant research attention has been devoted to examining the relationship between human resource (HR) practices and firm performance, and research support has assumed HR as the causal variable (Wright, Gardner, Moynihan, & Allen, 2005). The perils facing the traditional air carriers in the United States and around the world are largely the result of economic and technological changes far beyond the scope of anything human resources policies could influence directly. But if the airlines are to survive, changes in their workforce strategies and practices are crucial (Kiger, 2005). This is especially relevant given that there is broad agreement that HR policies and practices have a positive impact on firm performance (Becker & Huselid, 1998; Delaney & Huselid, 1996; Wright et al., 2005; Youndt, Snell, Dean, & Lepak, 1996).

According to the Air Transport Association (2007), approximately 23 US airlines (passenger and cargo) have filed for bankruptcy since 1978. It is common knowledge that airlines are continuously reducing the size of their labor force, negotiating reduction in compensation and benefits, and trying to reduce operating expenditures. Some even argue that the airlines are reaching the point of diminishing returns with such austerity and must turn to improving productivity and increasing revenue to regain their competitiveness.

In the past, economic downturns have led to large industry losses, but none of those periods posed as severe a threat to the industry's survival as did the aftermath of 9/11 (Corridore, 2005). Furthermore, as the airlines' losses mounted and available cash was rapidly depleted, most carriers were forced to shoulder new debt by tapping their credit lines and/or issuing bonds. These actions were vital to help the carriers survive the dramatic decline in passenger levels and fares, and the sharp increase in losses, but left most of the major airlines burdened with huge debt loads.

This paper examines the impact of various trends on HR policies and practices in the US airline industry; compares productivity, operational and financial performance measures at the major carriers; and explores future HR strategies to enhance organizational outcomes. The airlines invited to participate in the study were Alaska, American, Continental, Delta, JetBlue, Northwest, Southwest, United, and US Airways. The rationale for choosing these airlines was based on the fact that the selected airlines have the highest domestic market share according to the Bureau of Transportation Statistics (BTS, 2005).

Given the significant impact of the airline industry on the national economy of the country and the established impact of HR on firm performance (Delaney & Huselid, 1996; Guthrie, 2001; Huselid, 1995), this paper also attempts to make comparisons of current HR practices in the airline industry and theories linking HR and firm performance.

## LITERATURE REVIEW

The search for value creation strategies continues as companies seek ways to create sustainable competitive advantages and sometimes even survive in today's economy. Over the years, managers and scholars have increasingly included human capital, and the human resource management (HRM) systems that produce it, among the intangible assets that potentially have strategic value (Becker & Gerhart, 1996). Empirical research has examined various elements of the HR architecture with attention to role behaviors (Jackson & Schuler, 1995), employee commitment and involvement (Batt, 2002), and high performance work systems (Huselid, 1995; MacDuffie, 1995; Youndt et al., 1996).

Over the past ten years, there has been a significant number of studies attempting to establish linkages between HR practices and firm performance. One of those studies concluded that "based on four national surveys and observations on more that 2,000 firms, our judgment is that the effect of a one standard deviation change in the HR system is 10– 20% of a firm's market value" (Huselid & B. Becker, 2000, p. 851). Given such critical impact on a firm's performance, the role of HR in the airline industry becomes even more relevant. More recently, Cascio (2005) explained that in order for HR to add value to an organization, it must have several key competencies and highlighted through the example of SYSCO, that HR is a significant source of value in organizations.

By examining previous work on (a) the role of HR in organizations and (b) key HR strategies and practices that impact firm performance, this paper identifies and analyzes the findings within the airline industry and makes comparisons to the scholarly literature on these critical issues.

### The role of HR in organizations

In defining the role of HR in progressive organizations, Ulrich and Brockbank (2005) highlighted the critical need for the dramatic refocusing of HR from what is done to what is delivered, from building HR functions for efficiency to building them for stakeholder value, and implementing best HR practices to delivering value-added HR practices. This reinforces the belief of the relationship between HR and firm performance (Becker & Huselid, 1998; Delaney & Huselid, 1996; Huselid, 1995; Youndt et al., 1996).

With such relationships established through empirical studies, this research examines current HR practices at the major carriers and compares the findings with the established theories. Ulrich and Brockbank's (2005) categorized the roles of HR as: (a) employee advocates; (b) functional experts; (c) human capital developer; and (d) strategic partners. The sum of these four roles enables HR leaders setting clear goals, being decisive, communicating inside and out, managing change, and defining results in terms of value added for investors, customers, line managers, and all employees. The roles defined by Ulrich & Brockbank were used as the framework for classifying the role of HR at the respective airlines included in this study.

Today, there is widespread consensus that HR professionals have accepted the role as strategic business partners (Jamrog & Overholt, 2004). This conclusion was made based on studies conducted by the Society for Human Resource Management (2002) and on a smaller scale, the Human Resource Institute (2002). Among the various roles identified in these studies were strategic partner and strategic thinker as the most important components. In defining strategic partners, Ulrich and Brockbank (2005) explained that:

> HR professionals bring business, change, consulting, and learning know-how to their partnership with line managers, so that together they create value. Strategic business partners are business literate and savvy. They partner with line managers to help them reach their goal. (p. 212)

Adding to this view, Lawler (2005) said it is nearly unanimous that HR can and should add more value to corporations. The best way to do this is by being a business partner—by directly improving the performance of the business. As he explained, this can be accomplished by effective talent management, helping with change management, influencing strategy, and a host of other value-added activities that impact effectiveness.

Although there is substantial research on the relationship between HR and firm performance, one area of neglect in unpicking the link between HRM and performance is the role played by the HR department (Hailey, Farndale, & Truss, 2005). As well as focusing on hard, bottom-line financials, strategic HR professionals must also have a thorough understanding of the more intangible, cultural elements that impact business performance (Salkey, 2006). In being effective business partners, Mizra (2005) advised that HR professionals will need to focus on gaining additional skills, such as managing change, harnessing technological advances that affect the profession, and refining business and finance skills—especially in ways that help measure the effect and effectiveness of various HR practices.

Even as the role of HR continues to evolve, quite frequently HR seems unable to function effectively as a business partner. Lawler (2005) concluded HR does not seem able to position itself as a business partner in many cases and suggested that to succeed as a business partner HR has to think of itself as a business and what products it should offer.

**Driving firm success through HR**

HR and business leaders increasingly define organizational effectiveness beyond traditional financial outcomes to encompass sustainability—achieving success today without compromising the needs of the future (Boudreau & Ramstad, 2005a). As these authors explained, to make sustainability truly actionable requires a framework that connects decisions about the organizations talents with sustainability in a clear, deep and logical way, just as the decision sciences of finance and marketing tangibly connect decisions about money or customers to financial outcomes.

The argument is put forth that today's employers must use their resources as efficiently as possible. This includes continuous improvement in products, processes, and productivity, as well as sound procedures for compliance, risk management, and accountability. But customer satisfaction depends on employee discretionary behavior. The HR profession has the lead responsibility to design the policies and practices that elicit behavior leading to sustainable success (Armstrong, 2005). The quest becomes building HR functions to be competent, curious, courageous, and caring about people (Meisinger, 2005).

Changing organizational critical success factors, new expectations for human resources, and the changing roles and capabilities of HR professionals are discussed here. Today's top HR job encompasses enabling capable and courageous leadership; building a very strong and adaptive organizational culture; strengthening organizational productivity and performance; fostering creative innovations, products, and solutions; and building exceptionally high customer loyalty (Roberts & Hirsch, 2005).

It is more important than ever for organizations to master essential elements of human resources as improving economic conditions as well as shifting workforce expectations and demographics make the attraction, retention, and development of talent increasingly fundamental to achieving competitive advantage and exceptional business performance (Jensen, 2005).

As Boudreau & Ramstad (2005b) articulated, organizations are increasingly competing through talent, resulting in their investments in human capital helping to determine their competitive positions. Yet HR's way of managing this key resource stands in sharp contrast to how other organizational functions operate. Marketing, finance, and most other functions have well-developed methodologies for generating the information managers need to make strategic decisions. HR, however, often focuses principally on its own performance, carefully measuring cost per hire, the return on investment (ROI) on its programs, and how its initiatives affect skills and attitudes.

Boudreau & Ramstad (2005b) suggest that it is time for HR to shift its focus from what it does to the quality of the talent decisions it supports. HR needs to develop a systematic process for improving decisions, not just implementing them. HR should be able to help leaders answer critical questions, such as the following. Where does our strategy require talent that is better or more plentiful than our competitors? In what new business ventures do we have a strategic advantage because of our talent? What talent gaps do we need to close in order to keep our competitive advantage? And, most important, where would a change in the availability or quality of talent have the greatest impact?

Using the theories of Boudreau & Ramstad (2005a), the role of HR at the respective airlines is examined to determine HR's role in driving firm success. Even though most of the major airlines are under severe financial pressure, the responsibility of HR is to create firm success. Thus, the research seeks to determine how HR departments at the airlines are helping to increase financial success and at the same time building sustainable organizations.

## METHODOLOGY

This study examined HR practices and various financial and operational measures at the selected airlines in the United States. Data were collected through surveys from HR departments at the respected airlines and through interviews with the respective HR executives. In addition to current HR practices, the airlines provided specific information on the HR practices over the past two years. Given that the last two years' financial and operational measures were utilized in this study, the data enabled both predictive and contemporaneous analyses.

In a study conducted by Wright et al., (2005), the authors examined more than 60 research studies and found that only a few studies have explored whether practices assessed at one point in time were related to subsequent firm performance. The authors explained that such designs are the only true predictive designs. Another method utilized by many of the research studies utilized contemporaneous HR practice and firm performance data. For example, Huselid (1995) gathered both contemporaneous and subsequent year performance data and reported only the subsequent year data in his study in order to provide more conservative effect size estimates. Youndt et al., (1996) related HR practices to plant performance assessed 2 years later.

Financial data were obtained through published annual reports of the respective airlines. These reports were available on the airlines' websites. Additional financial data were obtained from sources such Standard and Poors, Department of Transportation (DOT), and BTS.

As a means to determine the content validity of the instrument and to enhance its effectiveness, a pilot study of the survey was conducted on a stratified sample of 15 HR professionals including Senior Executives, HR Managers, and HR Generalists. Respondents were asked to review the instrument, provide feedback on the utility of the questions, recommend additional questions, eliminate questions, and determine if the questions were able to collect the appropriate data needed to fulfill the purpose of the study. Items that were consistently identified by the focus group were included in the final survey. To ensure construct validity, all items listed in the survey were identified from academic publications discussing the linkages between HR and firm performance. The final survey instrument is shown in the Appendix.

Indeed, some will question the effectiveness of self-reporting and of one employee responding on behalf of an organization's point of view. Nevertheless, as cited by Huselid & Becker (2000), Gerhart (1998) concluded that even if a study were to have the benefit of multiple raters, conventional reliability statistics (James, Demaree, & Wolf's, 1984) would overstate estimated reliabilities.

To determine the reliability of the data collected, I used Cronbach's alpha to test the responses received. The goal was to determine the proportion of the variability in the responses to the survey that is the result of differences in the respondents. The result was 0.78. Hence, a satisfactory measure of how well the variables measure the respective constructs.

## Sample

The nine airlines with the highest market share in the US were chosen for this research. This list of airlines was accessed from the BTS reports published in 2005. The rationale for choosing these airlines was that they would have provided a realistic sample of the overall industry having been in operation for longer periods with substantially higher number of employees than the regional carriers, and largest HR departments in the industry. There was sufficient representation to infer generalizability and deemed adequately reliable to the overall industry.

## Measures

### *HR's role*

HR executives at the respective airlines were asked to identify the extent to which the HR department functioned as employee advocates, functional experts, developing human capital, and functioning as strategic partners. These roles were extracted from (Ulrich & Brockbank, 2005). As these scholars concluded, the roles listed represent an evolution of thinking about what an HR professional must do to deliver value. Highlighting the role of strategic business partner, the HR executives were also asked to identify which of their staff are business literate and savvy and the extent to which they partnered with line managers to realize the business objectives of the airline.

***HR strategy, formulation, implementation, and evaluation***

This component of the survey sought information on the process used for developing HR strategies and challenges faced by the respective airlines; and identified the most critical deliverables of the HR function to the business outcomes and how HR strategies enable the airlines to achieve their competitive advantages. In addition, data on the reporting relationships of HR and the number of employees in the HR department compared to total employees were also collected.

***HR practices***

Key practices identified and measured included recruiting strategies, HR planning, employee evaluation, employee training and development, and use of pay for performance initiatives. In addition, employee turnover data were collected and included voluntary and involuntary turnover. HR executives were also asked to provide data on work stoppage due to labor relations issues and the number of employees represented by unions.

***Operational & financial performance***

Some of the key operational measures in the airline industry include safety, on-time performance, lost/damaged luggage, and customer complaints. These data were gathered from the BTS, airline websites, DOT, and annual reports. The findings of each of these measures were compared to industry standards.

Two of the productivity measures used in this study were labor productivity and average time for flight turnaround. The financial measures included profitability, revenue, earnings per share (EPS), stock value, and return on assets (ROA).

***Firm size as control variable***

According to Barney (1991) firms with superior resources will be able to conceive of and implement unique strategies that rivals will find difficult to emulate. Given that large airlines have more such resource advantages than do small airlines, firm size is included as a control.

## RESULTS

Of the nine airlines identified to participate in the study, five responded to the survey. The other four declined to participate citing various reasons. The airlines are not identified but are coded as Airline A, Airline B, Airline C, Airline D, and Airline E as a means of not sharing proprietary information. These names were randomly assigned to protect the identity of the respective airlines. These five airlines have provided adequate information enabling a reasonable generalization of practices within the US airline industry.

### HR's role

Of the five airlines that responded to the survey, the HR focus is to be functional experts and serve as strategic business partners. As indicated in Table 1.0, among the five airlines 36% of the HR time is spent as functional experts, 24% as strategic business partners, 21% as employee advocates, and 19% developing human capital.

**Table 1. Percentage of Time (Collectively) that the Airline Human Resource Department Spends on Key Human Resource Roles**

| | Employee Advocates | Functional Experts | Developing Human Capital | Strategic Business Partners |
|---|---|---|---|---|
| Airline A | 10 | 60 | 10 | 20 |
| Airline B | 30 | 20 | 20 | 30 |
| Airline C | 30 | 15 | 25 | 30 |
| Airline D | 10 | 40 | 20 | 30 |
| Airline E | 25 | 45 | 20 | 10 |
| Overall Average | 21 | 36 | 19 | 24 |

Given the turbulence in the airline industry, it is easily understood the importance and necessity of HR being functional experts and quite strategic, HR professionals championed by the respective VPs of HR, the emphasis remains strong for HR to be true strategic business partners. As highlighted by Lawler (2005), Patterson (2003), and Roberts & Hirsch (2005), for HR to contribute effectively to organizational effectiveness, there has to be some level of emphasis on strategic contribution and utilizing the HR functional expertise. The reports provided by the respective airlines clearly indicate that HR professionals understand the value of HR and generally spend their time in the areas that would more likely contribute to organizational success.

Reporting on the question as to the extent to which the respective HR departments bring business, change, consulting, and learning know-how to their partnership with line managers, the responding representative for the respective airlines indicated an average score of 3.8 on a scale of 1 to 5 with 5 being the most positive. Four of the airlines indicated a score of 4 with one indicating a score of 3. This clearly indicates that HR believes it is not only spending time in the critical areas, but also making strong impact on the specific outcomes that are likely to help their respective airlines become more competitive.

**HR strategy formulation, implementation, and evaluation**

This section of the survey examined the process for developing the HR strategic plan, identified the challenges facing the HR departments, the most critical deliverables, the size of the department, and the reporting relationships among other factors. Results for each of the airlines and general analyses are reported.

***Process for developing HR strategies***

The representatives for the airlines indicated that in general the HR strategic plan is developed through partnership with other functional groups within the company and, except for one of the airlines, this process is facilitated internally. One of the airlines uses an external organization to facilitate the process. Two of the airlines indicated the lack of long-term planning but are taking action to develop stronger long-term planning.

***Challenges facing HR departments***

The representatives for the airlines indicated that in general the HR strategic plan is developed through partnership with other functional groups within the company and, except for one of the airlines, this process is facilitated internally. One of the airlines uses an external organization to facilitate the process. Two of the airlines indicated the lack of long-term planning but are taking action to develop stronger long-term planning.

***Critical HR deliverables to the business outcomes***

As articulated by scholars in the field of HR, the HR function must be able to deliver and help to make this happen. Hence, the question of identifying critical deliverables was included in the survey instrument. The following deliverables were identified: (a) hire staff—adequate qualified employees to help meet customers' expectations and needs; (b) manage performance; (c) develop appropriate expertise through learning; (d) develop and implement relevant policies; (e) support sustainable profitability (shift from pure operational focus); and (f) reduce voluntary turnover.

***Areas for improvement***

One representative indicated that the talent strategy needs to be more directly linked to the business strategy. Another reported that a more comprehensive approach to workforce planning is needed as the company prepares for growth in the future.

***Size of HR department and reporting relationship of the Chief HR Officer***

Table 2.0 provides a summary of the number of exempt and non-exempt employees that responded to the survey. As the table indicates, VPs of HR report to the company's CEO. This is quite significant given the history of HR where many of the heads of HR reported to other leaders and not necessarily the CEOs.

**Table 2. Size of Airline Human Resource Department and Reporting Relationship**

| | Number of Exempt Employees | Number of Non-exempt Employees | Reporting Relationship |
|---|---|---|---|
| Airline A | 73 | 68 | CEO |
| Airline B* | 200 | 120 | CEO |
| Airline C | Not provided | | |
| Airline D | 400 | 156 | CEO |
| Airline E | 64 | 29 | CEO** |

* Includes Training Personnel

** VP of HR is not part of the Executive Committee

## HR practices

This section addresses current HR practices within the industry. Areas such as recruitment, performance management, unions, employee turnover, rewards, and training are included. Table 3.0 provides a detailed summary of the respective practices and outcomes for the five airlines.

**Table 3. Human Resource Practices and Outcomes**

| | Airline A | Airline B | Airline C | Airline D | Airline E |
|---|---|---|---|---|---|
| Major Recruitment Strategies | Job fairs, internet, college recruiting, newspaper advertisements, and trade periodicals | Internet and college recruiting | Internet, trade journals, college recruiting, newspapers | MBA college recruiting, internet | Internal referral, intranet, internships, community involvement, and advertising, increase diversity, evaluate selection process with individual performances |
| Anticipated Hiring for the Next Year | 1500 - 2000 | 4000 | 2000 | MBA and undergrads – 100 | 1547 |
| Key Selection Criteria | Basic qualifications, soft skills, leadership ability, and interpersonal communication | Focus on technical knowledge, experience, organizational fit (core foundations of the culture) | Organizational fit | Job fit, organizational fit, and cultural fit | Work history, demonstrated commitment to customer service, communication skills, dependability, and emphasis on safety |
| Hours Spent on T&D Per Employee Annually (Average) | 40 – 60 hours of technical training and 8 hours of soft skills training | Exempt – 1 week | 1 – 2 weeks | 36 | 1 week |
| Pay for Performance System | Applicable to salaried positions | Exempt only | Exempt only | 1.5% increase | Integrated part of the total compensation system |
| Typical Benefits Provided to Employees | 80/20 plan | Basic/typical coverage | Basic/typical coverage | Defined contributions, matching 401k funds at 5.5%, competitive healthcare benefits, & generous time off | Basic/typical coverage |
| Employee Turnover (Voluntary /Involuntary)/ % | 8 – 10<br>8 | 7<br>7 | 6<br>10 | 11.4 overall | 9 overall |
| Number of Unions Representing Various Employee Groups | 6 | 0 | 3 | 3 | 5 |

As indicated above, all of the airlines are using standard practices to advertise their job openings. Much emphasis is being placed on using technology rather than depending on traditional sources to advertise the positions. Of significant note, all of the airlines are planning on adding a relatively substantial number of employees within the next year. Given that most have gone through significant layoffs, the airlines are confident of adding staff as the industry begins to improve its performance. Voluntary turnover as reported by the airlines is relatively low averaging approximately 9%. This percentage does not include layoffs.

## Operational & financial performance

The last few years have been tremendously difficult for the airline industry. Table 4.0 provides a comparison of the various operational and financial measures as reported by the carriers, BTS, and DOT.

> Although the US airline industry began 2001 with 24 consecutive profitable quarters, including net profits in 2000 totaling $7.9 billion, the impact of the 9/11 event on the industry was substantial. Whereas the recession that began in early 2001 signaled the end of profitability, the 9/11 terrorist attacks pushed the industry into financial crisis after air travel dropped 20% over the September–December 2001 period compared to the same period in 2000. (Blunk, Clark, & McGibany, 2006)

**Table 4. Operational and Financial Performance**[1]

| | Alaska Air | American Airlines | Continental | Delta | JetBlue | Northwest | Southwest | United |
|---|---|---|---|---|---|---|---|---|
| On-time Arrivals[2] | 74 | 76 | 73 | 76 | 73 | 76 | 80 | 74 |
| Total Profit or Loss/million (12/05) | -74 | 256 | 327 | -454 | -61 | 420 | 528 | 234 |
| Passenger Yield/Cents | 13.20 | 12.67 | 12.12 | 11.68 | 9.05 | 12.33 | 12.50 | 11.73 |

[1] As of September 2006
[2] November 2005 – October 2006

Many airline companies have tried to borrow more to fund their growing financial losses. The average debt-to-capitalisation ratio of the 11 largest US airline companies is now greater than 90 percent, with a total debt of $90bn (Velocci, 2003). The bankruptcies of airline companies reflect the rising business and financial risks that the airline industry has to face. Although there has been some level of stability, the industry is still in a state of turbulence especially with higher gas prices and security risks. Given the significance of the US airline industry to the country’s success, it is critical to understand the impact of HR practices on the performance of the respective measures.

## DISCUSSION AND CONCLUSION

The perils facing the traditional air carriers are largely the result of economic and technological changes far beyond the scope of anything HR policies could influence directly. But if the airlines are to survive, changes in their workforce strategies are crucial (Kiger, 2005). Based on the established theories and taxonomies on the relationships between HR and firm performance, the role of HR in helping air carriers become more competitive is of utmost importance. In 2009, the United States airlines industry is forecast to have a value of $139.2 billion, an increase of 19.7% since 2004 (DataMonitor, 2005). Furthermore, The US has the largest airlines industry, accounting for 39.7% of the global industry's value. Such is the relevance of the US airline industry and a prime opportunity for HR to be a true strategic partner in building higher levels of competitiveness.

This paper has examined and reported the current HR practices at some of the largest carriers in the US. The paper reports the roles of HR departments, identifies and analyzes current HR practices, and show how HR contributes to the business strategies of the airlines. With reports of merger discussions surfacing in the industry, HR departments continue to play a key role in ensuring internal and external customers' expectations are fully met.

For most of the airlines, the HR practices match to a significant level with the best practice reports in the scholarly literature. Most of the airlines have an integrated HR model where HR is a key part of the executive component of the company and function as a business partner. As concluded by Huselid, Jackson & Schuler (1997), strategic HRM can directly and positively influence individual performance, organizational commitment and job satisfaction. Top managers implementing a strategic HRM system can, therefore, expect improved organizational performance and improved levels of individual performance, job satisfaction and organizational commitment from the organization's HR professionals.

It is therefore argued and is expected that with such strategic HRM initiatives in the airline industry and with oil prices remaining relatively stable, HR will continue to add significant value and foster higher levels of profitability among the major carriers discussed in this study. As Benson, Young, & Lawler III (2006) found in their study of a sample of Fortune 1000 companies, high-involvement work practices are positively related to corporate financial performance. This is further evidence that with the high involvement of the HR departments in the airline industry and accounting for other variables, firm performance could be positively impacted.

To drive value and optimize company performance, human capital, skills and abilities of people that contribute to organizational success is an asset to be leveraged. Based on corporate culture, organizational values and strategic business goals and objectives, human capital measures indicate the health of the organization (Lockwood, 2006).

## REFERENCES

Air Transport Association. (2007). U.S. airline bankruptcies. Retrieved August 30, 2007, from http://www.airlines.org/economics/specialtopics/USAirlineBankruptcies.htm

Armstrong, G. (2005). Differentiation through people: How can HR move beyond business partner? Human Resource Management, 44(2), 195-199.

Barney, J. (1991). Firm resources and sustained competitive advantage. Journal of Management, 17(1), 99-120.

Batt, R. (2002). Managing customer services: Human resource practices, quit rates, and sales growth. Academy of Management Journal, 45(3), 587-598.

Becker, B., & Gerhart, B. (1996). Human resources and organizational performance: Progress and prospects. Academy of Management Journal, 39(4), 779–801.

Becker, B., & Huselid, M. (1998). High performance work systems and firm performance: A synthesis of research and managerial implications. In G. Ferris (Ed.), Research in personnel and human resource management, Vol. 16 (pp. 53-101). Bingley, UK: Emerald Group Publishing.

Benson, G. S., Young, S. M., & Lawler, III, E. E. (2006). High-involvement work practices and analysts' forecasts of corporate earnings. Human Resource Management, 45(4), 519-537.

Blunk, S. S., Clark, D. E., & McGibany, J. M. (2006). Evaluating the long-run impacts of the 9/11 terrorist attacks on US domestic airline travel. Applied Economics, 38(4), 363-370.

Boudreau, J. W., & Ramstad, P. M. (2005a). Talentship, talent segmentation, and sustainability: A new HR decision science paradigm for a new strategy definition. Human Resource Management, 44(2), 129-136.

Boudreau, J. W., & Ramstad, P. M. (2005b). Where's your pivotal talent? Harvard Business Review, 83(4), 23-24.

Bureau of Transportation Statistics. (2005). Airline domestic market share: December 2004 - November 2005. Washington, DC.

Cascio, W. F. (2005). From business partner to driving business success: The next step in the evolution of HR management. Human Resource Management, 44(2), 159-163.

Corridore, J. (2005). Industry surveys' airlines. New York: Standard and Poors.

DataMonitor. (2005). Airlines industry profile: United States. London: Market Research Reports.

Delaney, J., & Huselid, M. (1996). The impact of human resource management practices on perceptions of performance. Academy of Management Journal, 39, 949-969.

Gerhart, B. (1998). Human resource management and firm performance: Measurement issues and their effect on causal and policy inferences. In P. M. Wright, J. W. Boudreau, & G. T. Gerhart (Ed.), Research in personnel and human resource management, supplement 4 (pp. 31-51). Greenwich, CT: JAI Press.

Guthrie, J. (2001). High-involvement work practices, turnover and productivity: Evidence from New Zealand. Academy of Management Journal, 44(1), 180-192.

Hailey, V. H., Farndale, E., & Truss, C. (2005). The HR department's role in organisational performance. Human Resource Management Journal, 15(3), 49-66.

Human Resource Institute. (2002). Doing more with less: The results of HRI's survey on the role and structure of human resources. St. Petersburg, FL.

Huselid. (1995). The impact of human resource management practices on turnover, productivity and corporate financial performance. Academy of Management, 38(3), 635-672.

Huselid, & Becker, B. (2000). Comment on measurement error in research on human resources and firm performance: How much error is there and how does it influence effect size estimates? Personnel Psychology, 53(1), 835–854.

Huselid, M., Jackson, S., & Schuler, R. (1997). Technical and strategic human resource management effectiveness as determinants of firm performance. Academy of Management, 40(1), 171-188.

Huselid, M. A., & Becker, B. E. (2000). Comment on 'Measurement Error in Research on Human Resources and Firm Performance: How much error is there and how does it influence effect size estimates?' by Gerhart, Wright, Snell, McMahan, and Snell. Personnel Psychology, 53(4), 835-854.

Jackson, S. E., & Schuler, R. S. (1995). Understanding human resource management in the context of organizations and their environments. Annual Review of Psychology, 46(46), 237-264.

James, L. R., Demaree, R., & Wolf, G. (1984). Estimating within-group inter-rater reliability with and without response bias. Journal of Applied Psychology, 69, 85-98.

Jamrog, J. J., & Overholt, M. H. (2004). Building a strategic HR function: Continuing the evolution. Human Resource Planning, 27(1), 51-62.

Jensen, E. (2005). HR's role in helping companies achieve high performance. Employment Relations Today, 32(2), 39-52.

Kiger, P. J. (2005). Cabin pressure. Workforce Management, 84(2), 37-44.

Lawler, III, E. E. (2005). From human resource management to organizational effectiveness. Human Resource Management, 44(2), 165-169.

Lockwood, N. R. (2006). Maximizing human capital: Demonstrating HR value with key performance indicators. HRMagazine, 51(9), 1-10.

MacDuffie, J. P. (1995). Human resource bundles and manufacturing performance—organizational logic and flexible productions systems in the world auto industry. Academy of Management Journal, 48(2), 197-221.

Meisinger, S. R. (2005). The four Cs of the HR profession: Being competent, curious, courageous, and caring about people. Human Resource Management, 44(2), 189-194.

Mirza, P. (2005). The evolution to being a strategic partner. HR Magazine, 50, 44.

Patterson, S. (2003). HR plays critical role in business & strategy [Management Report]. Human Resources Department.

Roberts, R., & Hirsch, P. (2005). Evolution and revolution in the twenty-first century: Rules for organizations and managing human resources. Human Resource Management, 44(2), 171-176.

Salkey, J. (2006). HR for HR: Are your skills up to scratch? Strategic HR Review, Vol. 2.

Society for Human Resource Management. (2002). The future of the HR department. Alexandria, VA.

Ulrich, D., & Brockbank, W. (2005). The HR value proposition. Boston, MA: Harvard Business School Publishing.

Velocci, A. L. (2003). Chapter 11 stocks airlines as sector fights for recovery. Aviation Week & Space Technology, 57(21), 55–57.

Wright, P., Gardner, T., Moynihan, L., & Allen, M. (2005). The relationship between HR practices and firm performance: Examining causal order. Personnel Psychology, 58(2), 409-446.

Youndt, M., Snell, S. A., Dean, J. W., & Lepak, D. (1996). Human resource management, Manufacturing strategy, and firm performance, Academy of Management Journal, 39, 836-866.

## APPENDIX

### HR's role

1. Describe the percentage of time (collectively) that the HR department spends on
   a. being employee advocates ______
   b. serving as functional experts ______
   c. developing human capital, and ______
   d. functioning as strategic partners. ______
   *Please note the total should be 100%*

2. Using a scale of 1 – 5 with 5 being the most positive, indicate the extent to which your HR department exemplifies the following statement: *HR professionals bring business, change, consulting, and learning know-how to their partnership with line managers, so that together they create value. Strategic business partners are business literate and savvy. They partner with line managers to help them reach their goals*

   1 2 3 4 5

### HR strategy formulation, implementation, and evaluation

3. Describe the process you used for developing your HR strategy. Who was involved, how long was the process?

4. What would you describe as the major challenges facing the HR department and in particular your HR strategy implementation?

5. What do you consider to be the most critical deliverables of the HR function to the business outcomes?

6. How do the HR strategies enable the airline to be competitive and how are these measured? Please list the metrics utilized.

7. Which HR activities and programs currently support the business strategy and which need to be modified?

8. Who are all involved in the HR strategic planning?

9. What do you consider are the core competencies of your airline and how does HR support these competencies?

10. How many exempt and how many non-exempt employees are in the HR department?

11. Who does the head of HR report to?

**HR practices**

12. Please identify the major recruitment strategies your airline utilizes to hire your employees?

13. How many employees do you anticipate hiring in the next year?

14. What are the key factors and characteristics considered in evaluating a potential employee for hiring?

15. How many hours on average does an exempt and a non-exempt employee participate in training and development programs on an annual basis?

16. Do you use a pay for performance system? Please describe.

17. What are the typical benefits provided to employees?

18. What percentage of your workforce voluntarily and involuntarily left the organization last year?

19. How many different unions represent specific groups of employees? How many days of work stoppage did you experience last year?

# RADIO FREQUENCY IDENTIFICATION TECHNOLOGY: INVENTORY CONTROL ABOARD THE INTERNATIONAL SPACE STATION

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## ABSTRACT

Due to frustrating, lengthy, and labor intensive inventory audits, astronauts almost ran out of food which led to the near de-manning of operations on the International Space Station (ISS) (Carreau, 2004). Clearly, there was a need for an alternative method of inventory control aboard the ISS. Radio Frequency Identification (RFID) is a data capture technology that could alleviate the pre-mentioned inventory problems that astronauts face. In this paper we introduce a Design for Six Sigma Research (DFSS-R) methodology that allows for reliability testing of RFID systems. The research methodology uses a modified sequential design of experiments process to test and evaluate the quality of commercially available RFID technology. In the transcript, two generations of passive RFID technologies were tested in successive years. The results from the experimentation are compared to the requirements provided by NASA to evaluate the feasibility of using passive RFID technology to improve inventory control aboard the ISS.

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## INTRODUCTION

Previously, astronauts aboard the International Space Station (ISS) used manual audits and some barcode scanning to track perishable inventory (consumables). This presents a challenge due to the fact that these periodic inventory audits are very labor intensive, time consuming, and inaccurate (Phan et al., 2006). Although NASA is a not for profit business entity, there was a significant business case to develop an inventory management system using radio frequency identification (RFID) technology to reduce the labor involved with auditing consumable materials on the ISS. During this study simple calculations were used to determine the hourly cost of manual auditing by astronauts in space given the astronauts per mission costs. Further cost justification given was the fact that by reducing astronaut auditing times, astronauts could spend more time conducting experiments that contribute to the objectives of the mission. These labor savings and opportunity costs were equated into a dollar value.

Current operational procedures suggest that astronauts spend one week every six months taking inventory. The labor cost for this procedure is estimated at approximately $22.4 million dollars per year. The challenge is that these procedures are ignored and not performed due to time constraints. Thus, inventory accuracy is jeopardized. Evidence that the inventory auditing procedures needed to be improved was discovered in interviews from NASA ISS team members. Challenges such as items periodically vanishing from the inventory control system, inventory level accuracy in the system, and crew frustrations with auditing, led to the near de-manning of operations on the ISS (Leary, 2004). These aforementioned opportunities drove the need for the NASA, Barrios (a contractor to NASA), and University of Nebraska-Lincoln team to investigate the use of RFID technologies (Jones, 2005).

Previously, the team performed an initial justification analysis for the use of all automatic identification data collection (AIDC) technologies which included barcodes and RFID (Hou & Huang, 2006). The analysis evaluated how process improvements such as better barcode utilization or the use of RFID scanning would affect incremental labor cost. An astronaut uses approximately 50 consumable items per day. Time studies revealed that better accuracy can be attained by improving current bar-coding process but this would add an additional 10 seconds per manual scan, which would increase the labor cost to $5,787 per day per astronaut. The station contains 3 or 4 crew members at any given time which suggests that total labor cost would exceed $20,000 per day—almost $7.3 million dollars per year. Barcoding could represent an additional cost to the current labor cost of $22.4 million or it can be used as a replacement. This barcoding process in conjunction with a cycle counting strategy could eliminate the $22.4 million cost of audits to only the $7.3 million or 64% and improve inventory accuracy (Jones, 2005).

Unfortunately, many involved suggested that additional manual efforts would again become a low priority for the space crew and view automated audits from RFID as a preferred option. Further, the analysis suggested that other AIDC's such as RFID tags require less manual manipulation and would be better justified. In this paper we describe the brief background of RFID technologies, the Design for Six Sigma Research (DFSS-R) methodology, and the experimental results from testing first generation (Gen 1) and second generation (Gen 2) RFID tags produced in 2005 and 2007, respectively. We conclude with a summary and lessons learned (Jones & Nowak, 2007).

## BACKGROUND

### RFID basics

RFID technologies originated from radar theories that were discovered by the allied forces during World War II and have been commercially available since the early 1980s (Landt, 2001). Over the last two decades, RFID has been used for a wide variety of applications such as highway and bridge tolls, livestock tracking, transportation freight tracking and motorcycle manufacturing. Until recently, the technologies were considered expensive and limited, but as the tags, readers, and the associated equipment costs continue to decrease, a growing number of organizations have begun to explore the feasibility of using RFID systems (Jones, Clarke-Hill, Hiller, Shears & Comfort, 2004; Scholl, Schmidt & Wolff, 2001).

There are several methods of identifying items that use RFID. A standard RFID system consists of a tag, reader, air interface, and middleware software (Clampitt, 2006). Tags often consist of a microchip with an internally attached coiled antenna. Some include batteries, expandable memory, and sensors (Ranky, 2006). A reader is an interrogating device that has internal and oftentimes external antennas that send and receive signals. The data transmitted from the RFID tag may provide identification details such as information about the item's history, biometric information and environment information captured through tag sensor enhancements and specialized characteristics. The tags are very flexible in that microchips can record and store information, can be read from a range of distances, and through a variety of environmental factors. Further, many believe that RFID tags offer better security than barcodes and other labels because they can be embedded which makes them virtually free of tamper. Ironically, the discussion of RFID signal security has come under scrutiny (Brandner, 2005).

## RFID advantages in inventory control

There are many benefits of using RFID over traditional methods of inventory control. Table 1 details some advantages of using RFID versus using barcode technology (Juban & Wyld, 2004).

**Table 1. Benefits of Radio Frequency Identification versus Barcode Technology**

| RFID Tags | Barcodes |
|---|---|
| RFID tags can be read or updated without line of sight | Barcodes require line of sight to be read |
| Multiple RFID tags can be read simultaneously | Barcodes can only be read individually |
| RFID tags are able to cope with harsh and dirty environments | Barcodes cannot be read if they become dirty or damaged |
| RFID tags are ultra thin, and they can be read even when concealed within an item | Barcodes must be visible to be logged |
| RFID tags can identify a specific item | Barcodes can only identify the type of item |
| Electronic information can be over-written repeatedly on RFID tags | Barcode information cannot be updated |
| RFID tags can be automatically tracked, eliminating human error | Barcodes must be manually tracked for item identification, making human error an issue |
| RFID allows for real-time information | Barcodes must be manually scanned to obtain information |

*Note.* From "Would You Like Chips with That? Consumer Perspective of RFID," by Rusty L. Juban and David C. Wyld, 2004, *Management Research News, 27*(11/12), p. 29-44. Reprinted with permission of the authors.

## 2nd generation passive RFID tags

The 2nd generation of passive RFID Tags (Gen 2) of RFID technology became commercially available in the first quarter of 2006 (Collins, 2004). These Gen 2 RFID tags claim to have several improvements over the previous generation of tags as described in Table 2 (York, 2005).

**Table 2. Generation 2 Radio Frequency Identification Tag Improvements**

| Gen 2 RFID Tag | Improvements |
|---|---|
| Open Standard | Be available from multiple sources and it should bring prices down more quickly |
| Global Frequency | Spread spectrum, frequency hopping UHF with frequency-modulation capabilities to minimize interference with or from other wireless devices |
| Memory | 96 bit memory. This provides greater storage capability |
| Security | Tags have better security encryption of tag data; readers do not broadcast tag data being read |
| Size | Chips have ½ or 1/3 the size of Gen1 tags |
| Cross-Vendor Compatibility | All equipment from different vendors will be interoperable |
| High Reliability | Extremely high read rates with metal and liquid |
| Read Rate | Processing as ten times faster as Gen1 tags which allows high speed automated operations to deploy RFID tags effectively |
| Better Tag Identification | This eliminates duplicate reads during multiple tag scans |
| Kills | Tags can be permanently killed by a reader |
| Timing | Allows tags to enter reader field late and still be read; Gen 1 tags would be missed |

*Note.* From "RFID Strategy—What Does the Gen2 RFID Standard Mean to You?," by Chris York, 2005, *Industry Week, January 18.* Reprinted with permission from the author

Though the next generation tags describe technological improvements, many operations are skeptical of these improvements (Ferguson, 2005). The first generation of technology proved there are several environmental problems which include the fact that radio waves can be absorbed by liquid materials and distorted or reflected by metal materials. Both are instances which limit the abilities of RFID (Jones, 2005). These environmental problems require testing not speculation. Later we provide evaluation of this suggested generational improvement for the NASA ISS environment.

## PROBLEM STATEMENT AND HYPOTHESIS

### Problem statement

The processes aboard the ISS consist of manual scanning of barcodes by astronauts to capture data for the inventory management system software. Due to the aforementioned problems associated with this process, this study sought to answer the problem statement of whether RFID is reliable enough to use aboard the ISS. The primary project objective was to test and evaluate the reliability of commercially available RFID technologies and their ability to perform in the ISS environment. This paper details the experimental design and results of the experiments on passive EPC Global Passive Gen 2 RFID tags (GEN 2 RFID tag). Compared with the Gen 1 protocols, the Gen 2 protocols bear many performance enhancements, such as superior tag throughput, improved accuracy and compliance with global spectrum regulations (Meek, 2006). We relate the results to earlier analyses of Gen 1 tags and describe their performance.

Utilizing the list of consumable items on the ISS along with testing specifications provided by NASA a working hypothesis was formed. The main specifications are as follows:

1. Bag/container needs to be scanned within 10-15 seconds;
2. Tag read accuracy needs to be greater than or equal to 99%;
3. Tag size must not to exceed 3 inches x 2 inches;
4. Tagged items in each bag/container need be comparable with specific list of items provided.

Thus, the working hypothesis was given as an Gen 2 RFID tag can be reliably scanned 99% of the time on consumable items aboard the ISS. This study describes the testing of this hypothesis along with parameters that would allow for the best performance of those tags in the environment. Using Design of Experiments (DOE) methodologies the parameters tested were tag placement, antenna configurations, and antenna polarizations that provide the best performance for these tags in the ISS environment.

## Previous Gen 1RFID study

Previously, the team tested multiple RFID technologies which included the testing of EPC Global Passive Gen 1 RFID tags. Validation of the aforementioned problem statement was performed by identifying and confirming customer requirements. A common quality tool described as the House of Quality (HOQ) was utilized (Breyfogle, 2003). The results are shown in Table 3. In the HOQ analysis, the left side shows the customer requirements and the right side shows the result scores for meeting the requirements, while the top shows the design requirements. The tool takes customer preferences and demands and then turns them into technical requirements that can be quantified, measured, and analyzed. The HOQ tool directed the focus of the experiment and previous research. The customer requirements depicted on the left side of the HOQ showed that the three top criteria were accurate inventory, low crew interaction, and low infrastructure with scores of 335, 260, and 148. They also represent meeting approximate 60 percent of customer specifications.

**Table 3. Identification of 3 Top Criteria of Customers of Radio Frequency Identification Technology, as Determined by House of Quality Test**

Interactions

| | Readability of Tags in Environment | Time to Inventory | Cost of Development | Time of Development | Cost of Implementation | Time of Implementation | Life Expectancy of Tags | Life Expectancy of Reader | Power Life of Reader (Recharging) | Range of Tag |
|---|---|---|---|---|---|---|---|---|---|---|
| Time to Inventory | -1 | | | | | | | | | |
| Cost of Development | -1 | -1 | | | | | | | | |
| Time of Development | -1 | -1 | 2 | | | | | | | |
| Cost of Implementation | -1 | -1 | 1 | 1 | | | | | | |
| Time of Implementation | -1 | -1 | -1 | -1 | -1 | | | | | |
| Life Expectancy of Tags | -1 | -1 | -1 | | -1 | | | | | |
| Life Expectancy of Reader | | | -1 | -1 | -1 | -1 | | | | |
| Power Life of Reader (Recharging) | -2 | -2 | | | -2 | -1 | | | | |
| Range of Tag | -2 | -2 | | | | | 1 | | | |
| Size of Tag | -2 | -2 | | | | | -1 | | | -2 |

| Customer Requirements | Design Requirements | Readability of Tags in Environmen | Time to Inventory | Cost of Development | Time of Development | Cost of Implementation | Time of Implementation | Life Expectancy of Tags | Life Expectancy of Reader | Power Life of Reader (Recharging) | Range of Tag | Size of Tag | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | X | N | N | N | N | N | X | X | X | T | N | | |
| Accurate Inventory | 5 | 9 | 3 | 9 | 9 | 3 | 3 | 9 | 9 | 3 | 9 | 1 | 335 | 27.92% |
| Low Crew Interaction | 5 | 3 | 9 | 9 | 9 | 3 | 9 | 1 | 3 | 3 | 3 | | 260 | 21.67% |
| Low Infrastructure | 4 | 3 | 3 | 3 | | 9 | 9 | | 3 | 3 | 3 | 1 | 148 | 12.33% |
| Radiation Proof | 5 | 9 | | 3 | 3 | 3 | | | | | | | 90 | 7.50% |
| Low Power Requirements | 3 | | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 9 | 1 | 102 | 8.50% |
| Durability | 4 | 9 | 3 | 3 | 1 | | | | 3 | 1 | | | 80 | 6.67% |
| Non Intrusive (to packing) | 3 | 3 | 3 | 3 | 3 | 3 | 1 | 3 | | | 9 | 9 | 111 | 9.25% |
| Short Implementation Time | 2 | 1 | 3 | 3 | 9 | 9 | 9 | | | 3 | | | 74 | 6.17% |

The team recognized that to meet the aforementioned criterion of accurate inventory the tags should be tested for reliability. To meet this need tests were performed on read range, read accuracy and manufacturer reliability with different floor angles, polarizations and tag angles. After all tests were conducted, the minimum approximate read ranges of each specified RFID system were determined; three factors—floor angle, polarization and tag angle—were determined to be significant; and all Gen 1 tags were able to attain 100% readability given certain conditions. It was also determined that RFID passive technologies had the ability to help streamline the ISS inventory management systems. The limitations on implementation were that tagged items could only be scanned after they were taken from the NASA ISS stowage containers but could not be read through the containers. This limitation suggested that Gen 1 passive RFID tags could provide inventory validation not inventory audits. Other more expensive RFID solutions and developments such as Smart Shelf System, Door portals, and auto sensing tags were analyzed and ranked as alternatives.

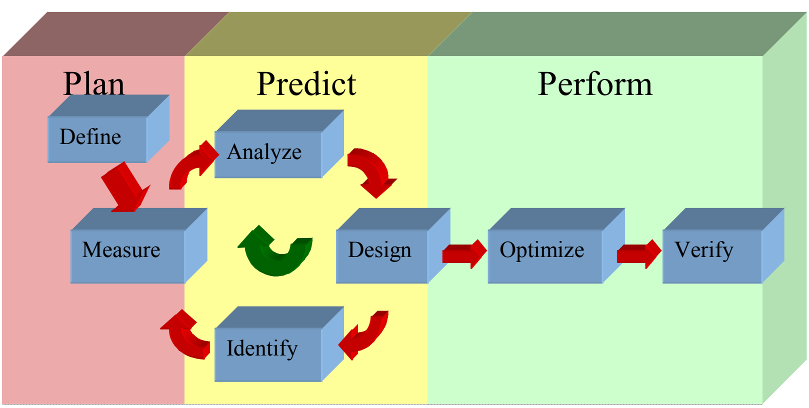
Approximately two years later, the development of a more powerful and useful Gen 2 RFID tag suggested great promise in solving the astronaut auditing problem. The next research step suggested is to test the abilities of these tags in the same environment and evaluate the results. We describe the results in the framework of our DFSS-R methodology.

## RESEARCH METHODOLOGY

### University of Nebraska-Lincoln DFSS-R methodology

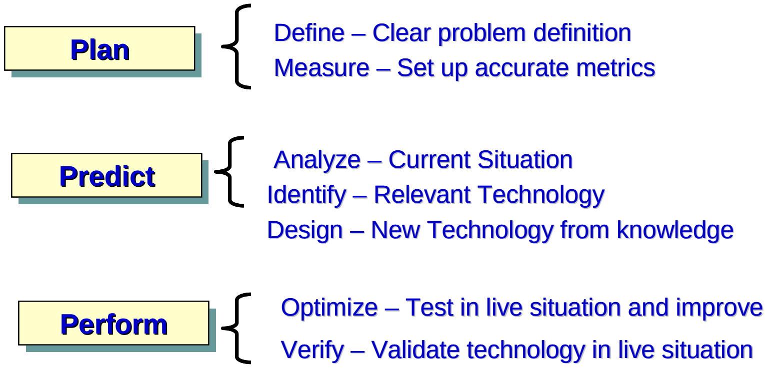
In this study the methodology used was derived in the RFID Supply Chain Lab at the University of Nebraska (RfSCL) called Design for Six Sigma Research (DFSS-R). It is based on the Plan-Do-Check-Act (PDCA) strategy and is a hybrid version of common Six Sigma and Design for Six Sigma methods (Yang & El Haik, 2003). Traditional research methods were fused with the industrial continuous improvement methodology Six Sigma to create the research methodology DFSS-R. The methodology is based on a strategy to test existing technologies that may later lead to operational prototypes and is organized into a theoretical Plan, Predict, and Perform model as shown in Figure 1.

**Figure 1. Design for Six Sigma Research Plan, Predict and Perform Methodology**




This paper describes the results of the predict phase of this methodology. This phase contains analyze, identify and design steps as shown in Figure 2. In this phase experiments are conducted, measured and evaluated. The analysis tool utilized in this phase is labeled as sequential design of experiments (Breyfogle, 2003).

**Figure 2. Explanation of Plan, Predict and Perform Process Steps**




**Sequential design of experiments**

DOE is a quality analysis tool that is utilized in the analyze, design and identify loop of the DFSS-R methodology. This tool uses information learned from the first or previous experiments to eliminate unnecessary or undesirable experimentation within the previous series of experiments. This method provides a powerful means to achieve breakthrough improvements in product quality and process efficiency (Anderson & Kraber, 2006). The four sequential experiments that were conducted are described below.

***Experiment 1***

The first experiment tested the off the roll quality of tags by using an acceptance sampling test. A method described in MIL STD 105E acceptance standard (a military AIDC standard) was used to verify if the roll of Gen 2 RFID tags had an acceptable quality level (AQL). AQL is the maximum number of defects per hundred units for purpose of sampling inspection that can be considered satisfactory as a process average. For rolls of 500 tags, 50 random tags were tested for read and write capabilities by tag manufacturer. A standard fixed Gen 2 reader and a standard mobile RFID Gen 2 reader were utilized for this reading and writing to the Gen 2 tags. An assortment of seven common Gen 2 RFID tags across 5 tag manufacturers was tested for performance. The common tags were determined by an informal survey of RFID tag users who performed research in the RfSCL, most tag users were associated with supply chain logistics operations.

***Experiment 2***

The second experiment tested tag read ranges. This experiment provided insight on the acceptable distances that tags could accurately be read using various types of readers. The experiment was setup by placing three RFID tags from the same manufacturer in front of each type of reader and testing for read accuracy as the tags were moved further away from the reader. The results from this experiment established two levels that we later used as our distance factors for mobile and stationary readers.

***Experiment 3***

The third experiment examined how different factors affected the read accuracy. The same type of Gen 2 RFID tag used in Experiment 2 was utilized to test four different factors (Clarke, Twede, Tazelaar & Boyer, 2005):

1. Equipment (tags and readers);
2. Read distance;
3. Tag orientation; and
4. Tagged materials.

This experiment used a standard $2^4$ factor DOE format. Generally, four factors or components are each tested at two different levels. The levels generally are the minimum and maximum (or lowest and highest) target values for the component. The factors and example level description in this study are listed below:

1. RFID Readers. Types of readers utilized (mobile and stationary readers).
2. Read distance. Distances that represent the shortest operationally acceptable average distance and the average maximum distance for the respective readers. A minimum operationally acceptable minimum distance for NASA ISS is 1 foot.
3. Tag orientation. Orientations (horizontal, perpendicular, etc.) with respect to the reader antenna. Examples are shown in Figure 3.
4. Tagged materials. Materials tested were consumable materials used on the ISS. Generally these items were packaged in cardboard, metallic and liquid containers. This packaging and contents is similar to the products utilized by NASA ISS. A sample of these items which contained both metallic and liquid based items is shown in Figure 4.

**Figure 3. Examples of Orientation of Radio Frequency Identification Tags**

**Figure 4. Samples of Radio Frequency Identification Tagged Materials**

### *Experiment 4*

The final experiment used the results from the previous experiments to create an optimal experimental setup in order to compare the performance of different Gen 2 RFID tags across multiple manufacturers in a simulated NASA ISS operational environment. Given that the Gen 2 RFID is a standard and all tag manufacturers produced acceptable performance in Experiment 1, the variance provided by this cross section of vendors was expected to provide insight to overall performance.

## RESEARCH RESULTS

The experiments were conducted and results of each were measured and analyzed. The analysis from each of the experiments is discussed below:

### *Experiment 1*

An acceptance sampling test was completed for all Gen 2 RFID tags used within the experiment. All randomly selected tags had read and write capabilities. Since there were no defects found on any of the tags, they were approved for further testing.

***Experiment 2***

The second experiment used the mobile and fixed readers and one of the tag manufacturers for providing a benchmark for performance. Since the results from this experiment only established the distinct distance levels for the next experiment, only one manufacturers tag type was tested. A summary of results were:

1. A read distance of one foot was consistently met as the acceptable maximum distance for the mobile reader. Other distances less than one foot could be achieved.
2. A read distance of three feet was the maximum distance for stationary readers. Other distances greater than three feet could be achieved.
3. Nine feet was the maximum mobile reader scanning distance but eight feet was the most reliable maximum scanning distance.
4. Twenty-seven feet was the maximum stationary reader scanning distance but twenty feet was the most reliable maximum scanning distance.

The overall results from the testing established the following acceptable distance levels for accurate tag reads:

1. Mobile reader. read range achieved is a minimum of zero feet to a maximum of nine feet, acceptable read ranges are a minimum of one foot to a maximum of eight feet.
2. Stationary reader. read range achieved is a minimum of zero feet to a maximum of twenty-seven feet, acceptable read ranges are a minimum of three feet to a maximum of twenty feet.

***Experiment 3***

The $2^4$ DOE experiment was also conducted with the mobile and stationary readers along with the same RFID tag type. Table 4 shows all the results of tag readability with the change of four different factors. A summary is described below:

1. RFID reader. Reader type had a significant effect on performance.
2. Read distances. Read distances in the range of 1 to 3 feet had significant effect on performance.
3. Tag orientations. Horizontal and a mixed (angled) orientations had significant effect.
4. Tagged material. Cardboard and mixed (metallic and liquid) packaged material had significant effect.

**Table 4. Impact of Selected Factors on the Readability of Radio Frequency Identification Tags**

| Reader | Distance | Orientation | Material | R1 | R2 | R3 |
|---|---|---|---|---|---|---|
| Mobile | 1ft-3ft | Horizontal | Cardboard | 10 | 10 | 10 |
| Stationary | 1ft-3ft | Horizontal | Cardboard | 10 | 10 | 10 |
| Mobile | Max | Horizontal | Cardboard | 8 | 9 | 10 |
| Stationary | Max | Horizontal | Cardboard | 7 | 6 | 5 |
| Mobile | 1ft-3ft | Mixed | Cardboard | 10 | 10 | 10 |
| Stationary | 1ft-3ft | Mixed | Cardboard | 7 | 7 | 8 |
| Mobile | Max | Mixed | Cardboard | 7 | 7 | 7 |
| Stationary | Max | Mixed | Cardboard | 2 | 2 | 2 |
| Mobile | 1ft-3ft | Horizontal | Mixed | 7 | 5 | 7 |
| Stationary | 1ft-3ft | Horizontal | Mixed | 3 | 2 | 2 |
| Mobile | Max | Horizontal | Mixed | 1 | 2 | 2 |
| Stationary | Max | Horizontal | Mixed | 0 | 0 | 0 |
| Mobile | 1ft-3ft | Mixed | Mixed | 3 | 3 | 2 |
| Stationary | 1ft-3ft | Mixed | Mixed | 0 | 0 | 0 |
| Mobile | Max | Mixed | Mixed | 0 | 0 | 0 |
| Stationary | Max | Mixed | Mixed | 0 | 0 | 0 |

The results from the experiment indicate that all of the selected factors had a significant impact on the readability of the tags (p-values < 0.01) as displayed in Table 5, as well as the interaction between each of two factors from the RFID reader, read distance, tag orientation and tagged material as indicated in Figure 5. The scanning equations yield an R-square value of 98.69% (Montgomery, 2000).

**Table 5. Analysis of Selected Factors on the Readability of Radio Frequency Identification Tags**

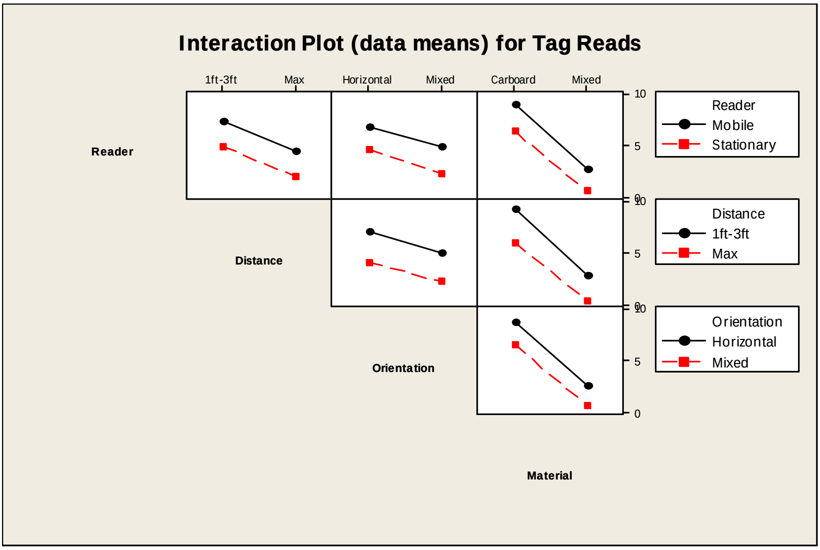
**Full Factorial Design**

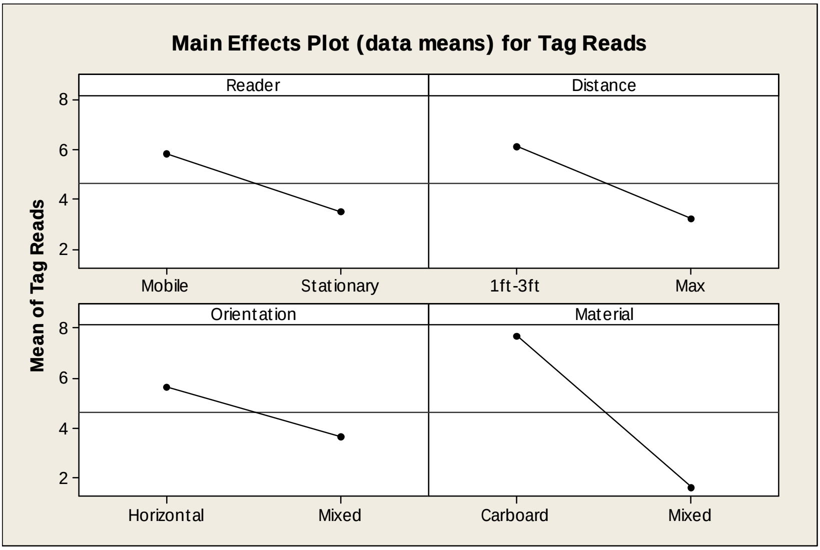
```
Factors:   4   Base Design:        4, 16
Runs:     48   Replicates:             3
Blocks:    1   Center pts (total):     0
```

**Factorial Fit: Tag Reads versus Reader, Distance, Orientation, Material**

```
Estimated Effects and Coefficients for Tag Reads (coded units)
Term                                 Effect    Coef  SE Coef       T      P
Constant                                      4.646  0.07795   59.60  0.000
Reader                               -2.375  -1.188  0.07795  -15.23  0.000
Distance                             -2.875  -1.437  0.07795  -18.44  0.000
Orientation                          -2.042  -1.021  0.07795  -13.10  0.000
Material                             -6.042  -3.021  0.07795  -38.75  0.000
Reader*Material                       0.292   0.146  0.07795    1.87  0.071
Distance*Material                     0.458   0.229  0.07795    2.94  0.006
Reader*Distance*Material              1.292   0.646  0.07795    8.29  0.000
Reader*Orientation*Material           0.958   0.479  0.07795    6.15  0.000
Distance*Orientation*Material         0.958   0.479  0.07795    6.15  0.000
S = 0.540062   R-Sq = 98.69%   R-Sq(adj) = 98.07%
```

**Figure 5. Interaction and Main Effect Plots for Factor Analysis on the Readability of Radio Frequency Identification Tags**



***Experiment 4***

The final situational experiment used the mobile reader to test all the available Gen 2 RFID tags in the simulated environment. The tags were tested within both a Russian ISS container and a knapsack type material used to simulate an ISS container (soft bag). This experiment tested tags on both cardboard (paper) based material and mix packaging materials including metallic and liquid based items. For each of the distinct scenarios, 15 observations were taken. The results from the analysis are showed in Table 6 and Figure 6. From Figure 6, we can see there is an evident difference between readability of tags attached on paper material and mixed materials within the Russian container and soft bag. Tags on paper material in the soft bag give us a much higher percent of tags read and smaller standard deviation than tags on mixed material in the metallic Russian container. All detailed read results for each brand of tags are shown in Table 7.

**Table 6. Analysis of Effect of Storage Device on Percent of Radio Frequency Identification Tags Read**

| | Analysis Variable : Percent of Tags Read | | | | | |
|---|---|---|---|---|---|---|
| **Storage Device** | **Materials** | **Mean** | **Std Dev** | **Min.** | **Max.** | **N** |
| Russian Container | Mixed Materials | 8 | 7 | 0 | 27 | 105 |
| | Paper Materials | 23 | 14 | 0 | 53 | 105 |
| Soft Bag | Mixed Materials | 38 | 18 | 7 | 87 | 105 |
| | Paper Materials | 99 | 3 | 87 | 100 | 105 |

**Figure 6. Plot of Analysis of Effect of Storage Device on Percent of Radio Frequency Identification Tags Read**

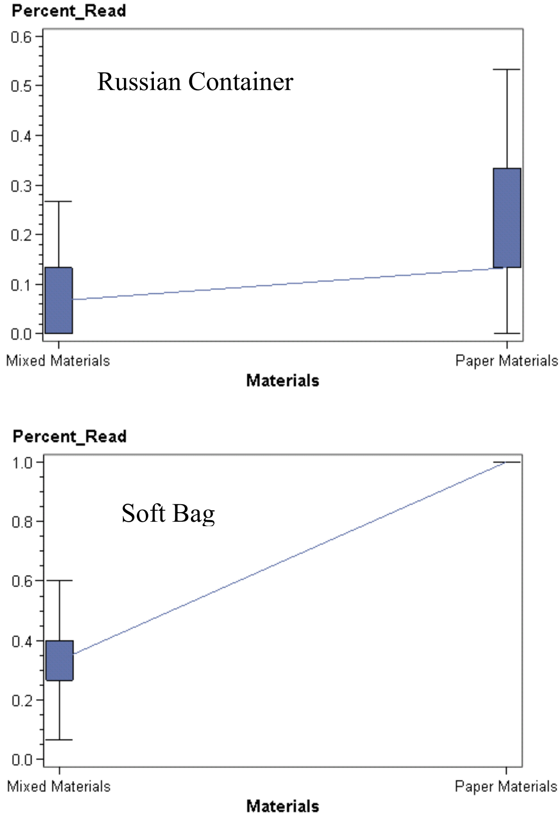


**Table 7: Tag Type and Storage Device Analysis on Percent of Tags Read**

| Analysis Variable : Percent of Tags Read | | | | | |
|---|---|---|---|---|---|
| **RFID Tag Type** | **Storage Device** | **Materials** | **Mean** | **Std Dev** | **N** |
| "Rafsec "G2" Short Dipole" | Russian Container | Mixed Materials | 4 | 3 | 15 |
| | | Paper Materials | 16 | 3 | 15 |
| | Soft Bag | Mixed Materials | 25 | 6 | 15 |
| | | Paper Materials | 1 | 0 | 15 |
| Alien Gen 2 Squiggle | Russian Container | Mixed Materials | 14 | 7 | 15 |
| | | Paper Materials | 39 | 5 | 15 |
| | Soft Bag | Mixed Materials | 27 | 8 | 15 |
| | | Paper Materials | 100 | 0 | 15 |
| Avery Gen 2 AD G12 | Russian Container | Mixed Materials | 16 | 8 | 15 |
| | | Paper Materials | 47 | 3 | 15 |
| | Soft Bag | Mixed Materials | 76 | 9 | 15 |
| | | Paper Materials | 100 | 0 | 15 |
| Impinj Thin Propeller | Russian Container | Mixed Materials | 6 | 5 | 15 |
| | | Paper Materials | 10 | 4 | 15 |
| | Soft Bag | Mixed Materials | 21 | 5 | 15 |
| | | Paper Materials | 95 | 5 | 15 |
| Omron Gen 2 Wave | Russian Container | Mixed Materials | 8 | 3 | 15 |
| | | Paper Materials | 11 | 3 | 15 |
| | Soft Bag | Mixed Materials | 35 | 8 | 15 |
| | | Paper Materials | 100 | 0 | 15 |
| Rafsec Frog G2 | Russian Container | Mixed Materials | 9 | 3 | 15 |
| | | Paper Materials | 24 | 4 | 15 |
| | Soft Bag | Mixed Materials | 43 | 7 | 15 |
| | | Paper Materials | 100 | 0 | 15 |
| Rafsec Short Dipole | Russian Container | Mixed Materials | 0 | 0 | 15 |
| | | Paper Materials | 12 | 3 | 15 |
| | Soft Bag | Mixed Materials | 38 | 4 | 15 |
| | | Paper Materials | 100 | 0 | 15 |

## RESEARCH LIMITATIONS

A single tag manufacturer was used in both Experiments 2 and 3 in order to reduce additional variation that would be caused by multiple vendors. Experiments 2 and 3 are utilized to identify significant factors and levels. It was hypothesized that minimizing variation in this fashion would be prudent. The multiple vendor variation would be identified in Experiment 4 when overall performance can be compared.

## CONCLUSION

The promise of using RFID technologies for NASA and the ISS is the opportunity to eliminate the labor aspect that is associated with having accurate inventory control. The cost of the astronauts' time and nuisance factors are key driving factors to identifying automated options that eliminate the human labor element. Current options available such as barcoding are limited in that they provide traceability but at the cost of human intervention. The previous generation of RFID provided an improvement on this option by providing automatic traceability after an item has been used or consumed. This benefit was documented in the previous study by Jones (2005). It was also demonstrated that automated audits of current containerized inventory was not possible.

Recent breakthroughs in the Gen 2 RFID tags provided the promise that automated audits may be achievable. The goal of this study was to investigate and evaluate if the technology is mature enough to implement this type of inventory control. Building on the methodology (DFSS-R) previously utilized by the research team testing of the Gen 2 automatic auditing capabilities were conducted. If the testing is proven valid the methodology has the means to make this type of inventory control operational.

In this paper we introduced the DFSS-R methodology investigated and derived in the RfSCL at the University of Nebraska. We also utilized DOE analysis tool in the circle of analyze, design and identify and designed four sequential experiments accordingly to test various factors impacting upon a tag's performance including tag placement, antenna configurations, and antenna polarizations. The DFSS-R methodology helps us build a scientific testing procedure and makes sure that the experiments eliminate unnecessary or undesirable experimentation from previous experiments and provides accurate information of tag performance in the ISS environment.

The testing of Gen 2 RFID technology used a series of experiments which provided detailed information for examining the read quality of Gen 2 RFID tags. The first experiment showed that Gen 2 RFID tags had an acceptable initial off the roll quality level. This quality level was an improvement from previous generations of RFID because the previous generations of tags had poor quality from the roll. The third experiment tested various factors affecting tag reads and provided information on how to achieve optimal results when using Gen 2 RFID tags.

The past problems with RFID that were identified in Gen 1 tags were tested in the final experiment and the DOE analysis shows that they still exist. As discovered in earlier experiments, the major problem with Gen 1 tags was the decrease of signal strength when attaching tags to liquid and metal materials. The final experiment verified that multiple types of Gen 2 RFID tags had the same aforementioned problem. In the simulated environment, the Gen 2 RFID tags would be read on liquid material with limited signal strength, but would not be read when placed on metallic packages or in metallic containers. Again, operations can utilize Gen 2 RFID tags for verification of inventory passing through portals to verify information but not for automatic auditing in the ISS environment.

Further, 100% read rates were only attainable when attaching tags to cardboard materials and were not close to the alleged 100% read rates with metal and liquid materials. Again, as discovered with Gen 1 tags a working space such as packaging that presents 1 inch gaps on metallic containers would be necessary. It was concluded that though Gen 2 technologies have improved over Gen 1 tags, the current environment requires another AIDC or RFID technology to support automated audits. Other RFID technologies such as real-time location systems, Active RFID (RFID tags with batteries), and other sensor based technology options have been discovered since this project that may provide this automation. For information on other RFID technology results please contact the researchers.

## ACKNOWLEDGMENTS

This work was completed as a part of National Science Foundation Industry/University Cooperative Research Centers Program (NSF I/UCRC). The University of Nebraska-Lincoln is the site for the Centers for Engineering and Logistics and Distribution (CELDI). Also, NASA EPSCOR and the Nebraska Space Foundation provided additional support. Dr. Erick C. Jones , University of Nebraska-Lincoln served as the principal investigators, with Micheal A. Cooke, Patrick Fink (NASA's Johnson Space Center), and Amy Schellease (Barrios Technology, a contractor for NASA Johnson Space Center). Other participants to the projects include graduate students at UNL, Tim Farnham and Adam Rogers, who were funded during these projects. Nathan Nowak conducted testing of these Gen 2 RFID tags and the initial reports, and Jane Silveray worked tirelessly on reviewing references. Also, I would like to thank David Cochran for his tireless revisions.

## REFERENCES

Anderson, Mark J., & Kraber, Shari L. (2006). Keys to successful designed experiments. Retrieved Dec 25th, 2007 from http://www.isixsigma.com/tt/doe/

Bradner, S. (2005). Security issues swamp RFID. Retrieved Dec. 25, 2007 from http://www. techworld.com

Breyfogle, F. W., III. (2003). Implementing Six Sigma (second edition). Hoboken, NJ: Wiley.

Clampitt, Harold. (2006). RFID: Certification textbook. Houston: PWD Group, Inc.

Clarke, Robert H., Twede, Diana, Tazelaar, Jeffrey R., & Boyer, Kenneth K. (2005). Radio frequency identification performance: The effect of tag orientation and package contents. Packaging Technology and Science, 2006(19), 45-54.

Collins, Jonathan. (2004). What's next for Gen 2. RFID Journal, Retrieved Dec 25th, 2007 from http://www.rfidjournal.com/article/articleview/1301.

Ferguson, Renee Boucher. (2005). New wave for RFID: EPC’s UHF Gen 2 works in dense reader environments. eWeek, 22(1), 30.

Hou, Jiang-Liang, & Huang, Chih-Hao. (2006). Quantitative performance evaluation of RFID applications in the supply chain of the printing industry. Industrial Management & Data Systems, 106(1), 96-120.

Jones, E. C. (2005). RFID technology for tracking inventory in the space shuttle. Proceedings of the Annual Meeting of the Nebraska Academy of Sciences Aeronautics & Space Science, Lincoln, Nebraska, 100(15), 26..

Jones, E. C., & Nowak, N. (2007). Testing of Gen 2 RFID tags for tracking inventory in the space shuttle. Proceedings of the Annual Meeting of the Nebraska Academy of Sciences Aeronautics & Space Science, Lincoln, Nebraska, 100(17), 23.

Jones, Peter, Clarke-Hill, Colin, Hiller, David, Shears, Peter, & Comfort, Daphne. (2004). Radio frequency identification in retailing and privacy and public policy issues. Management Research News, 27(8/9), 46-56.

Juban, Rusty L., & Wyld, David C. (2004). Would you like chips with that?: Consumer perspectives of RFID. Management Research News, 27(11/12), 29-44.

Landt, Jeremy. (2001). Shrouds of time: The history of RFID. Pittsburgh: AIM Inc.

Leary, Warren E. (2004, December 10). With food running low, space crew must cut back. New York Times, p. 38.

Carreau, Mark. (2004, December 10). Space station crew endures food shortage. Houston Chronicle, p. 4.

Meek, Michelle. (2006, January 11). Zebra technologies reveals top 5 RFID Gen 2 do’s and don’ts. PR Newswire. Retrieved Dec 25th, 2007 from http://www.prnewswire.com/cgi-bin/stories.pl?ACCT=104&STORY=/www/story/01-11-2006/0004247179&EDATE=

Montgomery, Douglas. (2000). Statistical quality control. New York: John Wiley and Sons.

Phan, Chan T., Arndt, D., Ngo, P., Gross, J., Ni, Jianjun, & Rafford, Melinda. (2006). Performance evaluation of a UWB-RFID system for potential space applications. Houston: Johnson Space Center.

Ranky, Paul G. (2006). An introduction to radio frequency identification methods and solutions. Assemby Automation, 26(1), 28-33.

Scholl, G., Schmidt, F., & Wolff, U. (2001). Surface acoustic wave devices for sensor applications. physica status solidi (a), 185(1), 47-58.

Yang, Kai, & El-Haik, Basem. (2003). Design for Six Sigma: A roadmap for product development. New York: McGraw-Hill Companies, Inc.

York, Chris. (2005). RFID strategy—what does the Gen 2 RFID standard mean to you? Industry Week, January 18, Retrieved Dec. 25, 2007 from http://www.industryweek.com/ReadArticle.aspx?ArticleID=9622

# BOOK REVIEW

Dismukes, R. K., Berman, B. A., & Loukopoulos, L. D. (2007). *The limits of expertise: Rethinking pilot error and the causes of airline accidents.* Aldershot, Hampshire: Ashgate Publishing Limited. Pp. 352. ISBN 0-75-464965-2. U.S. $39.95 soft cover.

REVIEWED BY BEN DALEY, Manchester Metropolitan University.
Daley is a Research Associate at the Centre for Air Transport and the Environment (CATE) at Manchester Metropolitan University. He holds a Ph.D. in Environmental History, awarded by James Cook University, Australia. Ben is currently working on the EFAS (Environmentally Friendly Airport ATM Systems) project, funded by the UK Department of Trade and Industry (DTI), investigating interactions between environmental impacts, aircraft operations and safety during the aircraft landing and take-off cycle.

Air travel has become remarkably safe as a result of advances in equipment systems, operating procedures and training. Each year, flight crews deal skillfully with sub-optimal systems and unexpected situations during the course of around 17 million flights world-wide. Yet airlines operate in a highly competitive market with pressures to deliver unprecedented levels of efficiency, so it is now more important than ever to understand what makes the air transport system vulnerable to failure. Since most aviation accidents have been attributed to deficiencies in the performance of flight crews, it is particularly important to understand what makes pilots vulnerable to error.

In this outstanding and original book, the authors argue that human skill and vulnerability to error are closely linked: errors occur because flight crews are expected to perform tasks at which perfect reliability is not possible—either for humans or machines. The authors show that the presence and interaction of factors contributing to error is probabilistic rather than deterministic. Accidents are rarely caused by a single factor, but rather by the complex interaction of many factors that combine in ways driven largely by chance. The authors argue that small, random variations in the presence and timing of those factors can drastically increase the probability of pilots making errors leading to an accident.

Consequently, it is crucial to understand the nature of vulnerability to error in order to reduce that vulnerability. While it is not always possible to determine exactly why accident crews did what they did, the authors demonstrate that it is possible to understand the types of error to which pilots are vulnerable—and to understand the interplay of various factors contributing to that vulnerability. The central questions posed in this book are: (a) why do highly skilled professional pilots make errors, with consequences that are sometimes fatal to themselves and to their passengers; and (b) how should we understand the role of these errors in accidents in seeking to prevent future accidents. The authors apply scientific knowledge of the nature of skilled performance of humans performing complex tasks to address these questions.

The book reviews the 19 major accidents in US airline operations during the period 1991-2000 in which crew errors played a central role, as defined by the US National Transportation Safety Board (NTSB), based on the NTSB reports and associated documents. While the NTSB must determine the probable cause of each specific accident, the authors take a different approach asking whether other pilots would be vulnerable to making the kinds of errors made by the accident crew and, if so, why. This original approach reveals factors that make all pilots vulnerable to specific types of error in certain situations. In adopting this approach, the authors challenge the assumption that, if expert pilots make errors, this is evidence of their lack of skill, vigilance or conscientiousness. Instead, the authors emphasise the interactions of subtle variations in task demands, incomplete information available to pilots, and the inherent nature of skilled performance. The authors go beyond accident investigation, therefore, to explore the common themes and 'deep structure' underlying the accidents.

In addition to the stand-alone accident chapters, the authors provide a statistical summary chapter that extends an earlier study by the NTSB and that reviews accident data for a longer period (1978-2001). In the final chapter, the authors identify the main themes and implications of their study, suggesting specific ways to improve aviation safety. Many issues are raised, including the significance of crew familiarity, crew fatigue, first officer experience levels, unstabilized approaches, plan continuation bias, misleading or absent cues, and monitoring/challenging errors. The authors reframe these airline accidents as 'system accidents' resulting from the lack of adequate information provided to crews, the inherent difficulties of assessing ambiguous situations, and the less than extremely conservative guidance given to pilots by the air transport industry.

Overall, this is an excellent and innovative text which reflects the authors' original approach to airline safety. The book is outstanding in its identification of common themes that run deeper than in previous analyses of aviation safety, and the final chapter contains clear, pragmatic guidance to the air transport industry and to researchers. In the final sections of the book, the authors sum up the central challenge faced by the industry in reducing vulnerability to error: pilots should be given more information, better interfaces and clearer decision-making guidance—backed up by prioritising adherence to that guidance over commercial pressures such as on-time performance.

The book will be informative for diverse readers in the air transport industry, including operational staff, researchers, safety analysts, accident investigators, designers of systems and procedures, training providers and students. Given the nature and scope of their study, the authors have focused on the US context, yet their approach could valuably be applied to other parts of the world: a comparable study for Europe, for instance, would be revealing. Their approach could also be extended to other parts of the air transport system, such as air traffic management, where the performance of skilled experts is also implicated in some airline accidents.

The main significance of this book is in its re-framing of the causes of airline accidents: the authors argue that, if we must continue to conceive of airline accidents in terms of deficiency, then that deficiency should be attributed to the overall air transport system. Such an approach can contribute to aviation safety by providing a foundation for improving equipment, training, procedures and organisational policy. In so doing, it is possible to reduce the frequency of ‘system accidents’ and to devise adequate protection against the types of errors to which many, if not all, pilots—as well as many other experts—are vulnerable.

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### Number 2 (2007) pp. 1-101

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