University of Nebraska at Omaha Aviation Institute

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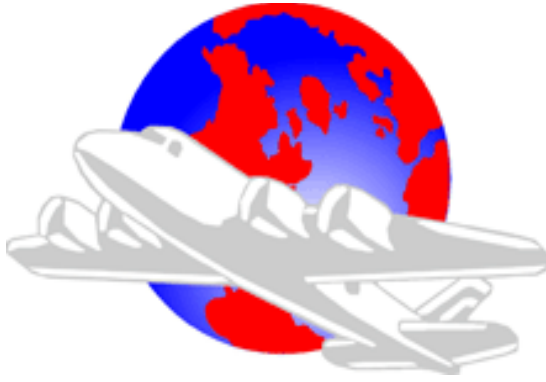
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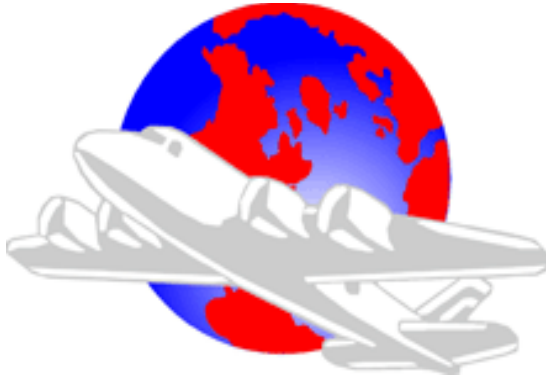
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The Editors

Brent D. Bowen

Dr. Brent Bowen is Director and Distinguished Professor, Aviation Institute, School of Public Administration, University of Nebraska at Omaha, and the University's Director of Aviation and Transportation Policy and Research. 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 Maintenance Department and member of the Technical Committee on Transport 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.

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THE EFFECTS OF SAFETY INFORMATION ON AERONAUTICAL DECISION MAKING

Jang R. Lee
Purdue University

Richard O. Fanjoy
Purdue University

Brian G. Dillman
Purdue University
West Lafayette, Indiana

ABSTRACT

The importance of aeronautical decision making (ADM) has been considered one of the most critical issues of flight education for future professional pilots. Researchers have suggested that a safety information system based on information from incidents and near misses is an important tool to improve the intelligence and readiness of pilots. This paper describes a study that examines the effect of safety information on aeronautical decision making for students in a collegiate flight program. Data was collected from study participants who were exposed to periodic information about local aircraft malfunctions. Participants were then evaluated using a flight simulator profile and a pen and pencil test of situational judgment. Findings suggest that regular access to the described safety information program significantly improves decision making of student pilots.

Dr. Jang R. Lee received a Master of Science in Aviation Safety from Central Missouri State University and a Ph.D. in Technology from Purdue University. He is currently assigned to Headquarters, Republic of Korea Air Force, Taejon, Korea.
Dr. Richard. O. Fanjoy received a Master of Arts in Industrial Management from Central Michigan University and a Ph.D. in Higher Education from Purdue University. He is an Assistant Professor, Department of Aviation Technology, Purdue University, with extensive flight experience in worldwide operations of heavy jet aircraft.
Brian G. Dillman received a Master of Arts in Curriculum and Instruction from Purdue University. He is an Assistant Professor and the Assistant Director of Flight Training, Department of Aviation Technology, Purdue University.

INTRODUCTION

Sound pilot decision making is essential to the safe completion of every flight. O'Hare (2003) indicates that "It is difficult to think of any single topic that is more central to the question of effective human performance in aviation than that of decision making" (p. 230). The term aeronautical decision making (ADM) has been used to describe and assess pilot judgment within many aviation circles (Jensen, 1997) Paradoxically, aeronautical decision making, so crucial to the safety of flight, often receives scant emphasis in pilot training. Richard Jensen, the General Chair of the Ninth International Symposium on Aviation Psychology, commented, "Unfortunately, most student pilots do not receive structured decision making or judgment training either in their initial or later flying experience…[and]…How can we expect them to reach above the level of competence if we do not teach judgment?" (Jensen, 1997, p. iv). Jensen suggests that training in aeronautical decision making/judgment can take the form of reading case studies about accidents and incidents as well as studying the experiences of other pilots in abnormal situations.

Eiff (1999) suggests that the state of intelligent and respectful wariness can foster a heightened state of vigilance for error potentials and dedication to performing safe acts. In addition, Reason (1997) notes that:

> In the absence of bad outcomes, the best way—perhaps the only way—to sustain a state of intelligent and respectful wariness is to gather the right kinds of data. This means creating a safety information system that collects, analyzes and disseminates information from incidents and near misses as well as from regular proactive checks on the system's vital signs. (p. 195)

Many safety information systems in aviation have been developed around the world, including the Aviation Safety Reporting System (ASRS) developed by the National Aeronautics and Space Administration (NASA), the Confidential Human Factors Incident Reporting Programme (CHIRP) used in the United Kingdom, and the British Airways Safety Information System (BASIS). Three years ago, Purdue University researchers created a safety information system entitled the Aircraft Discrepancy Analysis Metrics (ADAM). Dillman, Lee, and Petrin (2003) have reported on detailed features of ADAM and its utilization. ADAM was originally designed to gather, track, and analyze aircraft discrepancies as a tool for aircraft safety management. It has been used to compile five years of information on mechanical discrepancies for all Purdue aircraft. The description of every aircraft discrepancy written in each logbook has been analyzed and

categorized into a unified metric format. However, most Purdue aviation students are unaware of ADAM because its main application has been at the resource management level.

The content and structure of initial flight education, as in other fields of education, are extremely important. Jensen (1997) feels that "initial training can have an effect on certain aspects of flying that may carry throughout one's career" (p. v). Clearly, initial training in a collegiate flight program is one of the most defining stages for future professional pilots. It is imperative that students acquire sound decision making strategies from the very beginning as this skill forms the basis for an approach to safety decisions throughout their entire professional career. Since most flight education employs little structured judgment training, a safety information system would appear to be a valuable instrument for enhancing desired student aeronautical decision making.

The purpose of this study was to assess whether a safety information system could effectively improve aeronautical decision making for students in a collegiate flight program. Three theories support the potential benefits of safety information to flight students' decision making: the Detailed Judgment Model (Jensen, Adrion, Maresh, & Weinert, 1987), Naturalistic Decision Making Theory (Lipshitz, 1993; Orasanu & Connolly, 1993; Thargard, 1988), and the Learning Framework (Gredler, 2001).

Jensen, Adrion, Maresh, and Weinert (1987) use their Detailed Judgment Model to explain that aeronautical decisions are made with rational and motivational judgments. A safety information system is thought to be beneficial for rational judgment. While motivational judgment deals with personal motivation to execute a suitable course of action, rational judgment follows five sequentially connected steps: problem vigilance, problem recognition, problem diagnosis, alternative identification, and risk analysis. For these steps of rational judgment, a good source of information will help pilot vigilance. Pilots generally use the simplest or most economical interpretation of a stimulus to arrive at the interpretation most likely to match the source of stimulation during problem recognition. Problem diagnosis requires an understanding of prior probabilities for certain events, and comes into significant play when there may be a mechanical problem with the aircraft. The stage of rational judgment where alternatives are identified requires creativity and knowledge of the aircraft. Risk analysis requires computational approximation skills and knowledge of the relative safety in different courses of action (Jensen, 1995).

Naturalistic Decision Making Theory advocates support the beneficial effect of a safety information system. Lipshitz (1993) says that experts in naturalistic decision making tend to generate a single course of action as the best choice. Based on the classification of the problem, decision makers provide a single highly likely option and evaluate its appropriateness to the

current conditions. Orasanu and Connolly (1993) also say that decision makers use their knowledge to organize the problem, to interpret the situation, and to define what information is needed to arrive at a solution. This process allows the decision maker to make a speedy assessment, search, selection, and interpretation of relevant information.

Finally, the Learning Framework reported by Gredler (2001) depicts the potentially beneficial effect of a safety information system to flight students. The learning framework consists of the learner's prior knowledge and organization of the information (encoding) to be learned. The learner's prior knowledge serves to identify incoming information and also influences the inferences made by the learner about new information. Encoding is the process that prepares selected information for storage in long-term memory and later recall. Encoding requires the construction of meaningful links between the new concepts or ideas and the learner's prior knowledge. The higher cognitive functions are characterized by conscious awareness of the encoding process and permit the individual to make use of logical relationships and generalizations (Gredler, 2001).

RESEARCH QUESTIONS

This study considered the hypothesis that a safety information system such as ADAM would have a beneficial effect on student pilots' aeronautical decision making in critical flight safety situations. The following research questions were developed to direct the study.

1. Is the *recognition time* for abnormal aircraft conditions shorter for flight students exposed to periodic review of ADAM than for non-exposed students?

2. Is the *response time* for abnormal aircraft conditions shorter for flight students exposed to periodic review of ADAM than for non-exposed students?

3. Do the flight students who periodically review ADAM follow more appropriate procedures to resolve an abnormal aircraft condition than those who do not?

METHODOLOGY

Participants

Volunteers were recruited from a population of students who were in their second to fourth semesters of a baccalaureate degree program, had received their private pilot certificate, and were training for a commercial pilot certificate. Study participants were randomly selected from the volunteer pool and randomly assigned to equally sized experiment and control groups. Based on a statistical power analysis, forty volunteers were initially assigned to the study. However, six individuals later discontinued

their participation and were dropped from the study. As a result, study findings are based on data collected from 34 participants (17 in each group).

Research Design

    The study treatment consisted of measured access to current ADAM information. This access was through the university's online teaching structure using WebCT Vista. Each flight student in the experimental group was provided WebCT access to the ADAM database throughout the duration of the study. These students were directed to review ADAM prior to each flight and specifically focus on the discrepancy history of the aircraft that they would be flying. Furthermore, periodic reminders and announcements were posted online that directed students to be wary and focus on particular systems failures. This treatment was provided to the experiment group eight times over a five-week period and included information on aircraft system malfunctions. In addition, the control and experiment groups both completed a pre- and post-treatment pencil and paper test of decision making skills and a short simulator profile flight. The ADAM treatment was the independent variable for this study and the dependent variable was flight student judgment during critical flight safety situations, measured in terms of recognition time, response time, and appropriate actions. The ADAM treatment was postulated to positively influence flight student decision making.

Instrumentation

    To answer the research questions in this study, two types of instruments were used, the Situational Judgment Test (SJT) and a Frasca 141 profile flight. The SJT is a paper and pencil type instrument developed by the Federal Aviation Administration (FAA) to assess general aviation pilots' decision making skills. Hunter (2003) advises, "the SJT has potential for use in the assessment of judgment or aeronautical decision making by general aviation (GA) pilots, and might be useful in the evaluation of training" (p. 373). The SJT is used to evaluate differences between solutions recommended by an FAA-designated panel of subject matter experts and judgment/decisions made by general aviation pilots (Hunter, 2003).

    A Frasca 141 flight-training device (FTD) was used to measure study participants' decision processes during abnormal flight conditions. A detailed FTD test plan was developed under the supervision and guidance of a local panel of flight experts. This five-member panel was composed of FAA-designated flight examiners, flight instructors, and professional aviation maintenance technicians. The panel's advice concerning the technical and mechanical issues of aircraft and simulator operation were pivotal in the planning of the test events. Activity in the FTD included a preflight briefing and a flight profile with periodic malfunction trigger

events. Participant activity in response to the malfunctions was recorded on an assessment form.

Three variables were measured during the FTD flight: recognition time, response time, and appropriateness of response to the trigger events. Recognition time was measured from the introduction of a simulated aircraft system malfunction (trigger event) until the participant recognized the situation. The indications of recognition were either the participant's verbal expression or physical action of recognition, such as pointing out the appropriate aircraft performance indicator or initiation of corrective action (e.g., turning off an alternator switch for alternator failure). Maximum waiting time until a participant recognized the event was planned as 300 seconds (five minutes). If a participant did not recognize the event within the time line, the participant's recognition time was recorded as 300 seconds.

Response time was measured from recognition of a simulated abnormal aircraft condition (trigger event) until the participant completed the corrective actions. If a participant did not initiate any corrective action until after 300 seconds (five minutes), the response time was reported as 300 seconds.

Appropriateness of response to an abnormal aircraft condition was measured by analyzing the participant's sequence of corrective actions. These corrective actions were compared with recommended procedures in the Piper Warrior III pilot's operating handbook and the FAA-approved airplane flight manual (Piper Warrior, 1995). In measuring corrective actions, two considerations were applied: did the corrective actions include all steps from the recommended procedure, and were the corrective actions completed in the recommended sequence. These measurements were recorded with numeric scores on an assessment form.

Trigger events for the FTD profile were selected after consideration of guidelines provided by the flight expert panel. Only trigger events that could be initiated from the simulator instructor's control console were used. Profile standardization could only be assured if the timing for a trigger event, the control of the trigger event, aircraft position in the profile, and flight altitude were controlled in a consistent manner from the control console. In addition, trigger events should produce an immediate instrument or warning light indication when initiated. Recognition time for each trigger event was based on a video record that captured the elapsed time from when a trigger event was initiated until the participant recognized the event, as evidenced by an auditory cue or observable action. Therefore, immediate instrument or warning light indication was essential in order to have a starting point for measuring those times. Finally, each trigger event should have only one appropriate corrective action as specified by the Piper Warrior III pilot's operating handbook and the FAA-approved airplane flight manual (1995). Corrective actions to each trigger event were measured by counting

deviations from the recommended corrective action, missed steps in the procedure, and actions not completed in the recommended sequence by a participant. Using these guidelines, four trigger events were eventually selected for use during the FTD profile: alternator failure, high oil pressure, high load meter, and vacuum pump system failure.

A flight profile was developed to set uniform flight parameters for each participant. The flight profile was divided into four legs and each leg included one trigger event. During the flight profile, participants were asked to make periodic heading or altitude changes to make the flying condition more realistic and reduce the anticipation of trigger events. To minimize possible threats to internal validity caused by participant interaction with the FTD, the flight profile was only completed posttest (after the treatment). The SJT was completed pre- and posttest. Measurements for each test are summarized in Table 1.

Table 1. Study measurements

Instrument	Pretest		Posttest		Measurement
	Experiment Group	Control Group	Experiment Group	Control Group	
Frasca 141 FTD	N/A	N/A	Yes	Yes	Recognition Time
Frasca 141 FTD	N/A	N/A	Yes	Yes	Response Time
Frasca 141 FTD	N/A	N/A	Yes	Yes	Appropriateness of Response
SJT	Yes	Yes	Yes	Yes	Adherence to Recommended Solution

Since the Frasca 141 FTD cockpit display has no circuit breakers, unlike a real aircraft, a simulated circuit breaker panel was made and affixed to the instrument panel of the simulator to facilitate completion of required corrective actions. In addition, the front monitor screen of the simulator was set to represent Visual Meteorological Conditions (VMC) for participant reference. All flight performance was videotaped to capture data for later analysis. Data acquired with the SJT and Frasca 141 FTD was reviewed and analyzed using the *SAS System for Windows* (SAS Institute, 2004).

RESULTS

The SJT instrument is structured in a multiple-choice format with four alternative choices to each question. The answer choices for each SJT question were ranked from most correct to least correct by FAA-designated subject matter experts. Participants who took the SJT were asked to select

their best choice among the four possible answers to each question. Adherence of participant's decision to the recommended solution was measured by comparing how close the participant's choice was to the most correct answer recommended by the expert panel. An Analysis of Covariance (ANCOVA) analysis with the posttest SJT as the response variable and the pretest SJT as the covariate was applied to the data. The results of this test indicated a statistically significant difference between the control group and the experimental group for posttest SJT scores ($F = 36.40$, $p < 0.0001$), which suggests the positive effect of an ADAM treatment.

The difference between posttest and pretest SJT scores within the experimental group was analyzed with a regression model. This analysis examined the level of procedural accuracy before and after treatment. The regression analysis indicated that the posttest SJT result of the experimental group was significantly different from their pretest SJT result ($t = 4.71$, $p = 0.0003$). Again, this suggests the positive effect of an ADAM treatment.

Appropriateness of response to an abnormal aircraft condition was measured by analyzing the participant's corrective action to resolve the abnormal condition during the Frasca 141 simulator flight test. The participant's corrective actions were compared with the recommended procedures in the Piper Warrior pilot's operating handbook and the FAA-approved airplane flight manual (1995), and were recorded with numeric scores on a corrective action assessment form. A two-way Analysis of Variance (ANOVA) model with group and experience level as the main factors was used to analyze the difference of corrective action scores. The analysis indicated that the corrective action scores of the experiment and control groups were significantly different ($F = 25.63$, $p < .0001$).

Recognition time for this study was measured from initiation of a trigger event until participant recognition of the event. If a participant did not recognize a trigger event after five minutes (300 seconds), their recognition time was reported as 300 seconds. Recognition times from this study were not normally distributed. Since non-normality violates one of the assumptions for parametric statistical models, ANOVA or regression models could not be considered appropriate for the analysis of recognition times. In this situation, a non-parametric statistical test can be used. One of the most frequently used non-parametric statistical tests is the Kruskal-Wallis Test (Hollander & Wolfe, 1999), and the results for this study are reported in Table 2.

Table 2. Kruskal-Wallis test results for recognition time analysis between groups

Trigger Event	DF	Chi-Square	Pr > Chi-Square
1	1	2.5546	0.1100
2	1	9.5237	0.0020*
3	1	2.0334	0.1539
4	1	4.4361	0.0352*
All	1	14.4857	0.0001*

Note. α =. 05

Results from the Kruskal-Wallis Tests suggest that recognition times for trigger events 1 and 3 were not significantly different between the experimental and control groups. However, the recognition times for trigger events 2 and 4 were significantly different. Finally, the overall recognition time, which was the summed recognition times of trigger events 1, 2, 3, and 4, was significantly different between the experimental and control groups. These results suggest that flight students exposed to periodic review of ADAM had shorter recognition times for abnormal aircraft conditions than non-exposed students.

Response time for this study was measured from participant recognition of a simulated abnormal aircraft condition (trigger event) until the participant finished the corrective actions. If a participant made no corrective action after five minutes had elapsed (300 seconds), the response time was reported as 300 seconds. If a participant made corrective actions but none of the steps were correct, the response time was also reported as 300 seconds. Five participants (one in the experimental group and four in the control group) made corrective actions to trigger event 3, but none of their actions were correct. If a participant took corrective actions but the actions had a missed step, the ending point of the response time was recorded when the last correct action was made. Nine participants (four in the experiment group and five in the control group) made corrective actions with a missed action step in response to trigger event 1. Five participants (four in the experimental group and one in the control group) made corrective actions with a missed action step in response to trigger event 3. The response time data were found not normally distributed, similar to those seen in the recognition time data. Thus, the same methods used in recognition time analyses, the Kruskal-Wallis Tests, were implemented in response time analyses as reported in Table 3.

Table 3. Kruskal-Wallis test results for response time analysis between groups

Trigger Event	DF	Chi-Square	Pr > Chi-Square
1	1	6.1305	0.0133*
2	1	11.7060	0.0006*
3	1	17.2231	<. 0001*
4	1	1.7178	0.1900
All	1	22.1079	<. 0001*

Note. α = .05

The Kruskal-Wallis Test results suggest that response times to trigger events 1, 2, and 3 were significantly different between the experimental and control groups. However, the response time to trigger event 4 was not significantly different. Finally, the overall response time, which is the summed response time to trigger events 1, 2, 3, and 4, was significantly different between the experimental and control groups. These results suggest that the flight students exposed to periodic review of ADAM information completed corrective actions to abnormal aircraft conditions in less time than did non-exposed students. Study findings suggest the following answers to the research questions:

    1. Flight students exposed to periodic review of ADAM had shorter recognition times to the trigger events of high oil pressure and vacuum pump system failure than non-exposed students but not to the trigger events of alternator failure and high electrical load. The overall recognition time during abnormal aircraft conditions for flight students exposed to periodic review of ADAM was shorter than the overall recognition time of non-exposed students.

    2. Flight students exposed to periodic review of ADAM had shorter response times to the   trigger events of alternator failure, high oil pressure, and high electrical load than non-exposed students but not to vacuum pump system failure. The overall response time during abnormal aircraft conditions for flight students exposed to periodic review of ADAM was shorter than the overall response time of non-exposed students.

    3. Flight students who periodically review ADAM took corrective action closer to the recommended solutions than those who did not.

DISCUSSION

Jensen (1995) says that people learn to expect certain things to happen from their awareness of predictable elements developed during situational experiences. Barber (1999) mentions situation awareness as anticipating and

considering future situations by monitoring, assessing, and evaluating the current situation. Barber also suggests that situation awareness is essential for the initial stages of problem detection, with information gathering and summarization providing the necessary tools for understanding a more complex situation that may not be straightforward or which may not have been previously experienced. The outcomes from this study support Barber's work. Study participants who periodically reviewed safety information demonstrated enhanced situational awareness and recognized abnormal aircraft conditions sooner than the students who did not. Also, the corrective actions made by flight students who periodically reviewed this safety information were more appropriate than those made by the students who did not. Finally, the SJT results indicated that flight students who periodically reviewed safety information made more appropriate decisions to abnormal flight conditions that they had not previously experienced (many of the scenarios described in SJT were not cases that the study participants would normally encounter in a collegiate flight environment).

Hart (1988) notes that recognition and interpretation of incoming sensory information requires transformation based on expectations, information processing, previous experience, and knowledge of the current situation. In addition, Boff, Kaufman, and Thomas (1986) suggest that perception is the process by which particular relationships among potentially separate stimulus elements are determined and in turn guide the interpretation of those elements. The findings of this study indicate that flight students who periodically reviewed safety information recognized abnormal aircraft conditions in shorter time than the students who did not. Also, the corrective actions for abnormal aircraft conditions, made by the flight students who periodically reviewed the safety information, were more appropriate than the corrective actions made by the students who did not. These results suggest that regular access to safety information enhances flight students' recognition of abnormal aircraft conditions.

Orasanu and Connolly (1993), advocates of naturalistic decision making, say that decision makers use their knowledge to organize a problem, interpret the situation, and define what information is needed to formulate a solution. This process helps the decision maker complete a speedy assessment by searching, selecting, and interpreting relevant information. One of the findings of this study (recognition time) is that flight students who periodically review safety information make faster assessments of abnormal aircraft conditions than those who do not. The study findings also suggest that flight students who periodically review safety information make a more accurate interpretation of relevant information and are more likely to select correct actions.

Ritchie (1988) reports that, depending upon the nature of the display and the pilot's ability to use it, the pilot may be able to process visually provided

information at prodigious rates. One of the study finding areas, recognition time, supports this conclusion. The first trigger event of alternator failure during the Frasca 141 simulator flight tests had two types of indicators displaying the system failure: alternator failure warning light and ammeter. The other trigger events did not have system failure warning lights. The research findings show that the recognition time for the trigger event of alternator failure was much shorter (mean 11.17 seconds) than the recognition times for other trigger events (high oil pressure: mean 108.50 seconds; high load meter: mean 98.71 seconds; vacuum pump failure: mean 29.12 seconds). This result suggests the relative importance of a warning light in detecting system failures.

Inagaki, Takae, and Moray (1999) assert that a large number of flying hours do not define an expert, unless those hours include a variety of normal and abnormal experiences which lead to better judgment. In this study, participants were assigned to one of the three experience levels based on their flight education progress. Participants' total flight experience ranged from about 82 hours to 208 hours (at the beginning of this study), and each experience level had a range of about 50 to 70 hours total flight time. Study results suggest that there was no apparent significant impact of experience level on participant performance across all four areas that were monitored (adherence to a recommended solution, recognition time of an abnormal aircraft condition, appropriateness of response, and response time). This supports the notion that participants' experience levels were not greatly varied for this study.

Finally, flight simulator results for trigger event 4 (vacuum pump failure) did not demonstrate significant difference in response time between the experimental and control groups. The nature of the simulated failure could provide a possible explanation for this lack of difference between the groups. The vacuum system of an aircraft provides pneumatic power to several of the primary flight instruments. One of these instruments is the attitude indicator which provides the pilot with a primary reference for pitch and roll movements. The failure of the vacuum system is primarily indicated through a vacuum gage on the instrument panel but might also be recognized by the erratic performance of the attitude indicator. Once the vacuum pump was failed in the simulation, the vacuum pressure indication on the gage dropped immediately to zero. This was followed by the attitude indicator slowly becoming erratic, a condition that would be quickly noticed by the pilot. Thus, the participants from either the experimental group or control group who did not recognize the dropped in vacuum pressure indication might recognize the vacuum pump failure from the erratic attitude indicator display. Once they recognized the vacuum pump failure, the only possible step for the corrective action was to turn on the electrical vacuum pump switch. The lack of notable difference between the experimental and control

group responses may be attributable to the fact that more than one indicator of vacuum failure existed providing enhanced opportunity for identification of the problem.

CONCLUSIONS

This study has investigated whether safety information has a beneficial effect on aeronautical decision making for students in a collegiate flight program. Researchers monitored a group of flight students who periodically reviewed ADAM (safety information) and a group of flight students who did not. The data collected included participant responses in terms of: (a) adherence to a recommended solution, (b) recognition time of an abnormal aircraft condition, (c) appropriateness of response, and (d) response time. Research findings suggest that flight students who periodically reviewed ADAM completed more timely and effective responses to the four malfunction areas monitored during the study. Study participants who periodically reviewed ADAM also made decisions and took actions that were closer to the solutions recommended by aviation experts than students who did not have access to ADAM.

Study findings suggest that flight students who periodically reviewed safety information demonstrated an improved capacity for aeronautical decision making ability in comparison to those who did not. Although any generalization of these findings to all pilot trainee populations may be premature, they do represent an important area for further investigation. A safety information system similar to the one used during this study may not only assist in tracking of aircraft discrepancies for maintenance purposes, but also provide a valuable enhancement to pilot decision making for all flight training programs.

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DESIGN, DEVELOPMENT, AND INNOVATION OF AN INTERACTIVE MULTIMEDIA TRAINING SIMULATOR FOR RESPONDING TO AIR TRANSPORTATION BOMB THREATS

Christopher A. Chung
University of Houston

Shweta Marwaha
University of Houston
Houston, Texas

ABSTRACT

This paper describes an interactive multimedia simulator for air transportation bomb threat training. The objective of this project is to improve the air transportation sector's capability to respond to bomb threats received by commercial airports and aircraft. The simulator provides realistic training on receiving and responding to a variety of bomb threats that might not otherwise be possible due to time, cost, or operational constraints. Validation analysis indicates that the use of the simulator resulted in statistically significant increases in individual ability to respond to these types of bomb threats.

INTRODUCTION

The vulnerability of air transportation facilities and aircraft in flight has recently been underscored by the September 11, 2001, terrorist attacks. While the impact of this tragedy focused attention on hijacking type of attacks, there are actually a number of categories of aviation terrorism. These include hijackings; bomb threats, attempted bombings and bombings; shooting at aircraft in flight; and attacks on airports. This paper describes a research

Dr. Chung is currently an associate professor in the Department of Industrial Engineering at the University of Houston. He received a B.E.S. from the Johns Hopkins University and an M.S.I.E. and Ph.D. from the University of Pittsburgh. Dr. Chung is a former U.S. Army bomb disposal officer.
Ms. Marwaha is a recent master's degree graduate of the Department of Industrial Engineering at the University of Houston. Ms. Marwaha also has an undergraduate degree from the University of Delhi.

effort to improve the nation's ability to respond to bomb threats directed towards airports and aircraft in flight.

When a bomb threat is directed towards an air transportation facility or an aircraft in flight, even organizations with bomb threat response training may fail to respond effectively due to a lack of familiarity or practice. One reason for this is that proper bomb threat response exercises must include notification and coordination procedures, a bomb search, and evacuation and reentry of the area (BATF, 1987; Brodie, 1979; McCarthy & Quigley, 1992; Reilly, 1989). When conducted in an actual environment, these activities can constitute significant losses of operational time for the airline or airport involved in the exercise. As a result, it is simply unrealistic to expect many air transportation organizations to practice bomb threat response exercises enough to become sufficiently proficient. On the other hand, any air transportation organization which does not have comprehensive bomb threat response training nor conducts regular exercises is subject to more severe casualties, property damage, and loss of operational time in an actual bombing. Thus, the problem is how to develop a bomb threat response capability that reduces the severity of casualties, property damage, and loss of organizational productivity in the event of an actual bombing without at the same time losing additional operational time due to bomb threat response training.

RELEVANT LITERATURE

A literature search was conducted to identify efforts with direct relevance to this effort. The search yielded three major categories of relevant past efforts. The first category includes a large number of efforts involving the simulation analysis of airport operations. Representative efforts include terminal operations, departure gate assignment, ticketing counters, and passenger loading (Chung & Gopalakrishnan, 2003; Chung & Sodeinde, 2000; Gu & Chung, 1999; Setti & Hutchinson, 1994; Van Landeghem & Beuselinck, 2002). While all of these types of research efforts utilize simulation technology, they are do not directly address any aspects of responding to bomb threats directed at either air transportation facilities or in flight commercial aircraft.

The second category includes a variety of simulation related research efforts directed at improving emergency response efforts. These include CriSys management training software system (Sullivan, 1992), an emergency evacuation simulation model (Weinroth, 1989) and a group of virtual reality simulators involving military ordnance, nuclear weapons, and improvised explosive devices (Kiernan, 1994; Regan, 1995; O'Brien, personnel communication, June 11, 1997; Ryan-Jones, 1995; 1997). The CriSys software focuses on post-incident simulator management training of

crisis teams on chemical plant explosions and other disasters. The evacuation simulation model involves the simulation analysis of emergency evacuation routes in large buildings. The virtual reality simulators consist of simulator training programs for rendering safe ordnance by bomb disposal technicians. While these research efforts all involve the use of simulator training for emergency response, none focus directly on improving bomb threat response.

The third category of relevant research efforts includes a series of interactive training simulators directed at improving an organization's ability to respond to bomb threats. These include bomb threat training simulators for offices (Chung & Huda, 1999), medical clinics (Chung, 2000) and land transportation facilities (Chung & Panjrath, 2001). The literature search yielded a number of interactive training simulators associated with emergency response procedures. However, none of these simulators addressed the special issues associated with air transportation facilities or aircraft in flight.

PROBLEM STATEMENT

Bomb threats and bombs on aircraft in flight represent a significant issue to the safe and effective operation of commercial air transportation operations. Despite the high consequences of failure in responding to these types of situations; training costs and scheduling, as well as operational limitations remain a significant challenge. To help improve the commercial air transportation sector's ability to respond to bomb threats and bombs on aircraft in flight, this research effort designed, developed, and validated an interactive multimedia Air Transportation Bomb Threat Training Simulator. This simulator provides commercial air carriers with the opportunity to obtain realistic training on receiving and responding to a variety of bomb threats that might not otherwise be possible due to time, cost, or operational constraints.

METHOD

This section addresses the methodology used in the design, development, and validation of the Air Transportation Bomb Threat Training Simulator. The Participants section describes the different categories of individuals that participated in different phases of the research effort. The Materials section describes the design and development of the training simulator. The Procedure section describes the methodology used to assess the training validity of the simulator.

Participants

Two distinct types of participants were utilized in the research effort. The first type was used to assess the face validity of the training simulator. This population consisted of several U.S. government-trained bomb disposal officers. By virtue of their training and professional experience, these individuals were considered to be knowledgeable on the subject of bomb threats. Their involvement consisted of ensuring that the training simulator appeared to represent reality sufficiently for training purposes. The second type of participant was the test population. These participants were used to determine the training validity of the simulator. These individuals consisted of a group of engineering graduate students at the University of Houston. This population was presumed to be not knowledgeable on the subject of responding to bomb threats in airports and aircraft.

Materials

The materials section describes the design and development of the training simulator. This section specifically includes the System Description and the Scenario Operation. The System Description section includes a general description of the major components of the simulator. The Scenario Operation section describes the sequence of events that a user would experience during a training session.

System description

The Air Transportation Bomb Threat Training Simulator is an interactive multimedia application developed in Macromedia's Authorware 7.0. Authorware is a powerful software design program which facilitates the development of mission critical applications (Macromedia, 2003). Authorware is particularly effective in incorporating multimedia features such as wave sound files, animation, and interactive objects. Figure 1 illustrates the opening screen of the simulator.

Figure 1. Opening screen of the interactive multimedia training simulator for responding to air transportation bomb threats

The simulator consists of instructional, training, and testing components. The instructional component provides static non-interactive screen by screen instruction on receiving and responding to bomb threats. The module is based on both the Bureau of Alcohol, Tobacco, and Firearms (BATF) bomb threat and physical security planning pamphlet and the Federal Aviation Administration (FAA) operational procedures.

The training component provides the user with interactive training on receiving and responding to bomb threats from the perspective of the person receiving the threat. When the module is run, it allows the user to select the type and location of the bomb threat on which the user would like to receive training. There are scenarios involving bomb threats directed at commercial airport passenger gate areas, commercial aircraft at the loading gate, and commercial aircraft in flight. Once the user has selected the category of scenario, the program will generate scenario parameters such as background information, whether or not the threat is real, where the suspect devices is, and when the device will function. There are ten base scenarios in each category. The individual scenarios are based on data collected from actual bomb threat incidents. The parameters in each scenario are randomized. This means that each time the simulator is run, the user is presented with a different situation that requires a unique solution. On completion of the

scenario generation, the user is positioned in a first person environment and the interactive scenario begins.

The testing component consists of randomized automated multiple choice pretests and posttests. Under normal conditions, the user takes the pretest prior to using the training simulator. After using the simulator, the user can take the posttest. Each time the user takes the pretest or the posttest, the program randomizes the questions. This is designed to minimize the possibility of memorizing answers to the questions. On completion of the posttest, the program will automatically score both the pretest and the posttest. The program will also determine the increase or decrease between the two tests. Both training supervisors and individual users can use the testing component as a guide for assessing the level of user proficiency.

Scenario operation

In the case of an aircraft in flight scenario, the user is placed in the cockpit of a commercial jetliner. The program provides a background scenario briefing. The purpose of the briefing is to provide a frame of reference for recent bomb threats directed at the airline. Figure 2 illustrates this screen.

Figure 2. Example of scenario briefing screen of the Interactive Multimedia Training Simulator for Responding to Air Transportation Bomb Threats
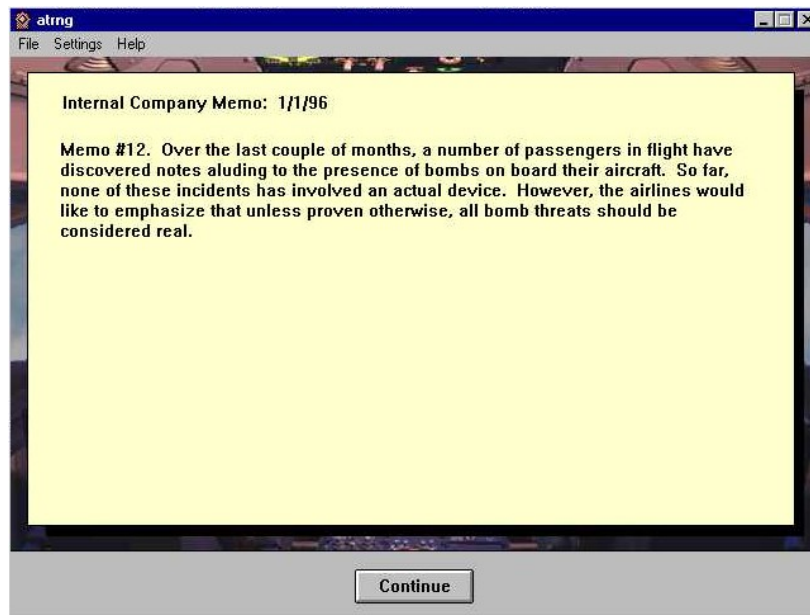
When this screen is cleared, the program issues the bomb threat to the user. With the aircraft in flight scenario, the flight crew is contacted by radio

with details of the bomb threat. This effect is achieved by playing a wave file. Once the user is given the details of the threat, the user then has the opportunity to try to obtain additional information from the control tower. This includes attempting to ask the following questions:

1. Who is the caller?
2. What does the bomb look like?
3. Where is the bomb?
4. When is it going to explode?
5. Why was the bomb placed?
6. How will the bomb go off?

If this information is available, the simulator will respond to these questions by playing additional wave sound files. When the call is terminated, three buttons pop up on the bottom of the desk screen. These buttons allow the user to make an initial decision to ignore or search the aircraft. This screen is illustrated in Figure 3. If the user either ignores the threat or runs out of time, the program immediately evaluates the user's performance on gathering information and responding to the threat. In the event that the threat was real, the user fails the scenario.

Figure 3. Example of a cockpit screen of the Interactive Multimedia Training Simulator for Responding to Air Transportation Bomb Threats

If the user decides to search the aircraft, he or she is presented with a diagram of the aircraft. Users may search different areas of the aircraft by clicking on the corresponding part of the diagram. This screen is illustrated in Figure 4.

Figure 4. Example of a search diagram screen of the Interactive Multimedia Training Simulator for Responding to Air Transportation Bomb Threats
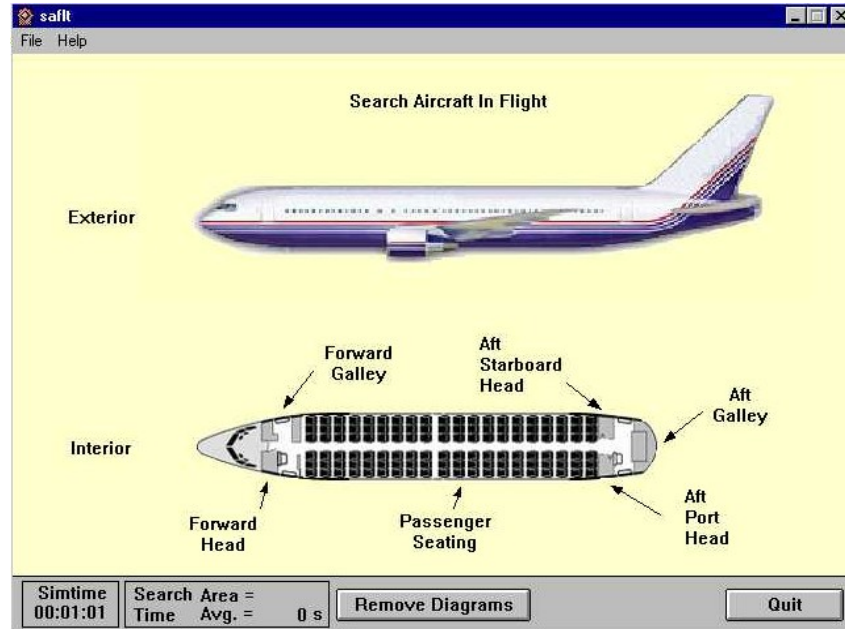
Users can then search for suspect devices by clicking on different objects in the selected part of the aircraft. This module retains a high degree of realism by using both digitized photographs of the aircraft and different interactive objects. For example, clicking on a seat will cause it to be lifted to allow the user to search underneath for suspect devices. Similarly, clicking on a compartment in the aircraft head will cause the door to swing open for inspection. This is illustrated in Figure 5.

Figure 5. Example of aircraft search screen of the Interactive Multimedia Training Simulator for Responding to Air Transportation Bomb Threats


When an object is examined, a sound wave file is played related to the status of the object. A harmless object would provide a sound file of a comment such as, "I know who that belongs to" or "That's ok." Similarly, a suspect device would yield a sound file of a comment such as, "Where did that come from?" or "That doesn't belong here." The program records the number of possible objects examined by the user. This statistic is later used to determine the completeness of the search effort.

In the event that a suspect device is found, the user must move the device to the least risk bomb location. This position is where a suspect device will have the least effect in the event of a detonation. Once the suspect device is positioned, the user must then properly prepare the least risk bomb location to best protect the passengers. This is accomplished by following specific procedures for barricading the device with material on hand.

The evacuation module is typically activated by the user when a search has resulted in the discovery of a suspect device. This module presents a diagram of the aircraft similar to that used during the search process. This time however, the user must decide how to position the passengers on the plan to minimize injuries in the event of a detonation. Normally users will want to evacuate the passengers to a point furthest away from the suspect

device which is now positioned at least risk bomb location on the aircraft. The evacuation screen is illustrated in Figure 6.

Figure 6. Example of safe zone evacuation screen of the Interactive Multimedia Training Simulator for Responding to Air Transportation Bomb Threats
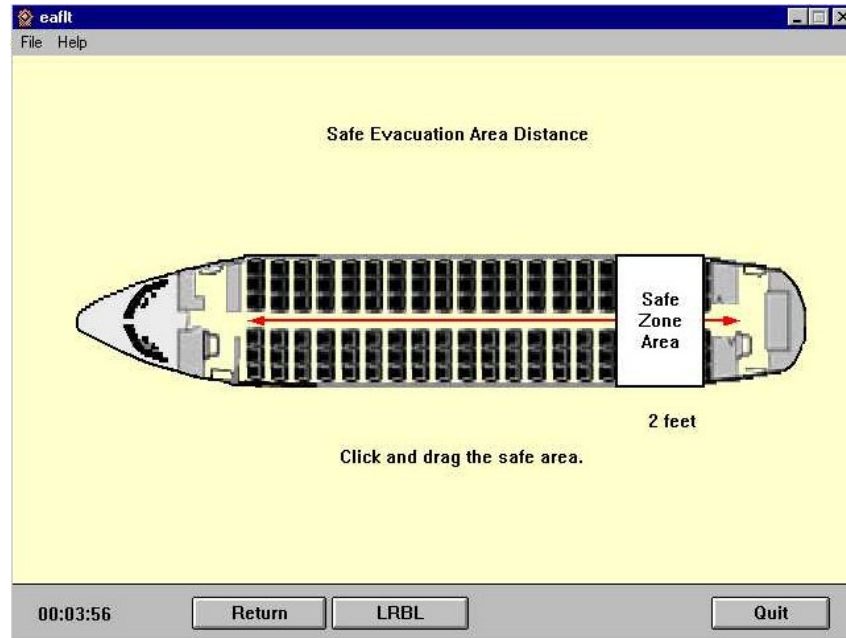
On either the completion of the scenario or the detonation of the device, the user is evaluated for their information collection, searching, and evacuation performance. Feedback on the user's performance is provided through both a summary screen and individual detailed screens. This feedback allows users to improve their ability to respond to the bomb threat. Training supervisors can also use this information to target future bomb threat training. The summary evaluation screen is illustrated in Figure 7.

Figure 7. Example of a summary evaluation screen of the Interactive Multimedia Training Simulator for Responding to Air Transportation Bomb Threats
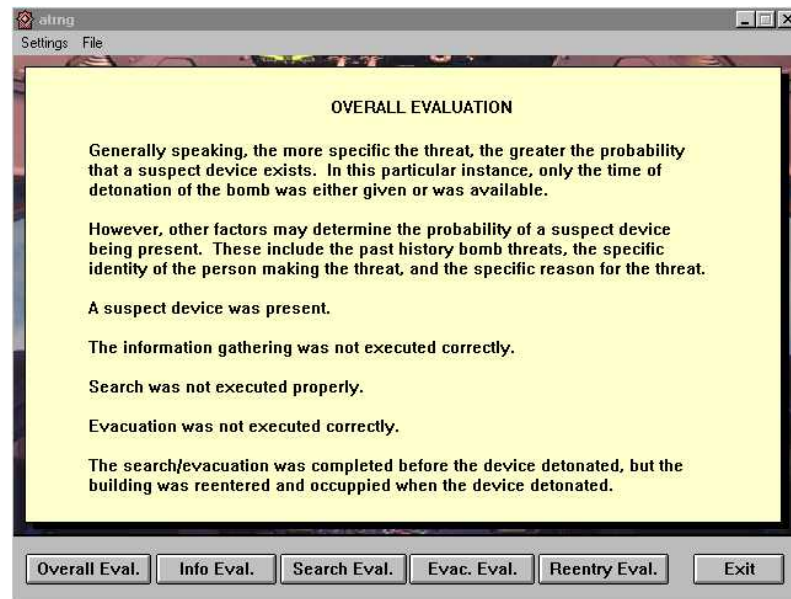
Procedure

In this type of research effort, the methodology procedure consists of establishing the validity of the simulator. With traditional simulation models, the validation process may include both an assessment of face validity and a quantitative comparison of behavior between the real world and the simulation model systems. With training simulators, the face validity assessment can still be performed; however the quantitative comparison between systems must be approached differently. Here, an assessment of training validity must be conducted. This is a quantitative comparison of whether or not the simulator adequately represents reality for the user to exhibit the same or increased user performance in the task that the simulator is designed to simulate. Thus, if the simulator is able to demonstrate equal or improved training effectiveness with users, then it can be considered to have training validity from the standpoint of adequately representing the real system.

Both face validation and training validation assessment were performed on the simulator. The face validation was achieved through a process of continuous review and improvement over a period of several months with the assistance of the Houston Police Department's Bomb Squad. The quantitative methodology was based on the use of pretests and posttests and

examination of the test scores using the paired t-test approach (Remus, 1981). The pretest and the posttest were based on information from the BATF Bomb Threat and Physical Security pamphlet and FAA documentation. The test consisted of twenty multiple choice questions on receiving and responding to bomb threats. The split half reliability of this test was 0.82. The test was face validated by representatives of the FAA.

As identified in the Participants subsection of the Method section, the test population to determine the training validity was a group of engineering graduate students at the University of Houston. This population was presumed to be not knowledgeable on the subject of responding to bomb threats in airports and aircraft. After an orientation session, the pretest was administered to the class. The test group then ran multiple training scenarios with the simulator. After the completion of this phase, test group were given the posttest.

RESULTS

The results for the pretest and the posttest for the test group are presented in Table 1.

Table 1. Pretest and posttest results for test participants of training validation of the Interactive Multimedia Training Simulator for Responding to Air Transportation Bomb Threats

	Pretest	Posttest
Number of test participants	26	26
Mean score of participants	32.88	69.42
Standard deviation of scores	13.86	19.14

The pretest and posttest scores were paired between individuals. The formal hypotheses are:

Null Hypothesis: There is no gain between the pretest and post test scores
Alternative Hypothesis: There is a gain between the pretest and post test scores

The difference in gain between the pretest and the posttest was calculated and a paired t-test was executed at an alpha level of 0.05. The results are presented in Table 2.

Table 2. Difference in gain between pretest and posttest of test participants of training validation of the Interactive Multimedia Training Simulator for Responding to Air Transportation Bomb Threats

	t statistic	t critical	t significance
		(1 tail, a=0.05)	
Paired t-test	10.22	1.708	0.000

The qualitative analysis of the training validity of the simulator was based on a paired t-test between the pretests and posttests from the test group. The critical value for a one tailed test at an alpha of 0.05 is 1.708. The paired t-test resulted in a test statistic of 10.22. Since the test statistic was greater than the critical value, the null hypothesis is rejected. This means that there is a statistically significant gain between the pretest and posttest scores at an alpha level of 0.05. Thus, there is evidence that the use of the simulator had an impact on how well the test group learned to respond to bomb threats of this type.

CONCLUSIONS AND SUMMARY

Bomb threats directed at airports and aircraft in flight can result in significant losses of operational time. In the event of an actual device there may also be casualties and property damage. By maintaining an effective level of bomb threat response training, air transportation organizations can help minimize the effects of bomb threats regardless of whether the threat involves an actual device or not. Unfortunately, due to time, cost, or operational considerations, many airports and airlines are simply not able to receive and maintain effective levels of bomb threat training.

The Air Transportation Bomb Threat Training Simulator was designed to overcome these limitations. The quantitative and qualitative analysis of the simulator has established its training validity. Thus, the Air Transportation Bomb Threat Training Simulator provides the opportunity for the commercial airlines industry to provide realistic and effective training in receiving and responding to bomb threats that might not otherwise be possible. While the testing at the University of Houston was performed under a controlled environment, it is expected that the same level of training effectiveness and acceptance will be present in the field environment.

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DISCOVERING THE REGULATORY CONSIDERATIONS OF THE FEDERAL AVIATION ADMINISTRATION: INTERVIEWING THE AVIATION RULEMAKING ADVISORY COMMITTEE

Chien-tsung Lu
Central Missouri State University
Warrensburg, Missouri

ABSTRACT

Maintenance Resource Management (MRM) training for aviation mechanics has become mandatory in many industrialized countries since 1998. Yet, to date, MRM training remains optional in the U.S. Interestingly, a similar safety discipline, namely Crew/Cockpit Resource Management (CRM), is mandatory for pilots, flight engineers, flight attendants, and dispatchers and is regulated in the Federal Aviation Administration's (FAA) Federal Aviation Regulations (FARs). If MRM training is important to enhance aviation technicians' working behavior, the rationale to not regulate it opens a window for study. This research aims to inductively investigate the FAA's regulatory rationale concerning MRM training based on direct inputs from the FAA's Aviation Rulemaking Advisory Committee (ARAC) members. Delphi methodology associated with purposive sampling technique was adopted. The result revealed that the FAA cannot regulate MRM because the aviation industry is strongly opposed to it due to the lack of training budgets, the need of a quantifiable cost-effect analysis, concern over the FAA's inspection workforce, an ongoing voluntary alternative called the Air Transportation Surveillance System (ATOS), the government's lower priority on maintenance after 9/11, and the airlines' tight embracement of operational flexibility without regulation.

INTRODUCTION

Alongside the prompt development of the air transportation system in the U.S., aviation safety has always been the foremost concern of the government (Carmody, 2001; Donnelly, 2001), the general public (Bowers, 1997; Wells, 1999), as well as the air transportation industry itself (Proctor,

Dr. Chien-tsung Lu obtained his Ph.D. from the University of Nebraska at Omaha and M.S. from Central Missouri State University. Lu is an FAA certified aviation maintenance technician (airframe and powerplant) and an FCC general radiotelephone with radar operator licensee. His research and teaching interests are in the areas of aviation policy, aviation law, aviation safety, system safety, and air transportation.

1999). Since 1978, the passage of the Airline Deregulation Act (the nature of laissez-faire and free marketing) has forced airlines to further promote, or at least maintain, a required level of safety in order to compete with business rivals, to provide better operations, to survive, and most importantly, to become profitable (Button & Stough, 2000; Chang, 1986; Marks, 1999). However, today's airline passengers tend to book their flights based on price either via the Internet or from traditional travel agencies (Johnston, 2001). In response, airlines have reacted by providing services that charge the lowest possible fares in order to attract more customers and ultimately survive in the Darwinian post-deregulation battlefield. However, maintaining a risk-free operation needs a sufficient financial backup. While charging passengers airfare with marginal or no profit, airlines may provide safety training for their employees only to satisfy the minimum mandatory requirements from the FAA. Providing non-regulatory safety training could become a financial burden to airlines.

REVIEW OF MAINTENANCE PERFORMANCE AND SAFETY TRAINING

The accident investigation of the fatal mishap of Alaska Airlines Flight 261 in January 2000 is pointing to flawed jackscrew lubrication and rushed inspection (Finnegan, 2002; Fiorino, 2001). After Alaska Airlines' accident, many aviation enthusiasts see again that the goal of zero accidents cannot be achieved without the cooperation of hazard-free maintenance. The fact is that Alaska Airlines' accident, which may be a result of non-flight errors, is not an isolated case in aviation history. The accidents of TWA Flight 800, ValuJet Flight 592, and Air Midwest Flight 5481 had alerted the air transportation industry that non-flight operation does play a significant role in today's aviation safety (Lu, 2001; Alexander, 2004). As a result, the task of eliminating non-flight errors cannot be overemphasized.

Maintenance Human Errors

The main purpose of aircraft maintenance is to keep aircraft airworthy (King, 1986). Although technologies have been enhanced, aircraft maintenance remains quite challenging and the working environment is still extremely intense (Butterworth-Hayes, 1997; Delp, Watkins, & Kroes, 1994; Richardson, Rodwell, & Baty, 1995). With this in mind, human factors affecting maintenance performance are inherent and should be treated carefully. A survey conducted by Boeing Company and other safety researchers revealed that the main factors contributing to maintenance mistakes were the following: (a) boredom; (b) failure to understand instructions well; (c) rushing; (d) pressure from management; (e) fatigue; (f) distractions at critical times; (g) shift work; (h) poor communication; (i) use

of incorrect parts and tools; and (j) unauthorized maintenance proceedings (Al-Almoudi, 1998; Taylor & Christensen, 1998). In addition, Transport Canada's human factors research resulted in the recognition of a so-called *Dirty Dozen*—lack of communication, lack of teamwork, lack of knowledge, lack of resource, lack of assertiveness, lack of awareness, fatigue, stress, distraction, pressure, complacency, and workplace norms—that identifies the human factors requiring immediate attention (Grant, 1995). Wood (1997) and Drury (1999; n.d.) echoed this and further reported the major problems of aviation maintenance technicians (AMTs)—fatigue, physical impediment, foreign object damage, ignorance, misconduct, and overlook—when conducting aircraft maintenance/inspections. Hence, when working on an aircraft, AMTs could make mistakes and are not error-free (Wood, 1997).

The nature of aircraft maintenance is complex and needs physical and mental strength. The working climate is tense, involving managerial pressure, working efficiency, shift work, interpersonal communication, and external sociological influences (Lu, 2001). Without a doubt, the maintenance issues associated with human factors are almost identical to those that affect flight performance—communication, workload, fatigue, stress, social environment, physical limitations, and personal health (Orlady & Orlady, 1999).

Maintenance Resource Management

Like CRM training for pilots and associated flight crews, MRM was developed based on the experimental findings of human factors research introduced by the National Aeronautics and Space Administration (NASA) in the early 1970s. Human factors studies the interaction between human and software (S), hardware (H), environment (E), and liveware (L), thereby forming the SHEL model of aviation safety theory (Krause, 1996; see Figure 1).

Figure 1. SHEL Model of human factor and aviation safety.[1]

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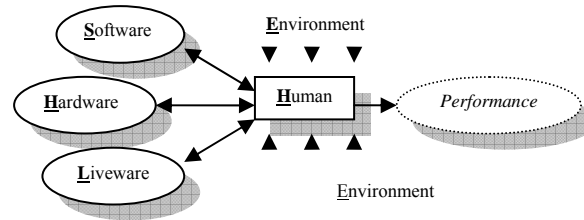
[1] Krause, S. S., 1996, Aircraft safety – accident investigations, analyses, & applications and Federal Aviation Administration, 2000, System safety handbook: Practices and guidelines for conducting system safety engineering and management.

Likewise, maintenance human factors training is an analytical science of the factors influencing maintenance performance and consequently seeks to eliminate or dilute the negative impact from an explicit safety factor (Orlady & Orlady, 1999). Because MRM training originated in the findings of human factors research, implementing MRM training could help improve an AMT's performing compatibility, self-awareness, interpersonal communication, and effectiveness at resource usage (Capitelli, 1988; Lavitt, 1995; Mudge, 1998; Orlady & Orlady, 1999).

Legislative Basis for MRM Training

Not until 1988, and after Aloha Airlines' accident resulting from the aircraft's aged fuselage being ripped open in flight, did the FAA conduct the first official safety meeting concerning aircraft maintenance. As a result, Congress proposed a bill—the Aviation Safety Research Act (H.R. 4686)— which was passed on November 3, 1988, by the Senate (Public Law 100-591). This bill provided grants to the FAA and expanded the research domain aiming to make a connection between aviation safety and human factors (US GPO, 1990). The Aviation Safety Research Act of 1988 sought to pursue the relationship between human factors and flying, aviation maintenance, and air traffic control (US GPO, 1997). The FAR Part 121 Subpart N and Special FAR Part 71 Training Program has regulated today's CRM training rooted in the human factors paradigm for flight crews (pilots and flight engineers) since 1990. The Aviation Safety Research Act was revised in 1996, mandating human factor training for flight attendants and dispatchers.

Moreover, in 1991, three years after the Aloha Airlines accident, Congress passed the Airline Passenger Safety Enhancement Act, which focused on improving airline maintenance procedures and standards. This legislation urged airlines to: (a) reform inspection routines for aging aircraft, (b) innovate inspection technology training for maintenance personnel and professionalism, and (c) restructure a 15-year inspection development (Bowen & Lu, 2000). Unfortunately, Congress did not identify the sociological factor behind Aloha's accident—the oppressive management pressure that constrained maintenance time (Friend, 1992). The fatal crash of ValuJet Flight 592 in 1996 was due to an oxygen canister fire resulting from ill-trained ground crews; it led to the passage of the Aviation Safety Protection Act of 1997. Congress proposed another bill, the Aircraft Safety Act of 2000 (H.R. 3862), after the tragedy involving Alaska Airlines Flight 261 in January 2000. This legislative reaction, in the wake of another aviation disaster, aimed to prevent fraud involving aircraft maintenance and defective parts (Bowen & Lu, 2000).

RESEARCH QUESTIONS

The aviation industry (Capitelli, 1988; Lavitt, 1995; Orlady & Orlady, 1999) and the FAA (Mudge, 1998) have recognized the benefit of MRM training to enhance aircraft maintenance safety. To date, MRM or an equivalent training is mandatory in EU nations (Joint Aviation Authority, 2001) and Canada (Transport Canada, n.d.). A similar training (CRM) for flight crews, flight attendants, dispatchers, and flight engineers is mandated in the FAA's FARs. With the legislative foundation upheld by the Aviation Safety Research Act, Passenger Safety Enhancement Act, and Aviation Safety Protection Act, the FAA's non-regulatory stance in relation to MRM is worth investigating. Without a mandatory requirement, the current training status quo in the aviation industry should be made known to the flying public as well.

> Question 1: From the viewpoint of Aviation Rulemaking Advisory Committee (ARAC) members, what is the rationale underpinning the non-regulatory status of Maintenance Resource Management (MRM) training for aircraft maintenance technicians (AMTs)?
> Question 2: What is the de facto safety training and attitude of the airlines toward Maintenance Resource Management (MRM) training under the current non-regulatory status quo?

RESEARCH METHODOLOGY

In order to manifest sound theories regarding the rationale of the FAA's decision making, the research questions were thoroughly explored through the use of a divergent approach, a qualitative methodology. The author selected the Delphi methodology and initiated purposive sampling skills.

Delphi Techniques

The Delphi method is an exploratory and discursive-format data collection tool that allows researchers to gain the highest creditability of data through reciprocal procedures (see Figure 2); Bellenger, Bernhardt, & Goldstucker, 1976; Rayens & Hahn, 2000; Zapka & Estabrook, 1999). In this study, the Delphi technique was directly applied to answer the research questions concerning the rationale of decision making and current industry-wide MRM training. The existing policy determinants can be coined and epistemological relations among variables can be identified.

Figure 2. Research execution processing – the flowchart of policy Delphi
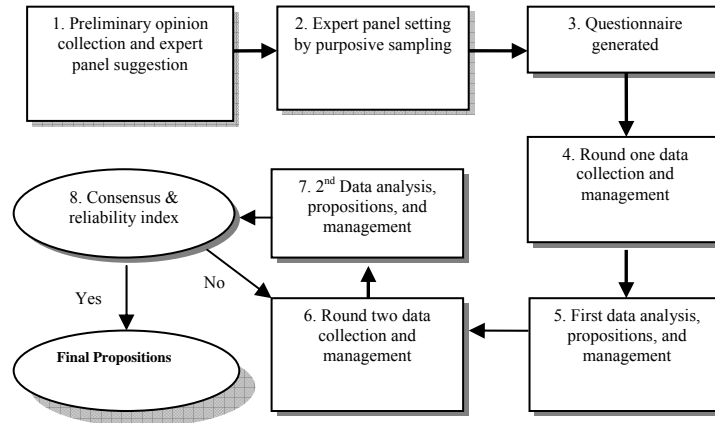
Purposive Sampling

In contrast to the widely recognized random sampling approach adopted in most quantitative studies, purposive sampling focuses on the heuristic exploration and in-depth interview of selected key informants who possess a direct connection to various essential data, practical experiences, and genuine resources (Babbie, 1998; Maykut & Morehouse, 1994). Key informants—as *representative units* rather than randomly selected samples (Bellenger, Bernhardt, & Goldstucker, 1976)—are those who are closely involved in the area being studied. In addition, the snowball technique was accompanied with the usage of purposive sampling because qualitative researchers often start their data collection from the accessible research sites of key informants (Babbie, 1998; Berg, 2001; Creswell, 1998; Maxwell, 1996; Royer & Zarlowski, 1999).

Aviation Rulemaking Advisory Committee

This study recruited FAA ARAC members as key informants. One of the attempts by the federal government to collect public opinion from external sources in order to assist policymaking was the passage of the Administrative Procedure Act of 1946 and the Federal Advisory Committee Act (FACA) of 1972 (Adamski & Doyle, 1999). Since 1972, the FAA has established various ARACs for different legislative issues such as aged aircraft, air traffic control, navigation system, cabin safety, flight operation, and maintenance safety. The purpose behind the FAA's establishment of an

ARAC is to build a communicative channel between the federal government, the public, and the aviation industry under the power of the FACA. ARAC members are also assigned with a task that focuses on regulatory communication and harmonization between the FAA FARs, Canadian Aviation Regulation (CAR), and Europe's Joint Aviation Regulation (JAR). This study selected fourteen ARAC members who worked with the FAA regarding mandatory maintenance human factors training (formerly proposed by the FAA as FAR Part 66). Unfortunately, three of the selected ARAC members could not participate in this study, resulting in an eleven-member Delphi panel.

Data evaluation methods

Coding is a systematic procedure for finding the significant meanings, norms, or unique themes of texts by cross-references and comparisons (Creswell, 1998; Gough & Scott, 2000). For grounded-theory type qualitative research, like that which uses the Delphi methodology, the design of topical subquestions can be considered the blueprint of qualitative data analysis (QDA) and meaningful coding (Maxwell, 1998; Miles & Huberman, 1994; Tafoya, 1986). In this study, computer software is useful to examine the reliability of data analysis. EZ-Text software was applied to manage database and to compile the index of coding reliability (CDC, 1998).

Reliability and validity of the research

The reliability of this project rests in the category of research consistency in addition to EZ-Text's index. This consistency involved the key researcher's operational processes of Delphi techniques and the informants' conformability of results (steps 4, 5, 6, 7, and 8 in Figure 2). Moreover, in addition to external peer-review for validity during the questionnaire generation phase, personal biases were clarified and rich and thorough descriptions were collected (Berg & Latin, 1994; Creswell, 1998; Lincoln & Guba, 1985). In this study, in order to gain the highest validity and reliability, the initial findings were returned to ARAC panelists for review and consequently gained their conformity based on Delphi criterions.

FINDINGS

This section outlines the findings after two consecutive personal interviews over a six-month period. The key informants, aged between 36 and 46 years old, have comprised the largest portion of the sample, whereas most panelists possess educational level with Bachelor of Science degrees or above. All panelists have more than 10 years of working experience in the aviation field. Eight of the 11 panelists have received MRM or human factors education before the date of the interviews. Panelists have

participated in the FAA's rulemaking activities at least once each year, and most of them have taken part in the FAA's rulemaking activities associated with maintenance safety regulations more than three times in the past. A brief analysis of the panelists' backgrounds is shown in Table 1.

Table 1. Demographic distribution of panelists (N=11)

	Number (n**)	Descriptor	Percentage
Age			
	6	36-46 years of age	54.5
	2	47-58 years of age	18.1
	3	59 years or older	27.4
Education			
	1	High School diploma	9.1
	1	Associate degree	9.1
	3	Bachelor's degree	26.3
	5	Graduate degree	46.5
	1	Doctorate degree	9.1
Working experience			
	11	10 years or more	100.0
ARAC activities			
	3	New member	27.3
	8	Senior member	72.7
MRM/HF training			
	4	Never received	36.3
	7	Received	63.6

Note. N = total number of panelists
** n denotes the number of particular panelists

Question 1: From the viewpoint of Aviation Rulemaking Advisory Committee (ARAC) members, what is the rationale underpinning the non-regulatory status of Maintenance Resource Management (MRM) training for aircraft maintenance technicians (AMTs)?

After the interviews and data coding process, the synthetic findings from the ARAC members were grounded. The panelists concurred that the following six policy determinants played a central role in the FAA's rulemaking in light of the current non-mandatory MRM or maintenance human factors education.

1. Budgetary constraints. The FAA should have to consider the possible cost and how that would impact the air transportation industry's current and future financial status. In particular, air carriers are facing ongoing financial difficulties that impede them from accepting any new regulations.

2. Lacking a persuasive cost-benefit analysis result. There is no strong or virtually quantifiable data showing a positive cost-benefit result from MRM. Therefore, lacking sound evidence, the air transportation industry would be reluctant to support such regulation.

3. The effective operation of the Air Transportation Oversight System. Despite its nature of volunteerism that requires the industry's participation from the bottom-up, the ongoing safety inspection mechanism—ATOS—is sufficient in maintaining a reasonable degree of aircraft maintenance safety.

4. The air transportation industry's demand for operational flexibility. The air transportation industry demands more operational flexibility to accomplish safety goals without coercion from the government. In addition, different categories within the industry would like to conduct their own safety training that focuses on specific needs. The standardized procedures and activities of MRM could hinder creative means to accomplish the goal of maintenance safety.

5. The FAA's capacity and the capability of safety inspectors. The FAA's safety inspection capacity and the capability of safety inspectors is one of the policy determinants that hampers the FAA in mandating MRM and the industry in upholding its proposed regulations. First, the FAA has long been criticized by the industry regarding the capability of their safety inspectors. Second, since the FAA is suffering manpower shortage of safety inspectors, new MRM regulations could worsen the situation since the FAA would have to dispatch more safety inspectors to scrutinize the industry's MRM training compliance.

6. Low policy priority. After 9/11, the FAA's manpower and budgetary resources had been reallocated to airport security and related safety issues. Most regulatory proposals petitioned by the government are mainly in favor of enhancing airport security as well as homeland security. National security and anti-terrorism activities had outweighed the importance of regulating MRM or maintenance human factors training.

Question 2: What is the de facto safety training and attitude of the airlines toward MRM training under the current non-regulatory status quo?

Based on the ARAC key informants' input, major air carriers voluntarily participate in the ATOS system; yet small/regional airlines and fixed based operators (FBOs) do not or only occasionally provide MRM or related training. Regardless of the major air carriers' engagement in ATOS surveillance, "when considering the degree of MRM training without regulation, a voluntary MRM conducted by the industry seems sporadic," as stated by one panelist. Some panelists echoed and noted that the most critical elements impeding the industry's voluntary implementation of MRM training are: (a) current financial hardship; (b) a long-term unpredictable cost; and (c) unclear benefits. Therefore, "the industry would like to

continuously comment on MRM training via participation in rulemaking rather than by supporting MRM regulation," as remarked by one panelist.

Regarding Question 2 concerning the contemporary U.S. aviation industry's training status without the regulatory enforcement, several important facts were discovered.

1. A profit-driven industry. Airlines are believed to be "exclusively profit-driven" as remarked by one panelist. Hence, the airlines' willingness to "conduct MRM training without federal enforcement is low due to cost concerns." Another panelist stated that "the support of the top management and cost-benefit analyses" were considered essential for an airline to decide whether or not to implement voluntary safety trainings. "When something is non-regulatory it will be done only if the management sees a cost-effect case" as echoed by another panelist. "Regional airlines or small FBOs would not implement MRM due to a budgetary shortage" as addressed by one panelist. However, "the major airlines would like to implement such training voluntarily because these airlines already have good technical training programs and MRM is a natural extension" as another panelist replied.

2. The pros and cons of a non-regulatory MRM status. There are some disadvantages of maintaining a non-regulatory MRM training, said the panel. One panelist pointed out that, "the lack of mandatory MRM training could be harmful and risky, and could impact maintenance safety in the long run." Without a doubt, "safety training would enhance safety performance," another panelist replied. Because MRM training focuses on human factors related to aircraft maintenance tasks, one panelists stated that "without MRM training, the AMTs might unintentionally perform tasks with risks." Another panelist further warned and argued, "not until the industry had encountered severe aviation mishaps caused by maintenance errors would the industry recognize the importance of communication, teamwork, self-awareness, and the dangers of physical fatigue, mental stress, and coercive management." In addition, one panelist stated, "without regulation of MRM or defined requirements, organizations wander all over the map in terms of an accurate path of [MRM] training." Moreover, according to panelists' feedback, there are also some advantages if MRM training remains optional in nature. One panelist argued, "to some extent, volunteer programs are more stringent than regulations." It is simply because airline services "are influenced multi-dimensionally" by customers' changing needs. Therefore, "if training requirements are flexible and lax, customer service can be easily and continually improved in a timely manner" as echoed by another panelist. Of course, not being mandated to do the training means cost saving. One panelist stated that "without mandatory enforcement from the government, the airlines do not have to conduct safety training and can therefore save on operational costs." The fact is that "a non-mandatory MRM means cost reduction," stated by another panelist.

3. The attitude of the industry regarding a mandatory MRM. "The industry is opposed to a mandatory MRM training" as one panelist addressed. "The air transportation industry is also afraid of any regulations because the FAA would possibly take the advantage if they have the chance," another panelist argued. Another panelist said that "any regulations without appropriate evidence, showing that MRM would create enough return on investments, would be denied" by the industry. Even within the regulatory sphere, the industry would "just implement enough training" for aircraft technicians as another panelist replied. In particular, while the FAA hoped to promote MRM training for aircraft maintenance technicians without regulation, "when it comes to the discussion of regulations, the air transportation industry would demand a thorough understanding of requirements beforehand, such as technical support, training duration, possible cost and benefit, and a quantifiable result," said another panelist.

Reliability Report

To ensure the reliability of qualitative findings, EZ-Text's index of coding reliability was measured after the completion of the second-round interview. According to EZ-Text's manual (CDC, 1998) and Miles and Huberman's (1994) rule of coding reliability, the percentage of agreement between two coded datasets should exceed 90 percent in order to ensure reliability. In addition, the Kappa Index should show 1 in the contingency table. In Table 2, the percentage of agreement regarding each code (policy determinant) is above 98 percent and the Kappa index is 1. This means that the coding process of raw data had high reliability across two codebooks.

Table 2. Reliability Report—Kappa Index

Codes	Percentage of Agreement	Kappa Index
Financial constraint	99.373	1
Cost-benefit analysis	98.746	1
ATOS	99.373	1
FAA's ability	99.687	1
Operational flexibility	99.373	1
Policy priority	98.746	1

DISCUSSION: THE MODEL OF DECISION-MAKING

The findings portray a conceptual picture for readers and pull most possible independent variables (policy determinants) together arriving at a description of the FAA's rulemaking rationale regarding a mandatory MRM training. A schematic chart of relations showing a theoretical construct (from processing phase of policy premise finding, agenda setting, implementing policy action, to policy evaluation) among all found themes and policy determinants is illustrated in Figure 3.

Figure 3. Schematic relationship among variables
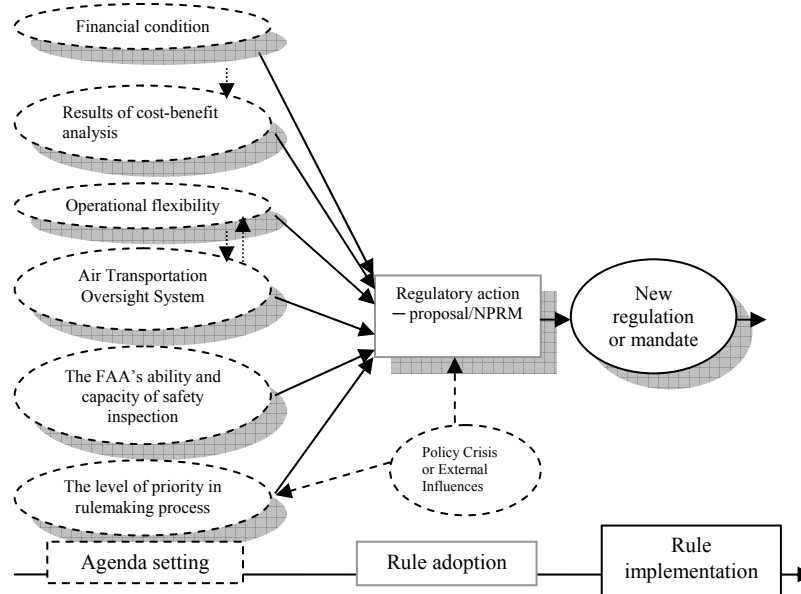
To further explain, this model of decision-making indicates that if the financial condition of the aviation industry was healthy or generating sufficient profits, the results of cost-benefit analyses would become less important. This is because the industry would then have enough monetary resources to implement MRM training. Furthermore, regardless of regulatory status, without sound evidence yielded from cost-benefit analyses, the willingness of supporting a mandatory MRM training is weak because the element of budgetary constraint is not compressed nor eliminated.

The aviation industry is tightly embracing ATOS on a voluntary basis. In addition, the demand for operational flexibility from the air transportation industry positively influences the FAA's decision making. These two elements (ATOS and operational flexibility) are impediments to the industry's acceptance of MRM regulation. Certainly, the air transportation industry would prefer to maintain the current voluntary nature of its cooperation with the FAA without the threat of violations. In addition, the industry is concerned with the capacity of FAA's safety inspectors. The shortage and quality of the safety inspectors has been a long-time criticism of the FAA's enforcement actions. If this manpower deficit can be removed, some of the resistance of MRM regulation from the industry could be reduced. Finally, the FAA will need to take priorities into account when enforcing the MRM agenda, especially in light of other priorities resulting from 9/11.

It is believed that—barring a legislative crisis such as a major airline accident resulted from the lack of MRM training—these six rulemaking determinants largely shape the FAA's decision-making behavior.

CONCLUSION

The core argument of this study is that while resource management or human factors training is mandatory for pilots, flight engineers, dispatchers, and flight attendants, it is controversial that such training becomes optional for AMTs or non-flight workers. A nonregulatory MRM also draws attention to the current training status for AMTs. This study has explored the rationale behind the FAA's stance in retaining a non-regulatory MRM or maintenance human factors training for the air transportation industry.

Based on the interview of ARAC members, policy determinants are unveiled showing that the FAA should closely evaluate several essential issues of the industry when it comes to the debate of proposed regulations. Those determinants are identified as (a) the industry's financial status; (b) a sound evidence of cost-benefit analysis; (c) the scope of malleability of the ongoing voluntary ATOS; (d) the allowance of operational flexibility for the industry; (e) the FAA's inspection capacity and the ability of inspectors; and (f) the level of policy priority.

Regarding the current training status without regulatory enforcement, major air carriers are willing to voluntarily participate in the alternative system, namely ATOS. Yet, the regional airlines and FBOs do not intend to provide MRM to maintenance technicians due to the cost. Despite the major air carriers' efforts, when considering the degree of MRM training without regulation, voluntary MRM conducted by the entire airline industry seems rare and difficult. While the industry as a whole does not likely support the

MRM regulation, only major airlines with more cash flow or revenue would be able to incorporate MRM into their current maintenance safety training.

Post-9/11, the financial status of the entire industry is increasingly fragile. Although ATOS requires a reasonable amount of MRM training for non-flight employees, top management would still evaluate the possible investment returns in safety training before taking further action. As a result, when MRM is non-regulatory, it will be done only when the advantages are identified or when sound evidence associated with cost-benefit analyses is accessible.

Finally, it is still possible to regulate MRM training in the future. The evidence underpinning this conclusion is the six policy determinants described. In other words, when any of the determinants prevails—that is, (a) the industry is making enough profits; (b) cost-benefit analysis shows a sound result; (c) the FAA has sufficient numbers of qualified inspectors; (d) the ATOS does not work well; (e) the FAA decides to grant the industry with operational flexibility; or (f) the government is aware of the urgency of such regulation—regulating MRM or related ground safety training would encounter less resistance.

Limitation

The results of this study were retrieved from two consecutive rounds of interviews with selected panelists from ARAC members who were closely involved in the debate of MRM regulation with the FAA. Unfortunately, one important resource—FAA's rule-makers—was not able to take part in this research due to a variety of reasons. Thus, future research should focus on the data collection and comparison from the FAA rule-makers. Moreover, although panelists addressed that the working culture may change if technicians receive MRM or maintenance human factors training, evidence of this has not been recorded nor is it accessible. The cost-benefit analysis of MRM training did play a crucial role in this study. To prepare a report for the FAA's future decision-making, follow-up research should focus on a longitudinal assessment of behavioral change, error reduction, and cost savings affiliated with MRM training.

Special Notice

Many aviation researchers have argued that the FAA has been *captured* by the industry (Carmichael, Kutz, & Brown, 2003) based on George J. Stigler's theory. In this study, regardless of the designated personnel from the FAA in charge with a specific regulatory provision, the author reviewed the backgrounds of ARAC members and discovered that most ARAC members are mainly from the industry such as unions, airlines, aviation organizations, and manufacturers. As a result of this study, the FAA's

decision-making process was, to a great extent, in favor of the industry and was captured accordingly.

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HOW TO CONTROL AIRLINE ROUTES FROM THE SUPPLY SIDE: THE CASE OF TAP

Kenneth Button
George Mason University
Fairfax, Virginia

Álvaro Costa
Universidade do Port

Vasco Reis
Universidade do Port
Porto, Portugal

ABSTRACT

Competition in the European airline industry is currently fierce in the face of depressed demand conditions, and in the wake of privatizations and liberalization. The Portuguese flag carrier, TAP Air Portugal, operates within this environment. It is a medium sized carrier that was part of the defunct Qualiflyer Group alliance and has recently joined the Star Alliance. It controls more than 50% of the air market between Europe and Brazil and Europe and Angola. Nevertheless, it has been experiencing financial losses. One reason for this is that, following the reasoning of Ronald Coase (1946), it is difficult for any company with decreasing average costs to recover full costs in a highly competitive market. One way of approaching the problem is to establish quasi-monopoly power and airlines have done this through such things as frequent flyer programs and hub-and-spoke operations. Other airlines, notably charter carriers, have sought to adjust capacity and services to meet an anticipated cash flow. In practice, many have used a combination of measures with mixed success. This paper focuses on how TAP has responded to changing conditions by adjusting its supply-side activities in terms of restructuring its network to maximize potential revenues.

Kenneth Button is a University Professor of Public Policy at George Mason University. He also serves as Professor in the Department of Civil Engineering at the Universidade do Porto, Portugal.
Álvaro Costa is an Associate Professor of CITTA (Centro de Investigação do Território, Transportes e Ambiente) Faculdade de Engenharia da Universidade do Porto, Portugal.
Vasco Reis is a faculty member of the Engineering Department, Centro de Investigação do Território, Transportes e Ambiente at the Universidade do Porto, Portugal.

INTRODUCTION

Over the past decade competition between airlines in Europe has been fierce. There have been important structural changes within the industry, and within the actors that participate in it. Some older companies such as Sabena and Swissair could not meet the challenges, while others such as Air France and KLM have sought some respite in merging. At the other extreme, several of the no-frill carriers such as easyJet and Ryanair have earned steady profits and subsumed some of their competitors. The changing networks of services being offered by air carriers in Europe has inevitable implications for spatial economic development and impacts on key industries such as tourism. Here we examine changes that have taken place in the network of TAP Air Portugal.

TAP is medium sized European carrier with about 38 aircraft in its fleet and is entirely state owned.[1] It is the primary airline in one of the European Union's peripheral areas. It was for awhile a member of the now defunct Swissair led Qualiflyer Group alliance and it joined the Star Alliance in 2004. Its financial situation is poor with large losses being experienced, although in 2003 it did make a marginal operating profit (€12 million on a turnover of €1144 million, but embedded in the accounts was a one-time gain of €20 million from the sale of shares in French Telecom and a write-back for a tax court case in Brazil), the first in many years.[2] Despite this, in 2004 it sought a loan guarantee for €400 million from the Portuguese government.

A major location problem is that its main hub, Lisbon Airport, is located on the western extreme of Europe, away from the main economic growth centre of European Union and thus unsuited to be a major strategic hub. Portugal is a long thin country that is not ideal for domestic hubbing. However, external to Europe, TAP does control over 50% of the air transport market between Europe and Brazil, and between Europe and Angola. This is the result of the exploitation of bilateral government agreements on these markets, and the legacy of Portugal's colonial past.

There are a plethora of business models that have been applied to the airline industry. The concern here is with the strategy that TAP has adopted to improve its market position at a time when many other carriers of comparable size have found survival difficult. Public ownership obviously helps, although the advantage is now diminished, but the concern here is

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[1]   ICF/Button (2003) offers a categorization of European Union airlines.

[2]   This is also after receiving $1,100 million in restructuring grants in 1994 designed to allow the airline to become commercially viable.

with the structural changes that the company has made to reduce is long-standing cash outflows.

There is a basic problem encountered by firms in all industries that have committed costs (in this case a commitment to a scheduled service) and that has been recognized since the pioneering works of Edgeworth (1881), Coase (1946), Telser (1978), and others. In a fully competitive environment it is impossible to recover full costs in this situation of declining average cost. Full costs can only be recovered if either the concern receives a subsidy (and that, Coase correctly points out, is, irrespective of any distributional concerns, going to impose an excess efficiency burden elsewhere in the economy) or by somehow gaining a degree of market power and extracting economic rent from customers. TAP has in the past enjoyed state subsidies but these are no longer acceptable under EU legislation, and hence there has been the need for a re-examination of how costs may be recovered.

THE MARKET SETTING

The demonstration effects of the outcome of the U.S.'s 1978 Airline Deregulation Act experience stimulated changes elsewhere, although reforms in Europe tended to be more gradual, with a liberalized market within the European Economic Area akin to that of the U.S. domestic market only emerging in 1997. One reason for these more gradual changes was it mainly entailed reaching agreement on international air services between member states, rather than being an entirely internal matter as with the U.S. Countries such as France, Spain and Greece, where domestic aviation is relatively important, have a tradition of heavily regulating entry and fares, and this extended to their views of international aviation policy in Europe. There was also a pervasive philosophy that air transport serves public needs and that to ensure adequate provision and to avoid the economic distortions of monopoly power, state ownership best served the public interest. The problem was that these countries with well-entrenched systems of market controls, even if appreciative of the probable adverse implications of this for the overall welfare of the EU, still sought to cushion their airlines from competition.

Reform of the European internal airline market materialized as a series of steps. Initially these were largely ad hoc measures brought about by judicial interpretations of EU laws, but a series of *packages* of reform followed (Button, 2004). The First Package in 1987 made the existing bilateral air service agreements (ASAs) more flexible. The Second Package passed in 1990, alleviated capacity sharing and market access, and largely removed governments' role in setting airfares for international services within the EU. The Third Package, adopted in 1991, initiated a phased move that, by 1997, resulted in a regulatory framework similar to U.S. domestic

market. With the EU, it provided protection against national discrimination in airline licensing, eliminated capacity sharing, and allowed for a phased introduction of cabotage by 1997.

More recently, the EU Commission has switched its attention to the relationship between EU air transport policy and EU external relations (Mencik von Zebinsky, 1996). The traditional right of governments to negotiate bilateral air service agreements with non-EU states has been brought into question. The EU Commission was given permission in 1996 to negotiate on behalf of all EU countries on soft issues regarding aviation. The growth of strategic alliances, and the adoption by many member states of the Open Skies bilateral ASA with the U.S., more recently led in 2003 to the EU Commission gaining approval to negotiate transatlantic agreements on behalf of the EU with the intent of ultimately creating a single U.S./EU air transport market.

AIR CARRIERS' REACTION AT THE EUROPEAN LIBERALISATION

The outcome of all these reforms is that the competition faced by scheduled EU airlines has increased considerably. The latter stages of reforms also coincided with weak economic growth on the part of many European economies combined with exceptionally depressed air travel demand as the combined result of the September 2001 attacks on New York and Arlington, the Gulf conflict, and SARS. The emergence of no-frill carriers such as Ryanair at the lower end of the market have added to long standing competition from charter carriers, whilst in some markets there are now, generally subsidized, high-speed rail services.

The schedule airlines thus face a major problem. They commit to a schedule and then attempt to raise enough revenue to cover the costs involved; there is a fixed cost to be recovered. In a monopoly situation this poses few problems, capacity is limited and premium fares can be charged to recover costs, to earn an economic rent, or to enjoy inefficiency. But as Coase and others have pointed out, if there is competition, then airlines will compete fares down to short-run marginal costs.[3] They may all thus enjoy a high load factor, but not recover sufficient revenues to meet their long run financial outlays.[4]

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[3] Similar problems can also emerge if the market is contestable——see Baumol, Panzar & Willig, 1982, for the conditions where this pertains.

[4] Indeed, whist virtually all the members of the Association of European Airlines were experiencing severe financial problems in 2003 their load fatctors had risen to an aveargy of 73.4% from factors in the low 60% in the late 1990s when they were at least covering their opertating costs.

To overcome this, some airlines received subsidies, but EU regulations now largely prevent this. An alternative is to adopt measures within competition laws that allow for the creation of some degree of market power, even if it is only short term.[5]

Non-pricing factors have been one way airlines have tried to create quasi-market power. This has included variations in in-flight and pre/post flight services, as well as scheduling and type of aircraft differentiation. More recently, there have been attempts, led by no-frill carriers, to unbundle services allowing customers to choose the portfolio of services they prefer. The difficulty is that ultimately Hotelling (1929) effects seem to exert themselves, with a trend towards meeting the preferences of the median passenger.

The advent of computer reservation systems (CRS) and the growth of travel agents provided an initial advantage to individual airlines over both competitors and customers. This allowed segmentation markets and dynamic price discrimination systems in the form of yield management.[6] Legal actions on both sides of the Atlantic, however, limited the ability of airlines to exploit this, and now technology changes, especially the World Wide Web, have weakened any CRS effect that may exist.[7]

Retaining customer loyalty offers not only more revenue, but also a more predictable flow of revenue and the ability to adjust assets accordingly. Enhanced information systems allowed carriers to develop as part of their yield management strategy frequent flyer bonuses that went to their loyal customers. Frequent flyer loyalty has been dissipated, however, as it has become more difficult to reclaim miles—a fact one would anticipate from the basic premise that carriers seek to maximize payload at marginal cost. In some countries, such as Germany, frequent flier miles are also now taxed.

Mergers, franchises, and alliances have occurred with the aim of offering a superior service through such things as code-shares, common frequent flyer programs, common airport lounges, and more coordinated scheduling. Sheer size is sometimes seen as an advantage because of the S-curve effect—after a threshold is reached, the share of a market rises faster than an airline's (or alliance's) share of the capacity (Fruhan, 1972). The

[5]   Not all would agree that market power is needed but argue that there are gaming solutions (e.g., Levine, 2002) but this begs a number of questions and may ultimately revolve around how monopoly power is used rather than market power per se.
[6]   If the objective of the company was to simply recover costs then Ramsey Pricing would be adopted, but airlines are profit-maximizing entities and will seek pricing strategies that maximize rent.
[7]   It has also led to a very considerable decline in the number of travel agents in the U.S., although less so in Europe National Commission to Ensure Consumer Information and Choice in the Airline Industry (2002).

difficulty has been that airline companies vary considerably in their managerial styles and ethos, making it problematic to gain the full benefits of such unions.

Some European carriers have benefited from operating in multiple markets. They enjoy a degree of quasi-monopoly power in some markets because potential existing competitors are reluctant to compete fearing retaliation in other markets where they were the incumbent dominant carrier (Edwards, 1955). This possibility has been reduced as no-frill carriers have emerged with no legacy services to protect and thus with nothing to lose from piece-meal route entry.[8]

Vertical integration may also be used for cost recovery. The larger value chain reveals that while European airlines have been making large losses over the business cycle since liberalization, many upstream elements in the chain have not (Button, 2004). Airports, global distribution systems, airport services, airframe manufacturers, and others have consistently made relatively high returns. These upstream inputs operate in much less competitive conditions than the airlines. Attempts by airlines at capturing some of this upstream rent are increasing. In the U.S., airlines have combined to create Orbitz to compete with the four large global distribution systems, and Opodo is gradually growing as a European counterpart. Companies like Ryanair in the EU have sought to extract some of the economic rent enjoyed by airports.

There can also be other changes on the supply-side and airlines' route networks can also be used to extract rent for full cost recovery. The initial successes in the U.S. came when airlines adopted hub-and-spoke systems (Oum & Tretheway, 1990) that generated network economies of scope and density on the cost side and economies of market presence on the revenue side (Levine, 1987). A structure similar to the hub-and-spoke system existed in Europe prior to liberalization with bilateral ASAs restricting routes to the flag carrier of each country, and services to their main airport. Radial networks were thus common, but airlines were unable to fully exploit their potential benefits because of a lack of fare and capacity setting freedoms, and the frequent requirement to revenue pool. Post deregulation has seen only small changes, mainly because congestion limits flexibility.

Airlines, when confronted with losses, are also forced to look at their cost structures. While it may be correct that, in a highly competitive environment, falling average costs result in an inability to recover costs, the situation is exacerbated if costs are not being minimized. European airlines have seen the emergence of no-frill carriers that have removed some costs from their operations and significantly reduced others. The traditional

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[8]   Dresner (2004) offers conformation of this theory in the context of the U.S. domestic airline market.

carriers have followed this example. In the end, however, if there is truly a decreasing costs issue then relative costs will only determine which carriers remain in the market, rather than the overall viability of the market.[9]

While the general pattern of events following the deregulation of air transport in Europe has been studied, and no-frill carriers have attracted some interest,[10] analysis of individual European scheduled carriers is scant and what has been done has tended to look at those that failed to survive in the new competitive conditions (e.g., Suen, 2002). Equally, changes in network structures have only received limited attention.

TAP AIR PORTUGAL

TAP Air Portugal was founded in 1945 by the Portuguese government and was regarded as the extension of Portugal abroad and as a way to get closer of the rest of the Portuguese Empire. The first commercial European route was established in September 1946 and the first non-European route to Luanda in December. Seven years later TAP was privatized. Meanwhile the number of destinations increased without any defined overall strategy. The first route to Brazil was inaugurated in 1961, and 10 years later the first route to North America (Montreal.). In 1974 came the Portuguese revolution that ended several decades of dictatorship. A program of nationalization that included TAP Air Portugal in 1975 followed this.

The Portuguese government has recently sought to privatize TAP but a proposed purchase of 34% of the company in 2001 by Swissair fell through when the latter went bankrupt. A firmer legal commitment to gradually privatize was legislated in 2002, and a more modest proposal to sell 51% of its handling division emerged in 2003. This initially entailed the establishment of a new company—Serviços Portugueses de Handling (SPdH)—which began operations in October 2003 with the short term intent that TAP would retain a 94% stake and the private PGA-Portugália Airlines have 6%. TAP itself remains a publicly owned airline.

TAP is a small to medium sized carrier, with a fleet in 2004 of 38 airplanes.[11] It is a mixed carrier providing European and intercontinental services. It is essentially a carrier that focuses its attention on meeting the

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[9]   As the American economist Frank Knight (1921) once said, "Costs merely register competing attractions."

[10]   For example there is a widely held view that no-frill carriers have been a universal success. In fact only Southwest in the U.S. and Ryanair in Europe have consistently made profits, and both enjoyed first-mover advantage. A significant nuber of no-frill carriers on both sides of the Atlantic have surcome to commercial pressures.

[11]   In terms of passengers, carried TAP ranked 13th amongst Association of European Airlines members and 12th by passenger kilometers.

demands of its regional market although this region extends geographically well beyond the boundaries of Portugal, although not throughout Europe (ICF & Button, 2003). TAP offers a more limited geographical coverage than the large global carriers such as British Airways or Lufthansa, although it does serve a range of major airports.[12] The carrier has a significant intercontinental coverage, but because of the bilateral ASA structure, and the large-scale movements of Portuguese nationals to specific markets, it focuses on intercontinental services to Brazil and Angola. Table 1 offers some current comparisons with a sample of the other legacy carriers in Europe.

Table 1. Number of passengers, passenger kilometeres and available seat kilometers of selected EU carriers, 2003

Airline	Passengers (thousand)	Passenger kilometeres (million)	Available seat kilometers (million)
Air France	43490.3	99073.8	131647.6
Alitalia	22244.7	31254.2	43564.5
Austriamn	6895.1	14537.5	20386.6
British Airways	34815.4	100425.7	137843.3
Finnair	5672.3	8653.3	13815.2
Iberia	24669.8	41957.6	55926.2
KLM	18719.2	56540.6	72409.6
Lufthansa	44463.3	96616.8	124166.0
Olympic	5105.1	6083.6	9720.3
SAS	20456.5	23020.3	33332.7
TAP	5633.7	12011.5	16836.5

Source: Association of European Airlines. (2004). *Yearbook 2004*. Brussels.

Normally carriers like TAP are either alliance members to gain the advantages of scope, density, and market coverage that this brings, or have a range of code-share agreements on a route basis with other carriers. Although TAP was involved in the European Qualiflyer alliance and has now joined the Star Alliance, more recently it pursued the path of multiple code shares with second tier carriers (e.g., with bmi, Finnair, Iberia, Olympic, and SN Brussels). However, because of its focus on particular regions (both intra-Europe and intercontinental), there tends to be limited network-based competition in many of its intercontinental markets. Indeed, TAP is a near monopolist European carrier for many of its Brazilian

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[12]   In 2003 TAP served 36 destinations, 7 in Portugal, 15 in the rest of Europe, and 14 beyond Europe. As a benchmark, British Airways serves 153 destinations with 76 beyond Europe.

destinations (which comprise 33 flights a week and contribute about 20% of its revenue). There is much tougher competition on busier continental (although this is to some extent constrained by code-share agreements), and some denser intercontinental routes.

TAP has not traditionally been a highly efficient airline. For example, looking at the total factor productivity of 41 airlines from around the world in 1983, Windle (1991) found that TAP came 38th (and 12th of the 14 European carriers included). In terms of unit costs measure it came 29th. Analysis of 1992-1995 data by Ng and Seabright (2001) shows that whilst the carrier had the third lowest cost for cockpit crew and fifth lowest for cabin crew of the 12 EU carriers studied, its labour productivity in terms of million revenue passenger kilometres per employee was the second lowest, and less than half of that of U.S. carriers which overall outperformed the European airlines.

The recent performance of the carrier has seen a steady rise in patronage (from just over 3 million passengers in 1990 to nearly 5.5 million in 2002). Parallel growth in available seat kilometres in the 1990s led to a fairly static load factor of around 60%. As deregulation has allowed greater fare flexibility and enhanced competition stimulated lower prices, load factors have risen since 2002 to something over 70% (compared to 73.4% for Association of European Airlines carriers as a whole in 2003). In terms of financial results (Figure 1), however, TAP has not done well, although there is some indication of improvement in the last few years.

The interest here is the extent to which TAP has sought to recover more of its costs, and also contain those costs, through manipulation of its route network. This network comprises unregulated intra-European Economic Area routes and ASA regulated intercontinental services. This manipulation offers the potential for the exploitation of economies of density and scope whilst extracting additional consumer surplus from the monopoly elements of the network. An element of fixed cost recovery is thus theoretically possible.

Figure 1. TAP net financial results, 1995-2003
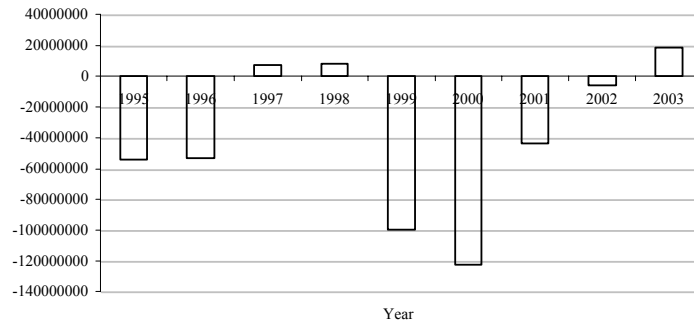
Source: Data was compiled from TAP Annual Reports, 1995-2003.

TAP AIR PORTUGAL'S NETWORK

With significant governmental protection, little competition and guaranteed coverage of financial losses, the nationalized TAP Air Portugal had not traditionally been excessively worried about its efficiency. Its labour productivity, and productivity in general, was low even compared to other state owned European flag carriers. Some of the difficulties were simply due to poor internal management, but one of the problems was route structure.

After 45 years, the network of TAP (see Figures 2a to 2d) represented a piece-meal of routes without any clear perspective or orientation. A decade or so ago, there was limited evidence of flight concentrations in a hub-and-spoke structure as we now understand it. Moreover, non-European routes often involved stopovers, or some very circuitous routings, that reduced cost efficiency and the attractiveness of the services to potential users. The European network involved duplication of several services and in some cases there was a triplication of flights to the same destination from several Portuguese airports. No Portuguese airport had a clearly dominant role as a hub.

Figure 2a. TAP European network in 1990

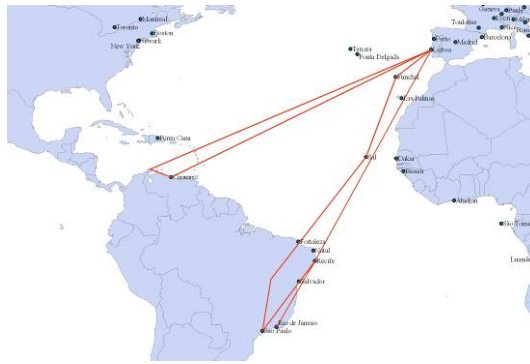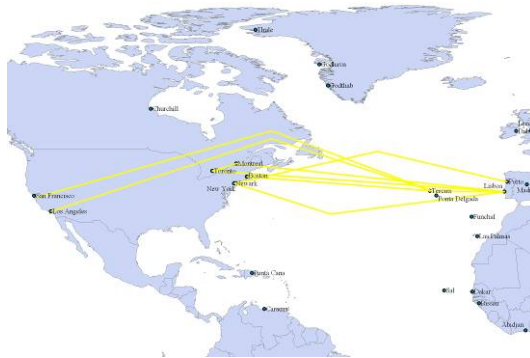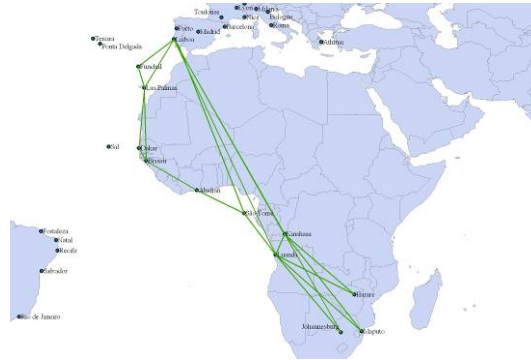**Figure 2b. TAP South American network in 1990**

Figure 2c. TAP North American network in 1990

Figure 2d. TAP African network in 1990

However, with the onset of European Union liberalisation process in mid-1990s, combined with the beginning of the downturn in the world economic situation, and especially the European situation, from the late 1990s, TAP began to make very significant loses that clearly required some form of major structural adjustment. The government's restructuring grant offered some prospect for change, but was largely used to cover short-term deficits and to expand the already gangly route network. In 1997 the company was still operating with a mixed fleet of Boeing, Airbus, and Lockheed aircraft and thus forgoing the economics of synergy that accompany fleet standardization. Demand was down, and was unlikely even in an economic upturn to be as vibrant as in the mid-1990s. And there was new competition to face in Europe—by 2000 the no-frill carriers were supplying 600,000 seats a year, up from virtually zero five years before, and the trend was irrepressibly upwards. The low cost, no-frill carriers although still predominantly focusing on UK rooted services were expanding their networks across Europe.

The European TAP service network that existed in 2000 (see Figures 3a to 3d) had changed little over the unstructured form of a decade earlier. Elsewhere, TAP had made some changes. The rather volatile South American routes had seen a notable expansion of services, the African network had been increasingly concentration on flights from Lisbon Airport, and the longest haul North American routes had been abandoned. Nevertheless, the networks continued to involve numerous stopovers, routings were often circular, and there remained duplication of flights from different Portuguese cities.
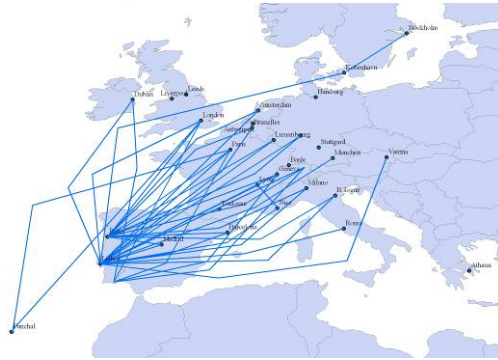
Figure 3a. TAP European network in 2000

Figure 3b. TAP South American network in 2000

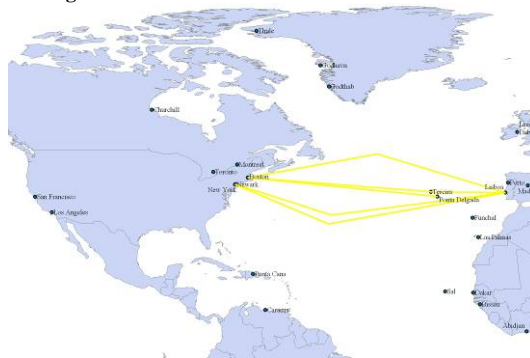**Figure 3c. TAP North American network in 2000**

Figure 3d. TAP African network in 2000

In the face of this, and with the reality of EU rules now preventing further explicit government subsidies, the concept of the flag carrier was effectively passé. TAP was forced to radically rethink its philosophy.[13] Management soon understood that the airline was unable to compete head-on with the major European carriers such as British Airways, Lufthansa, and Air France, because it simply did not enjoy the massive economies of scale and scope they did, nor did TAP have the domestic feeder traffic. Its fleet was also unsuitable to this task. Portugal is also located on the periphery of the EU, far way from the largest markets and the most vibrant economies. Establishing even a medium size, stand-alone hub in these conditions is not viable.

Thus, TAP had to find alternative solutions. Portugal has tended to enjoy good relationships with several former colonies such as Brazil and those in Africa. The bilateral ASA agreements, coupled with the problems that airlines of these countries encountered, effectively gave TAP substantial de facto monopoly power in these intercontinental markets. Many of the routes involved were also unattractive to the larger European airlines because they did not fit conveniently in their network structures and their domestic feed was limited. Long-haul routes also have the advantage that demand tends to be less fare elastic (Gillen, Morrison & Stewart, 2002) and

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[13] The rethink coincided with the appointment of a Brazilian as chief executive officer, Fernando Pinto, that effectively removed the airline from traditional Portuguses political ties and moved it towards commercial management.

they tend to attract a larger number of business class fare paying passengers (Button, 2004).[14]

In 2001 (see Figures 4a to 4d) only small changes to the TAP route service structure of a decade earlier were visible, but by 2002 (see Figures 5a to 5d) significant changes were beginning to emerge. The total number of routes offered, together with the number of destinations served, was beginning to fall with indirect and longer routings all but eliminated and replaced by direct ones. Moreover, there was a clear concentration of services on a Lisbon hub and with this came an elimination of duplicated long-haul flights. For example, Porto lost a number of services. These changes, combined with a modest macroeconomic upturn in several of the countries served by TAP, and a range of internal cost cutting measures, brought about a modesty upturn in the company's financial performance.

Figure 4a. TAP European network in 2001

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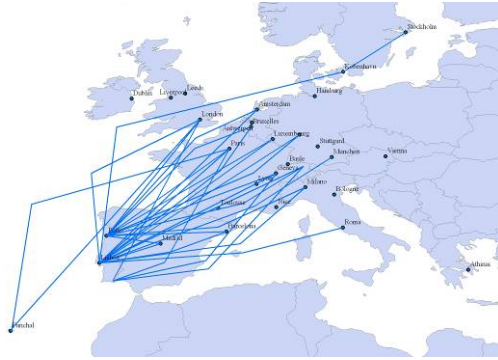
[14]   Even in cases where there are no restrictive bilateral ASAs the traditional carriers tend to face less threat of competition from low cost carriers partly because it is more difficult to enjoy the high crew and aircraft utilization rates that no-frill airlines seek. This is not to say that low cost operations are absent from deregulated long-haul routes, indeed Laker Airways in the late 1970s may be seen as a pioneering venture in low cost airlines.

Figure 4b. TAP South American network in 2001

Figure 4c. TAP North American network in 2001

Figure 4d. TAP African network in 2001

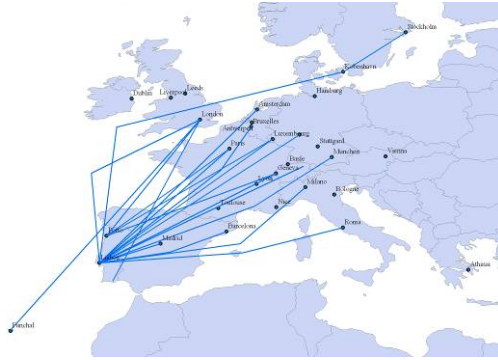**Figure 5a. TAP European network in 2002**

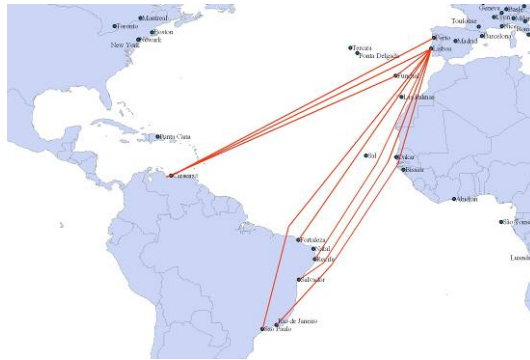**Figure 5b. TAP South American network in 2002**

Figure 5c. TAP North American network in 2002

Figure 5d. TAP African network in 2002

The current TAP route service network (see Figures 6a to 6d) is similar to that of 2002. Lisbon Airport is the major hub in the system with a network of European flights (including code shares that are not shown) feeding a range of intercontinental destinations in South American and Africa. At the non-European end of routes, it has began domestic services in Mozambique to feed its long-haul routes and in 2005 plans to relocate its Africa hub to Angola—it is currently in Johannesburg. The European network has remained dramatically simplified even as some European economies have begun to recover. Costs have also been contained as the airline has moved to standardize its fleet on Airbuses (its last Boeing leaving service in 2002) and to reduce its labour force.

Figure 6a. TAP European network in 2004

Figure 6b. TAP South American network in 2004

Figure 6c. TAP North American network in 2004

**Figure 6d. TAP African network in 2004**

The relative concentration on direct services has been pushed furthest in its long-haul markets as can be seen in Figure 7. Basically, TAP changed the structure of its network over a 4-year time span to focus on what it considers to be its profit centres, where it enjoys a degree of monopoly power, and to provide feeder traffic to those centres. Joining the Star Alliance offers the other members of the group complimentary services to South America and Africa and Portuguese feed to their own service networks.

Figure 7. The evolution of the TAP Air Portugal network
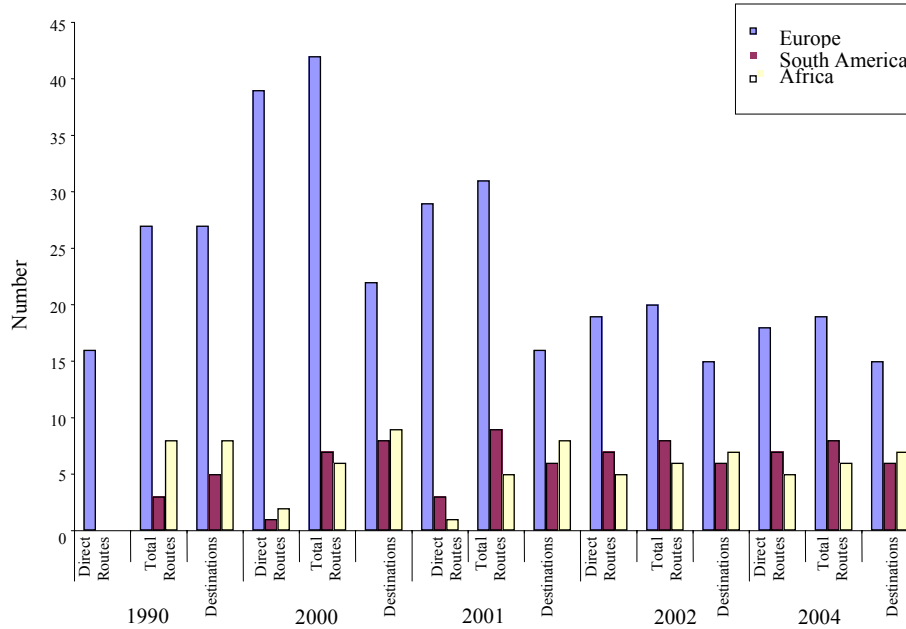
Source: Data was compiled from TAP Annual Reports, 1990-2004.

It provides the potential for TAP to feed more traffic from a number of European catchments areas into its South Atlantic and African routes.

CONCLUSIONS

The new institutional environment in the EU has brought about significant changes in the conditions confronting the management of the region's scheduled airlines. Although the change has been phased-in, unlike that which affected U.S. domestic carriers in the late 1970s, the reaction of many of the incumbent flag carriers has often been slow. Inertia has been the

common feature and restructuring has generally been slow and reactive to crises rather than representing a proactive management philosophy. In part this can be explained by the reluctance of some governments to appreciate that a European Single Market entails just that; it means competition, commercialization, and free entry. Those entrenched in the airline industry, both on the management and labour sides, have often lacked vision about what the new conditions entail, and it has been left to newcomers such as Ryanair and easyJet to meet the demands of customers.

The incumbent EU airlines' initial response to the rigors of the market was to emulate their U.S. counterparts that had experienced two decades of competition. Sophisticated yield management regimes were introduced, frequent flyer programs were initiated, existing hub-and-spoke networks were further developed, and alliances were joined. As with their U.S. cousins, however, these measures have not protected all from heavy financial losses and, in some cases, bankruptcy. The importance of network configurations, however, has tended to be overlooked in the literature in this field, but is beginning to be appreciated on both sides of the Atlantic. In Europe, British Airways, for example, has moved towards a focus on long haul activities, and the chairmen of both Delta and United have stated their intent to do the same. These airlines, however, have the advantage of scale and a tradition of commercial management to define their strategies; other carriers often have neither.

TAP has had the particular handicap of 100% state ownership, relatively small size, and a disadvantageous, peripheral-market location. It has thus experienced serious financial problems. Coase's (1946) arguments, in particular on cost recovery in a decreasing average cost, competitive industry now seem difficult to refute in the context of TAP. The only way full costs are likely to be recovered in these circumstances is through ad hoc efforts to minimize fixed costs and to seek some market advantage, however short-lived, wherever possible. The examination of TAP Air Portugal's manipulation of its route structure provides some insights into the way one carrier seems to have bought itself some breathing time. It has focused its energies on longer haul routes where demand tends to be less elastic and competition from no-frill carriers is likely to be less intense. The beautiful thing about markets, however, is that they are never still. Whether the TAP route restructuring offers a one-year respite or one of longer duration is not clear (and, indeed, should not be clear in a market) but certainly, as past experience has shown, good management should already be looking for new strategies now that it is within the Star Alliance to cope with the next crisis.

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AN ATTEMPT TO MEASURE THE TRAFFIC IMPACT OF AIRLINE ALLIANCES

Kostas Iatrou
Hellenic Aviation Society
Athens, Greece

Nikolaos Skourias
Beta Securities S.A.
Athens, Greece

ABSTRACT

This paper analyzes the effects of airline alliances on the allied partners' output by comparing the traffic change observed between the pre- and the post-alliance period. First, a simple methodology based on traffic passenger modelling is developed, and then an empirical analysis is conducted using time series from four global strategic alliances (Wings, Star Alliance, oneworld and SkyTeam) and 124 alliance routes. The analysis concludes that, all other things being equal, strategic alliances do lead to a 9.4%, on average, improvement in passenger volume.

INTRODUCTION

In the last years, strategic alliances have become extremely popular among airlines since major and smaller carriers have increasingly sought to extend their service network through alliance schemes in order to build global network and, therefore, to attract more passengers. It seems that strategic alliances enable the carriers involved to expand, without investing new resources, the reach of their network and services to many parts of the world where it may be not be economical for stand-alone carriers to operate on their own and/or where they are not authorized to operate because of regulatory constraints.

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Kostas Iatrou holds an MBA from ESLSCA Business School, Paris and a PhD from Cranfield University, UK. His main area of study is airline alliances and passenger traffic. He is the secretary general of the Hellenic Aviation Society.
Nikolaos Skourias holds an MBA and a PhD in Economics from University Aix Marseille III. He is currently employed as Chief Economist at Beta Securities S.A. in Greece.

This paper examines the effects of airline alliances on the allied partners' output by comparing the traffic change observed on alliance routes between the pre- and the post-alliance period. It focuses exclusively on a quantitative analysis of the impact of alliances on passenger traffic, trying not only to determine whether there is indeed any impact on traffic as a result of alliances but also to quantify it. In this sense, its seeks to confirm the results of previous empirical and theoretical studies, whose findings indicate that alliances do lead to a significant increase in passenger traffic.

A two-step approach is used. In the first step, a specific methodology of determining and measuring the impact of alliances is developed. This methodology is mainly inspired by that used by Iatrou (2004) and Bissessur (1996). It is based on a passenger traffic model which relates passenger traffic to a limited set of exogenous variables: (a) the per capita gross domestic product (GDP) expressed in real terms as an index of income/economic activity and (b) a capacity index (available seats), Herfindahl-Hirschman Index (HHI) and fares. The second step consists first of the econometric estimation of the above regression model using time series data, and then of the isolation and quantification of the alliance impact. This latter is derived from the comparison of the traffic variation induced by non-alliance factors (real GDP) with the observed traffic variation during the post-alliance period.

The work contains significant innovative elements both in relation to the time period examined and to the sample of routes-airlines studied. Not only does the evaluation study extend to the 1990s covering the period 1982-2001 so as to include even the most recent years, but it also covers 124 alliance routes served by the four global strategic alliances actually in force at the time of the study (Wings, Star Alliance, oneworld and SkyTeam). Furthermore, it does not concentrate exclusively on North Atlantic flights, on hub-hub routes, nor on major airlines, as most previous studies on traffic have done. At the same time, a more innovative and functional definition of the alliance date formation is proposed in order to correctly assess the alliance impact on passenger traffic.

LITERATURE REVIEW

The available empirical studies that have attempted to identify and evaluate the potential impact of alliances on traffic volume (and load factor) are quite limited in scope and most of them have been carried out recently. In their majority, they conclude that there is indeed a positive impact as far as alliance routes and complementary alliances are concerned, confirming the theoretical predictions of previous works (Brueckner, 2001; Oum, Park & Zhang, 2000; Park, 1997; Park & Zhang, 1998).

A brief overview of previous empirical works is presented below giving emphasis to their qualitative conclusions.

Improvement in connecting services and flight frequencies, which can generate increased traffic without having to expand networks, are among the major benefits airline alliances can bring to passengers. More particularly, Youssef and Hansen (1994) found in the particular case of the Swissair/SAS alliance a rise both in quantity and quality of Swissair/SAS connecting services, with the change in quantity of services being derived from an increase in the number of flights between the two carriers hubs, while the improved quality was brought about by both flight increases and better coordination under the alliance. In a search that attempts to measure the effect of alliances on passengers' schedule delay of three transatlantic alliances (KLM/Northwest Airlines, Lufthansa/United Airlines and Delta Air Lines/Swissair/Sabena), Oum, Park and Zhang (2000) suggest that complementary alliances (where partners have non-overlapping routes) enable partners to offer higher flight frequency to those passengers who fly beyond non-stop city-pair routes, as well as to the majority of connecting passengers. Parallel alliance partners (where partners have overlapping routes) are also expected to increase flight frequencies.

While there is some evidence of increases in flight frequencies and market share resulting from alliance agreements, this does not automatically mean that there are more users, that is, more passengers. However, these rather limited in scope studies tend to conclude that alliances do impact positively on passenger traffic especially as far as complementary alliance routes are concerned.

Gellman Research Associates (1994), in a study/research conducted at the request of the U.S. Department of Transportation (US DOT), measured the impact of the codesharing agreements between British Airways/USAir and KLM/Northwest Airlines on market share and welfare. In this study, they measured, using U.S. Origin and Destination Survey ticket sample data for the first quarter 1994 and flight alternatives, the market share effect by relating the estimation over a sample of city-pair markets of a discrete choice econometric model. This model relates market share to the attributes that characterizes the flights offered (such as fare, overall trip time, service quality, code share, online versus interline service, etc.). The results indicate significant impact across the KLM/Northwest Airlines and the British Airways/USAir code share markets in the sample: lower market share by 8.0% points for the former and 11.2% points for the latter under the counterfactual scenario (no code share).

The U.S. General Accounting Office (GAO, 1995) concluded, mainly based on interviews with representatives from governments and airlines, that strategic alliances between U.S and foreign airlines, which involve code share on a vast number of routes so as to strategically link airlines' flight

networks, have generated large gains for the participating carriers in terms of passengers and revenues. U.S. GAO indicated that British Airways/USAir, KLM/Northwest Airlines, and Lufthansa/United Airlines have increased their annual traffic on their alliance routes as a result of the formation of those alliances and that these gains can be attributed to: (a) code sharing and block-space sales agreements on numerous alliance routes covering a wide geographical area the alliance routes and (b) a high degree of operating and marketing integration.

There is also evidence that traffic gains can occur whether airlines re-align their strategies or not. Dresner, Flicop and Windle (1995) studied the outcome of three equity alliances (1988-Continental Airlines/SAS, 1989-Delta Air Lines/Swissair and 1989-KLM/Northwest Airlines) in order to see whether they have led to changes in airline route structure or not and to determine whether they have been successful in generating traffic or increasing market share on international routes. Using before and after alliance data for the years 1987-1991, the analysis indicated that in only one out of three agreement cases have the airlines increased their transatlantic traffic volume and increased their load factors after realigning their route systems to take advantage of the alliance. More precisely, it showed that although both KLM/Northwest Airlines and Continental Airlines/SAS followed re-aligning strategies, only the former achieved some successes in terms of traffic increase. On the contrary, Delta Air Lines/Swissair managed to increase their traffic and load factors despite not having re-aligned their route structure strategies. Whether these results can be generalised is uncertain because the study was limited only to equity alliances on the transatlantic routes. The overall conclusion was that alliances do not appear to guarantee success in the very competitive North Atlantic environment.

In his attempt to evaluate alliances' impact on passenger traffic, Bissessur (1996) estimated a traffic model over the 1982-1992 period with data for 52 inter-hub routes and from six major alliances (European Quality Alliance, Global Excellence, British Airways/USAir, KLM/Northwest Airlines, Continental Airlines/SAS and Iberia/Aerolineas Argentinas/Viasa). By comparing the traffic change induced by non-alliance factors (real GDP) with the actual level of traffic change between the pre- and post-alliance periods, he showed that major alliances lead to traffic increases on hub-hub routes with the exception of two routes (Copenhangen-Zurich and Vienna-Geneva). A further cross-section indicated that the main factors behind the alliances' operational success are: (a) the partners' network size and the compatibility of these networks, (b) the frequency of service between the hubs of the partners, (c) the flight connection time at the hub, and (d) the level of competition on their networks.[1]

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[1] See also Bissessur and Alamdari (1998).

Park and Zhang (1998) and Oum, Park and Zhang (2000) looked at the effects of an airline alliance on partner airlines' outputs by comparing traffic changes on alliance routes with those on non-alliance routes for the period 1992-1994. Using panel data of the four major alliances (British Airways/USAir, Delta Air Lines/Swissair/Sabena, KLM/Northwest Airlines and Lufthansa/United Airlines) operating non-stop routes on North Atlantic markets (19 alliance and 36 non-alliance routes) for the 1992-1994 period, they found that most of the partners have recorded greater traffic increases on their alliance routes than on their non-alliance routes. More specifically, the alliance routes of the eight airlines studied showed traffic increases ranging between 6.8% and 66.8% whereas non-alliance routes showed traffic decreases of as much as 3.2% and increases of up to 9.1%.

Oum, Park and Zhang (2000*)* sought to empirically investigate the effects of alliances on air fares, passenger volume, and consumer surplus by studying four major alliances operating on the transatlantic markets for the period 1990-1994. By estimating a system of demand and price equations using a database consisting of seventeen transatlantic alliance routes, they concluded, by comparing pre- and post-alliance outcomes, that the British Airways/USAir, KLM/Northwest Airlines and Lufthansa/United Airlines alliances, which can be considered as complementary alliances, increased aggregate demand on their alliance routes during the post-alliance period, while the Delta Air Lines/Swissair/Sabena, which can be viewed as a parallel alliance, decreased aggregate demand on their alliance routes during the post-alliance period. In a separate analysis studying the effect of alliances on the partners', the non-partners' and total traffic, they found that: (a) complementary alliances increase total output by an average of 11-17%, while parallel alliances decrease total output by an average of 11-15% and (b) the results for the non-partners' traffic are consistent with their theoretical predictions, which indicate that complementary alliance adversely affect non-partners' output.

Finally, Iatrou (2004) and Iatrou and Alamdari (2003) showed, through a series of interviews and questionnaires with the executives of the alliance department of airlines participating in the four global strategic alliances (Wings, Star Alliance, oneworld and SkyTeam), that alliances have indeed produced the expected positive impact in terms of traffic.

METHODOLOGY AND DATA

The methodology used in order to measure the alliance impact relies on a time series estimation of a traffic regression model. It is mainly based on the comparison of traffic variation induced by non-alliance factors, that is, per capita GDP in constant prices (RGDPPC), with the observed traffic variation during the post-alliance period.

Modelling the Airline Alliance Impact on Traffic

A simple way, but not an exhaustive one, to model traffic demand is to relate passenger traffic positively to real economic activity—as this is reflected by the per capita GDP in constant prices (RGDPPC)—and capacity (CAP) as a proxy of airline frequency, HHI for route specific competition and negatively to real fares (RY).[2]

Thus, the following multiplicative traffic model[3] results:

$$PASS_{ijt} = A \ RGDPPC_{jt}{}^{b} \ CAP_{ijt}{}^{c} \ RY_{ijt}{}^{d} \ 10^{(eHHI_{jt} fD)} \tag{1}$$

where $PASS_{ijt}$ = Passenger Traffic for the airline pair i, route j and year t,
               $RGDPPC_{jt}$ = Real GDP per capita of the origin country for the route j and year t expressed in local currency,
               CAP_{ijt} = Capacity for the airline pair i, route j and year t,
               RY_{ijt} = Real yield for pair i, route j and year t. As a proxy of real yield, the world nominal yield—in United States Dollar (USD)—converted into local currency and deflated by national inflation rate is chosen, while local and national refer to the origin country. The world passenger revenue per passenger kilometre, in USD, is used as a measure of nominal yield,[4]
               HHI_{jt} = Route specific competition for route j and year t, and
               D = A dummy variable which takes value one for the years 1980-81 (Second oil shock), 1991 (Gulf war) and 2001 (terrorist attacks on September 11) and value zero in all the other years;

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2 Of course, traffic for any given route tends to arise from the complex interaction of a much larger set of factors that affect the different market segments differentially. Two main categories of factors can be distinguished (Doganis, 2002). The first one includes those factors affecting all markets (level of personal disposable income, supply conditions, convenience of air travel, level of economic activity/trade, population size and growth rate, social environment, attitudes to travel, etc.). The second one includes the factors that affect only particular routes but may be totally absent on others (level of tourist attraction, exchange rate fluctuations, travel restrictions, historical/cultural links, earlier population movements, current labour flows, nature of economic activity, etc.).

3 A major disadvantage of using load factor when measuring the alliance impact is that the alliance impact is highly affected by service frequency. Any alliance is usually accompanied by an increase in service frequency, as the partners attempt to integrate their networks and gain market share, which in turn will affect negatively load factors given that traffic is likely to respond only gradually to any increasing frequencies.

4 It is acknowledged that the use of a global measure of nominal yield could lead to a mis-estimation of the price variable impact and thus increase the chances of finding a non-significant price impact.

which may alternatively be expressed as:

$LogPASS_{ijt} =$
$a + b \, LogRGDPPC_{jt} + c \, LogCAP_{ijt} + d \, LogRY_{ijt} + e \, HHI_{jt} + f \, D$ (2)

where $Log(\ )$: log to the base 10,
           $a = LogA$,
           b, c and $e > 0$,
           $d < 0$.

Disposable income

Any development in personal income affects the level of the purchasing power and the propensity to undertake leisure travel in general and air travel more specifically. As income increases two things take place: First, a greater part of the disposable income is spent on non-necessary consumer goods including air travel. Second, air travel, which constitutes a more expensive but also a more convenient means of transport for longer distances, becomes more accessible and more competitive (Lansing & Blood, 1984). Therefore, greater income results in an increase of expenditure on leisure traveling, but also in air transport being favoured over other competitive and alternative means of transport, especially for longer destinations. Taking into account that data concerning disposable income are not always available and that the way of measuring it differs from country to country, the use of GDP as a proxy measure is considered as essential.

The use of GDP is considered as the most appropriate measure for at least two more reasons.[5] First, it does constitute a measure index of national income and wealth and is included among the major determinants of leisure travel. As real GDP increases, people tend to have more income to consume (Kanafani, 1983) and at the same time the improvement of living standards leads to changes of consumer habits. These changes favour certain categories of goods and services, such as leisure activities, including travelling, which present high demand/revenue elasticities. Second, it does constitute a measure index of business activity and therefore wealth, and is included among the major determinants of business traveling.[6]

Any increase in population also leads to an increase in passenger traffic with the exception of the less developed countries, for which this relation

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5 The choice of per capita GDP as an approximation of personal disposable income does entails certain risks and restrictions as it assumes a homogeneous allocation of income among all classes and citizens.

6 The demand for business travel is not directly related to the disposable income of the business travelers themselves but to the needs of the businesses they work for. These needs are however directly related to the economic activity, and thus to national income and wealth.

does not apply in most cases, if at all; for the simple reason that a large part of the population simply cannot afford air travel.

RGDPPC as an explanatory variable presents many advantages, given that it is a composite variable that combines real GDP and population, two important explicative determinants of passenger traffic, as mentioned above, while it permits the avoidance of a third one, that of exports. Furthermore, it can be considered as a variable totally independent of the alliance formation.

Capacity

The use of *seat kilometre available* as an index measure of capacity and proxy of frequency entails a positive impact on passenger traffic for two reasons. First, any increase of available seats for any given level of demand can lead to higher supply and to fares' decrease, which can boost passenger traffic. Second, any increase in frequency can lead to the improvement of service quantity, which in its turn enables airlines/alliances to attract more passengers and convince them to use airplanes over any alternative and competitive means of transport, especially in relation to short haul and domestic flights, always provided of course that air fares remain affordable. Increased service frequency can also stimulate traffic as more flights are offered at convenient times.[7] At the level of specific airlines or routes, there is certainly an additional argument that renders frequency/capacity a significant parameter: increases in service frequency can increase the market share of an airline in relation to that of its competitors; this principle has been conceptualised in the generally accepted S-curve variation of market share with frequency (Taneja, 1981).

In a way, CAP can be considered as an index of the improvement of the quantity of service and, contrary to RGDPPC, it can be indeed

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7 An implicit assumption of the traffic regression model is that the cause-and-effect relationship, if any, between traffic and frequency/capacity is unidirectional: The explanatory variables are the cause and the dependent variable is the effect. It seems however, that in the particular case of traffic and capacity, such a one-way cause-and-effect relationship is not meaningful. This occurs because traffic is determined by frequency/capacity, and frequency/capacity is, in its turn, partly determined by traffic. As a matter of fact, higher frequency/capacity can stimulate traffic, but at the same time, a rising demand resulting from an increase in GDP can lead to an increase in frequency/capacity to accommodate the higher number of passengers, which makes the relationship a two-directional one. In short, this simultaneous relationship renders any distinction between dependent and explanatory variables dubious, and the least-squares estimators are, in this case, not only biased but also inconsistent since the endogenous explanatory variables become stochastic as they are correlated with the disturbance term of equation in which it appears as an explanatory variable (Gujarati, 1995). In order to overcome the problem of the simultaneous-equation bias, one could proceed to the estimation of a simultaneous two equations model, one for each of the jointly dependent variables, but first, it is necessary first to test the hypothesis of the mutual dependency using, for example, the pair wise Granger causality test (Granger, 1969).

considered as an alliance factor since the formation of the airline alliance can change dramatically the frequency of service (Youssef, 1992).

Fares

Apart from income and capacity, price is another variable that might have a major impact on air travel demand. Obviously, air travel prices are expected to have a negative impact, since price and demand usually move in opposite directions. If a fare goes up, demand is expected to fall, and vice versa. Given that low fares, or a limited change of fares, are likely to stimulate demand particularly in the leisure market,[8] it is necessary to include them in the regression model. Moreover, it would be illogical not to ascribe some part of the dynamic development of passenger traffic observed in recent years to the moderate evolution of nominal fares (Iatrou, 2004).

Previous studies on the issue of traffic have made use of airline yield as a good approximation of fare levels (Bissesur 1996; Morrison & Winston 1990). Airline yield indicates the passenger revenue per passenger-kilometre, that is, the ratio revenue to passenger-kilometres.

The choice of yield instead of fares is due to the various problems that have arisen from the use of ABC World Airways Guides that constitute the most official and sole information source of fares. First, available data are not very reliable in that they do not give the actual fares being paid. Indeed, owing to various unofficial discounts, the fares paid by consumers differ, often widely, from the published fares. In addition, the fare data are very complex with many different fare classes. Another restriction associated with the use of fares is that the available guides do not list fares for all destinations. The only fares that are consistently listed are those between the major hubs. On the whole, what characterizes all routes is the virtual non-availability of data for fares, their relative unreliability, which resulted in a difficult data processing to obtain the required complete and consistent time series. For this reason, it was decided that fares should not used as a variable measuring air travel demand, and yield is used instead.

In any case, it becomes obvious that yield has to be adjusted for price inflation so as to establish the real cost of air travel in relation to other goods or services and hence to correctly assess the role of air travel prices.

The Herfindahl-Hirschman Index (HHI)

Competition is a key factor of traffic growth and is expected to influence it negatively. In order to take into account the competition impact the well-

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8 Of course, fares are not expected to influence business and leisure travel in a uniform way. Since business travellers do not pay for their own travel, their demand would be relatively insensitive to fare changes and their price elasticities would be lower than those of leisure travellers. An examination of price elasticities in some studies shows this to be true (Straszheim, 1969).

know Herfindahl-Hirschman Index (HHI), is used. The HHI is used to measure the impact degree of competition and market concentration a certain market faces by investigating the market share of each firm. The HHI takes into account the relative size and distribution of the firms in a market and approaches zero when a market consists of a large number of firms of relatively equal size. The HHI increases both as the number of firms in the market decreases and as the disparity in size between those firms increases. It is intended to correct the possible misleading results guided only by the number of firms in the market. For example, an index of the number of firms will consider a market with 100 firms as competitive without recognising that two firms share 90% of the market, with the other 98 firms sharing only the remaining 10%. To account for both the number of firms and their market shares, the HHI is defined as the sum of the squared market share of each firm in a market as expressed in following equations 3 and 4:

$$A_i = \frac{S_i}{\sum_{i=1}^{n} S_i} \qquad (3)$$

$$\text{HHI} = \sum_{i=1}^{n} (A_i)^2 \qquad (4)$$

where
i   : the i-th airlines in the market,
n   : the number of airlines in the market,
S_i : the annual volume of the i-th airlines,
A_i : the market share of the i-th airlines, and
HHI: the Herfindahl-Hirschman Index of the market.

According to the definition of the HHI, the greater the HHI the less the competition exists in the market. In the extreme cases, a monopolistic market has an HHI equivalent to 1, and the HHI of a market with a perfectly competitive structure is close to zero.

Therefore, HHI is expected to have a positive sign since a low-competition environment will all others things being equal induce a higher traffic growth.

Isolation of the Alliance Impact by Separating Alliance and Non-alliance Effects

Given that traffic is explained by alliance and non-alliance factors, alliance impact can be deducted by neutralizing the influence of the latter. In

other words, the evaluation of the alliance impact relies on the isolation of the RGDPPC effect, and therefore, on the comparison of the observed traffic variation with the traffic variation induced by RGDPPC during the post-alliance period.

Suppose that passenger traffic is a function of RGDPPC according to the equation below:

$$LogPASS_t = a + b \ LogRGDPPC_t \tag{5}$$

It follows that parameter b represents the elasticity of traffic with respect to RGDPPC, given that the endogenous and the exogenous variables are expressed in logarithmic terms:

$$b = \frac{\dfrac{PASS_t - PASS_{t-1}}{PASS_{t-1}}}{\dfrac{RGDPPC_t - RGDPPC_{t-1}}{RGDPPC_{t-1}}} \tag{6}$$

In the case of an autoregressive traffic regression model—that is, one where the lagged value of the dependent variable appears as an explanatory variable on the right-hand side of the equation—b represents only the RGDPPC short term impact on traffic. Its long term or total impact is then given by:

$$b_{LT} = \frac{b}{(1\text{-estimated coefficient of } PASS_{t-1})} \tag{7}$$

Considering that the percentage variation in RGDPPC from alliance formation (t) to post-alliance period (t_+) is g%, it follows the passenger traffic change induced by RGDPPC will be bg% (or b_{LT}g%). If the observed percentage traffic variation during the given period is k%, then the percentage change in traffic brought about by the alliance formation can be approximated by (k-bg)% [or (k-b_{LT}g)%]. An approximate value of the absolute change in traffic that results from the alliance formation is then given by r[(k-bg)/100] or r[(k-b_{LT}g)/100] where *r* indicates the passenger traffic level at (t).

Because, as the airlines themselves have mentioned in the aforementioned survey and interviews, any given impact on traffic is generally observed quite rapidly—that is, within the first two years after their joining the alliance—t_+ is set arbitrarily to t+2 and k% is equal to:

$$k\% = \frac{PASS_{t+2} - PASS_t}{PASS_t} \tag{8}$$

One of the main weaknesses of this methodology is that it assumes that the alliance impact is equal to the observed variation in traffic volume, that is, k%, whenever the RGDPPC is found to be non-significant (b = 0). The reason is that RY and CAP are considered as alliance factors whereas RGDPPC as a non-alliance factor. This can lead to a misestimation of the alliance impact on passenger traffic insofar as fares and capacity do not depend solely on alliance strategies; they are clearly influenced by a set of other factors independent of alliance formation[9].

ESTIMATION METHOD AND DATA

The parameters will be determined by a time-series linear regression using ordinary least squares (OLS) unless the detection of heteroskedasticity, autocorrelation or both, requires the use of generalized least squares (GLS) in order to obtain efficient estimators and to render the usual hypothesis-testing procedure valid. In the case of heteroskedasticity, the White's heteroskedasticity-consistent covariance matrix is chosen in order to produce consistent coefficient's standard errors. In the autocorrelation or both heteroskedasticity and autocorrelation, the estimated generalized least squares (EGLS) is required; but one can also simply introduce the one-period lagged dependent variable among the explanatory variables.

The time span is the pre-alliance period (1982 to t) where t is defined as the date when the two partners involved extended their bilateral agreement to the route under consideration. Whenever the cooperation agreement entered in force in the first semester of year t, year t is considered as the alliance formation date. In case the cooperation began later in the year, In the opposite case, t+1 year is supposed to be the alliance formation date. One major problem which could not be overcome is that the pre-alliance period is often quite short to allow consistent econometric results. This is especially true for the partnerships that began in the late 1980s and early 1990s.

The main tests used to assess the quality of the estimation are the adjusted R^2 statistics, which gives a measure of the goodness of fit, and the F

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9 A fare and capacity model should have been estimated in order to quantify exactly the impact of an alliance on these variables, that is, which part of their changes during the post alliance period is due to the alliance and which is not. If it is assumed that φ and ω indicate respectively the part of the variation of fare and capacity that is not due to an alliance then the alliance impact is equal to (k-bg-φdf-ωcv)% when $b \neq 0$ or (k-φdf-ωcv)% when b = 0, where f% and v% represents respectively the variation of fares and capacity over the t+2 and t period. The approach used above supposes explicitly that φ and ω are zero. It follows there is overestimation of the alliance impact on traffic whenever (φdf)% > -(ωcv)% and underestimation whenever (φdf)% < -(ωcv)%.

statistics, which constitutes a measure of the overall significance of the estimated regression (joint test that all the regression coefficients are zero). Furthermore, some additional tests will be used to check whether some important assumptions of the classical linear regression model are fulfilled. More specifically, the hypothesis that disturbances are homoscedastic (White test) and uncorrelated (Durbin-Watson test) has to be controlled for. In the particular case the lagged dependent variable appears among the exogenous variables, the h-Durbin test will be used to test the error serial autocorrelation of order one.

In all cases, the e-Views software package is used in parallel with SPSS. The latter has been chosen in order to proceed to a step-wise regression which aims at determining which of all the explanatory variables is the most significant one.

The passenger and capacity data have been obtained by the series "Traffic by flight stage" published by International Civil Aviation Organization (ICAO). When such data were missing, they were obtained directly from the airlines (Air Canada year 1997) and the US DOT (KLM/Northwest Airlines years 1999-2001, American Airlines/Finnair years 1996-1997, Aeromexico/Delta Air Lines year 2000, Air France/Delta Air Lines year 1997 and SAS-United Airlines year 1991). Since the US DOT does not publish data on a one-way basis but on a round trip basis, data for any specific year, for which data are missing, had to be split based on each one-way route's past average percentage of total traffic.[10] For five additional routes, specific computation was needed in order to overcome the problem with missing data in relation to traffic and capacity for some specific years.[11] It should be stressed that in all cases, the estimation of non-available data, whatever method is used, tends to exacerbate the problem of measurement error, a phenomenon frequently met in econometrics.

Real GDP per capita was obtained from the International Monetary Fund (IMF) World Economic Outlook Database. All GDP series are expressed in local currency.

The world passenger revenue per passenger kilometre (in USD) was obtained by ICAO Financial Data Commercial Airlines. The data concerning the National inflation rates (Consumer Prices Index change of rate) data were obtained from the IMF World Economic Outlook Database. For both

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10 That was the case of New York-Mexico-New York (Aeromexico-2000), Paris-New York-Paris (Air France-1997), Amsterdam-Chicago-Amsterdam (KLM-1999/2000), Amsterdam-Los Angeles-Amsterdam (KLM-1999/2000), Amsterdam-New York-Amsterdam (KLM-1999/2000), New York-Helsinki-New York (Finnair-1996/1997), Paris-Chicago-Paris (Air France-1997), Miami-Mexico-Miami (Aeromexico-2000) and Merida-Miami-Merida (Aeromexico-2000).

11 London-Madrid for 1986 and Iberia, Frankfurt-Stockholm for 1991 and SAS, Copenhagen-Frankfurt for 1991 and SAS, Bangkok-Copenhagen for 1991 and SAS and Copenhagen-Bangkok for 1991 and SAS.

national inflation rates and cross-currency exchange rates, annual average measures instead of year-end measure are used.

The time span is covering the period beginning in 1982 and ending the year of the alliance formation.[12] Of course, there are some cases of routes for which the observation period begins after 1982 because of the data non-availability: for example, in the case of SkyTeam data are available only since 1985.

There were 124 routes examined. They include hub-hub, hub-non hub and non hub-non hub routes, all served by airlines which are members of the major four global airline alliances, that is, Wings, Star Alliance, oneworld and SkyTeam. Only routes with consistent and sufficient data are included in the analysis since the aim of the data collection process was to minimize potential sources of measurement error bias, which could affect the econometric results and lead to misspecification problems. At any rate, special attention has been given to the selection of routes. The selection was effected in a way so as to retain the representative character of the sample regarding the degree of cooperation and the type of routes for each global strategic alliance.

The sample, as it becomes clear from Table 1, is mainly dominated by hub-hub and hub-non hub routes, which represent 96.8% of the total number of routes analysed (43.6% and 53.2%, respectively) and 99.2% of the total passengers carried during the year 2001 (62.1% and 37.1%, respectively). Moreover, Star Alliance tends to be over-represented, while the other three major alliances are under-represented compared to their respective weights in the total traffic of the four global strategic alliances taken together. This fact is related mostly to: (a) the belated entry of certain airlines in a given alliance, (b) the late start date of cooperation between two airlines within a given alliance, (c) the late start of some flights which began during the 2000s, and (d) the availability of relevant data.

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12 Digest of Statistics on the Traffic by Flight Stage Series arranged by flight stage are available since 1969, but for the pre-1982 period, data were only published for the four selected months of March, June, September and December. Series containing aggregate annual data are only available since 1982. This is the main reason why the observation period began in that year.

Table 1: Number of routes examined for traffic impact of alliances, by alliance, type of routes and number of passengers in 2001

		Hub-Hub	Hub-Non Hub	Non Hub-Non Hub	Total
Wings	No of routes	0	10	0	10
	No of pass.	*(0)*	*(1,222,255)*	*(0)*	*(1,222,255)*
Star Alliance	No of routes	44	46	2	92
	No of pass.	*(8,240,293)*	*(4,568,748)*	*(91,796)*	*(12,900,837)*
oneworld	No of routes	4	4	0	8
	No of pass.	*(1,409,335)*	(316,727)	*(0)*	*(1,726,062)*
SkyTeam	No of routes	6	6	2	14
	No of pass.	*(1,697,388)*	(663,506)	*(51,416)*	*(2,412,310)*
Total	No of routes	54	66	4	124
	No of pass.	*(11,347,016)*	(6,771,236)	*(143,212)*	*(18,261,464)*

EMPIRICAL RESULTS

The econometric results tend to indicate that strategic alliances lead, on average, to a clear improvement in passenger traffic.

Traffic Model

Overall, the estimated models on the route level are quite satisfactory, all having a high goodness of fit and consequently high explanatory powers, except for certain routes. In fact, the explained variance of passenger traffic represents more than 90% of total variance in 68.5% of the cases, while it exceeds the 70% level in 93.5% of the cases. Although, the stepwise regression method was used in order to obtain the best specification—that is, that which includes the most significant set of exogenous variables and guarantees the highest goodness of fit—significant results could not be achieved for eight routes. For these routes the adjusted multiple coefficient of determination does not exceed 60%. One probable explanation for the low explanation of these models could be the short observation period and the small number of data points upon which the regressions were based. In any case, the conclusion reached is that for these routes, the selected set of explicative variables cannot be considered as major and significant determinants of passenger traffic.

Further, the models also present high F-statistics ascertaining their validity and the significance of the retained exogenous variables, at least for 96 routes. Independent variables all had high t-statistics implying that the

probability of them actually being zero is null at the 5% significance level. On the other hand, the Durbin-Watson statistic indicates that serial autocorrelation of first order of the disturbance was a serious problem for 68 routes. Thus, a correction was necessary, whether by introducing the lagged dependant variable ($PASS_{t-1}$) in 23 cases or by estimating an Estimated Generalized Least-Squares (EGLS) in 41 cases, supposing that the disturbances follow an autoregressive error model (AR).

In all cases, the heteroskedasticity was not a major problem, but whenever and wherever it was detected, it was automatically corrected by the White method, namely by the estimation of a consistent covariance matrix.

As expected, the CAP has been revealed as the most important factor in explaining the variation in passenger numbers, since it appears in the majority of the models (97.6%, i.e., 121 routes) and exhibits a high degree of statistical significance,[13] while the RGDPPC seems to have a more reduced impact, being significant in less than half of the cases (49.2%, i.e., 61 routes). That tends to indicate that these markets—the routes included are mostly non North-American originating—have not yet reached maturity. At the same time, RGDPPC is not significant for U.S. and Canadian originating routes. The short-term elasticity of traffic to RGDPPC lies in a wide range from 0.16 to 3.72, while it varies between 0.5 and 2.0 in 65.6% of the routes (80.3% when one takes into account the long term elasticity as well). These values are satisfactory considering that Bissessur (1996) obtained a similar range of values, but they exceed the values obtained previously for the income elasticity of demand for international air travel traffic (0.9 to 1.1). Finally, it seems that for 50.8% of the selected routes the alliance impact is equal to the traffic variation observed during the post-alliance period, since the methodology used supposed that whenever RGDPPC is found to be non-significant, any traffic variation induced by RGDPPC is null.

As indicated above, the capacity provided by the alliances is present in nearly all the models. This tends to demonstrate that any change in capacity introduced by an alliance is very likely to affect the traffic carried by the partners and therefore the network economies which might result. In one-third of the cases, the coefficient is less than unity, which means that any change in alliance capacity results in a lower than proportional increase in traffic.

As far as the real yield is concerned, the results were quite disappointing given that the price variable does not appear in many regressions. This variable seems to influence significantly the passenger traffic only in the case of 16 routes (12.9% of the total routes). This contradicts previous

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13 One should indicate that the Granger causality test performed on the route level does not support the hypothesis of

a two-way relationship between CAP and PASS revealing that passenger traffic does not Granger-cause capacity.

findings obtained by Iatrou (2004), which pointed to a negative and statistically significant price elasticity of demand for international passenger traffic. One possible reason is that the price variable retained is a global one, that is, one which measures the world trend of fares. Even if the fares listed in the ABC World Airways Guide had been used, there would have many chances that the same problem would have appeared, as Bissessur (1996) had already pointed out, since these fares are not the actual fares passengers are required to pay owing to the widespread practice of discounting. As for the hub-hub routes, one additional reason is that often they do not represent the passengers' final destination but an intermediary point to their final destination. In that case, the fares paid are those of the origin country and not those of the hub country. This is certainly valid also for the hub-non hub routes but not for the non hub-non hub routes.

The HHI variable introduced to measure the route specific competition effect on traffic does not appear to be a major determinant of passenger traffic since it is significant for only 22 routes (17.7%). The estimated coefficient is positive in all cases and lies between 0.05 and 0.5 except for one route where it exceeds 1 (1.322). The competition measure has therefore the expected sign indicating that low competition positively affects allied airlines traffic. HHI limited impact could be due in some extent to the limited degree of competition which characterized the routes of our samples.

The coefficient for the dummy introduced in order to capture and neutralize the consequences of war or/and recession have the expected negative sign in all the models it appears (42 routes, i.e., 33.9%). On average, the coefficient lies between -0.012 and -0.098: this means that adverse events reduced traffic from 2.7% to 27.2%.

Alliance Impact

As stated earlier, the alliance impact is given by the traffic variation observed during the post-alliance period, when such variation cannot be attributed to non-alliance factors. So it is necessary to remove the RGDPPC effect in order to obtain this impact at least for those routes which are affected by RGDPPC. In a total of 124 routes, 61 were affected by both alliance and non-alliance factors (GDP). For the rest however, it can be safely concluded that the change in traffic is mainly due to alliance strategies. Table 2 presents the results for each global strategic alliance separately.

Global Impact

All in all, the impact of global strategic alliances is, on average, significant and positive. The computation gives an estimated passenger increase of 9.4%, which implies an additional traffic of 1.5 millions (Table 2). The main part of this effect appears however, by the second year of the alliance formation since in the first one the traffic increase is just 2.3% compared with 6.9% for the second year (Table 3).

Table 2: Traffic impact of airline alliance, for four major global strategic alliances as observed in the second year after the alliance formation in relation to the pre-alliance period

Alliance	Additional traffic (vol.)	Traffic increase (%)
SkyTeam	227,694	11.0%
Oneworld	-62,875	-3.4%
Star Alliance	1,272,787	11.7%
Wings	43,327	4.6%
Total	1,480,933	9.4%

Table 3: Traffic impact of airline alliances, for four major global strategic alliances, during the post-alliance period of each alliance. The first column presents the t+1 effects while the second column the changes observed in year t+2 in relation to the year t+1

Alliance	1st year effect	2nd year effect
SkyTeam	-3.1%	14.6%
oneworld	2.1%	-5.6%
Star Alliance	3.8%	7.6%
Wings	-3.0%	7.8%
Total	2.3%	6.9%

Impact by global strategic alliance

Two of the strategic alliances considered, that is, Star Alliance and SkyTeam, present a traffic increase directly attributable to the alliance

formation which exceeds the average observed: 11.7% and 11.0%, respectively.

The results are quite different for the two other alliances: Wings presents a rise much lower than the average estimated (i.e., 4.7%), while oneworld a substantial decrease (i.e., -3.4%). The lower impact as far as the former alliance is concerned can be explained by the fact that the given strategic alliance is made up of only two airlines, which cover mainly the transatlantic area, and also by the fact that the sample is exclusively composed of hub-non hub routes since the hub-hub routes cooperation (Amsterdam-Detroit, Amsterdam-Minneapolis and Amsterdam-Memphis) began quite early, with the alliance formation (1993). The positive impact found in the case of Wings hub-non hub routes should be stressed; this finding shows that the strategic alliance has positive benefits for the entire flight network, and not only for hub-hub routes, and that the existence of antitrust immunity acts in that way. The negative impact as far as oneworld is concerned is due to several reasons. Two of the major members, American Airlines and British Airways, have not managed to extend their cooperation as they would have wished, as their proposed strategic cooperation has not been granted antitrust immunity by the US DOT for anticompetitive reasons. This has excluded the possibility of any code share cooperation on the transatlantic routes and between U.S. and European hubs. Besides, these two airlines were late in developing code share practices on behind-beyond flights. These facts have obviously affected in the same adverse way the other alliance members, since American Airlines and British Airways constitute the main alliance decision makers—it should not be forgotten that these two airlines have a 10% stake in Iberia.

On the opposite side, the high alliance impact observed for Star Alliance seems to be due the existence of an extended network in which 17 airlines participate (October 2003), and to the antitrust immunity enjoyed by of the two core members of the alliance (Lufthansa and United Airlines). The same seems to be true in the case of SkyTeam since it presents an extended and complementary network. The positive results of SkyTeam can be attributed to: (a) the worldwide geographical coverage which Air France and Delta Air Lines, the core members, offer; (b) the participation of two of the most efficient hubs (in Europe and in United States) in terms of traffic and connections provided (Charles de Gaulle and Atlanta); and (c) the tighter cooperation adopted in 1998 after the signing of a new bilateral agreement between France and the U.S. (which provided for more flights connecting the two countries).

Impact during the Post-alliance Period

A more in depth analysis of the alliance impact per period, as presented in Table 2, reveals that alliances have led to a reduction in traffic for both

SkyTeam and Wings during the first year of the post-alliance period. This negative impact can be attributed to the fact that the selected routes sampled include airlines which can be characterized as founding members: Air France, Delta Air Lines and Aeromexico for SkyTeam; KLM and Northwest Airlines for Wings. This tends to show that the alliance needs time to produce any positive benefits in terms of higher traffic. Further, Air France and Delta Air Lines used to cooperate with other airlines before setting up SkyTeam. Delta Air Lines was a member of Atlantic Excellence having a partnership with Swissair. Thus, some time was certainly needed not only to overcome the change of partner, but also to achieve network harmonization, to transfer Delta Air Lines European hub activities from Zurich to Paris, and for Delta Air Lines passengers to get familiarized with the new partnerships. Additionally, it is commonly acknowledged that a strategic alliance needs more time to produce positive results than a simpler type of cooperation.

As far as Wings is concerned, the negative results might be due to Northwest Airlines facing financial situation in that particular period and to the exclusive analysis of hub-non hub routes.

By contrast, Star Alliance, which seems to be the most successful global alliance among the four considered here, presents a positive and gradually increasing impact during the two years following the alliance formation: 3.8% for the first year and 7.6% for the second one.

Impact by Type of Routes

One would expect that hub-hub routes would have shown a larger impact as one of the very aims of alliances is to forward a greater percentage of the allied partners' traffic through hubs. It seems that this is not the case since an equivalent positive impact for hub-hub and hub-non hub routes is found: 9.3% and 9.4%, respectively.[14] Two reasons can explain this unexpected result. First, it can be explained by the existence of a large number of U.S. *(*New York, Dallas, Boston and Chicago, for example) and European final and non-hub destinations, which can be reached directly without necessarily passing through hubs. Secondly, it can also be due to the fact that the hub-hub system needs time to function efficiently. The creation of a common network, pricing and scheduling policy as well as the harmonization of terminals and technology systems (for example, Computer Reservation Systems), that would enable the partners to forward behind-beyond destinations passengers through their hubs, require certain time to be implemented. In addition, certain hubs such as London-Heathrow and Frankfurt were already important business centers and had therefore

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14 In absolute numbers of course, the impact for hub-hub is twice as large as that for hub-non hub given their larger traffic.

significant traffic. In addition, these airports are seriously congested with little space for expansion.

The non hub-non hub routes present a positive increase in traffic, an increase directly attributable to the alliance formation, but this result cannot be considered a significant one, given the very limited number of routes (4) included in the sample studied.

Table 4: Traffic impact of airline alliances, by type of routes

Type of route	%
Hub-Hub	9.3%
Hub-Non Hub	9.4%
Non Hub-Non Hub	11.6%

Alliances seem to have important spill over effects as they influence positively the allied airlines' traffic on their entire network.

Impact by Type of Cooperation

The greater impact by far is brought about by strategic alliances with and without antitrust immunity: 14.6% and 9.8%, respectively. A strategic alliance with antitrust immunity presents a higher increase, since it enables partners to follow a common scheduling/pricing policy and to coordinate networks. This result confirms that the simple joining of a given alliance is not sufficient by itself to lead to traffic improvement and that the tighter the cooperation, the higher the benefits enjoyed in terms of traffic.

A quite surprising result is that of code share since the estimated increase in traffic brought about by this type of cooperation is almost insignificant (1.3%) and well below that of frequent flyer programs (FFP), the simplest type of cooperation. This is entirely due to the negative impact on Star Alliance code shared routes (-2.1% versus 7.6% for oneworld the other alliance for which code share routes are considered in the selected sample). The more plausible reason for this paradox is that the sample under examination included routes on which there is virtually no competition, and therefore there was no additional traffic to gain over from other competitors. FFP on the other hand, tends to register a more significant increase since the customers gain more tangible and immediate benefits from FFPs, such as mileage, than from code share.

Table 5: Traffic impact of airline alliances, by type of cooperation

Type of cooperation	%
Frequent Flier Programs	4.6%
Code share	1.3%
Strategic alliance without antitrust immunity	9.8%
Strategic alliance with antitrust immunity	14.6%

In comparison with FFP, which is a cost-free and quickly-producing results-type of cooperation, strategic alliances seem to present a more pronounced positive impact in the second year of the post-alliance period, since they obviously need more time to produce their benefits. This conclusion agrees with Gallacher's statement (1997) that FFPs' ability to influence business class travelers has made them more important to global alliances than code share.

Impact by Route Distance

As expected, the largest impact is observed on long haul flights in comparison with short haul ones[15] (11.8% versus 7.4%) since a larger part of passengers with behind-beyond destinations prefers to travel with allied airlines which offer better scheduling and connection times. Another reason contributing to this result might be the limited competition, which characterizes these types of routes, given the cooperation between allied airlines.

However, the short haul routes present—in the short term, and more particularly in the first year of the post-alliance period—a greater increase in traffic since they constitute in many cases the final destinations of the travelers or tourist or/and business centers especially in the case of Europe (Paris, London, Amsterdam and Frankfurt). By contrast, the greater impact for long haul routes is observed during the second year of the post-alliance period, as the positive effect of tighter cooperation in an increased number of behind-beyond destinations, network harmonization and the entrance of new airlines into the alliance.

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15 Long haul routes are the intercontinental (from to continent to continent) ones while short haul routes are those effected within the same continent.

Table 6: Traffic impact of airline alliances, by distances of routes

Route distance	%
Long haul	11.8%
Short haul	7.4%

Short haul routes register a smaller traffic increase because these routes present more options in terms of fares, face increased competition from low-cost airlines and alternative means of transport. On long haul routes however, allied partners put an emphasis as customers seek more benefits in terms of mileage and quality of service.

CONCLUSION

On average, it seems that strategic alliances lead to a significant increase of traffic on alliance routes.

As expected, the alliance impact has been higher in the case of hub-hub routes given the airlines' increased interest to serve behind-beyond destination passengers through their hubs by the creation of an efficient hub-and-spoke system. Equally important is the finding that a similar increase, even though slightly lower, was observed for hub-non hub routes. This means that alliances tend to influence positively airlines' extended networks and not only their hub-hub routes.

The more strategic the cooperation among the allied partners, the greater the impact, as this type of cooperation with the tighter links provides for common scheduling, pricing policy, etc.

Further, long haul routes lead to better results in terms of additional traffic since the competition on those routes tends to be limited or even non-existent, and since the partners tend to offer a worldwide coverage. However, any alliance impact seems to become apparent within two years after the alliance formation.

Finally, it is the global strategic alliances, which can be characterized by a greater number of allied airlines and thus an extended network, by the existence of antitrust immunity, at least between the core members, and by an efficient and productive hub-and-spoke system (Star Alliance and SkyTeam, for example) are the ones that tend to take more advantage of the alliance formation.

The above conclusions confirm those drawn by the recent surveys conducted by Iatrou and Alamdari (2003) and Iatrou (2004), which interviewed a large number of carriers' executives of the four alliances involved. A quick comparison shows that global strategic alliances lead to an

increase in traffic, all others things being equal, within the first two years after the alliance formation, since 64% of the interviewees answered that the alliance impact on traffic exceeded 6%, while 43% of them has indicated that this effect was apparent within the first two years of the alliance formation. While the survey showed that 50% of the interviewed airlines believed that the impact is of the same range for each of the first two years of the post-alliance period, according to the econometric analysis, it is in the second year of the post-alliance that the alliance impact on traffic reaches its peak and it is double that observed during the first year.

Obviously, the above research could be extended and completed in many ways to get a more accurate assessment of airline alliance effects on traffic. First, the hypothesis considering real fares and capacities as alliance factors should be relaxed given that they cannot be considered as totally dependent of alliances, and this is especially true as far as fares are concerned. Secondly, a more accurate fare measurement should be taken into account in order to capture the price effect on traffic, since it has been shown, at least on a global level, that traffic volume is negatively correlated to real fares (Iatrou, 2004). More specifically, a route level measure should be retained as it was done in the research by Bissessur (1996). Thirdly, in theory, non-alliance routes could be used to benchmark the alliance impact in a attempt aiming to measure true alliance traffic impact, so as to reach a more reliable assessment. But such a comparison will be possible only in the future when new routes are introduced because there are practically no data about the non-alliance routes to use for benchmarking purposes. Most likely, any new routes introduced in the future will follow the alliance/code share practice. Since partner airlines tend to feed domestic traffic onto their alliance routes and or reroute it through their alliance routes (Oum, Park & Zhang, 2000; Park & Zhang, 1998), non-alliance routes traffic could decline and as a result the alliance impact could be lesser than that estimated. Finally, one should extend the analysis of the effects of complementary and parallel airline alliances on partner airlines' outputs in order to confirm the conclusion drawn by Oum, Park and Zhang (2000) and Park and Zhang (1998) according to which complementary alliances lead to a increase in partners' output while parallel ones lead, on the contrary, to a decrease in partners' output.

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STUDY RESULTS ON KNOWLEDGE REQUIREMENTS FOR ENTRY-LEVEL AIRPORT OPERATIONS AND MANAGEMENT PERSONNEL

Stephen M. Quilty
Bowling Green State University
Bowling Green, Ohio

ABSTRACT

This paper identifies important topical knowledge areas required of individuals employed in airport operations and management positions. A total of 116 airport managers and airfield operations personnel responded to a survey that sought to identify the importance of various subject matter for entry level airport operations personnel. The results from this study add to the body of research on aviation management curriculum development and can be used to better develop university curriculum and supplemental training focused on airport management and operations. Recommendations are made for specialized airport courses within aviation management programs. Further, this study identifies for job seekers or individuals employed in entry level positions those knowledge requirements deemed important by airport managers and operations personnel at different sized airports.

INTRODUCTION

In a speech given at the fifth annual General Aviation Forecast Conference, then University Aviation Association (UAA) President James E. Crehan called upon the aviation industry to define future personnel needs in terms of entry level qualifications and experiences so that UAA member institutions could respond to those needs. Previously, Lehrer (1992) had brought to the attention of the aviation community the increasing emphasis of university and college accrediting bodies to assess the learning that occurs within an aviation program. He raised the question of what skills, knowledge and values should a well educated aviation graduate possess? His question followed his previous work (1985) of trying to identify an aviation management curriculum for the benefit of students and the industry.

Stephen M. Quilty, A.A.E., is an Associate Professor in the Aviation Studies Program, Department of Technology Systems, at Bowling Green State University, Bowling Green, Ohio, USA. His experience and research focus is in the area of airport management, operations, education and training.

Documentation of industry needs in flight education has been well developed. Not as well developed is documentation in the aviation management field and, in particular, airport management and operations. Research is still needed to help validate the degree of importance for various knowledge requirements as they apply to specific areas and various types of aviation management. In his critique of aviation management programs, Philips (2004) recommends that the term "aviation management" needs to be better defined and have improved pedagogical development. This paper helps to articulate future personnel knowledge requirements for entry level positions in airport operations, drawing on the assumption that the most common path to the position of airport manager or director begins with entry level airfield operation positions. This assumption is supported by Sackett (1992), Howell (1997), Prather (1999) and Quilty (2004).

Most university curricula have but one course in airport management as a result of guidelines established by the Council on Aviation Accreditation (CAA), an accrediting body for non-engineering university aviation programs. Those guidelines reflect an earlier industry and U.S. Federal Aviation Administration (FAA; 1989) assessment of what was important for a broad aviation management education. The broad education perspective was all inclusive and covered air traffic management, airline management, airport management, general aviation service management, aviation manufacturing management and other service sector management. Invariably, in attempting to cover such broad areas, the recommended courses tended to be generic and left many specific career track topics lacking in the requisite knowledge or skill content necessary to fully understand the intended career track.

The current CAA guidelines (2003) identify a singular course called aviation management. It also calls for singular courses in aviation law, aviation business administration, aviation economics, and aviation safety. Not identified in the guidelines are what specific content or knowledge requirements are to be included in each course title. Quilty (2004) asserted that a single course in aviation management did not adequately prepare students for entry level or career positions in airports. Adequate research study related to the requirements of the airport industry is lacking. The study results included in this paper strive to address the knowledge and topic areas required by the airport industry for an airport management curriculum.

Previous journal articles have sought to quantify and validate knowledge requirements for airport management degree programs at colleges and universities. Lehrer (1985) identified 31 academic course titles and descriptions. He stated in his dissertation that one of the first attempts to define an airport management curriculum was in 1949 (p. 45). Truitt, Hamman, and Palinkas (1994) identified courses important for a graduate program in airport administration. Kaps and Widick (1995) suggested

educational requirements for a career in airport management at the undergraduate level. Fuller and Truitt (1997) surveyed airport consultants about course curriculum matters.

Prather (1998) conducted a study seeking the views of airport managers on the most appropriate fields of study, academic degrees, and aviation courses. Ruiz et al. (2000) conducted a study to determine the degree to which graduates of a university aviation management program perceived the usefulness of the program for their career choices. Kaps and NewMyer (2001) reviewed published material from State Aviation organizations that provided advice to airport managers and identified important and common subject matter material. Quilty (2004) reviewed airport job descriptions over a three year period and identified common knowledge and skill requirements listed in the descriptions.

Most of the studies suggest that skills and knowledge requirements for airport operations and management have changed over the years. Based on these studies, the requirements are becoming more diverse, challenging and technical. While identifying specific courses similar to the CAA guidelines, much of the research is lacking in the more descriptive content knowledge requirements necessary for today's airport management graduates. The research also is lacking in identification of the importance of skills and knowledge for different sized airports.

This paper contributes to the aviation and airport management field by identifying knowledge requirements deemed important by airport managers and employees for those who seek entry level positions in the field of airport operations. This information forms a basis for establishing both performance objectives, learning outcomes, and curriculum content for educational and training programs.

METHODOLOGY

The survey instrument used in the study was targeted toward individuals whose job positions are related to the safe operation of an airfield, such as airfield operation, maintenance and inspection personnel. Surveyed for this study were individuals having responsibility for hiring or supervision of airfield operation employees, and individuals employed in operations positions. The study specifically targeted airfield operations rather than terminal or landside operations as airfield operations is an area of qualified concern for the FAA in light of changes to Part 139 (Certification of Airports), 14 Code of Federal Regulations (CFR).

The survey instrument was developed by identifying 92 knowledge variables derived from Part 139; job descriptions analyzed and used in Quilty's (2004) study; the CAA Accreditation Standards Manual (CAA, 2003); Flouris and Gibson's (2002) survey instrument, curricular material

from various university aviation programs, and a similar knowledge list developed for the National Business Aviation Association (NBAA) Corporate Aviation Management Development Committee (Quilty, 1996). The survey was approved for use by the Human Subject Review Board at Bowling Green State University, Ohio, and was pretested among members of the American Association of Airport Executives (AAAE) Airport Training Committee.

Data were collected from both large-hub, medium-hub, small-hub, non-hub and general aviation airport operators. The airport categories are identified by the FAA National Plan of Integrated Airport System (NPIAS). The hub designation relates to the number of operations and passenger enplanements an airport has over a calendar year time. For the year 2003, there were 31 large-hub airports, 37 medium-hub airports, 68 small-hub airports, 247 non-hub airports, and 2,961 other airports (other commercial service, reliever, general aviation) in the NPIAS (U.S. Department of Transportation, 2004, p. 5).

An initial electronic mailing of the survey was made in July, 2004, to 356 individuals who were identified in the 2003 membership directory of AAAE. Of the initial mailing, 82 e-mail addresses were returned undeliverable and 274 e-mails were successfully transmitted. There were two follow up e-mails requesting responses in August of 2004. Receipt of surveys was stopped in late September. Of the 274 valid e-mails delivered, 116 responses (42.3%) were received and deemed usable for evaluation.

Demographic information collected for this study included the respondent's position and title; whether the respondent was in a supervisory position or an entry level position; the number of years a respondent was employed in the airport profession; gender; the level of formal education received; and the size of the airport.

The survey requested Likert-type responses in two columns. The survey asked individuals employed in airport management and operation positions their perception of those knowledge requirements important for individuals employed in the field of airfield operations or for those individuals having duties for inspection or safety of the airfield. It further asked them to rank the level of knowledge they believed new hires or recent applicants had about the topic areas. This paper reports only on the results from the first column—the ranking of knowledge topics in importance by managers and operations personnel. Participants in the study were given the instructions shown in Table 1.

Table 1: Instructions given to survey respondents

_____

In the LEFT COLUMN, identify how important the topic is to an airfield operations person, based on the numbers 1 through 6 below.	In the RIGHT COLUMN, identify how prepared you feel operation new hires or applicants are, using the scale A through E below.
1 - EXTREMELY IMPORTANT	WELL PREPARED - A
2 - VERY IMPORTANTADEQUATELY	PREPARED - B
3 - SOMEWHAT IMPORTANT	SOMEWHAT PREPARED - C
4 - NOT VERY IMPORTANT	LESS THAN PREPARED - D
5 - NOT AT ALL IMPORTANT	NOT AT ALL PREPARED - E
6 - DO NOT KNOW IMPORTANCE	

_____

A mean and standard deviation analyses were accomplished for all 92 variables from which their overall ranking (1 is most important) was determined (Table 3). Statistical analysis was accomplished by the Statistical Consulting Center at Bowling Green State University using SAS programming. Because changes were made by the FAA to 14 CFR Part 139 during the data collection time period, the variable "knowledge of airport certification specifications requirements and content (Table 2, item 11 and Appendix B)" was made obsolete by the changes and therefore was not included in subgroup analysis. Performing a statistical comparison to determine the degree of importance between each of the remaining 91 topic variables would provide an analysis of questionable detail due to the number of variables. A grouping of like topics with a comparison between the groups would have more meaning to practitioners.

Due to the individual statistical processing difficulty, the 91 variables were first grouped into 26 subgroups. Grouping of the 26 variables into topical subject matter was accomplished by the researcher in conjunction with a review of the groups by knowledgeable individuals in the field of airport management. To allow for further statistical analyses, the 26 subgroups were placed into the 7 major groups. The major groupings reflect further similarity of topic areas and are grouped as they may relate to a particular course content or offering within a university department. The 7 major groups and respective subgroups are listed on Table 3. The subgroups are described in Appendix A. The variables listed in Appendix A were randomly listed in the survey.

To determine the degree of reliability and consistency among the multivariate factors that made up each major group, a Cronbach's Alpha analysis was performed on each group (Table 4). Determination of Cronbach's Alpha will help to assess whether or not the choice of an included variable in a group is appropriate or not.

In assessing whether significant differences exist among the major group means, a repeated measures analysis of variance was performed. The analysis looked at one major group mean and compared it to the other group means to see whether or not differences exist between the groups. A Tukey analysis was then conducted to identify where those differences occurred (Table 5). The Tukey analysis allows for clusters or groups of variables to be compared to each other to determine significant differences among them.

Study Limitations

This study was limited to AAAE members employed at various airports in the United States. It is unknown how many individuals in management, supervisory or entry level operation positions are not members of AAAE, and therefore were not included in the solicitation. Another limitation is the degree of understanding respondents may have about the meaning behind each of the knowledge topics identified, or the degree of semantic bias individuals may have for the various words used to describe the knowledge topic. The study did not attempt to mitigate these limitations.

Another limitation is the geographic area solicited for the study. For example, responses to some topic variables such as "knowledge of snow and ice control plans and snow removal operations" would receive widely disparate rankings depending upon whether one was employed in the southern or northern part of the United States. The study did not attempt to mitigate this limitation.

A further limitation of the study is the seasonality of the survey. The survey was conducted in the summer months of July to August and so responses may reflect several seasonal factors such as staffing shortages due to vacations, non-winter operations, or heavy construction activity. The study tried to minimize this limitation by seeking response to the survey over a three month period.

Whereas the survey covered different airport hub sizes, errors may exist in applying the findings to specific operations. Differences do exist in the specific duties and responsibilities of airport operation managers or officers depending upon the organizational structure, size of the airport, type of operation, and different forms of ownership/operation. This would impact how one responded in ranking a particular topic.

An example of this would be the rating of environmental law and regulations as very important by an operations officer at one particular airport because he or she is responsible for handling environmental issues associated with aviation fuel tanks, deicing, noise or other. An operations officer at another airport may rate environmental law low because their organization is of such size as to have a separate person or staff function responsible for handling that issue. The survey did not ask if environmental issues actually existed, only the degree of importance from a knowledge

perspective. This particular limitation is minimized to the extent that the study sought to better identify specific knowledge *areas* necessary for entry level positions at airports overall, rather than seeking actual specifics for different sized airports. However, the latter is presented for basic analysis in Appendix B.

One other limitation placed on the study relates to the educational knowledge of the respondents. A respondent's educational background could have an effect on the results in that knowledge or skills learned or practiced are more likely to be implemented or used, and those not learned or practiced will be less likely to be considered a requirement. For example, an individual having an educational background in, or an understanding of, business statistics is more likely to incorporate or recognize its use in airport operations and therefore would consider it more important than someone who did not have similar knowledge or education. Collectively, the study attempts to minimize this limitation through the collection of data from diverse respondents. Of the respondents, 13 had high school degrees, two had 2-year associate degrees, 59 had a 4-year undergraduate degree, 31 had a masters or higher degree, one had military education only, and 10 had military education plus some college course work but no degree.

RESULTS

Of the 116 responses, 18 (15.6%) were from airport managers, 62 (53.4%) from airport operations supervisors, and 36 (31.0%) from entry level employees. The airport managers were primarily from small-hub, non-hub or general aviation airports because that position was targeted as having more direct involvement in airfield operations.

Responses from large-hub airports numbered 22 (19.0%) of the total, medium-hub airports numbered 19 (16.4%), small-hub airports numbered 16 (13.8%), non-hub airports numbered 31 (26.7%), and general aviation/reliever airports numbered 28 (24.1%) respondents. The demographic responses included 94 males (81.0%) and 22 females (19.0%). These demographics provided a cross section of the airport organizations sought for the study.

Table 2 provides the overall mean ranking of the 91 variables (with shortened titles) identified in the survey. A full description of the knowledge variables listed in Table 2 is provided in Appendix A.

Table 2: Priority ranking of 92 knowledge variables important for individuals employed in the field of airfield operations or for those individuals having duties for inspection or safety of the airfield

Rank	Topic	M	SD
1	Ground Vehicle Operation	1.181	0.468
2	Self Inspection	1.198	0.514
3	Lighting	1.216	0.524
4	Airport Emergency Plan	1.224	0.439
5	Notices to Airmen (NOTAMs)	1.250	0.558
6	Part 139 compliance	1.259	0.674
7	Airport Certification Manual	1.293	0.673
8	Acronyms	1.388	0.656
9	Security ID Area	1.422	0.748
10	Construct Activity	1.526	0.751
11	Airport Certification Specifications	1.527	0.955
12	Wildlife	1.569	0.836
13	Airport Security Plan	1.578	0.876
14	Part 77 Obstructions	1.724	0.809
15	Airport Design and Layout	1.802	0.836
16	General Aviation Operations	1.809	0.837
17	Air Traffic Control Operations	1.828	0.738
18	Airport Rescue/Firefighting	1.888	0.967
19	Fueling Operations	1.914	0.830
20	Aircraft Regulations	1.922	0.886
21	Federal Regulations	1.978	0.861
22	Communication Center Operation	2.017	0.995
23	Form 5010 Master Record	2.036	0.914
24	Snow Removal Operation	2.052	1.369
25	Airline Operations	2.078	1.039
26	Management	2.112	0.930
27	Form 7460-1 Obstructions	2.121	1.065
28	Construction Methods	2.155	0.871
29	Air Carrier Security Plan	2.198	1.105
30	Air Traffic Control Equipment	2.241	0.947
31	Word and Spreadsheet Applications	2.296	0.878
32	New Security Technology	2.336	2.336
33	Air Cargo Security Plan	2.345	1.080
34	Public Relations	2.353	0.837
35	Material Safety Data Sheets (MSDS)	2.365	0.911
36	Organizational Communication	2.379	0.939
37	Air Taxi Operations	2.379	0.939
38	Environmental Compliance	2.388	0.892
39	Department of Transportation (DOT) Hazmat	2.397	0.893
40	14 CFR Part 191 Sensitive Security Information (SSI)	2.402	1.135
41	Environmental Laws	2.414	0.781
42	Public Administration	2.417	0.955
43	Pavement Deicing	2.474	1.206
44	Air Cargo Operations	2.483	1.051
45	Occupational Safety and Health Administration (OSHA) regulations	2.483	0.909

Table 2: Priority ranking of 92 knowledge variables important for individuals employed in the field of airfield operations or for those individuals having duties for inspection or safety of the airfield

46	Police Procedures	2.491	0.880
47	Noise Requirements	2.500	0.860
48	Capacity/delay Impact	2.578	1.048
49	Speech Communication	2.595	1.004
50	Project Management	2.595	0.942
51	Human Resource Development (HRD) Processes	2.716	0.940
52	American Disability Act (ADA) compliance	2.741	0.915
53	Meteorology	2.750	0.959
54	Military Operations	2.819	0.965
55	Bid Specifications	2.828	1.137
56	Ground Transportation	2.862	1.003
57	Aviation History	2.862	0.932
58	New Airport Technology	2.871	0.860
59	Equipment Operation	2.897	1.281
60	Contract Administration	2.897	0.954
61	Aviation Law	2.930	1.041
62	Facility Maintenance	2.931	0.958
63	Information Systems (MIS)	2.991	0.982
64	Master Planning Process	3.009	0.797
65	Parking Operations	3.043	1.111
66	Aircraft Deicing	3.071	1.124
67	Labor Relations	3.104	0.931
68	Science Principles	3.123	0.933
69	Risk Management	3.138	0.986
70	Accounting	3.157	0.979
71	Travel and Tourism	3.181	0.956
72	Finance	3.190	0.922
73	Property Management	3.328	0.949
74	Electricity Basics	3.345	0.952
75	Contract Law	3.351	1.064
76	Building Codes	3.422	0.815
77	Marketing	3.422	0.886
78	Helicopter Operations	3.452	0.830
79	Building Systems	3.461	0.981
80	Tort Law	3.504	1.045
81	Politics	3.526	0.952
82	Civil Engineering	3.531	0.897
83	Computer Aided Design/Geographical Information System	3.539	1.045
84	Programming	3.638	1.083
85	Architecture	3.693	0.832
86	Social Psychology	3.708	0.820
87	Statistics	3.741	0.878
88	Micro Economics	3.781	0.870
89	Foreign Language	3.796	0.937
90	Socioeconomics	3.796	0.857
91	Macro Economics	3.825	0.905
92	International Commerce	3.895	0.856

Note. Rank scale is 1 to 5 with 1 being the most important.

Table 3 identifies the grouping of the 91 variables into 26 topical subject matter subgroups which are further categorized into seven major groups A-F. The grouping allows for better statistical analyses and meaning of the individual variables. The major groupings reflect similarity of topic areas and are grouped as they may relate to a particular course content or offering within a university department. Appendix A provides the descriptive wording used in the survey.

Table 3: Identification of seven major groups of knowledge combining the 26 subgroups of the 91 knowledge variables important for individuals employed in the field of airfield operations or for those individuals having duties for inspection or safety of the airfield

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Group A - 22 variables subgrouped as:
> Lighting signs and markings (1.22)
> Self-Inspection (1.49)
> Part 139 Regulation (1.52)
> ARFF and Emergency Plan (1.56)
> Wildlife (1.58)
> Part 77 Obstructions (2.03)
> Ground Vehicle Operation (2.19)
> Hazardous Material (2.22)
> Snow and Ice Removal (2.24)

Group B - 7 variables subgrouped as:
> Security (2.11)

Group C - 19 variables subgrouped as:
> Aviation general (2.48)
> Aircraft Characteristics (2.50)
> Record management (3.12)
> Science (3.13)

Group D - 17 variables subgrouped as:
> Environment and Noise (2.42)
> Master Planning and Design (2.47)
> Ground Transportation (2.96)
> Building Systems (3.21)

Group E - 8 variables subgrouped as:
> Project Management/Construction (2.64)
> Communication (2.70)
> Management and Supervision (2.91)

Group G - 8 variables subgrouped as:
> Administration (2.98)
> Contracts and Law (3.10)

Group F- 10 variables subgrouped as:
> Marketing (3.21)
> Finance and Accounting (3.35)
> Economics (3.71)

Note. Mean (M) of the subgroup is in parenthesis.

Table 4 represents the ranking of the knowledge groups deemed important for individuals holding positions in airfield operations at U.S. airports. The ranking is based upon the mean (M). The standard deviation

(SD) is provided to give an indication of the range of responses from the mean.

A Cronbach's Alpha analysis (Table 4) was performed on each major group to determine the degree of reliability and correlation among the multivariate factors comprising each group. Determination of Cronbach's Alpha will help to assess whether or not the choice of an included variable in a group is appropriate or not. A correlation of 0.700 or higher is acceptable for this study. Due to the multidimensionality of the variables making up each group, standardized index values were used.

Of the seven groups, only Group E had individual topic variables having less than 0.700. Reliability in Group E was weak due to low Alpha's for the variables speech communication, management, and human resource and development. This means these three topic variables should be included in a new or different group.

Table 4: Means and standard deviation for the major groups of knowledge important for individuals employed in the field of airfield operations or for those individuals having duties for inspection or safety of the airfield

Variable	Mean	Standard Deviation	Cronbach's Alpha
Group A	1.906	0.398	0.821
Group B	2.109	0.698	0.836
Group C	2.721	0.458	0.806
Group D	2.713	0.455	0.793
Group E	2.793	0.573	0.744
Group F	3.430	0.603	0.866
Group G	3.078	0.708	0.871

Note. Alpha deemed reliable for values > 0.700

In assessing whether significant differences exist among the major group means a repeated measures analysis of variance was performed. The analysis compared one major group mean and to the other group means to see whether or not differences existed between the groups. A Tukey analysis was then conducted to identify where those differences occurred. The Tukey analysis allows for comparing clusters or groups of variables to each other to determine significant differences among them.

Table 5 shows the difference between groups resulting from the Tukey analysis. Where a major group shows a significant difference to another group (marked by X), an argument can be made that the groups can be treated as distinct content areas to be addressed in an education or training curriculum.

**Table 5: Tukey analyses identifying significant differences between major groups of
knowledge important for individuals employed in the field of airfield operations or for
those individuals having duties for inspection or safety of the airfield**

	Group A	Group B	Group C	Group D	Group E	Group F	Group G
Group A		X	X	X	X	X	X
Group B			X	X	X	X	X
Group C				O	O	X	X
Group D					O	X	X
Group E						X	X
Group F							X
Group G							

Note. Tukey critical value w = q.05(7,672) ≈ 0.158.
   X = column and row means are significantly different.
   0 = no difference between column and row means.

Appendix B lists the responses to the survey according to airport size of large-hub, medium-hub, small-hub, non-hub, and general aviation reliever as defined by the U.S. Department of Transportation (2004). The data are listed in both value and graphic form. The graphic form breaks the responses into groups of 15, except for the last group of 17. It assists in comparing the rank of importance for the 91 variables between the different airport sizes. Statistical analysis using airport size is not supported due to the small number of responses in each category. However, the breakout does allow for some interpretation of what is important at the different sized airports.

DISCUSSION

Group A from Table 3 is primarily made up of the operational requirements of Subpart D of 14 CFR Part 139 Certification of Airports. Subpart D of Part 139 spells out the required inspection and safety measures necessary for compliance with the federal regulation. It is not surprising that Group A is the most important subject matter grouping. The means of each subgroup in Group A is more important than the means for any other subgroup except security (Group B). These rankings would reflect the 76 percent response rate received from airports with airport certification requirements. If an airport is certificated under 14 CFR Part 139, it is also required to have an airport security plan under 14 CFR Part 1542.

Cronbach's Alpha is valuable in ascertaining the degree to which the variables contained in the major groups are linked or consistent with one another. While the reliability of the variables within each group is shown to exist for all (Table 4), Group E has marginal reliability or consistency. This means the topic variables contained in Group E are better treated as separate

topics. Otherwise, the other groups show consistency of their topic variables and allows for further analysis.

The Tukey analysis is valuable in ascertaining the degree to which the variables contained in the major groups are distinct from one another. With the exception of Group C and Group D, the remaining groups appear to be made up of variables that can be treated as having distinct degrees of importance from the other groups (Table 5). The variables in Group C and Group D do not show the same degree of distinction and require reconstitution.

The distinction of the major group is of value in that they identify the overall degree of importance of the knowledge and content areas within the industry and they can be used to identify content to be included in a particular course. For instance, the content of Group A could be included in a single course or split into two. The content in Group B could also be a singular course. While Group C and Group D would need to be reconstituted, general aviation principles and aircraft characteristics (Group C) could be taught as one course, and environmental, master planning and ground transportation (Group D) could make up either a single or dual course as well. Within Group E, Group G and Group F, each subgroup is easily recognized as a current course at many colleges and universities.

For those who provide training seminars and workshops to the industry, the first two groups of variables shown in Appendix A (subgroups 1-11) and B (top 15 topics) should receive the most attention. Developing a university curriculum focusing on airport management and operations, however, may be a little more difficult to address. This is because colleges and universities are expected to provide a broad skill and knowledge set balanced with specialized skills and knowledge.

The data show several of the courses normally associated with university curricula in management were rated very low. For instance, micro and macro economics, business statistics, and marketing ranked in the lower portion of the list (Appendix B). Yet a basic management curriculum accredited by the American Assembly of Collegiate Schools of Business (AACSB) or CAA calls for a knowledge foundation in those courses (AACSB, 1993; CAA 2003). It is difficult to imagine that in practice an entry level position does not utilize the basic theories and concepts in those courses, but entry level airport position descriptions detail more aviation specific knowledge concepts (Prather, 1998; Quilty, 2004).

The reason for the low rankings of the traditional courses is not clear. They could have been ranked low simply because they are considered fundamental compared to the other topics. Respondents may have had the expectation that an individual would have certain basic knowledge to have made it to the level of consideration for an airfield operations position. A second reason could be that theory and concepts taught in those courses are

not well discerned in practice. This has implications for developing a university aviation management curriculum where the basic knowledge concepts of economics, statistics and other similar courses need to be incorporated into courses such as airport operations, regulatory compliance, and security.

The comparison of topics found in 14 CFR Part 139 to traditional business and aviation courses is new in the research. Except for in Kaps and NewMyer's 2001 study, the other research referenced in this paper focused primarily on the traditional course offerings in their rankings. Results from those studies can be used to gauge the relative importance of traditional courses.

Clearly of importance for entry level airport positions, however, is knowledge about the operations of an airport, generally delineated in 14 CFR Part 139, but also applied to general aviation airports. Evidence presented by Quilty (2004) indicates current post secondary courses related to aviation management do not adequately address the skill development or knowledge acquisition identified in this study. The results of this study can be used to develop a matrix of knowledge requirements that would be addressed within an overall curriculum on airport operation and management. Combined with information culled from other studies mentioned in this paper, the academic community can better respond to the needs of the airport industry by incorporating the content identified into course offerings, or by developing more specialized course offerings.

A positive aspect of the identification of specialized courses is that they can better prepare an individual for the needs and demands of the airport industry. The drawback that exists for specialized course offerings is that they often are at the expense of other skills and knowledge area development due to the limitation placed on the number of total credit hours allowed at most universities. For this reason, it is important for the aviation academic community and CAA to think through at what level courses should be taught and what skills and knowledge should be addressed at each level. This raises the question then of what is the proper balance of courses that will result in a reasonable number of credit hours, meet university accreditation and policy requirements, and satisfy the needs of the industry? This question corresponds to the issues raised by Quilty (2004).

Based on the study results, it is recommended that a course titled "Aviation Management" be dropped from aviation curricula and be replaced by a title indicating the specific study area of management to be taught, such as airport management, airline management, air cargo management, fixed base operations (FBO) management, small airport management, or aviation service management. The term "aviation management" should refer to the collective offering of courses and material that will develop the skills and knowledge of an individual for the purpose of ensuring the safety of the

aviation system and furthering its economic and social benefits. Within a college or university program, an aviation management curriculum should have identifiable tracks or study areas that address the more specific study areas mentioned.

Appendix B provides insight into the relative importance of the topic variables between the different sized airports. The reporting of response data by airport size is of value in that it is generally the general aviation, non-hub and small-hub airports that hire recent graduates, based upon a review of job listings posted over the years by AAAE. The qualifications for medium-hub and large-hub airports generally require several years of experience for consideration. Many airport position announcements seek or prefer at least one year of experience in airport operations (Howell, 1997; Quilty, 2004).

There is unanimous agreement on the 12 top ranked variables for all airport sizes, with the notable exception of airfield lighting, signs and marking for general aviation airports (Appendix B). Within the top 13 ranked topics is a notable variable of interest: knowledge of airport certification specifications. Airport certification specifications are no longer a component of federal regulation, having been discontinued in February of 2004 with revision to 14 CFR Part 139. The purpose of airport certification specifications was to address safety and operation of airports receiving limited air carrier service. It is understandable that many respondents still view the purpose as being important.

Below the rank of 13, the topics have varying degrees of importance among the different sized airports. The variations generally reflect the type and nature of airport operations at the different sized airports. For instance, general aviation operations is a knowledge requirement ranked 16 for all but large-hub airports, which have very little general aviation activity. Therefore, one would not expect it to have as much importance overall. Knowledge about air traffic control equipment is ranked higher by non-hub airports most likely because those airports have locally operated and supported navigational aids, or have contract control towers in operation that require the airport to operate and maintain.

Some topic variables, such as snow removal operations, airline operations, air cargo operations, pavement deicing, impact of capacity and delay issues, and speech communication are mitigated in importance because of the geographic location of the airport or its size. For instance, pavement deicing and air cargo operations carry less importance at general aviation airports, most likely because of a lack of financial resources for deicing and the lack of pavement or air cargo activities, respectively. Environmental compliance and knowledge of police procedures will receive varied response depending on the organizational structure, personnel staffing, expertise available, and location of the airport. An analysis of the standard deviations listed in Table 2 provides some explanation for the varied ranking.

CONCLUSION AND RECOMMENDATIONS

The study results included in this paper strive to address the knowledge and topic areas required by the airport industry for a curriculum in airport management. While providing support for the generalized knowledge requirements identified by the CAA, this study provides insight into the degree of importance for the knowledge areas sought by the industry. This information is of value to universities and accrediting bodies in improving airport management degree programs. The study reported in this paper can assist academicians, human resource directors, and airport managers in understanding basic knowledge requirements deemed important for individuals seeking employment in the field of airport operations and safety.

From the ranking of knowledge requirements, course content can be refined to include and address the most important topics. Drawing on the assumption that the most common path to the position of airport manager or director begins with entry level airfield operation positions, current aviation management programs do not adequately address the needs of the airport industry. The position that most educational programs claim they prepare an individual for—that of airport manager or director—is not normally an entry level position. Based on the results from the survey, academicians and trainers can better prepare aspiring individuals for careers in airport operations and, subsequently, management. The research results also provide insight into the importance of skills and knowledge for different sized airports, as this data is lacking in previous studies.

Based on the study results, it is suggested that the need exists for a specialized track or study area in airport management that contains the following dedicated courses: airport operations that cover in detail 14 CFR Part 139; emergency planning; airport security; general aviation operations; environment and noise; and airport design and construction. A recommendation is made to eliminate any course titled aviation management and reserve that term for describing an overall aviation program. Within the aviation management program would be specific tracks or study areas with more specialized courses addressing each area. The term "aviation management" is suggested to be defined as the collective offering of courses and material that will develop the skills and knowledge of an individual for the purpose of ensuring the safety of the aviation system and furthering its economic and social benefits.

The CAA (1992) states in its criteria for aviation management:

> Care must be taken to avoid preparation in a field that is too narrow; however, without adequate depth of study in a specific area, the student is not likely to have the special expertise that will set him or her apart from others. (p. 27)

Answering the question of what is the proper balance of courses that will result in a reasonable number of credit hours, meet university accreditation and policy requirements, and satisfy the needs of the industry requires further dialogue and debate among academicians and the industry. This paper contributes to the dialogue by identifying topics to be included in an airport operations and management curriculum. Colleges and universities preparing individuals for entry level positions at airports should undertake a review and modification of their curriculum and courses to address important knowledge areas.

Still in question is at what educational level should these courses be taught and to what degree of specialization? In his 2004 issue paper, Quilty proposed a performance outcome model that provides a simple analogy for what skill, ability and knowledge attainment should be addressed at different institutional levels. He suggested a graduate of a 2-year associate program would have skills and knowledge to obtain entry level positions but would require supervision and direction, while a graduate from a 4-year institution would be able to function more autonomously, and a graduate program would allow students to move directly into supervisory positions.

Further dialogue and debate should be centered around the mission and role of an aviation program at the 2-year or 4-year undergraduate level, and around how to balance the needs of university accreditation requirements against the need for specialized training and education in aviation. Should the role be that of preparing an individual with the specific skills needed or a broad educational perspective? It is a specialized training versus general education debate that should be continued within the industry by practitioners, academicians, and the accrediting bodies of aviation programs. The results from this study would indicate a need exists within the airport industry for more specialization.

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APPENDIX A

Identification of subgroups and applicable survey ranking stems for 91 knowledge variables important for individuals employed in the field of airfield operations or for those individuals having duties for inspection or safety of the airfield

Subgroup 1 - Part 139 Regulation
Knowledge of 14 CFR Part 139 requirements and airfield operations responsibilities.
Knowledge of Airport Certification Manual Requirements and Contents.
Knowledge of federal regulatory and enforcement process.

Subgroup 2 - Self Inspection
Knowledge of FAA Form 5010.
Knowledge of airport self-inspection components and techniques.
Knowledge of airport condition reporting and issuance of NOTAMs.

Subgroup 3 - Lighting, Signs, Marking
Knowledge of airfield lighting, signage and marking requirements and maintenance.

Subgroup 4 - Wildlife
Knowledge of wildlife hazard mitigation problems and techniques.

Subgroup 5 - Vehicle Operation
Ability to operate light and/or heavy vehicles and equipment .
Knowledge of ground vehicle operation and radio procedures.
Knowledge of bid specifications related to equipment and other purchases.
Knowledge of air traffic control operations and procedures.

Subgroup 6 - Snow and Ice
Knowledge of Snow and Ice Control Plans and snow removal operations .
Understanding of the application and use of deice and anti-ice compounds for pavements.

Subgroup 7 - Part 77 Obstructions
Knowledge of air traffic navigational equipment and operation.
Knowledge of 14 CFR Part 77 Objects Affecting Navigable Airspace.
Use of FAA Form 7460-1 Notice of Construction and/or Alteration.

Subgroup 8 - ARFF and Emergency Plan
Knowledge of Aircraft Rescue/Firefighting techniques and application.
Understanding of the Airport Emergency Plan (AEP) and response capabilities.

Subgroup 9 - Hazardous Material
Knowledge of the DOT hazardous substances and materials markings and placards.
Knowledge of material data safety sheet information.
Knowledge of fueling operations and fuel storage tanks/trucks safety.

Subgroup 10 - Aviation General
Understanding of acronyms, terms and common phrases used in aviation and on the airfield.
Understanding of airport history and development.
Understanding of aviation law application to airports and aircraft operations.
Knowledge of meteorology and flight planning.

Subgroup 11 - Security
Knowledge of airport security plan responsibilities under TSA Part 1542 (former Part 107).
Knowledge of air carrier security plan requirements under TSA Part 1544 (former Part 108).
Knowledge of air cargo security plan requirements under TSA Part 1546 (former Part 109).
Knowledge of SIDA, access control, and identification procedures.

Knowledge of new security technology and its application on airports.
Knowledge of 14 CFR Part 191 security disclosure requirements.
Understanding of police and law enforcement procedures.

Subgroup 12 - Master Plan and Design
Understanding of airport design and layout.
Understanding of airport and transportation master planning processes.
Understanding of airport capacity, delay and transportation impacts.

Subgroup 13 - Aircraft Characteristics
Knowledge of helicopter and V/STOL operations.
Knowledge and understanding of general aviation operations and regulations.
Knowledge and understanding of air taxi/charter operations and regulations.
Knowledge and understanding of airline operations and regulations.
Knowledge and understanding of air cargo/freight operations, regulations and logistics.
Knowledge of requirements and procedures for airlines/aircraft deicing.
Knowledge of military operations and activity on airports.
Knowledge of aircraft operations and regulations.

Subgroup 14 - Environment and Noise
Understanding of noise, noise measurement and laws related to aviation noise.
Understanding of environmental laws and regulations.
Knowledge of Environmental Acts, compliance and audits affecting airports.

Subgroup 15 - Ground Transportation
Understanding of ground transportation (taxis, limos, buses, shuttles, etc.) operations.
Understanding of parking garage/lot function and operations.

Subgroup 16 - Building Systems
Knowledge of building system operation (heating, air conditioning, utility, plumbing).
Knowledge of facility maintenance methods and processes.
Knowledge of American Disability Act (ADA) regulations and their applicability to airports.
Knowledge of architectural principles and practices.

Subgroup 17 - Communication
Ability to speak, read and understand a second languages.
Knowledge of speech and public communication principles and application.
Knowledge of interpersonal, group and organizational communication.
Understanding of a communications center function and operation.

Subgroup 18 - Management and Supervision
Understanding of general supervision and management principles.
Knowledge of human resource and employee development processes.
Understanding of labor relations.
Understanding of social psychology principles and application.

Subgroup 19 - Administration
Understanding of political science and organization politics.
Knowledge of airport/public administration principles and practices.

Subgroup 20 - Economics
Understanding of micro economics (local or national activity).
Understanding of macro economics (global activity).
Understanding of geographic and socioeconomic principles.
Knowledge of civil engineering principles and practices.

Subgroup 21 - Project Management and Construction
Knowledge of airfield construction methods and processes.
Understanding of project management practices.
Knowledge of building construction codes, methods and processes.
Knowledge of airport construction activity monitoring and practices.

Subgroup 22 - Marketing
Understanding of public relations and information dissemination.

Understanding of marketing practices and principles.
Understanding of the travel and tourism industry.
Knowledge of international commerce relations, business practices and handling processes.

Subgroup 23 - Contracts and Law
Understanding of contract and lease administration.
Understanding of property and real estate management.
Understanding of risk management and insurance administration.
Understanding of contract law application to airports.
Understanding of tort law application to airports.
Knowledge of OSHA regulations and insurance requirements.

Subgroup 24 - Finance and Accounting
Knowledge of finance and capital funding methods and processes.
Knowledge of accounting and budgeting methods and processes.
Knowledge of applied business statistics.

Subgroup 25 - Record Management
Understanding of records management and management information system manipulation.
Use of computer science skills associated with programming.
Use of computer skills associated with word, draw and spreadsheet applications.
Use of computer skills associated with Autocad and GIS application.

Subgroup 26 - Science
Understanding of basic electricity and electronic principles and application at airports.
Knowledge of new technology development and application at airports.
Knowledge of science principles and their application to airport operations.

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Note. The variable "Knowledge of airport certification specifications requirements and content" was not included in the statistical final rankings due to revisions to 14 CFR Part 139 during the study making it obsolete as a knowledge requirement.

APPENDIX B

Ranking of 92 knowledge variables important for individuals employed in the field of airfield operations or for those individuals having duties for inspection or safety of the airfield, by airport size using visual and numeric coding.

Overall Rank	Visual Code	Topic	Airport size rank distribution					Visual rank distribution				
			LH	MH	SH	NH	GA	LH	MH	SH	NH	GA
1	XXX	Ground Vehicle Operation	2	7	2	6	5	XXX	XXX	XXX	XXX	XXX
2	XXX	Self Inspection	6	3	1	3	1	XXX	XXX	XXX	XXX	XXX
3	XXX	Lighting	7	1	5	4	16	XXX	XXX	XXX	XXX	
4	XXX	Airport Emergency Plan	11	11	6	1	2	XXX	XXX	XXX	XXX	XXX
5	XXX	NOTAMs	1	6	7	9	3	XXX	XXX	XXX	XXX	XXX
6	XXX	14 CFR Part 139 compliance	4	2	4	2	4	XXX	XXX	XXX	XXX	XXX
7	XXX	Airport Certification Manual	3	4	9	5	8	XXX	XXX	XXX	XXX	XXX
8	XXX	Acronyms	9	8	11	7	10	XXX	XXX	XXX	XXX	XXX
9	XXX	Security ID Area	5	9	3	8	6	XXX	XXX	XXX	XXX	XXX
10	XXX	Construct Activity	13	5	12	13	7	XXX	XXX	XXX	XXX	XXX
11	XXX	Airport Certification Specifications	8	13	10	12	14	XXX	XXX	XXX	XXX	XXX
12	XXX	Wildlife	10	12	13	10	15	XXX	XXX	XXX	XXX	XXX
13	XXX	Airport Security Plan	14	10	17	18	12	XXX	XXX			XXX

Overall Rank	Visual Code	Topic	LH	MH	SH	NH	GA	LH	MH	SH	NH	GA
14	XXX	Part 77 Obstructions	17	15	14	19	19		XXX	XXX		
15	XXX	Airport Design and Layout	23	24	22	17	20					
16		GA Operations	20	14	8	11	11		XXX	XXX	XXX	XXX
17		Air Traffic Control Operations	21	18	15	14	17			XXX	XXX	
18		Airport Rescue/Firefighting	12	25	18	22	9	XXX				XXX
19		Fueling Operations	18	22	19	15	28				XXX	
20		Aircraft Regulations	29	23	25	21	13					XXX
21		Federal Regulations	25	16	21	16	26					
22		Communication Center Operations.	22	17	24	20	27					
23		Form 5010	15	28	16	25	21	XXX				
24		Snow Removal Operations.	27	44	31	24	35		***	***		***
25		Airline Operations	30	31	40	23	23		***	***		
26		Management	33	20	26	27	36	***				***
27		Form 7460-1 Obstructions	28	29	29	42	41				***	***
28		Construction Methods	26	26	20	26	39					***
29		Air Carrier Security Plan	31	34	27	30	38	***	***			***
30		Air Traffic Control Equipment	32	33	23	46	18	***	***		√√√	
31	***	Word and Spreadsheet Applications	24	43	43	45	24		***	***	***	
32	***	New Security Technology	16	19	33	35	42			***	***	***
33	***	Air Cargo Security Plan	48	21	28	37	50	√√√			***	√√√
34	***	Public Relations	19	30	44	36	30			***	***	
35	***	Material Safety Data Sheets	53	27	46	39	32	√√√		√√√	***	***
36	***	Organizational Communication	36	47	34	29	37	***	√√√	***		***
37	***	Air Taxi Ops.	49	48	37	40	34	√√√	√√√	***	***	***
38	***	Environment Compliance	44	32	30	38	59	***	***		***	√√√
39	***	Department of Transportation Hazmat	42	37	41	28	45	***	***	***		***
40	***	Part 191 Sensitive Security Information	47	40	38	34	46	√√√	***	***	***	√√√
41	***	Environmental Regulations	38	35	32	41	31	***	***	***	***	***
42	***	Public Administration	39	36	65	32	49	***	***	-----	***	√√√
43	***	Pavement Deicing	41	38	51	49	29	***	***	√√√	√√√	
44	***	Air Cargo Operations	37	39	54	47	25	***	***	√√√	√√√	
45	***	Occupational Safety Health regulations	40	50	53	43	47	***	√√√	√√√	***	√√√
46	√√√	Police Procedures	34	66	45	52	33	***	-----	***	√√√	***
47	√√√	Noise Requirements	35	41	48	31	40	***	***	√√√	***	***
48	√√√	Capacity/delay Impact	45	52	55	62	57	***	√√√	√√√	-----	√√√
49	√√√	Speech Communications	43	58	36	50	22	***	√√√	***	√√√	
50	√√√	Project Management	54	45	47	44	62	√√√	***	√√√	***	-----
51	√√√	Human Resource Department Processes	58	63	39	33	43	√√√	-----	***	***	***
52	√√√	ADA Requirements.	57	46	35	60	51	√√√	√√√	***	√√√	√√√
53	√√√	Meteorology	46	51	56	55	74	√√√	√√√	√√√	√√√	-----
54	√√√	Military Operations	68	42	42	56	61	-----	***	***	√√√	----
55	√√√	Bid Specifications	52	55	66	51	48	√√√	√√√	-----	√√√	√√√

Overall Rank	Visual Code	Topic	LH	MH	SH	NH	GA	LH	MH	SH	NH	GA
56	√√√	Ground Transport	56	54	52	63	58	√√√	√√√	√√√	----	√√√
57	√√√	Airport History	61	53	67	48	70	-----	√√√	-----	√√√	-----
58	√√√	New Airport Technology	51	49	57	59	44	√√√	√√√	√√√	√√√	***
59	√√√	Equipment Operations	50	64	61	54	55	√√√	-----	-----	√√√	√√√
60	√√√	Contract/Lease Administration	71	62	50	61	64	-----	-----	√√√	-----	-----
61	-----	Aviation Law	66	56	59	53	60	-----	√√√	√√√	√√√	√√√
62	-----	Facility Maintenance	63	60	60	65	69	-----	√√√	√√√	-----	-----
63	-----	Management Information Systems	55	68	49	64	72	√√√	-----	√√√	-----	-----
64	-----	Master Plan Process	64	65	58	57	52	-----	-----	√√√	√√√	√√√
65	-----	Parking Operations	60	72	68	71	53	√√√	-----	-----	-----	√√√
66	-----	Aircraft Deicing	67	59	69	69	56	-----	√√√	-----	-----	√√√
67	-----	Labor Relations	72	70	64	58	54	-----	-----	-----	√√√	√√√
68	-----	Science Principles	65	71	63	67	67	-----	-----	-----	-----	-----
69	-----	Risk Management	70	57	75	67	75	-----	√√√	-----	-----	-----
70	-----	Accounting	84	67	62	79	76	$$$	-----	-----	$$$	$$$
71	-----	Travel and Tourism	69	83	73	73	81	-----	$$$	-----	-----	$$$
72	-----	Finance	83	69	71	70	78	$$$	-----	-----	-----	$$$
73	------	Property Management	77	78	79	72	79	$$$	$$$	$$$	-----	$$$
74	-----	Electricity Basics	62	87	70	75	68	-----	$$$	-----	-----	-----
75	-----	Contract Law	59	76	82	76	73	√√√	$$$	$$$	$$$	-----
76	$$$	Building Codes	92	74	78	80	63	$$$	-----	$$$	$$$	-----
77	$$$	Marketing	81	61	84	77	66	$$$	-----	$$$	$$$	------
78	$$$	Helicopter Operations	73	79	74	66	77	-----	$$$	-----	-----	$$$
79	$$$	Building Systems	82	82	72	78	80	$$$	$$$	-----	$$$	$$$
80	$$$	Tort Law	86	89	83	68	65	$$$	$$$	$$$	-----	-----
81	$$$	Politics	89	77	85	82	86	$$$	$$$	$$$	$$$	$$$
82	$$$	Civil Engineering	75	88	80	85	71	-----	$$$	$$$	$$$	-----
83	$$$	Computer Aided Design/GIS	90	73	77	83	82	$$$	-----	$$$	$$$	$$$
84	$$$	Programming	91	85	76	81	87	$$$	$$$	$$$	$$$	$$$
85	$$$	Architecture	80	75	89	90	85	$$$	-----	$$$	$$$	$$$
86	$$$	Social Psychology	76	84	81	84	83	$$$	$$$	$$$	$$$	$$$
87	$$$	Statistics	87	91	87	88	88	$$$	$$$	$$$	$$$	$$$
88	$$$	Micro Economics	88	90	86	86	90	$$$	$$$	$$$	$$$	$$$
89	$$$	Foreign Language	78	81	92	91	91	$$$	$$$	$$$	$$$	$$$
90	$$$	Socioeconomics	85	80	88	89	84	$$$	$$$	$$$	$$$	$$$
91	$$$	Macro Economics	74	86	91	92	92	-----	$$$	$$$	$$$	$$$
92	$$$	International Commerce	79	92	90	87	89	$$$	$$$	$$$	$$$	$$$

Note. All airports N = 116; LH = Large-Hub (n = 22), Medium-Hub = MH (n = 19); Small-Hub = SH (n = 16): Non-Hub = NH (n = 31); General Aviation/Reliever = GA (n = 28).