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- Space Transportation Safety, Communication, and the Future
- Other areas of air and space transportation research, policy, theory, case study, practice, and issues

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Sorenson Best Paper Award Recipient

ANALYSIS OF SYSTEM-WIDE INVESTMENT IN THE NATIONAL AIRSPACE SYSTEM: A PORTFOLIO ANALYTICAL FRAMEWORK AND AN EXAMPLE

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The MITRE Corporation

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ABSTRACT

In this paper, the authors review the FAA's current program investments and lay out a preliminary analytical framework to undertake projects that may address some of the noted deficiencies. By drawing upon the well developed theories from corporate finance, an analytical framework is offered that can be used for choosing FAA's investments taking into account risk, expected returns and inherent dependencies across NAS programs. The framework can be expanded into taking multiple assets and realistic values for parameters in drawing an efficient risk-return frontier for the entire FAA investment programs.

Dr. Dipasis Bhadra is a Principal Economist with the MITRE Corporation's Center for Advanced Aviation System Development (CAASD), a federally-funded research and development corporation. At CAASD, Dipasis works in areas of quantitative modeling of air transportation system including passenger flows between airports, positioning of aircraft, configuration of networks, and program management via portfolio analysis. Prior to joining CAASD in early 2001, Dipasis worked at the World Bank evaluating feasibility of infrastructure projects in South Asia. With a Ph. D. in economics (1991) from the University of Connecticut, Dipasis also teaches introductory economics at the local community college, and holds professional positions at the Transportation Research Board (TRB), American Institute of Aeronautics and Astronautics (AIAA), and Transportation Research Forum (TRF).

Frederick Morser is an Outcome Leader at CAASD. Mr. Morser supports forecasting, business case analysis, strategic planning, and performance modeling work. He has been with MITRE for eight years.

INTRODUCTION[1]

The United States' National Airspace System (NAS) contains a network of air transportation markets linking 485 commercial airports located in and around 363 metropolitan statistical areas. The total number of origin-destination markets in the NAS ranges somewhere between 36,000-40,000 pairs depending upon seasons and economic cycles. There are 315 air traffic control (ATC) facilities that are used to serve these markets meeting the daily travel needs of around 1.5 million passengers. Every day, roughly 40,000 scheduled commercial departures and 13,000 high end[2] general aviation (GA) departures fly in the same controlled airspace. Other GA traffic flying under visual flight rules — perhaps as many as 60,000 departures per day — use terminal facilities services at both commercial and non-commercial airports. In addition, there are military flights that also require terminal and enroute services. This expansive network renders an estimated annual commercial value of around US $70-110 billion for scheduled GA services and around US $25-40 billion for unscheduled GA services and an undetermined amount from other services including military (President's Aerospace Commission Report, 2003).

Maintaining this network is expensive. The Federal Aviation Administration (FAA) spends over US $14 billion annually to fund facilities and equipment (F&E: approx. US $3B), operations (approx. US $7B), airports (approx. US $3B), and research and engineering (approx. US $0.2B) expenditures. The FAA's NAS modernization program, the impetus behind F&E funding, consists of three elements: the NAS Architecture Plan (i.e., the engineering blueprint);[3] the Capital Investment Plan (CIP);[4] and the

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[1] An earlier version of this paper was presented at the 5th Annual Aviation, Technology, Integration, and Operation of the American Institute of Aeronautics and Astronautics (ATIO/AIAA) conference at Crystal City, VA, Sept. 26-28, 2005. The authors would like to thank those who participated and for their suggestions. They would also like to thank their colleagues, Joseph Sinnott, E. J. Spear, Michele Steinbach, Felipe Moreno-Hines, Debby Pool, Dr. Katherine Harback and Dr. Bill Kuhn, whose comments and suggestions improved the focus of this research.

[2] Turbo fan and turbo prop aircraft flying under instrument flight rules.

[3] This is the comprehensive plan for modernizing the NAS. The plan covers information about architecture concepts, capabilities and plans for development in the future.

[4] The CIP is a 5-year plan that provides details on NAS projects that can be funded within the Office of Management and Budget's future year targets, presently set for 2006-2010. Through the CIP, the FAA fulfills public law obligations (PL 108-447) under which the Agency is "to transmit to the Congress a comprehensive capital investment plan for the Federal Aviation Administration which includes funding for each budget line item for fiscal years 2006 through 2010, with total funding for each year of the plan constrained to the funding targets for those years as estimated and

Operational Evolution Plan (OEP).[5] The FAA has six goals which are the primary focus of their CIP investing strategy:

1. Maintain a high level of safety;
2. Enhance greater mobility throughout the NAS;
3. Promote economic growth;
4. Promote harmony with human and natural environment;
5. Attain a high degree of national security; and
6. Maintain organizational excellence (FAA Flight Plans, 2006).

At present, there are 190 identified programs in the CIP, rolled up into 90 investment programs, designed to serve these broad 6 goals

Currently, CIP programs are evaluated on their individual merits where cost-benefit ratios, net present values, and internal rates of return reflect program effectiveness in meeting the stated FAA goals. While program cost estimates are relatively straight forward, benefits (total benefits) are often hard to quantify. Typically, a mixture of federal cost savings (e.g., higher productivity gains from investments in labor-saving technology) and external social benefits (e.g., better movement of aircraft at the congested airports thus reducing congestion), wherever applicable, are estimated to calculate the net present value of these investments. A combination of Treasury note interest rates (for federal government cost savings) and a real discount rate of 7% (for external social benefits) have been recommended by the Office of Management and Budget (OMB) to evaluate the associated project investments (OMB, 2005).[6] This evaluation criteria and process is fairly common throughout government programs. The A-94 also indicates that "benefit-cost or cost-effectiveness analyses should include comprehensive estimates of the expected benefits and costs to society." Furthermore, "*possible interactions* between the benefits and costs being analyzed *and other government activities* should be considered." [see OMB (2005) Section 6; emphasis added].

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approved by the Office of Management and Budget". See http://www.faa.gov/asd/ for more details on both the Architecture Plan and CIP.

[5] The OEP is the FAA's 10-year rolling plan to increase both the capacity and efficiency of the NAS while enhancing safety and security. For more details on OEP, see http://www.gov/programs/oep/index.htm

[6] The OMB publishes annual discount rates for calculating benefit-cost analysis of federal programs titled "Guidelines and Discount Rates for Benefit-Cost Analysis for Federal Programs", or what is commonly known as OMB Circular A-94 (see www.whitehouse.gov/omb for more details).

The FAA's current investment analysis (IA) framework/process[7] determines program value and suitability by evaluating performance, lifecycle costs, benefits, program-specific risk, schedule, affordability and compatibility with the overall system architecture for a particular program. This approach is, however, somewhat limited when it comes to incorporating financial and other forms of programmatic interdependencies. The need to fill this gap, that is, the lack of apparent reconciliation between the requirements of system-wide architecture and that of financial requirements, has become even more urgent (GAO, 2005; FAA, 2005) and points to the direction of a "comprehensive strategy for modernizing the NAS (so that) …major acquisitions are delivered within cost, schedule, and performance milestones" (FAA, 2005, p. 3)

This need leads one to seek alternative methodologies that tie investment programs with potential economies of scope, and benefit that arise from interdependencies among programs. The goal of the engineering architecture and its associated investments is to improve the flow of aircraft in a safe manner that eventually generates economic value in the system. Commercial aviation interests and fiduciary obligations required of the FAA call for system wide financial optimization built alongside the engineering architectural requirements.[8] Broadening the investment evaluation framework may also add new dimensions to understanding true values inherent in the NAS, efficient programs leading to modernization of the

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[7] This was primarily led, until recently, by the Office of System Architecture and Investment Analysis, commonly known as ASD-400. After the Air Traffic Organization [ATO; see http://www.ato.faa.gov/ for more details] was formed, ASD transitioned into the ATO's Offices of Systems Engineering, Business, Planning and Development, and International (SE BP&D, and International). The Public Law 106-181 (AIR-21) that was passed in April 2000 authorized the FAA to create a Chief Operating Officer (COO) position who would be responsible for overseeing day-to-day traffic control operations, undertaking initiatives to modernize air traffic control (ATC) systems, increasing productivity and implementing cost-saving measures, among other things. In December 2000, the President issued the Executive Order 13180 that authorized the creation of the ATO, headed by the COO (GAO, 2005). The new office leads NAS architecture, system engineering, investment analysis and operations research. The ATO was created in February 2004 by combining FAA's Research and Acquisitions, Air Traffic Services, and Free Flight Offices into one performance-based organization.

[8] The SE BP&D and International of the ATO leads the effort for the investment analysis process and is responsible for formulating investment analysis teams (IATs). By evaluating alternative investment strategies from a broader perspective, these IATs are responsible for putting together investment analysis report and recommendations that are then presented to the Joint Resources Council for the final investment decision. For a selective list of these analyses, see http://www.faa.gov/asd/ia-or/ia-reports.htm.

NAS, and interdependencies across programs. Indeed, the ultimate outcome from applying this methodology is to invest in the optimum set of programs, which have embedded interdependencies that maximize return and minimize risk.

FAA investment selection criteria, as with most government investment, require special consideration due to the lack of market signals. In the business world, good investments differentiate themselves from bad investments through measures of return. Markets match consumers with products and services. Bad investments that fail to produce sufficient returns are weeded from the portfolio. FAA investment occurs outside of a market. There are no alternative air traffic service providers with a different portfolio of investments from which consumers can buy air traffic services thus providing market value signals. For this reason other means must be used to measure the value of investments.

In pursuit of a more comprehensive investment strategy we draw upon the literature of financial economics (Bodie et al., 1996; Ross et al., 1999) and offer a portfolio investment framework that is well specified to account for program interdependencies across cost, benefit and risk sharing and accommodate the surrogate market requirements. A Markowitz efficient frontier of risk and return has been built to facilitate the selection of sets of optimal programs within the scope of the FAA's programmatic engineering requirements. Using this framework and applying it to a set of hypothetical program costs, returns and interdependencies, we attempt to demonstrate that choices resulting from how portfolio analysis may provide useful information for optimizing a financial portfolio specified over risks and returns, as opposed to traditionally optimized individual programs.

The paper is organized along the following lines: the next section discusses the structure of the present FAA investments. The third section provides the analytical framework of an experimental approach laying out the empirical underpinnings. The fourth section provides an example of some hypothetical experiments and discusses implications on program implementation. The final section provides conclusions and recommendations for further research.

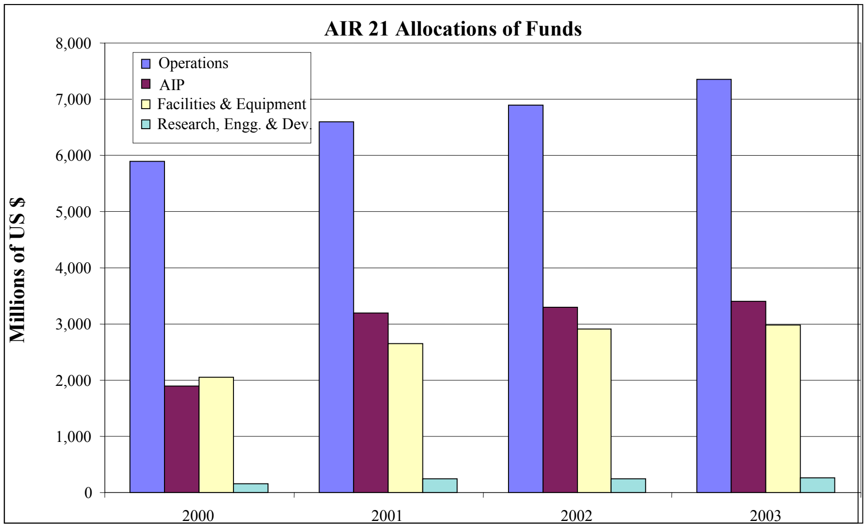
BACKGROUND

The FAA's reauthorization plan, called the AIR-21, aligns the NAS architecture and the CIP with the OMB's five-year budget planning process. The majority of AIR-21 funding was earmarked to improve RADAR modernization and airport construction projects. Under the AIR-21, the total authorized funding for federal aviation programs, starting in 2000, was $40 billion over three years. An estimated $33 billion was guaranteed from the

Aviation Trust Fund, while the remaining $6.7 billion was to be drawn from the General Fund.

Figure 1 provides a broad overview of the allocation of budgetary resources under AIR-21 during the period 2000-2003. Of the total 2003 annual expenditure of $14 billion, operations consumed the largest share (52%) followed by airport improvement project (AIP) (25%) and F&E (21%). It is interesting to note that since 2001 expenditures for operations have experienced a relatively faster growth rate compared to all other broad expenditures including research, engineering and development (RE&D).

Figure 1: Allocations of funds under AIR-21, 2000-2003

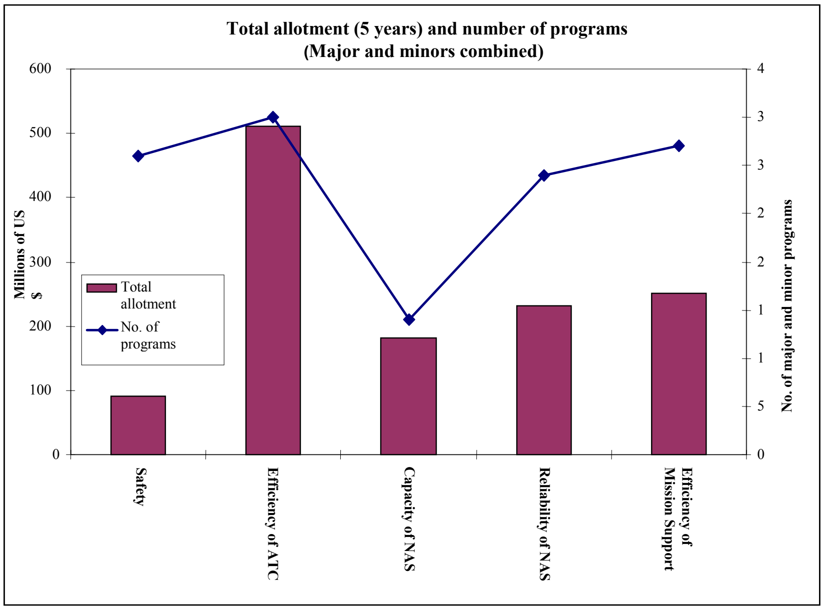


Source: Capital Investment Plan (CIP)/FAA (2004); See www.faa.gov/asd/ for more details.

At present, there are 485 tower facilities (118 of them are towers with RADAR coverage), 185 terminal radar approach control (TRACON) facilities and 21 enroute centers within the continental US (20 in the contiguous US and 1 in Anchorage). In addition, there are five oceanic centers that handle incoming and outgoing traffic beyond the contiguous territories of the US. There are a little over 7,000 air traffic controllers directly associated with terminal facilities, while the rest, around 7,450 are assigned to enroute traffic, both TRACON and enroute.

The FAA uses standard performance measures to establish the suitability and effectiveness of its programs. Generally speaking, programs are designed to support five broad categories: safety, efficiency of ATC, capacity of the NAS, reliability of the NAS, and effectiveness of mission support. In order to track these more systematically, the FAA collects data on aspects of these categories: average minutes late per flight, percent of flights on time, ground stop minutes, average daily arrival capacity, average daily flights, airport efficiency rate, airport capacity in visual meteorological conditions, airport departure rate, airport arrival rate, airport capacity in instrument meteorological conditions, and airport instrument meteorological conditions index, and other statistics relating to safety.

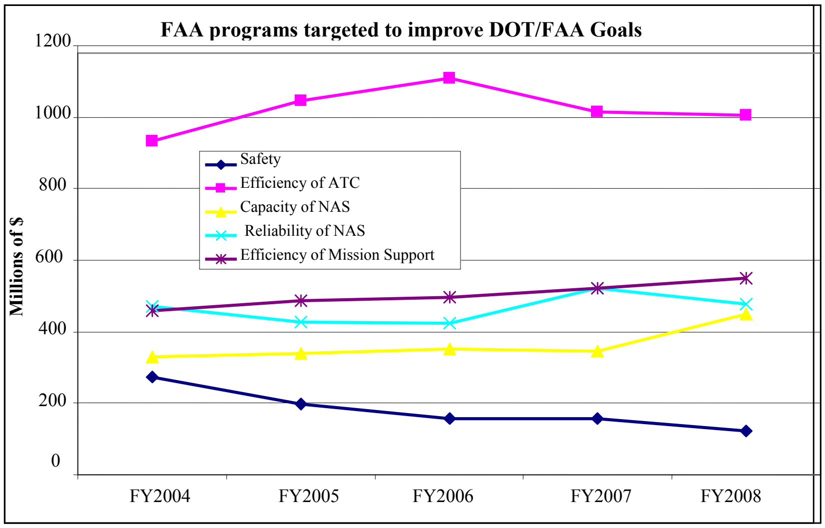
Figure 2: Allotment of funds for FAA programs, FY 2004-2008



Source: FAA (2005, May 26). "Status of FAA's Major Acquisitions: Cost Growth and Schedule Delays Continue to Stall Air Traffic Modernization," Report No. AV-2005-061. Washington DC: Office of the Inspector General, Federal Aviation Administration.

A look at the total expenses and program allocations over the five years from FY2004-2008 indicates that the FAA's portfolio of programs are distributed with a major focus on improving the operational efficiencies of the NAS. This focus in programmatic choice is reflected by the FAA's expenditures over time as well (see Figures 2 and 3).

Figure 3: FAA program investments over time, FY2004-2008

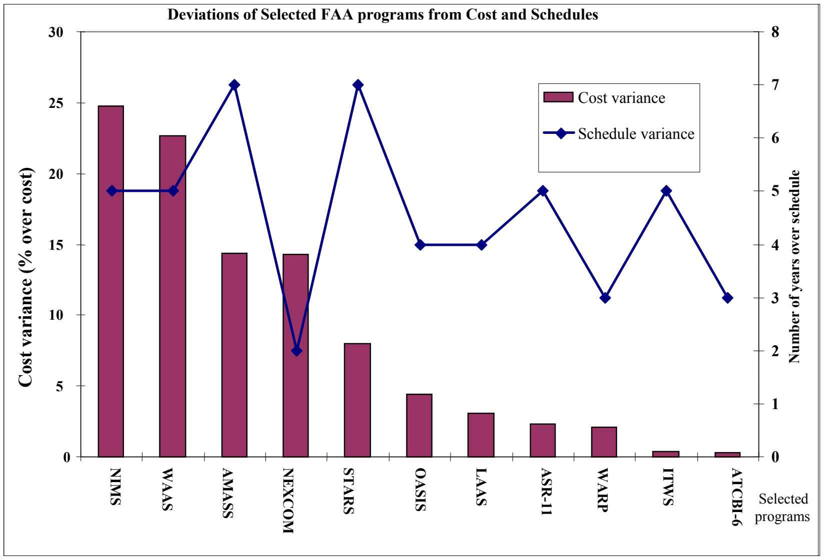


Source: CIP/FAA (2004); see www.faa.gov/asd/ for more details.

Congressional inquiries (GAO, 2005), an Inspector General (IG) report (FAA, 2005) and independent reviews (Shantz & Hampton, 2005) found that the NAS investment programs are inherently *risky*. Evaluated by the two most commonly used measures, that is, cost and schedule variances, for the FAA's major programs (16 of them presently), the IG (FAA, 2005) found that 11 of these programs[9] have experienced a total cost growth of over $5.6 billion (see Figure 4), which is more than twice the FAA's F&E budget in FY2005.[10] Furthermore, many of these programs have had schedule variances ranging between 2-12 years. Two programs, local area augmentation system and Next Generation Communication, (LAAS and NEXCOM) have been withheld until further evaluation (2008) on the merits of each program (FAA, 2005).

[9] These represent approximately 71% of the funds available for developing and acquiring air traffic control modernization projects (FAA, 2005).
[10] The cost growth is not unique to F&E programs alone. Operational costs from air traffic services, for example, grew by nearly $1.8 billion in real terms or by 43% during FY 1996-2004 (GAO, 2005).

Figure 4: Schedule and cost variance of some selected FAA programs (calculated over different periods ranging between 1998-2005; and 2005-2013)

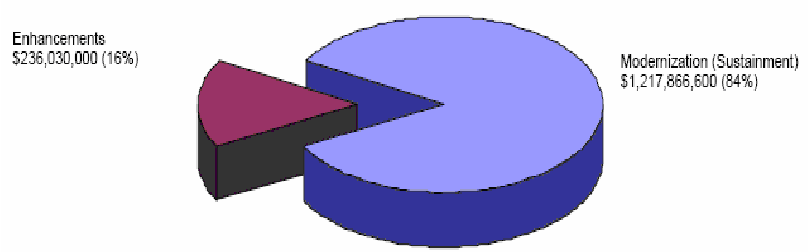


Source: FAA (2005, May 26). "Status of FAA's Major Acquisitions: Cost Growth and Schedule Delays Continue to Stall Air Traffic Modernization," Report No. AV-2005-061. Washington DC: Office of the Inspector General, Federal Aviation Administration.

As the industry restructured in the wake of 9/11, the Airways Trust Fund revenue, the main source for F&E expenditures, dwindled considerably. Numerous estimates (Chew, 2005) indicate that the gap between the trust fund collections and cost commitments are expected to widen, potentially affecting FAA program funding. Presently, the FAA spends considerably more on sustaining the NAS, than on enhancing it [see Figure 5 as reported in FAA (2005)].

The program decisions underlying Figure 5 indicate that, under present budgetary arrangements, modernization sustainment programs dominate investment. Most analyses conclude that the FAA in general, and ATO in particular, needs to develop a comprehensive strategy for modernizing the NAS while minimizing risks for all the major acquisition programs. In other words, the FAA should meet the cost, schedule, and performance milestones for all its acquisition programs, especially in this fiscally challenging environment (FAA, 2005; GAO, 2005).

Figure 5: Breakdown of air traffic control modernization funding by investment area, 2005



Source: FAA (2005)

A sense of urgency dominates the current budget cycle. The FAA routinely manages unprecedented levels of traffic while maintaining record low fatal accident rates. Studies have repeatedly shown that the level and complexity of traffic and the productivity of controllers and NAS assets is unparalleled. Traffic is projected to grow. Current budgetary pressure and the changing business environment have made prudent investing more important than ever. F&E and AIP budgets growth has lagged behind the operations budget. An aging infrastructure and higher future traffic levels portend the need for an investment approach that extracts the most from the FAA's limited resources.

THE ANALYTICAL FRAMEWORK

Risk[11] is an essential part of any investment program, private or public. Managing risk is the job of a portfolio manager. Risk exists because the investor can no longer explicitly associate payoff[12] with investment in any asset. In the market place, where return or price provides explicit signals, risks are traded for lower returns and vice versa. Nevertheless, similar trade-offs can be performed in government investments, and hence, an optimal set of public investments can be made if choice sets (i.e., range of possible programs), their interdependencies, and fiscal constraints can be specified adequately.

The analytical framework presented here captures the trade-offs between risks and expected returns in a portfolio consisting of multiple assets. Instead of considering that an investor's preferences are defined over the entire probability distribution of the assets with every possible outcome, this framework supposes that investor's preferences can be described by

[11] Without being too specific, risks in this paper generally represent (a) technical risks; (b) financial risks; and (c) program management risks.
[12] Payoff is described by a set of outcomes each associated by the return distribution (i.e., probability of occurrence).

considering a few summary statistics of the probability distribution[13] of the asset holdings. Mean and variance are two such key statistics that can describe the probability distribution of asset holding fairly well. Originally developed by Harry Markowitz,[14] the mean-variance model has been the foundation of corporate finance for decades.

In the framework presented below, dependencies across assets or projects have been given explicit consideration. This is in contrast with current procedure where capital investment programs are considered to be mutually exclusive. That is, decisions to invest depend primarily on returns (i.e., net present value, internal rate of return, or benefit-cost ratio) from the project alone. The lack of recognition of dependencies across projects often leads to selection bias and leaves very little room for a portfolio manager (i.e., ATO program manager) to compare relative risks versus relative returns in prioritizing projects.

Under the present format of evaluating government projects, risks are considered but only in terms of evaluating cost schedules. Trade-offs between risks and returns—the primary driver for choice in a portfolio—is not present under the current investment analysis framework. The analytical framework presented below is offered as an alternative to evaluate decision rules for selecting programs within the overall capital investment programs.

For demonstrating this framework, it is assumed that investors (or, a manager who decides on investments for NAS improvement, or a NAS portfolio manager) hold a portfolio of assets. Therefore, the focus is on the *expected return and risks from the whole portfolio, not individual assets*. Notice, however, that the financial and economic analysis for individual projects (i.e., standard cost-benefit analysis leading to internal rate of return) may provide important information regarding expected returns, estimated risks, and underlying relations or dependencies between individual assets. Risk is quantified by the standard deviation of the portfolio while returns are evaluated by the probability of events. For example, for a given expected return, different expected standard deviations can be obtained depending on the mix of assets due to varying correlations among the assets. Hence, the authors were able to estimate and predict some form of expected returns along with risks, and correlations among the assets. Furthermore, the underlying preference structure of the portfolio manager, that is, investor's

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[13] Two most commonly used aggregate measures of the probability distribution of asset holdings are average returns (i.e., expected averages over the entire distribution) and standard deviation, a measure of risk or dispersion around the mean.

[14] This research that provided the foundation for portfolio theory in corporate finance earned Markowitz the Nobel Prize in 1990 along with William Sharpe and Merton Miller for developing the theory of price formation for financial assets [Capital Asset Pricing Model (CAPM)] and the theory of corporate finance, respectively.

preference for expected returns against risks, can be postulated by some hypothetical function.

A portfolio of assets is characterized by two elements: expected return which is computed as weighted average of the return on the individual assets where the weight applied is the fraction of the portfolio invested in the asset. Thus, returns on the portfolio are calculated as the sum of all fractions of the portfolio held in each asset multiplied by the expected return in each asset. The variance, on the other hand, measures the dispersion or the expected value of the squared deviations of the return on the portfolio. In other words, expected return of an asset is a probability-weighted average of its return in all scenarios: $E(r) = \Sigma_S P_r(s) r(s)$ where $P_r(s)$ is the probability of scenario s and r(s) is the return in scenario s. Variance of an asset's return is the expected value of the squared deviations from the expected return, represented by the equation:

$$\sigma^2 = \Sigma_S P_r(s)[r(s) - E(r)]^2$$

The rate of return on the entire portfolio is a weighted average of the rates of return of each asset comprising the portfolio, with portfolio proportions as weights. This implies that expected rate of return on a portfolio is a weighted average of the expected rate of return on each component asset. When a risky asset is combined with a risk-free asset, the portfolio standard deviation equals the risky asset's standard deviation multiplied by the portfolio proportion invested in the asset.

One way to capture and quantify the effect of hedging and diversification of the portfolio is to construct the covariance and correlations (Ross et al., 1999) across individual items in the portfolio. Covariance measures the degree to which returns on two risky assets move in tandem. A positive covariance thus indicates that asset returns move together. A negative covariance, conversely, means that they vary inversely. Covariance between project i and j can be defined as: $\text{Cov}(r_i, r_j) = \Sigma_S P_r(s) [r_i(s) - E(r_i)][r_j(s) - E(r_j)]$.

Often, it is easier to interpret correlation coefficient (ρ) than the covariance. The correlation coefficient (ρ) is constructed by scaling covariance to assume a value between -1 (perfect negative correlation) and +1 (perfect positive correlation). It is constructed as follows: ρi, j] = $\text{Cov}(r_i, r_j) / \sigma_i \sigma_j$. That is, the correlation coefficient between two projects equals their covariance divided by the product of the standard deviations.

When two risky assets with variances σ_i^2 and σ_j^2, respectively, are combined into a portfolio (p) with portfolio weights w_i and w_j, respectively, the portfolio variance σp^2 is given by: $\sigma p^2 = w_i^2\ \sigma_i^2 + w_j^2\ \sigma_j^2 + 2\ w_i w_j$ $Cov(r_i, r_j)$.

Given this background on the structure of assets in terms of their return distribution (i.e., mean, standard deviation or variance; and dependencies within the portfolio that is defined by covariance and/or correlation coefficient), one can postulate the standard investor's choice problem defined over several asset classes comprising the portfolio to maximize utility. Given the inherent property of the portfolio, the utility is also defined as a function of expected returns and standard deviation of return of the selected portfolio. More precisely,

$$u = E(r) - \sigma^2/t(k) \qquad (1)$$

where u is the utility of the portfolio for the investor; E(r) is the expected return of the portfolio; σ^2 is the variance of the portfolio return; and t(k) is risk tolerance for an investor, k, that is, t(k) is the investor's marginal rate of substitution of variance for expected value (i.e., trade-off). Evaluating Equation 1 slightly differently, it is obvious that u is the measure of portfolio utility that represents risk-adjusted expected return, since it is computed by subtracting a risk penalty [$\sigma^2/t(k)$] from the expected return E(r). Thus, for the portfolio as a whole, the utility function can be defined as the following:

$$pu_x(p, k) = E(p) - \sigma^2 (p)/t(k) \qquad (2)$$

where E(p) is the expected value or return of portfolio p, $\sigma^2(p)$ is its variance, t(k) is investor's risk tolerance, and $pu_x(p, k)$ is the utility of portfolio p for investor k. Portfolio utility is measured in the same units as expected returns, E(p). Thus, for a given level of utility, pu_x, all portfolios must satisfy the following condition:

$$pu_x(p, k) = E(p) - \sigma^2 (p)/t(k)$$

or $\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad$ (3)

$$E(p) = pu_x + [1/t(k)]^* \sigma^2 (p)$$

where pu_x = associated portfolio utility. Different levels of utility associated with higher portfolios can be depicted by a set of indifference curves[15] (see Figure 6).

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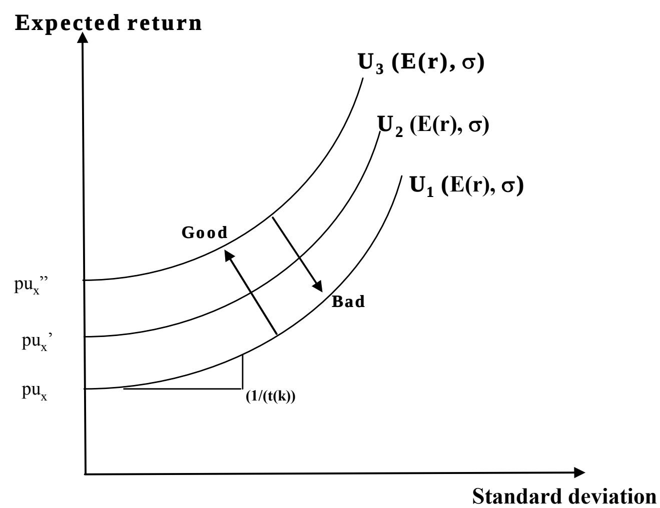
[15] Indifference curves measures investor's indifference between expected returns and standard deviation (risk). It simply states that higher expected returns have to accompany higher risks in order to provide same levels of utility. Alternatively, given the same expected return, investor prefers less standard deviation (i.e., variability in portfolio) than more. Obviously, the underlying assumption here is that risk is

Finally, 1/(t(k) measures the slope along the indifference curve that measures the trade-off ratio of expected return for variance, or marginal rate of substitution of variance for expected value.

Given the above preference structure, how does one determine the choice along the indifference curve or a point on the distribution defining a portfolio? That is, would the investor have $10,000 for certain or a 50/50 chance of receiving $0 or $25,000? While detailed knowledge about the investor's preference structure may be revealing, it is neither necessary nor sufficient to prove that a portfolio choice may exist even without it. The answer to that choice problem, thankfully, may be found through investigating the trade-off that an investor is willing to make in the market place (or at some alternative shadow of such prices), other constraints, and levels of risk tolerance (Varian, 1999).

Figure 6: Structure of preferences for a portfolio of asset choices



Suppose that risky assets and risk-free assets can be traded at the market place. This hypothetical exercise (i.e., trading risk for expected returns) allows us to construct the investor's affordability set for a portfolio with risk to a risk-free investment.[16] The weighted average of the expected return (R_p)

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inherently *bad*, and therefore, has to be compensated by some *good* which is higher returns (Varian, 1999).

[16] Defining risk-return trade-off in the market, not the actual return in a particular month or year, is the foundation of CAPM.

on two assets, one risky return (R_m) and one not-risky (R_f), therefore, can be written as:

$$R_p = bR_m + (1\text{-}b)R_f$$

where b is the fraction of investment on these two assets, or,

$$= R_f + b(R_m - R_f) \qquad (4)$$

Since R_f is risk-free, therefore, standard deviation of the portfolio (with one risky and one risk-free asset) is the fraction of the portfolio invested in the risky asset (b) times the standard deviation of the asset (v_m):[17]

$$\sigma^2(p) = b^2\sigma^2(m)$$

or

$$\sigma(p) = b\sigma(m)$$

and

$$b = \sigma(p)/\sigma(m)$$

Therefore, Equation 4 can be rewritten as:

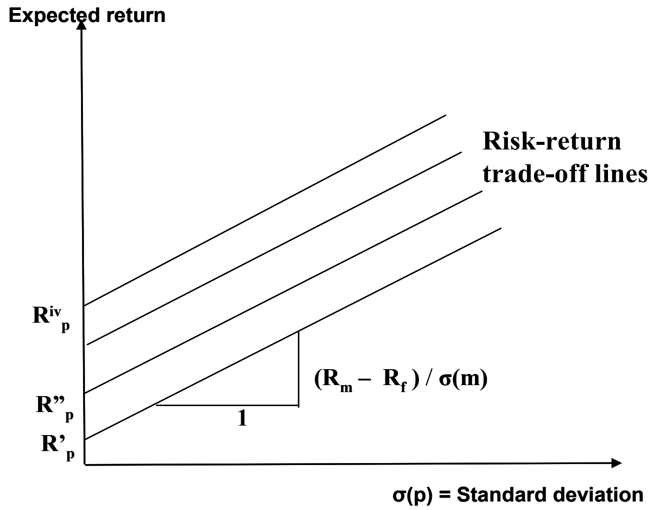
$$R_p = R_f + [(R_m - R_f)/\sigma(m)]^* \ \sigma(p) \quad (5)$$

which is the affordability line because it describes the market trade-off between risk [σ(p)] and expected return (Rp). Note, R_m could be any portfolio, but is considered here as a single choice for simplicity.

Thus, for a given level of portfolio returns or R_p, the iso-affordability line (i.e., trade between R_m and R_f yielding the same portfolio return of R_p) or security-market line can be described by the following figure.

[17] In other words, b measures the responsiveness of expected return (Rp) to movements in the market portfolio (Rm). If the portfolio were to expand to include multiple risky assets, then, b would be equal to covariance between the return on asset i and the return on the market portfolio divided by the variance of the market. This statistic (also known as *beta* from the portfolio theory) can reveal a great deal of information regarding the effectiveness of the portfolio.

Figure 7: Affordability set



Notice that when the portfolio consists of no risk (i.e., standard deviation = 0), then, $R_p = R_f$ (i.e., vertical intercept). The slope of the iso-affordability line is equal to $(R_m - R_f)/\sigma(m)$ which measures the price of risk, that is, extra risk an investor must incur to enjoy a higher expected return. In other words, the line will be upward sloping as long as the expected return on the market is greater than the return on the risk free asset.

Affordability is incomplete without the constraints and boundaries on portfolio choice selection. Thus, investment choices are constrained by the following two conditions:

$$\text{sum}(x) = 1;$$

or, more generally,

$$\text{sum}(x) = L \qquad (6)$$

where L is a constant.

That is, sum of all portfolio investments exhaust the entire budget, that is, full-investment constraint (i.e., no slack left in budget constraint). In addition, project investments may require that some parts of the budget sets may be outside the feasibility bounded from lower and upper ends,[18] that is:

[18] For many of the capital investment projects, too low an investment solution may be trivial, while too high a solution may be budget busting.

$$x <= ub$$
$$x >= lb;$$

or

$$lb <= x <= ub \qquad (7)$$

Now that we have defined both the choice set and the constraints, the goal is to find the best portfolio, that is, the one with the maximum possible utility. The decision variables are the asset holdings, that is, the elements of vector x that form the portfolio p.

Notice, as these elements are varied, the utility of the associated portfolio will change. The authors wish to vary those choices (i.e., elements of x) until the maximum possible utility is attained. Finally, the allowable combinations of x choice sets are typically constrained by other factors (i.e., investment and boundary constraints). Therefore, the standard asset allocation problem (i.e., trade-off between expected return and risk that give rise to an efficient solution in elements of x) can be stated as:[19]

Select:

$$x(i)$$

to maximize:

$$u = E(p) - \sigma^2(p)/t(k) \qquad (8)$$

where:

$$E(p) = x'*e$$
$$\sigma^2(p) = x'*C*x$$

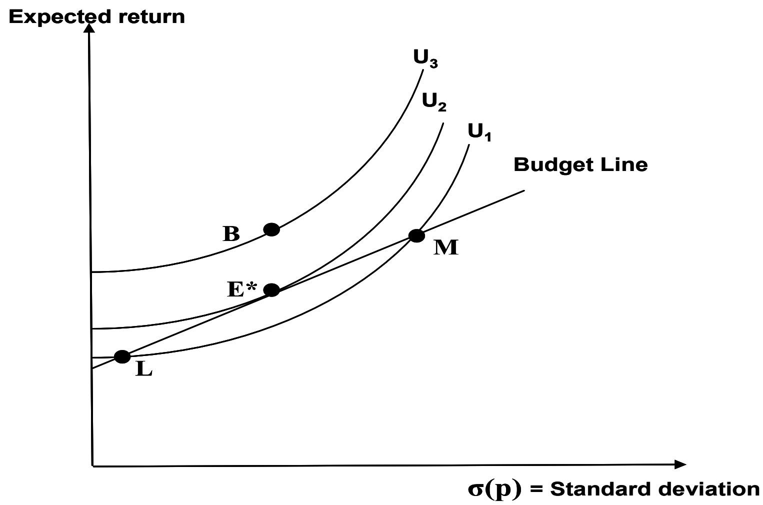
subject to:

sum(x) = L : Fully Invested

lb <= x <= ub : ceiling and floor conditions.

[19] The dual of this primal problem is: Minimize variance subject to fixed utility, u = $\underline{u}$.

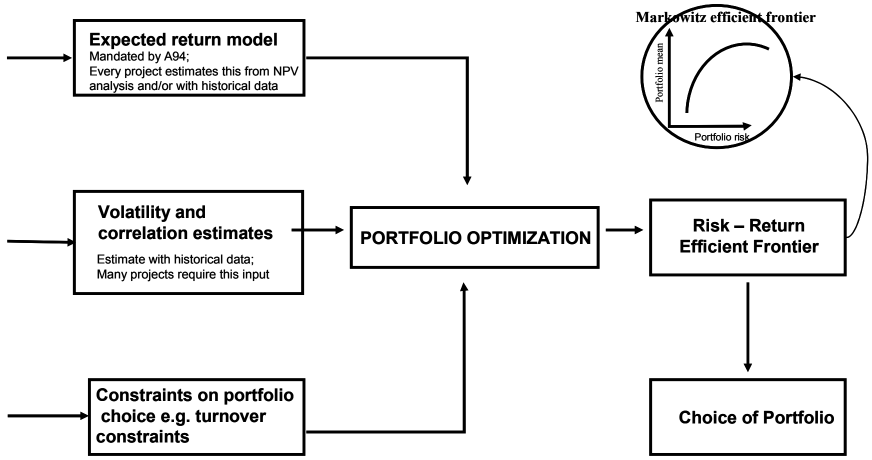
Figure 8: Equilibrium portfolio choice resulting from optimal choice of expected return and risk



The solution to the above problem can be best summarized in Figure 8. The process of finding optimal solution (E*) is reached by varying levels of risk and/or alternatively, by offering minimum risk for varying levels of expected return. Thus, from a point such as L, an investor would prefer to accept higher risk for more returns thus attaining a higher utility from the portfolio choice. Alternatively, starting from point M, the investor would do just the opposite and attain a higher level of utility. Thus, the point E* at which, the slope of the indifference curve is equal to the slope of the budget line, that is, $(t/k) = (R_m - R_f)/\sigma(m)$, would represent the optimal choice of expected return and risk for a particular portfolio. Thus, to the northeast of E* is the efficient frontier for the choice set while to the southeast is feasible.

By iteratively finding the optimal choice points varying the parameters of the above choice problem, different portfolios can be derived while maintaining the most efficient risk-return frontier, also known as Markowitz efficient frontier. The figure below summarizes the entire choice problem described above (Markowitz, undated).

Figure 9: Summary of the portfolio choice in investment process



Source: Markowitz (undated).

Notice that the above choice problem involves the maximization of a quadratic (utility) function of the decision variables, subject to a set of linear constraints (i.e., fully invested), some of which are inequalities (i.e., floor and ceilings). This non-differentiable non-linear problem is termed as a quadratic programming (QP) problem. It may be solved with a general QP algorithm; or with a procedure designed to deal only with problems that have similar structures. However, solutions to this problem can also be parametrically approximated by piece-wise linear programs, but it is somewhat limited.

In this exercise, the authors demonstrate an algorithm[20] that can solve the standard asset allocation problem in a simple and intuitive way keeping the QP structure. More complexities can be added on later, both in terms of expanding assets and recasting the problem in different ways altogether. While somewhat limited in its range of application, the standard problem is easy to program for illustrating key economic principles that may also apply to a very broad range of optimization problems involving project investment analysis.

[20] The example constructed here is based on Sharpe's *Gradient Method* solution to a standard three-asset allocation problem [see http://www.stanford.edu/~wfsharpe/mia/opt/mia_opt1.htm for more details]. While his original algorithm was written on MATLAB, other software can be used to replicate this or other allocation problems.

SOLUTION TO A COMPLEX PROBLEM: AN EXAMPLE OF AN ALGORITHM USING GRADIENT QUADRATIC PROGRAMMING METHOD

Applying the described investment portfolio methodology, the authors offer the following hypothetical example using hypothetical distributions and names for programs, for example, Program A, B, and C evaluated against holding cash. Accordingly, the numbers in this exercise are imaginary. They are not intended to reflect actual program costs and benefits, but rather as an illustration of this form of comparative analysis. A complete benefit cost analysis would be required with estimated risks and interdependencies for actual investment decisions. While this should be done, for this example it has not been done.

The authors assume the following functional forms and other associated inputs for the QP:

Assumed Utility function:

$$U(p) = E(p) - [(\sigma^2)/tk]$$

where: U(p) = the utility of the portfolio; E(p) = the portfolio's expected return; σ^2 = the portfolio's standard deviation of return; and tk = parametric risk tolerance for investor. The following table provides the parameters of the choice problem along with other constructs.

Table 1: Parameters for the choice problem[21]

Correlation Matrix[22]

INPUTS

	MIN	INIT	MAX	ExpRet	StdDev	c:cash	c:progA	c:progB	c:progC
cash	0.000	0.200	1.000	2.800	1.000	1.000	0.100	0.150	0.170
ProgramA	0.000	0.050	1.000	6.300	7.400	0.100	1.000	0.350	0.223
ProgramB	0.000	0.400	1.000	10.800	15.400	0.150	0.350	1.000	0.425
ProgramC	0.000	0.350	1.000	17.280	27.320	0.170	0.223	0.425	1.000

Source: Sharp (2006), The Gradient Method, Available at http://www.stanford.edu/~wfsharpe/mia/opt/mia_opt1.htm; Accessed on April 26, 2006.

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[21] All numbers in this demonstration here are hypothetical and for illustration purposes only.

[22] Correlation coefficient is an easier statistic to interpret than covariance, +1 representing perfect correlation and -1 representing perfectly negative. Correlation coefficient between 2 variables equals their covariance divided by the product of the standard deviations.

The MIN and MAX, or lb and ub from the above choice problem, represent lower (all zero) and upper bounds (all 1) of proportion of investment on four investment choices, cash, PROGRAM A , PROGRAM B and PROGRAM C.[23] ExpRet [i.e., E(p)] and StdDev (i.e., σ^2) represent, respectively, expected returns and standard deviations of the assets stated in terms of percent return per year.[24] Correlation matrix estimates correlations among the asset classes which can be calculated on the basis of the covariance matrix, C.[25]

Finally, three more inputs are required. For simplicity, we assume L = sum(x) = 1, that is, sum of all allocations equal to 1; somewhat moderate risk-taking attitude, and hence, Rt = t/k = 50 (100 would be complete risk taking while 0 representing complete risk averse) and finally, trading decisions (i.e., swapping one investment for another) has been set at marginal utility cut-off ($MU_{buy} – MU_{sell}$) at 0.0001. In other words, if there is a possibility of slight change (0.0001) in utility, through buying and selling (also known as swapping) and hence cumulative impacts through marginal utilities, then, the investor would alter his portfolio to realize the potential gain.

Notice that our example involves four assets, that is, cash, PROGRAM A, PROGRAM B, and PROGRAM C. With optimized utility, the solution space is five-dimensional. With added restrictions (i.e., full-investment constraint) imposed, we are able to present the allocations in three dimensions (since the fourth asset is the residual sum). This makes it possible to graph the relationship between three of the assets (not with the utility). The resulting surface will have some of the attributes of a hill. Notice, however, that only a portion (not all) of this utility hill is feasible given the constraints. We must therefore restrict our search to coordinates in which the sum of the amounts invested in all assets to be 1.0 or less and both upper and lower boundaries have been met.

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[23] Similarly, these hypothetical names have been used to represent different investment choices that the portfolio manager may have.

[24] Notice that for real applications, as opposed to the hypothetical example presented in this paper, expected returns from similar projects (or those which have been estimated by individual project's cost-benefit analyses) can replace these values. Similarly, the standard deviations and correlations among their returns can best be estimated from projects' financials and/or from expert opinions. In absence of these parameters, one can experiment with range of expected values (e.g., expected returns with range of values from 5-30% annually) with corresponding assumptions regarding correlations in order to derive the solutions.

[25] As discussed earlier, the correlation coefficient between 2 variables equals their covariance divided by the product of the standard deviations.

Optimizing the four-asset portfolio requires climbing to the highest feasible point, given restrictions, on the hill by swapping assets. This can be performed in multiple stages. First, we start with a feasible portfolio that satisfies all the conditions stated above. Second, we find the feasible direction in which we can move upward at the greatest rate. More specifically, we select the direction that will result in the greatest increase in altitude (utility) per step (change in portfolio holdings)—that is, the steepest gradient[26]. Third, having selected a direction, we continue climbing until a new peak or a boundary line have been reached and no more gain can be had from further climbing. That is, given the restrictions on the portfolio, a climb through swap/buy is feasible when the following conditions have been met: (a) the asset to be sold is below the upper bound (ub); (b) the asset to be bought is above its lower bound (lb); and, finally, (c) marginal utility gain from this swap is higher. Then we determine the feasible direction of steepest ascent again and repeat the process. When no feasible direction leads upward, we stop. These rules together also give optimal amount to swap when the process of improvement stops yielding the equilibrium. Given the nature of the terrain in a standard problem, this procedure will place us on the highest allowable point, that is, provide the portfolio with the greatest possible utility.

Figure 10 presents the output of the portfolio choice simulation that we performed using Sharpe's algorithm. Starting with baseline distribution of asset holding, clearly, there is a scope for reallocation that may improve the investor's utility. For example, given the parameters, the optimal portfolio allocation indicates that investor's welfare can be improved by moving away from cash holding altogether.

A large beneficiary of the portfolio realignment, given the assumed hypothetical parameters, appears to be Program A. The results of these reallocations are reflected in the market portfolio as a whole via the increase in expected returns (from 11.243% to 11.516%) and a reduction in risk (from 13.558% to 13.285%). The increase in expected returns and reduction in risk exposure, in our hypothetical example, increased utility (from 7.566 to 7.987, or 5.56%) in the investor's market asset holding—clearly an optimal move.

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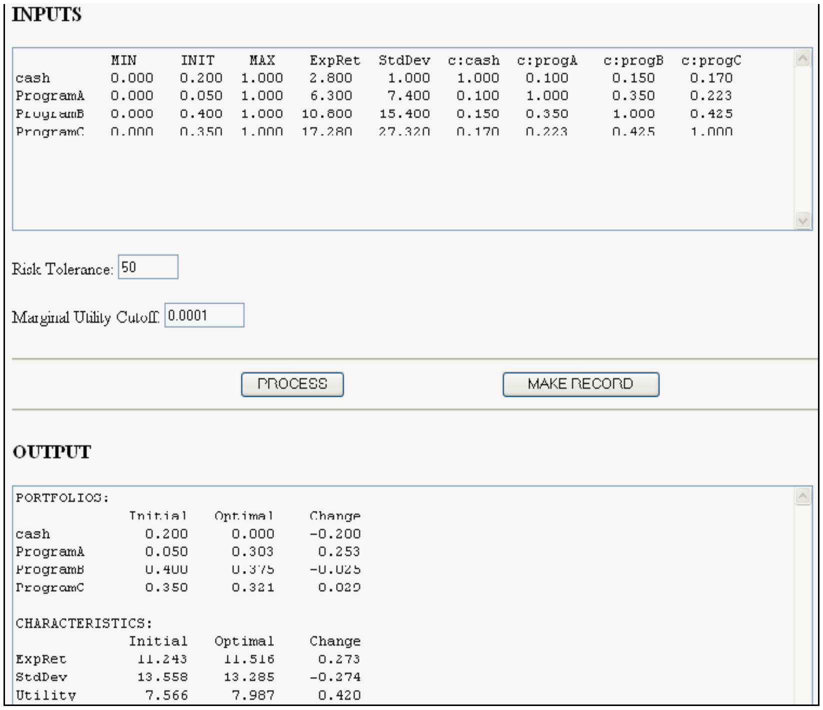
[26] This method is called Gradient Method.

Figure 10: Output of the portfolio choice simulations



CONCLUSION AND FURTHER RESEARCH

In this paper, the FAA's current investment methodology and budget allocations were reviewed. A preliminary investment portfolio analytical framework that may address some of the noted deficiencies was laid out. By drawing upon the well developed theories of corporate finance, the authors have offered an investment framework that takes into account risk, expected returns, and inherent dependencies across NAS programs. The authors present an algorithm in this paper and apply it to a hypothetical four-asset allocation problem. By iteratively solving the QP problem, the authors demonstrate that reallocation may in fact result in improvement in investor's welfare.

This proposed framework is relatively simple and has been used for demonstration purpose only. It can be improved in numerous ways. For example, the framework can be expanded to include multiple assets and realistic values for parameters to include expected returns, standard deviations, and interdependencies, in particular, tasks that may be dealt with in future research.

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REGIONAL AIR TRANSPORT IN EUROPE: THE POTENTIAL ROLE OF THE CIVIL TILTROTOR IN REDUCING AIRSIDE CONGESTION

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ABSTRACT

The volume of air traffic worldwide is still in constant growth despite unfair events that sometimes occur. The demand for regional air transport is also increasing, thanks in part to the use of new vehicles purposely designed for short range flights which make this means of transport more attractive than in the past. This paper studies the possibility of using aircraft capable of vertical or short takeoff or landing (V/STOL), in particular the tiltrotor, in the regional air transport market and the impact on airport capacity that the use of this craft would have. With this in mind the advantages and disadvantages of using this vehicle are identified, as well as the changes to be made to the air transport system in order to exploit its full potential.

Vincenzo Correnti is full professor of Transportation Technique and Economics at the University of Palermo. He is author of more than 70 scientific volumes and monographs concerning Transport Engineering and Economics. From 1980 to 1989 he was at the head of the Transportation Finalized Project of the Italian National Research Council.
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INTRODUCTION

Recent air traffic developments have shown a consistent increase in the volume of traffic handled by regional airports. The growth in regional airport traffic has been considerably furthered by an increase in inter-European connections and flight frequency, boosted by an increase in point-to-point passenger transport between the most important European cities and, therefore, more flights feeding the European hubs. This new phenomenon does not question the role of these hubs, but does open interesting perspectives. It is, in fact, in a country's interest to support growth in European and domestic point-to-point traffic, develop its potential for capturing tourist traffic and favor conditions that avoid a loss of traffic to competing hubs.

The regional airline sector today is one of the most dynamic. More than 300 million passengers from around the world crowded regional aircraft during the last year. This was due to various strategies adopted by regional companies in order to become more integrated and to a change in their operational networks in an effort to define and maintain their role within the current movement towards liberalization and globalization (Graham, 1997).

An element emerging from an analysis of regional air transport developments is that the increase in flights has considerably increased the problem of airport congestion to levels almost reaching saturation point and, as a consequence, has overloaded the air traffic control (ATC) system taking it to the limit of its operational capacity and safety limits. The consequence is that airports are no longer able to handle all the converging flights, producing frequent delays which result in the airport losing its main characteristic: speed of transfer.

The use of aircraft capable of vertical take-offs and landings (VTOL) and/or capable of short take-offs and landings (STOL) offers one possible way of making the situation less critical. An aircraft capable of vertical and short take-offs and landings (V/STOL) is a category of aircraft to which the helicopter traditionally belongs and, more recently, the tiltrotor. This latter is between rotating wing and fixed wing craft (i.e., between the helicopter and the traditional airplane). It was developed for military use and is now being developed for the civilian transport market.

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In this context, regional air traffic transport operating with rotating wing craft can be inserted into the wider transport system offering, prevalently, a supplementary rapid link service for specific types of connection. If it is true that there is a certain diversion from other means of transport towards air transport, this is certainly, to a considerable degree, due to the time saved in connections and a reduction in delays.

V/STOL can use different flight procedures from fixed-wing craft. Exploiting the maximum flight potential of these machines, it would be possible to achieve a very evident reduction in approach, landing, take-off, and departure times. Benefits could come from an operative use of the tiltrotor passenger craft by increasing the number of operations per hour in the airports and deviating part of their traffic towards this aircraft—especially for minor routes—thereby freeing some slots that could be used for larger aircraft with a greater operating range. On the other hand, with suitable procedures, inter-regional connections could be increased to and from the large hubs departing from *vertiports* more widely distributed over the territory and therefore able to ensure a better integration in a territorial context.

In addition, airport congestion is not only limited by runway capacity. Sometimes it is also limited by inadequate access by ground transportation systems. A V/STOL feeder line could improve the system. Despite several helicopter services at some airports, which have not been so successful, the world in 2030 will be even more congested and complex and V/STOL could be part of an integrated transport concept (Schmitt, 2001).

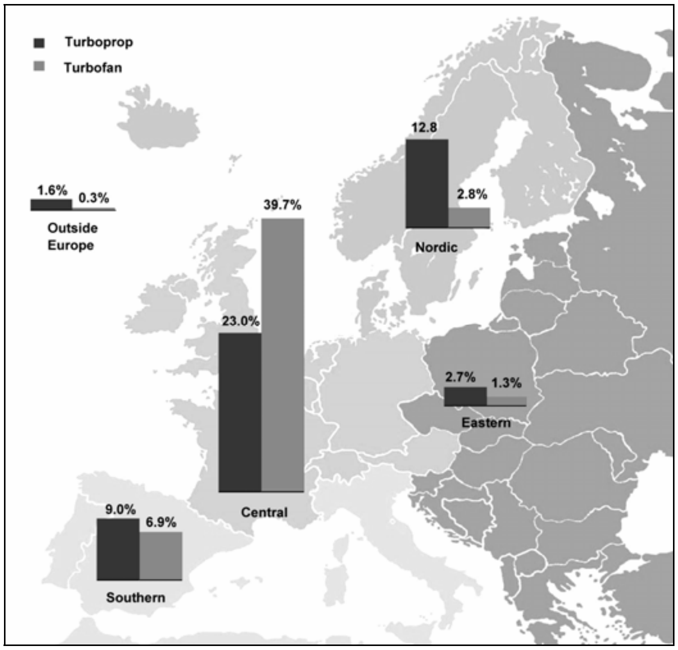
REGIONAL AIR TRANSPORT IN EUROPE

The business of regional air companies is a continuously developing phenomenon, strengthened by the events in past years and encouraged by forecasts of ever increasing traffic. A possible scenario for regional air transport in the near future is greatly influenced by the fact that airports have now reached their capacity limit and problems created by noise and atmospheric pollution are obliging the aeronautical industry to make precise choices when buying aircraft.

The forecasts of both air companies and airplane producers tend towards a choice of larger models than before (e.g., the almost complete abandoning of the 50 seat models for the 70 seat ones). The perspective of regional aircraft manufacturers is that of producing a family of aircraft that offer operational and cost flexibility with maintenance and running aimed at simplicity and savings.

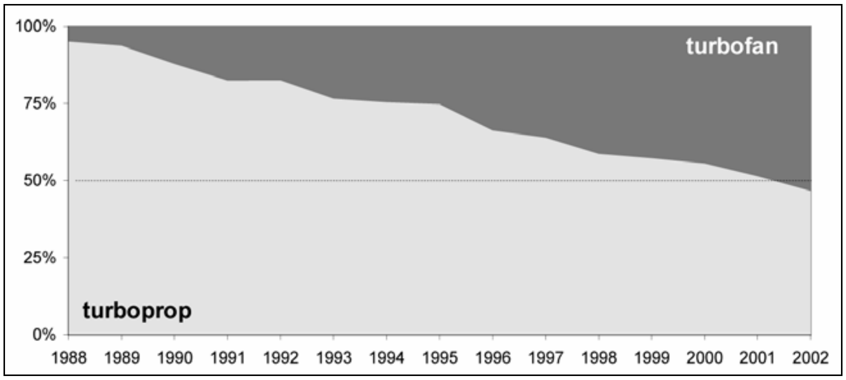
In the European regional air transport market there is still a lot of confusion and many differences between the various airlines. One area of confusion is the total variety of aircraft that fill the skies and airports. This non-uniformity of the fleet leads to an inevitable increase in costs both for maintenance and crew training. Figure 1 shows the geographical distribution of two large families of aircraft—turbojet and turboprop—in European regional areas.

Figure 1. Fleet distribution of European regional airlines, by region, 2002



Source: (ERA, 2002)

Figure 2. Passenger fleet, turboprop and turbofan split for European regional airlines, 2002



Source: (ERA, 2002)

Figure 2 shows the trend of regional transport fleet distribution according to propulsion type (turbofan and turboprop). It shows an increase in jets compared to turboprops. This is the case especially in aircrafts seating from 40 to 70. Over the years, a reduction in the number of large turboprops (40-60 seats) has also been seen, replaced by the turbojet with the same capacity but offering better performance and having more advanced technology, that better meets the needs of the market, and also receives a positive reaction from its users, due to the greater comfort they offer.

From sales forecasts and orders placed by the main aeronautical industries it is possible to define even further the near future scenario for regional air transport. The manufacturing industries agree that aircraft with 20-39 seats will increase by 12%, while about 45% of the total will be represented by aircraft with 40-59 seats; 33% represented by aircraft with 60-79 seats, while the remaining 10% made up of planes with 80-99 seats (Bombardier, 2001).

The airline fleets undertaking regional transport will, therefore, undergo substantial modifications. Forecasts show that almost 50% of the world market will be represented in the near future by planes with 50 seats, those with 70 seats will constitute 31% of the total, while those with 30 seats will decrease from the present 38% to 12%. The number of craft with 70 seats or more will, instead, almost double going from today's 7% to 13% in the next few years (ERA, 2002).

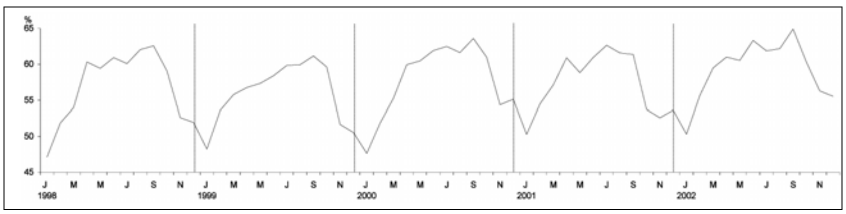
The main pointers for establishing the state of health of European airlines, especially those offering regional transport services, can be deduced from the following graphs and tables that summarize the fundamental factors for the characterization of air transport. The data that follow are from

European Regions Airline Association sources and refer to 2002 and the beginning of 2003.

It can be seen that in the last period examined (2002 – first quarter 2003) the increase in regional passenger traffic underwent a slight drop, which according to the experts can be attributed to the war in Iraq, but nevertheless constituted about 7-8% monthly. This is controversial data that, on the one hand provides an incentive for companies to develop this sector but on the other reinforces worries regarding an imminent collapse of the air transport system due to airport congestion.

Figure 3 illustrates the trend of the load factor of aircraft, which is defined as the ratio between the number of passengers and the available capacity, and represents another important parameter for evaluating both airlines and aircraft manufacturing companies. It shows how there have not been significant increases, except for the seasonal ones, in the load factor value in the last years.

Figure 3. Passenger load factor growth for European regional airlines, 1998-2002.



Source: (ERA, 2002)

From an evaluation of all these factors it emerges that aircraft fleets have adapted in order to respond better to market needs, in which the new aircraft models must satisfy the variability of all these features.

From an observation of the collected data it can be deduced that turboprop models continue to lose favor with both the airlines who should buy them and the manufacturers, who view turbofan models more favorably. One of the causes for this change in strategy on the part of the producers is that, besides having higher operating speeds and consequently shorter connection times, they also offer greater comfort to passengers.

THE TILTROTOR AND ITS FEATURES

Overview

After more than twenty years of research and development the craft known as the tiltrotor—in particular model BA609 produced by Agusta, capable of combining the speed and autonomy of a turboprop and having the capacity to land and take-off in the same way as a helicopter—is now on the point of becoming a reality in the field of commercial transport services. This is proved by the fact that the first model ever realized for the commercial sector will be on the market in the near future and also by the interest demonstrated by research organizations [Ames Research Center, National Aeronautics and Space Administration (NASA)] and manufacturers (Eurocopter, Bell, Sikorsky) for the development of this kind of aircraft. A study carried out on behalf of the United States Department of Transportation (US DOT, 1995) concluded that a new kind of civilian transport system based on tiltrotors would be possible in the medium term and that a craft carrying from 10 to 40 passengers was technically, economically and environmentally feasible.

At the same time, Sikorsky is actively developing the technology for the next generation of tiltrotors, based on engine gondolas having rotors of varying diameter created in order to reduce flight problems after conversion (excessive penalization of performance due to the large rotor disc). They all descend from one model, the XV-15, developed by NASA, the U.S. Army and Bell Helicopters Textron, Inc., together at the Ames Laboratory. Over the course of more than twenty years' research carried out on them, there is now a sufficiently large database to be able to develop two projects, the V-22 and the BA609.

As already mentioned, the tiltrotor has cruising capability typical of the modern turboprops (comfort, speed and autonomy) and a take-off/departure and landing/approach capability typical of rotating wing machines, consequently making ground operations in much more limited spaces possible, with less expensive, less complicated and less bulky infrastructures than those necessary for conventional aircraft (CTOL).

Structurally the tiltrotor is equipped with a special propelling apparatus (proptors). This is made up of two engine gondolas mounted in correspondence to the wing extremities capable of rotating entirely at an angle of more than ninety degrees. In this way not only is vertical take-off possible so is backward movement while in helicopter mode (HELO mode). Once vertical take-off has taken place, the rotation of the gondolas is the most critical phase of the craft's whole flight complexity, both for landing and take-off. In this phase the flight mode changes from being supported by the propulsive equipment to a normal cruising flight phase. The considerable workload to which pilots of the V-22 military transport aircraft are subject has made the creation of a commercial model deriving directly from them highly improbable. The same reasons dictated the choices of controls implemented in the BA609.

In general the tiltrotor, the natural evolution and union of fixed wing and rotating wing aircraft, is a machine characterized by the possibility of operating indifferently as a CTOL, STOL or VTOL aircraft according to the needs of the moment. A commercial tiltrotor could take off vertically and change to the typical flight conditions of a plane in less than thirty seconds, accelerate to a speed of more than 200 knots (like a jet) to fly to a height of more than 30,000 feet and, once cruising, fly at more than 300 knots for the whole stretch. On arrival, a steep descent at maximum speed can be hypothesized with the aid of navigation systems based on global positioning system (GPS) precision equipment, a rapid deceleration then a transfer to HELO mode to complete the final approach up to a vertical touch down using instrumental meteorological conditions navigation systems.

Compared to a conventional regional turboprop (for example the SAAB 340 or the DHC-8-100) the tiltrotor has a better turning range (3800/3900 feet at 60 knots compared to 7700/7800 feet at 120 knots) and steeper descent and ascent angles (more than 55° in ascent at a speed of 110/120 knots and 12/15° in descent at less than 45/90 knots against 12° and 3° at 65/120 knots).

The departure phase of the tiltrotor can be divided into 4 sub-phases:

1. Take-off;
2. Acceleration to ascent speed in HELO mode;
3. Change to aircraft (A/C) mode; and
4. Ascent and acceleration in A/C mode.

Once the critical decision point at about 55 feet has been overcome, the pilot from this point on begins vertical acceleration in order to take the aircraft to a height where he or she can start to vary the propeller configuration, rotating them and bringing them to the A/C flight mode position (i.e., similar to an airplane). For the tiltrotor to take off using this type of take-off procedure certain criteria should be followed. In fact, it is necessary to have (a) enough height to overcome any obstacles near the platform, and (b) in the case of failed take-off, the distance to the departure point must be about 600 feet.

Descent in A/C mode is very similar to that of a normal fixed-wing airplane with an angle depending mainly on traffic control and passenger comfort; to begin the change back to tiltrotor form, speed must be reduced to about 140 knots while the flaps must be positioned at about 30° and propeller speed must be increased from 80% to 100%. At the same time a sophisticated system instantly adjusts the propeller angle with variations of 2°, considerably helping the complicated maneuvers of the pilot.

The principal differences of a V/STOL from both a traditional plane and a helicopter are reported in Table 1, from which it can be particularly noted that the landing and take-off (LTO) distances are considerably less that those of normal fixed-wing craft, giving a high flexibility, above all, in areas near the airport where the final LTO operations take place.

Table 1. Characteristics of helicopter, tiltrotor and conventional aircraft

	Helicopter	Tiltrotor	Conventional Aircraft
Speed	-25 - +160 kts	-25 - +350 kts	+100 - +480 kts
Sideward Movement Capability	20 kts right and left		None
Maneuverability at Low Speed	Excellent		Extremely bad
Landing and Take-off Distance	0 – 600 ft.		3,000 – 10,000 ft.
Climb Path Angle	Up to 90°		Up to 15°
Approach Path Angle	Up to15° (STOL)	Up to 20° (STOL)	Up to 6°

Due to the tiltrotor's particular features, the development of the BA609 posed some fundamental objectives:

1. Reduce the pilot's workload. This objective is to allow the pilot to obtain the desired result from his or her controls by adopting both the control techniques that are peculiar to the tiltrotor and using conventional control techniques. This will simplify the transition of pilots coming from helicopters or planes;
2. Improve flight safety and reliability. From its conception the V/STOL has been endowed with an excess of controls and monitoring equipment with well-timed alarms that guarantee complete safety in the case of transitory phases due to faults and the automatic reconfiguration of the system;
3. Reduce costs and weight. This has been reached thanks to the use of the most advanced flight systems developed during simulations that reproduced high risk situations as faithfully as possible and comparisons made with results coming from flight trials of other crafts.

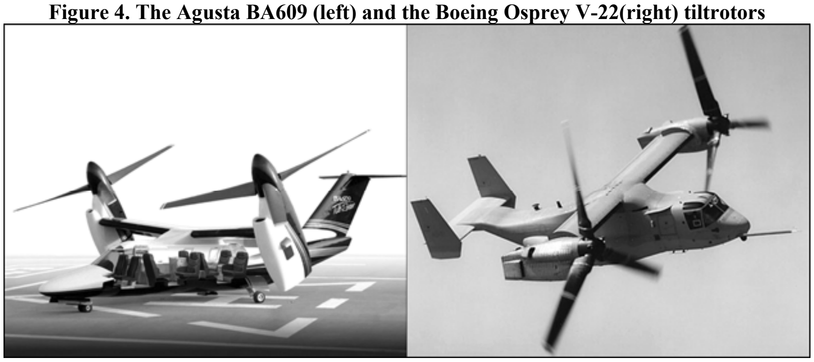
The two best-known tiltrotor models are the Agusta BA609 and Boeing Osprey V-22 (see Figure 4). The Agusta BA609 is now at an advanced point of certification by the Federal Aviation Administration (FAA) and should start production and commercialized service in the first months of 2007, having already met with considerable success. The manufacturer has received about 700 orders from all over the world (Augusta, personal communication). The Boeing OSPREY V-22 is in a renewal phase having already completed many flight hours for verification and certification.

The V-22 has various drawbacks deriving from its implementation and the reason for its creation, being in fact conceived essentially as a war plane.

It has, therefore, some specifications that distance it from the commercial transport field, for example its high noise level goes over the limits imposed by the FAA. The fuselage is very heavy, originally built with materials designed to impede projectiles in a war situation. It has limited maneuverability and is a heavy workload for its pilots. However, it is presumed that some of its problems will be resolved in the near future (Jaworowski & Dane, 2003).

Apart from the two models already described there are, of course, others in various stages of development, due to the need to improve their properties, especially in terms of the number of passengers carried. Both NASA and space agencies in Europe have carried out studies and begun planning and feasibility studies of the various models, having already carried out research regarding replacement of 30-40 passenger (pax) jets. Studies of the European Future Advanced Rotocraft (EUROFAR) 30 pax started in 1988 and it is expected to be produced in three different versions.

Figure 4. The Agusta BA609 (left) and the Boeing Osprey V-22(right) tiltrotors



Agusta, utilizing previous research and prototype experience and also data coming from ERUOFAR, has set up the planning of a new convertible plane called the Enhanced Rotorcraft Innovative Concept Achievement (ERICA). ERICA will succeed the EUROFAR. This represents a new model of the tiltrotor concept, as it will be a union of the concepts coming from the EUROFAR 30 pax and the BA609 projects, in addition, more technologically advanced solutions will also be introduced. An innovative solution is represented by the fact that a portion of the wings is attached to the engine. This is a particularly important aspect in that it greatly reduces the aerodynamic drag produced by the wing surface during vertical take-off, giving the aircraft a much easier take-off with less fuel consumption.

Advantages of the Civil Tiltrotor (CTR)

In synthesis, tiltrotors compared to traditional airplanes have:

1. The possibility of rapidly ascending and descending;
2. Great maneuverability, even at low speeds, which permits a very steep glide slope for approach and take-off, thanks also to their responsiveness in reacting to commands;
3. A not-necessarily fixed approach direction for LTO;
4. Excellent maneuverability at low speeds which gives flight precision during the final phases of landing, ensuring a minimum occupation of airspace; and
5. Extreme flexibility at low speeds making it less sensitive to adverse atmospheric conditions as compared to traditional fixed-wing aircraft.

For all this, if tiltrotors are forced to function within the same approach and take-off lines as traditional aircraft, the potential of the CTR will be negated. That is why the introduction of suitable, independent procedures is needed in order to allow them to be fully exploited. This system would be simultaneous and non-interfering (SNI) and allow a combination of the aircraft's peculiar features with control procedures and flight rules be based on its specific performance so that instrument flight rules (IFR) simultaneous and independent operations are possible. The system is based on the differentiation of the final approach and take-off area (FATOs) for V/STOL and on establishing new instrumental standard flight paths associated to transition corridors for V/STOL ascent and descent. Therefore, SNI operations complete the standard arrival system, by introducing steeper instrumental approaches to a separate touchdown and lift-off area or a parallel/converging runway.

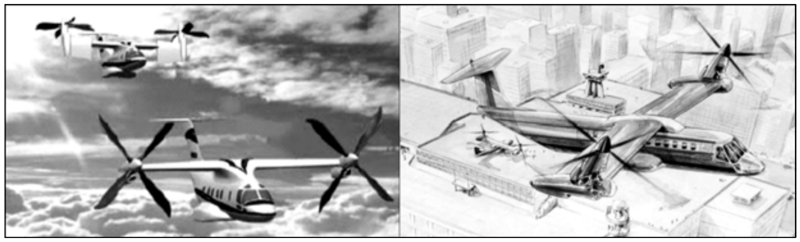
Actually, such improvements require the full operational application of a GPS to air navigation, which would allow the highest capacity levels to be obtained, even if the microwave landing system and distance measurement equipment approach seems to be a good temporary solution for navigation in the ascent and approach stretches, permitting curved trajectories.

The positioning of the new V/STOL site is regulated by three fundamental parameters:

1. Located far from fixed-wing airplane runways in order to have the maximum independence between operations;
2. Be a relatively short distance from the terminal buildings, a maximum of five miles, so as not to lose the V/STOL's advantages of speedy air transfer due to excessive ground transfer times; and
3. Near to the existing airport structure in order to minimize the noise effect; however, as shown in Figure 5, V/STOL noise

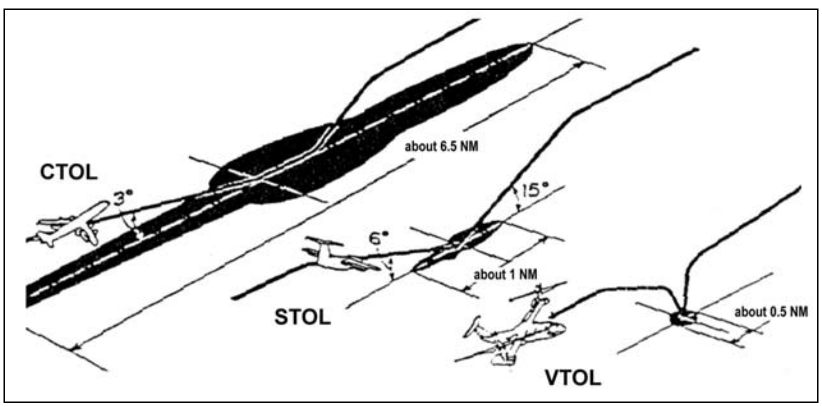
tracks are smaller than CTOL ones, due to the steeper climb and approach path angles.

Figure 5. The new concepts of Enhanced Rotorcraft Innovative Concept Achievement (left) and European Future Advanced Rotorcraft 30 passenger (right) tiltrotors



Many studies have been carried out about the noise effect of tiltrotors and there is no doubt that this problem could create environmental limits for the civilian use of tiltrotors, especially near urban areas. One study was performed in which the noise levels of the EUROFAR 30 pax tiltrotor and a normal transport aircraft were compared in zones in the immediate vicinity of an airport. This kind of research found that a CTR has a noise level that, in vertical flight configuration, is comparable to that of a normal large helicopter and even as much as three effective perceived noise levels less.

Figure 6. Comparison of noise tracks for aircraft with conventional take-off and landing (CTOL), short take-off and landing (STOL) and vertical take-off and landing (VTOL)



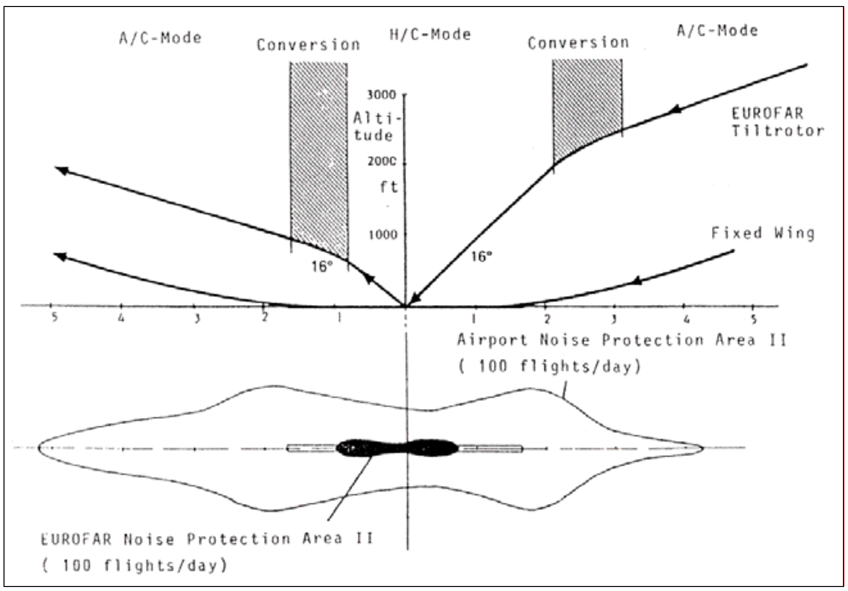
Source: Ferrara, 2002

At the same time, the noise level of a CTR is higher than that of a traditional airplane, particularly during take-off. These results are shown in Figure 6, in which the airport protection area and the noise restraints imposed by the International Civil Aviation Organization certification are highlighted. From this figure it can be seen that if tiltrotors were used in vertical flight mode in a normal airport, the protection zone could be reduced considerably.

Operating costs

The authors are carrying out a study aiming at the definition of the operating cost of the tiltrotor, in comparison with other aircraft, used for regional air services. These aircraft are the: (a) ATR-42; (b) Cessna Citation 2; and (c) Bell Helicopter 412EP. Figure 7 shows some crucial data of these aircraft, in terms of general features, performance and costs. Some data have been provided directly or indirectly by the manufacturers, and the others have been calculated.

Figure 7. Tiltrotor and fixed-wing airport noise protection areas



Source: Ferrara, 2002

Operating costs are divided into direct operating costs (DOC) and indirect operating costs (IOC). The DOC concern all the activities that are directly connected to the transport service; they include fuel consumption, crew wages, maintenance costs, and also amortization and assurance costs. The IOC depend on the general layout of the company and its management criteria.

Taking into accounts both the operating costs and the general features of the considered aircraft (especially the maximum passenger pay load), we get a (rough) estimate of the breakeven fare, which is the fare to apply to meet exactly the cost of the service, without any profit. The values shown in Figure 7 refer to an IOC incidence of 30% and a load factor of 60% and are expressed in dollars per passenger per hour.

As a result of these estimates, the 9-seat tiltrotor operating costs (and the breakeven fares) seem to be at the same level than the ones typical of the regional turbojets, thus confirming two facts:

1. The present tiltrotor can be a convenient alternative to the regional turbojets along short distances, where the speed gap can be covered by the lower terminal time; and
2. Future CTRs, with a pay load of about 30 pax, may be even more convenient, assuming that operating costs increase less than proportionally with the number of seats.

Disadvantages of the CTR

Until a few years ago the use of this type of rotating wing aircraft within airports as regular scheduled transport was not feasible, given that procedures specifically studied for IFR flights did not exist. Having to follow standard LTO procedures made it impossible for V/STOL craft to maintain the regulation speeds (to name just one parameter) because the standard approach speeds were studied for faster machines. For this reason it was not possible to complete this phase within the assigned slot, thereby occupying more than one. This is why it is often preferable to follow the general aviation norms, that is, contact flying and low altitude flying, negating its potential for IFR flight. New flight procedures come from this need to modify the present state of affairs, which as regards airport airspace means, steeper approaches, instrumental flight with the help of precision GPS, and other elements.

With the new CTR models some problems have been resolved that, during the years, have heavily penalized and continue to penalize other V/STOLs, for example high maintenance costs due to mechanical complexity and critical conditions of usage or environmental problems (noise) linked to the features of the craft and the type of usage (e.g., at low quota or not, or whether over urban or rural areas). Up to now these limiting factors have been the reason why use of this vehicle has not been more widespread, especially in areas in which they do not operate but in which suitable conditions for their use could exist.

THE CIVIL TILTROTOR AND AIRPORT CAPACITY

Delays due to airport overcrowding and congestion cost international air carriers approximately 4 billion dollars in 2000 and an estimated 5.2 billion dollars in 2004. The European Commission estimates the cost of delays in 2000 due to air traffic congestion was 3.8 billion Euro. This situation is matched by the fact that inter-European flight departures have an average delay of 15 minutes in 28.3% of cases (Ferrara, 2002). It can be noted that more air traffic means not only more traffic in the sky but also more activity and obstructions on the runways and apron, as well as inside the airport landside.

The airport capacity

An airport's capacity is defined as the number of flights (landings and take-offs) that can be carried out within a determined period of time with an average delay falling within acceptable time limits. Considering that with an increase in the number of flights, the average delay also increases, it is therefore necessary to choose a reasonably tolerable delay in order to determine capacity.

Ideal maximum capacity is when the time intervals between successive operations are equal to the respective occupation times of the aircraft using the runway and there is no variation either in the time intervals between aircraft or between their runway occupation times. Naturally these are ideal conditions. In practice, during peak periods queues can produce ever increasing delays as the queue lengthens. Therefore, the practical operating capacity of a single runway with many exits can be considerably less than the ideal, according to the amount of delay considered acceptable. Normally four minutes is held to be acceptable (Ignaccolo & Inturri, 2001).

Airport capacity depends on factors such as the layout of the aerodrome, the runways and taxiways, the characteristics of the aircraft using the airport, weather conditions and control techniques for air traffic management in the terminal area.

Why the tiltrotor may increase capacity

In the 1960s and 1970s when the first studies regarding the V/STOL concept were carried out, it was already time to start resolving specific problems such as excessive connection times between the starting points and destinations of a journey and the airports and the lack of really convenient alternative solutions to road or rail connections over short-to-medium distances. The same can be said of technical capacity, such as excessive consumption of fuel by the engines of that time, excessive noise and pollution, and considerable plane weight requiring the use of oversized engines needing greatly increased fuel loads.

The idea of using tiltrotors within airports for regional/inter-regional airport movements with the primary aim of increasing capacity came from a renewed interest in the market for such machines. The reasons are obvious, in that:

1. They constitute a really valid, competitive substitute to other highly expensive and not easily accomplished solutions (the building of new runways for example); and
2. They can replace planes of an equal capacity because their particular design characteristics make them highly versatile and easy to handle.

Estimating capacity increase

In this section of the paper we try to establish quantitatively the contribution in terms of capacity resulting from the use of tiltrotors as substitutes for medium capacity planes, using the Blumstein model for movements relating only to arrivals (Horonjeff & McKelvey, 1994). We have referred, therefore, to an airport using only one runway and for which the precise composition in terms of aircraft types using the terminal area is known.

For this part of the analysis we do not refer to the use of CTRs in completely vertical take-off mode, but imagine their use only in short take-off mode. Compared to a turboprop aircraft, the CTR has the ability to land and take-off in relatively short distances of around 600-1,000 feet with a runway occupation time of less than 35 seconds. We also considered a descent path equal to 2.5 nautical miles (NM), as stated in the producer's technical specifications, and less restrictive separation spaces than those of the turboprop, given the low level of disturbance caused by turbulence coming from the wake vortex of preceding planes.

In the following tables the data used for determining airport capacity are estimated for three case studies:

1. Without tiltrotors;
2. Using CTRs to completely replace medium aircraft;
3. Using CTRs in an ever-growing percentage of substitution for heavy and large aircraft.

Table 2 shows the types of aircraft considered for the relative percentages and ground speeds, as well as the relative runway occupation times once the craft has landed and finally the length of the common descent path. The space separations among aircraft types, due to wake vortex effects, are shown in Table 3.

Table 2. Aircraft compositions and characteristics for airport capacity evaluation

Aircraft Type	Composition Case Study 1	Composition Case Study 2	Final Approach Speed [kts]	Final Approach Speed [km/hr]	Runway Occupancy Time [seconds]	Common Path Length [nm]
Heavy	30%	30%	140	259.84	70	5
Large	30%	30%	125	232	60	5
Medium	35%	0%	110	204.16	55	5
Small	5%	5%	90	167.04	50	5
V/STOL	0%	35%	100	185.6	35	2.5

V/STOL – aircraft capable of vertical and short take-off and landing

Table 3. Space separations among aircraft types, in nautical miles

		Aircraft Type				
		Heavy	Large	Medium	Small	V/STOL
Preceding Aircraft Type	Heavy	4	5	5	5	4
	Large	2.5	2.5	2.5	4.5	2
	Medium	2.5	2.5	2.5	4	1.9
	Small	2.5	2.5	2.5	2.5	1.9
	V/STOL	2.5	2.5	2.5	4	1.9

V/STOL – aircraft capable of vertical and short take-off and landing

Referring to the Blumstein model, it is possible to calculate the time separations among the aircraft types. These are presented in Table 4.

Table 4. Time separations among aircraft types, in seconds

		Aircraft Type				
		Heavy	Large	Medium	Small	V/STOL
Preceding Aircraft Type	Heavy	102.86	128.57	128.57	128.57	102.86
	Large	79.71	72.00	72.00	129.60	60.00
	Medium	99.35	91.64	81.82	130.91	62.18
	Small	135.71	128.00	118.18	100.00	88.40
	V/STOL	100.00	100.00	100.00	160.00	68.40

V/STOL – aircraft capable of vertical and short take-off and landing

These values lead to a capacity estimate for a runway used only for arrivals in Case Study 1, with no use of tiltrotors, equal to 36.71 movements per hour. For Case Study 2, we assume a complete substitution of the medium aircraft with tiltrotors. The time separations do not vary, while the compound probability P_{ij} of having an aircraft of type j following an aircraft of type *i* varies with respect to Case Study 1. For Case Study 2 the runway capacity is equal to 38.55 movements per hour.

The increase in airport capacity from Case Study 1 to Case Study 2 is quite slight, about 5%. Obviously, when the percentage of medium aircraft is greater than that (e.g., in regional airports), the capacity increase may be more relevant.

On the other hand, for congested airports, even a slight increase in airport capacity can lead to a significant decrease in the average delay suffered by all aircraft, thus lowering operating costs and making that airport more attractive to them.

Hypothesizing an ever-growing percentage use of the tiltrotor, which corresponds to the introduction of larger crafts, we calculated the respective increase in airport capacity, which is shown on Table 5.

Table 5. Estimates of airport capacity increase for five case studies of varying aircraft composition

	Size/type of aircraft						
Case Study	Heavy	Large	Medium	Small	V/STOL	Capacity [movements/hour]	% Increase
1	30%	30%	35%	5%	0%	36.71	
2	30%	30%	0%	5%	35%	38.55	5.00%
3a	20%	20%	0%	5%	55%	40.80	11.14%
3b	15%	15%	0%	5%	65%	42.29	15.18%
3c	10%	10%	0%	5%	75%	44.07	20.03%
3d	10%	10%	0%	2%	78%	45.74	24.58%

V/STOL – aircraft capable of vertical and short take-off and landing

Capacity for CTR exclusive runways

The situation examined does not presume using a CTR capable of vertical take-off, but instead imagines using a version capable of short take-off. The commercial tiltrotor can board a greater number of passengers and take-off in a greatly reduced space, not vertically, but still with relatively shorter distances than those necessary for normal fixed wing aircraft.

The FATO for an aircraft using VTOL can be any surface (about 1,000 feet long)—both inside or outside the airport—that can be used as a LTO area. It could therefore be a taxiing area, or a runway no longer in use, or a segment of a secondary runway used for STOL operations. Once the steep descent starting point had been reached or when ATC requests it, a descent procedure with elevated glide slopes and maximum speed up to the touchdown zone would begin.

The concept of minimum speed associated with the IFR flight certification disappears with the tiltrotor's capability to conserve all its maneuverability even at very low speeds. In the absence of a lower speed limit for approach the potential steepness of the descent path can comfortably reach 12/13 degrees. Simulations have even foreseen a capacity to operate with glide slopes at speeds of less than 50 knots. Eventually approach/take-off paths could be defined that are considerably narrower than the present ones so as to minimize the airspace necessary compared to the present standards for traditional planes.

The areas destined for the transition phase will have to be reserved areas, in order to carry out the conversion from ordinary plane mode to that of HELO mode. This is to avoid interfering with the normal operations of fixed wing aircraft in departure/take-off or approach/landing on the main runways. It must, of course, be emphasized that such areas will be airspaces in which operations will strictly follow procedures. The capacity to land in IFR independently of the rest of the traffic is an essential requisite in order to increase airspace capacity. Simultaneous, converging instrumental approaches without interference allow traffic to be sorted in the best possible way without extra work for ATC.

The location of potential sites for these new means of transport must pay attention to three particular conditions:

1. Maximum operational independence must be guaranteed;
2. Shortening of transfer times to and from the tiltrotors, both for passengers in transit to and from other aircraft and for passengers departing or arriving, so as to optimize landside sorting; and
3. Minimal acoustic impact on the surrounding territory (reason for locating within the airport itself).

Little-used runways with a length of less than 5,900 feet, called stub runways (Stouffer, Johnson, & Gribko, 2001), are the most attractive for CTR traffic except in the cases where these runways were closed because of interference with the instrument landing system operations of traditional planes, in which case the inter-dependence could have a negative effect on the expansion of capacity.

An alternative to the use of little-used runways would be the use of aprons and taxiways so as not to upset traffic on the flight runways. An attempt was made to identify areas outside airports but in many cases the surrounding zones were already occupied by residential or industrial installations which impeded the creation of exclusive CTR runways. In the cases in which it is possible to locate these areas, it is necessary to keep in mind the problems both of noise pollution and the distance of the CTR terminal from the main terminal, which should not be more than 5 NM in order to not compromise the benefits of using tiltrotors by excessive terminal transfer times.

Airport reconfiguration

Airport reconfiguration, with the hypothetical introduction of such machines, would include the opening or reallocation of runways or taxiways, or even the building of new exclusive runways. The CTR can be used on almost all runways without difficulty, while traditional take-off aircraft must necessarily be used in airports with suitable runway characteristics and therefore with adequate space according to the type of aircraft.

A NASA study (Johnson, Stouffer, Long & Gribko, 2001) tried to establish for several airports whether it had sufficient space to permit CTRs to operate independently of traditional traffic. This information is valuable due to the considerable increase in airport capacity that can be obtained in this way. The research took into consideration the infrastructural characteristics of the airport and the existing structures and the location and availability of areas for the new aircraft. The result is a scale of values for operating potential for those American airports at which 85% of passenger traffic movement takes place. The study concluded that only one airport out of the 63 studied did not possess the specific features necessary to permit CTRs and traditional planes to operate independently. The examined interventions and the respective number of airports for which they are feasible are shown on Figure 8.

Figure 8. Comparing the tiltrotor to other conventional aircraft

	manufacturer		CESSNA	ATR	BELL	BELL-AGUSTA
	model		Citation 525 Bravo	42	412EP	BA609
	type		turbojet	turboprop	rotorcraft	tiltrotor
	wingspan	ft	52	82	-	59
	length	ft	46	75	43	43
	max load	pax	10	50	14	9
	range	NM	1.890	1.000	375	750
	max cruising speed	kts	400	300	125	275
	min takeoff distance	ft	3.400	4.800	0	0
	min landing distance	ft	3.000	3.600	0	0
	MTOW	kg	6.500	18.600	5.200	7.300
	operational ceiling	ft		18.000		25.000
	approximate price	M$	4,4 (1997)	12,2 (1994)	4,9 (1999)	9 (1998)
DOC	administration	$/h	231	645	433	355
DOC	crew	$/h	270	534	202	202
DOC	maintenance	$/h	383	485	362	294
DOC	fuel and oil	$/h	314	725	186	203
	total DOC	$/h	1.197	2.389	1.182	1.053
DOC+IOC	IOC 20%	$/h	1.436	2.866	1.418	1.264
DOC+IOC	IOC 30%	$/h	1.556	3.105	1.537	1.369
DOC+IOC	IOC 40%	$/h	1.676	3.344	1.655	1.474
	breakeven fare	$/paxh	259	104	183	254

MTOW – Maximum take-off weight
IOC – Indirect operating costs
pax – passengers
kts – knots
M$ - millions of dollars U.S.
$/paxh – dollars per passenger per hour
DOC – Direct operating costs
ft. – feet
NM – nautical miles
kg – kilograms
$/h – dollars per hour

The type of capacity increase considered is in terms of an increase in independent or dependent operations that allow an increase in the number of supplementary flights and that improve the time flow of other airports. The number of additional operations depends not only on the runway types, but especially on the layout of the whole airport infrastructure and the respective runway configurations. For example, a new independent runway can permit about 70 operations per hour, but if the runway is not completely independent that value decreases considerably. The FAA regulations establish that independence between two parallel runways takes place at the moment in which there is a distance of more than about 4,200 feet between them. If the distance is less then 4,200 feet, they are dependent runways on which operations are carried out under IFR control. Completely independent operations make the greatest contribution to an increase in capacity. This is realized when a new runway can be built at about one NM from preexisting runways so as to give approaching aircraft two parallel, simultaneous and completely separate approach routes.

It is evident that the problem of insufficient airspace capacity can find an immediate solution in the operative use of new generation CTRs, rationalizing the use of traditional aircraft and adapting flight procedures for V/STOL, particularly in view of their future implementation in airports.

CONCLUSION

It appears clear how the problem of insufficient airspace capacity can be rationally faced. It means that starting from now the operational use of the new generation of craft must be programmed, rationalizing the use of existing aircraft and adapting flight procedures for rotating-wing craft especially in view of their future use in airports.

The results coming from different studies must be kept in mind, particularly those indicating that the use of tiltrotors would represent a fraction of the cost of the necessary structural enlargements, but that if used correctly could lead to an increase in capacity equal to that obtainable from the building of a new runway, besides other effects such as increasing the number of available slots (quantifiable as 50% of arrivals and departures, 40% during peak hours).

In conclusion, the introduction of the new V/STOL can represent the least expensive, most efficacious and safest way of improving airspace flexibility and productivity by reducing delays and increasing capacity.

It can be understood that the introduction of these craft and the parallel development of optimal procedures for their use together represent an optimization of the use of airspace capacity without involving disproportionate additional costs and at the same time leading to a significant improvement in airport performance.

Nevertheless, there is a great deal of skepticism on the part of ATC authorities and the airlines themselves of changing immediately to the use of tiltrotors. The airlines in particular, who would benefit only indirectly from an increase in airport capacity, need to thoroughly understand the simulation data and examine performance before placing orders that could turn out to be uneconomic.

It is the opinion of the authors that if the tiltrotor's passenger transport capacities are confirmed and models with a suitable capacity for commercial service are produced, the choice of these aircraft could be one of the best solutions to the often-posed question of how to improve airport congestion without extending the infrastructure.

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APPENDIX

List of Acronyms and Abbreviations

A/C	aircraft
ATC	air traffic control
CTOL	aircraft using conventional take-off and landing mechanisms
CTR	civil tiltrotor
DOC	direct operating costs
ERICA	Enhanced Rotorcraft Innovative Concept Achievement
EUROFAR	European Future Advanced Rotocraft
FAA	Federal Aviation Administration
FATO	final approach and take-off area
GPS	global positioning system
HELO mode	flying a V/STOL in helicopter mode
IFR	instrumental flight rules
IOC	indirect operating costs
LTO	landing and take-off
MTOW	maximum take-off weight
NASA	National Aeronautics and Space Administration
NM	nautical miles
pax	passengers
SNI	simultaneous non-interfering
STOL	short take-off and landing
V/STOL	aircraft capable of vertical or short take-off and landing
VTOL	vertical take-off and landing

THE DEVELOPMENT OF JOMO KENYATTA INTERNATIONAL AIRPORT AS A REGIONAL AVIATION HUB

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ABSTRACT

Air transportation plays an important role in the social and economic development of the global system and the countries that seek to participate in it. As Africa seeks to take its place in the global economy, it is increasingly looking to aviation as the primary means of connecting its people and goods with the world. It has been suggested that Africa as a continent needs to move toward a system of hubs to optimize its scarce resources. Jomo Kenyatta International Airport in Nairobi, Kenya, is one of the airports in the eastern region of Africa that is seeking to fill this role. This paper discusses the prospects for success and the challenges that it will need to overcome, including projections through 2020 for the growth in passenger and cargo traffic.

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INTRODUCTION

Air transportation plays an important role in the social and economic development of the global system and the countries that seek to participate in it. According to the Air Transport Action Group, the world's airlines carried over 1.8 billion passengers and 29 million tons of freight in 2004. The air transport industry as a whole provided over 28 million jobs directly and supported another 192 million in the travel and tourism industry. Air transport is one of the fastest growing sectors of the world economy, expanding 2.4 times above the Gross Domestic Product (Air Transport Action Group, 2000, 2005). Although the aviation industry has suffered from the combined effects of economic recession, Severe Acute Respiratory Syndrome, war, and terrorist attacks (September 11, 2001, and later), traffic in all regions has returned to pre-September 11, 2001, levels and the global economy shows signs of continued growth (Air Transport Association, 2002).

One region that did not see a decline in air traffic following September 11, 2001, was Africa which posted a 1.4 percent gain in 2001 and is expected to witness continued traffic growth for the foreseeable future (ICAO, 2002). A number of factors account for this growth. First, Africa is the second largest continent in the world with a large population base that is separated by geographically challenging terrain. Because of the "poor state of land transport and the enormous cost of addressing these deficiencies" (Abrahams, 2002. p. 3), aviation is seen as a particularly ideal means of connecting Africa with itself and the rest of the world (Rhoades, 2003). Second, it is estimated that less than one in every twenty Africans currently has access to air travel. Thus, the potential for growth is substantial if the countries in the region can overcome the many barriers that exist today (Airports Company South Africa, 2004). These barriers include poverty, lack of aviation infrastructure, maintenance and financial support, safety and security concerns, and competition from non-African airlines (Abrahams, 2002; Graham, 1995; Rhoades, 2003; World Bank Group, 2002).

It has been suggested that Africa as a region must move toward a system of hubs "rather than the proliferation of competing yet unviable airport infrastructure across the continent…which detract from the much needed investment in other areas of development within African states" (Abrahams, 2002, p. 7). Further, traffic forecast would seem to indicate that three major hubs in Sub-Saharan Africa would be ideal for serving both international and regional needs. Based on general air traffic patterns, these hubs would be located in Southern, Eastern, and Western Africa. Johannesburg in South Africa appears to be the most likely candidate for Southern Africa. The situation in Western and Eastern Africa is less clear (Abrahams, 2002). One contender for Eastern Africa is Kenya. The major north-south and east-west air routes pass over the country at present and Kenya already possesses several international airports used for technical and refueling stops. This geographical advantage could help facilitate the development of one of Kenya's airports as a regional hub and major player in transport development in the continent (USAID/REDSO/ESA, 2001).

The objective of this paper is to discuss the development of Jomo Kenyatta International Airport (JKIA) as a regional aviation hub within the airline context of a hub-and-spoke system itself. Existing patterns and forecasted trends in passenger and cargo traffic are examined as a means of assessing the possibilities of a viable hub. In addition, the regional competition faced by JKIA and the potential investment required are explored to understand some of the challenges facing JKIA efforts to establish itself as the premier Eastern African hub.

HUB-AND-SPOKE CONCEPT

Button (2002) has noted that "there is in fact no unique or even widely used, definition of what exactly constitutes a hub airport" (p. 179). It may be used to refer to a geographical area whose airport (or airports) enplane a significant number of passengers or cargo (Button, 2002; Wells, 1994). It may also be used to refer to the broader concept of a hub-and-spoke system. In such a system, the hub is the central point in a radial airline network. This network allows 'an airline to increase frequency in thin markets by connecting the thin markets (the spokes) to a central airport (the hub), trading off the inconvenience of a stop and connection for greater frequency and the ability to match the right sized aircraft to each route (Taneja, 2003). Hubs are not unique to air transportation having application to any form of transportation that serves markets of varying sizes. It is also not unique to the U.S. aviation system even though thirty years of deregulation have created a system in the U.S whereby most large carriers have created a series of hubs and feeder carriers (Button, 2002). Part of the observed difference between the U.S. system and the rest of the world is the different historical development of the industry. In much of the rest of the world, countries established through consolidation a single large international flag-carrier that utilized that country's national capital as the hub for an international route network (Graham, 1995).

Button (2002) addresses a number of the cited problems with the hub-and-spoke system including: a) the loss of direct service suffered by small communities; b) airport congestion; c) potentially higher fares resulting from airline concentration and control of hub markets; d) restriction of new entrants; and e) environmental damage, but concludes that the system is not inherently flawed and can result in wider choices and lower overall costs.

For the purpose of this discussion, the issue of congestion is a critical element in discussing potential hub airports since it relates directly to the question of infrastructure. Traffic at a true hub-and-spoke airport typically arrives and departs in a series of banks, that is, a number of different flights arrive at around the same time, connect to another flight and depart around the same time, hopefully with minimum delay. However, this strategy may lead to congestion in several areas: a) on the ground as passengers for various flights attempt to arrive (or depart) at around the same time; b) within the airport as peak volumes of passengers move from one area to another; and c) in the air as a number of aircraft try to use a limited amount of airspace.

While debate is likely to continue over the costs and benefits of hub networks, there is general agreement that too many hubs for a carrier or a region is not economically viable (Shaw, 2004; Taneja, 2003). As already noted in the introduction, traffic patterns and forecasts seem to indicate that Africa would best be served with a system of three continental hubs in Southern, Western, and Eastern Africa (Abrahams, 2002). If this is true, the question now becomes which airport is best positioned to assume this role and what types of investment, infrastructure, and regulatory support will be required. Hub airports compete on a number of factors including "the number of destinations and frequency of the services offered, transfer times, comfort levels at airports, ticket prices charged by carriers, airport taxes, etc." (Reitveld & Brons, 2001, p. 248). In international aviation, a hub airport serves as the home base for its national carrier as well as the arrival and departure point for international carriers as set out in the bilateral air service agreements between nations. The strength of the home carrier as well as the nature of the bilateral air service agreements with other nations will effect the destinations and frequency at the airport. Transfer times are another important issue for hub (or potential) hub airports. If congestion creates delays that result in missed connections, then passengers are likely to choose other travel routing, particularly if limited flight schedules result in extended stays for rebooking. Inadequate seating in airports, lack of facilities for dining, shopping, etc., become important to passengers waiting for connections. Ticket prices can also affect customer trip selection. The President of the African Civil Aviation Commission recently acknowledged that in order to find an affordable fare from one African capital to another many passengers were forced to fly to Europe and back on a European carrier (Africa must open the skies, 2005). From an airline (and indirectly a passenger or shipper) perspective, airport taxes, gate fees, and fuel prices are additional considerations. In short, many factors will influence the behavior or passengers, shippers, and airlines in selecting trip routing. The successful hub must attempt to address the concerns of all major stakeholders.

DEVELOPMENT OF AIR TRANSPORT IN KENYA

Air transport has, in the recent past, gained popularity among the residents of Kenya and is no longer considered as a reserve for rich foreigners and senior government officials. There are new trends in the country, as elsewhere in Africa, which will create opportunities for aviation to thrive. These opportunities include a huge population, the vast physical size of the country, inadequate surface transportation, emerging commercial links with the outside world, and the low level of development of the country leading to great potential once the development process begins (USAID/REDSO/ESA, 2001). As in other developing countries, air transportation was imposed wholly from outside the country. Similarly, the spatial pattern of important routes emerged early and has remained basically the same, with the majority of the air routes geared to Europe and Asia. The existing pattern of air transportation network in Kenya, like that of the rest Africa can be traced from the colonial origins of the international network (Hogenauer, 1975).

Scheduled domestic air transport services

Domestic air transport services began in Kenya soon after World War I with the first air passenger services offered by Wilson Airways, a private airline established in 1929. This transport company had its headquarters in Mombasa. In August 1932, Wilson Airways introduced regular passenger services between Nairobi and Dar es Salaam through Zanzibar, Tanga and Mombasa on a weekly basis. The inauguration of this service offered the first inter-territorial (regional) communication linking East African towns with the main Imperial Airways Trans-Africa (Cairo-Cape Town) route. Later in the year, Wilson Airways launched another weekly service, this time to Entebbe through Nakuru, Kisumu and Jinja. This marked the development of the first international air routes in East Africa. With the outbreak of World War II in 1939, the airline was liquidated. The East African Airways Corporation (EAAC), a regional airline operated by the three East African countries of Kenya, Uganda and Tanzania, replaced it in January 1946. EAAC operated until 1977 when the East African Community collapsed. The demise of EAAC led to the development of national carriers such as the Kenya Airways, Air Tanzania and Uganda Airlines.

Currently, domestic air transportation in Kenya serves the tourism industry by transporting tourists to and from Mombasa, Nairobi and other tourist sites such as the Maasai Mara, Mt. Kenya, Malindi, Western Kenya and Lake Turkana region. Air passenger services are operated to and from Nairobi, Mombasa, Kisumu, Eldoret, Malindi, Lokichogio and Maasai Mara among other destinations. Certain areas in the northern and eastern parts of Kenya have low levels of accessibility by road and are totally lacking in railway transportation (Irandu, 1995). Aviation is also important in the transportation of perishable horticultural products, fish and other meat products to overseas market.

Scheduled international air transport services

International air passenger services in Kenya were established during the 1930s. The services were provided by the Imperial Airways the forerunner of the British Overseas Airways Corporation (BOAC). In January 1932, Imperial Airways started the London-Cape Town service which initially passed through Mwanza but was later changed to pass through Nairobi. Imperial Airways merged with BOAC in April 1940. With the attainment of independence, Kenya renegotiated all the Bilateral Air Service Agreements previously entered into on her behalf by the then colonial government of the United Kingdom. This involved the review of traffic rights for all scheduled foreign airlines operating into and out of Kenya. On February 4, 1977, Kenya established its own airline, Kenya Airways (KQ) to provide both domestic and international scheduled services. Together with its partner KLM, KQ provides the highest service frequencies to Europe from Nairobi via Amsterdam's Schipol hub. The two airlines provide convenient and regular connections to continental Europe, North America and the rest of Africa.

By 1987, Kenya had more inter-Africa connections than other nations in Africa when the Yamoussoukro Declaration on a New African Air Transport Policy—established in 1988—committed African nations to total integration of their airlines through the liberal exchange of air service rights, unbiased computer reservation systems, and joint infrastructure projects. Unfortunately, there has not yet been any significant implementation of this policy. International air traffic in Africa continues to be concentrated on a few large airports with intercontinental connections and limited feeder lines from other African capitals. Between 1986 and 1996, Johannesburg, Nairobi and Dakar developed into the most important international hubs in sub-Saharan Africa (Pedersen 2000). In terms of inter-African connections, Johannesburg has become the most important hub. However, its location further south puts it at a disadvantageous position compared to Nairobi, which has served as a gateway to parts of Africa south of the Sahara. Nairobi also has a greater frequency of flights to cities such as Dar es Salaam, Entebbe, Lusaka or Harare. Nairobi's location vis-à-vis the principal north-south alignment between Europe and Southern Africa requires little deviation in terms of route kilometers flown and yet offers a convenient stopover for passengers, freight and fuel.

Air transport infrastructure

The growth of air traffic in Kenya after independence has led to rapid development of airport infrastructure. Numerous airports and airstrips have been developed. Today, the country has about 568 aerodromes spread all over the country, including national parks and game reserves. About 160 of them are public aerodromes manned by Kenya Airports Authority (KAA), a parastatal that was established by an Act of Parliament in 1991. There are different categories of airports, with each having different requirements for communications, navigation, surveillance and air traffic management facilities and equipment. These are international airports such as JKIA and Moi International Airport (MIA); Category A aerodromes such as Wilson and Malindi. Categories B and C are aerodromes and airstrips. Examples of Category B airports include Keekorok, Wajir and Voi while Category C include local airstrips found in national parks and game reserves throughout the country. International Airports operate 24 hours a day with aircraft landing and taking off any time. Category A airports operate 12 hours a day, usually between 6:30 a.m. and 8:30 p.m. Categories B and C operate during daylight hours only from 6:00 a.m. to 6:00 p.m. The three international airports in the country also have the basic infrastructure needed for airports according to International Civil Aviation Organization (ICAO) Air Safety Standards. These include Instrument Landing System for night landing a Very High Frequency (VHF) control tower to enable the air traffic controller to see the whole airport and radar surveillance of a bigger area. Category A (domestic airports) use VHF and air field lighting for communicating. Smaller airports use locaters such as VHF omni-range or Non-Directional Beacons or Distance Measuring Equipment. Out of 568 airports in the area only seven are manned. These are JKIA, MIA, Eldoret International Airport, Wilson, Malindi, Kisumu and Lokichogio. The rest of the aerodromes are unmanned and lack navigation equipment and proper maintenance.

Today, Kenya has a relatively well-developed air transport industry with three international airports in Nairobi, Mombasa, and Eldoret and four main domestic airports at Wilson, Malindi, Kisumu, and Lokichogio. Of the domestic airports, Wilson generally records the largest number of aircraft movements because it serves as the base for domestic charter planes to and from the National Parks and Game Reserves dotting the country. It also handles aircraft taking relief aid to neighbouring countries such as Sudan, Somalia and the Democratic Republic of Congo. Airfreight traffic has increased rapidly in the country over the years, particularly the export of high quality horticultural produce. At the domestic-only airports, domestic cargo is dominant. For example, at Kisumu airport, domestic cargo accounts for 97 percent of the total cargo handled (USAID/REDSO/ESA, 2001). Currently, most of domestic cargo in Kenya is carried by roads or railways as air transport is expensive and not well developed. International airfreight is dominant at the international airports such as JKIA and MIA. According to a recent survey, the Europe-African southbound air freight grew by 14.4 percent in 2004 while the northbound market grew at 3.4 percent (Clancy & Hoppin, 2005).

As already discussed, most aerodromes in the country are poorly maintained and lack essential navigation aids. Some of the crucial air transport infrastructure such as control towers and buildings housing radar stations are in a sorry state and require urgent rehabilitation (Ministry of Transport and Communications, 2003). Poor infrastructure and services such as roads, electricity, information technology and water and sanitation services are still poor in most airports. Sufficient and effective linkages between airports and other transport modes such as railways and roads are lacking. Roads linking airports at present are in a bad state of repair and public bus services are poorly developed and infrequent. A case in point is JKIA, which has only one bus service (Route 34) and the buses using the airport route are often overcrowded.

Facilities and capacity at JKIA

JKIA is Kenya's premier airport and is increasingly growing in status as an international aviation hub in East Africa, handling substantially more passengers than either Entebbe or Kotoka (Table 1). At present, JKIA handles about 60 percent of the total visitors to Kenya by air. The airport was initially equipped to international standards with a handling capacity of 2.5 million passengers per annum and about 200,000 tons of cargo per year. The airport has already exceeded its planned maximum capacity for handling passengers. The airport now handles on average about 4 million passengers per year (Table 1). KAA manages JKIA like other airports in Kenya. Tables 1 and 2 compare passenger volume and aircraft movements for JKIA, Entebbe and Kotoka airports. Table 3 compares air cargo traffic for JKIA, Entebbe and Kotoka airports while Table 4 presents cargo throughput for selected international airports throughout Africa. According to Table 4, Nairobi is ranked second to Johannesburg in terms of the volume of cargo handled. JKIA handles about 130,000 tons of cargo per year. This constitutes about 65 percent of its planned cargo capacity (USAID/REDSO/ESA, 2001).

Table 1. A comparison of passenger throughput* at Jomo Kenyatta International Airport (Nairobi, Kenya), Entebbe International Airport (Entebee, Uganda) and Kotoka International Airport (Accra, Ghana), 1996-2004 (in thousands).

Year	JKIA	Entebbe	Kotoka
1996	2,677	325	402
1997	2,551	356	429
1998	2,350	367	484
1999	2,668	377	554
2000	2,945	373	592
2001	-	-	622
2002	3,053	-	636
2003	3,451	494	756
2004	4,000	544	806

* Includes total domestic and international passengers
Source: Airports Council International. (2005). *2004 Worldwide airport traffic report.* Geneva, Switzerland.

Table 2. A comparison of numbers of aircraft movements* at Jomo Kenyatta International Airport (Nairobi, Kenya), Entebbe International Airport (Entebee, Uganda) and Kotoka International Airport (Accra, Ghana), 1996-2004.

Year	JKIA	Entebbe	Kotoka
1996	41,549	15,624	6,664
1997	42,191	15,057	6,209
1998	41,528	17,038	7,210
1999	45,576	17,806	9,107
2000	46,808	16,190	10,414
2001	-	-	9,064
2002	49,897	-	8,161
2003	58,588	26,116	11,701
2004	59,927	26,265	11,852

* Includes total domestic and international movements
Source: Airports Council International. (2005). *2004 Worldwide airport traffic report.* Geneva, Switzerland.

Table 3. A comparison of air cargo traffic* at Jomo Kenyatta International Airport (Nairobi, Kenya), Entebbe International Airport (Entebbe, Uganda) and Kotoka International Airport (Accra, Ghana), 1996-2004 (in metric tons).

Year	JKIA	Entebbe	Kotoka
1996	74,963	27,010	37,045
1997	75,690	26,926	37,623
1998	116,205	30,967	45,767
1999	125,552	25,633	46,757
2000	139,619	26,015	46,826
2001	-	-	44,779
2002	168,803	-	40,877
2003	166,517	36,617	47,667
2004	183,470	48,585	46,918

* Includes total domestic and international cargo
Source: Airports Council International. (2005). *2004 Worldwide airport traffic report.* Geneva, Switzerland.

Table 4. International cargo traffic for top 20 airports in Africa, 2003 (in metric tons).

Ranks in Africa	World Rank	Airport	Traffic (tones)
1.	62	Johannesburg	262,151
2.	85	Nairobi (JKIA)	173,926
3.	-	Cairo	166,056
4.	116	Luanda	117,143
5.	163	Lagos	55,496
6.	151	Kinshasa	51,183
7.	180	Accra	47,667
8.	187	Casablanca	44,834
9.	202	Entebbe	36,617
10.	224	St. Denis-Gillot	29,705
11.	226	Brazzaville	29,294
12.	251	Algiers	21,942
13.	255	Addis Ababa	20,875
14.	269	Lusaka	18,224
15.	271	Tunis	18,189
16.	284	Doula	15,958
17.	287	Libreville	15,768
18.	288	Abidjan	15,727
19.	294	Antananarivo	14,835
20.	301	Mwanza	13,702

Source: Air Cargo World. (2004), Top Airports, International Edition, p. 22

TRAFFIC GROWTH AND FORECAST

Growth of passenger traffic

One thing that needs to be noted is the holiday or tourist nature of the majority of visitors to Kenya by all means of transport (King, 1984). For example, in 1987, such visitors accounted for about 63 percent of the arrivals. In 2002, the visitors on holiday accounted for 75 percent of the total departing visitors. Over 90 percent of Kenya's holiday visitors arrive by air with most of them arriving in Nairobi (JKIA) on scheduled flights (World Tourism Organization, 2002b).

According to a recent forecast by the World Tourism Organization (WTO), Africa should be able to triple the size of its tourism industry by 2020 if proper efforts are made to ensure safety and security of visitors (2000a). The number of tourist arrivals in the continent is forecast to reach 77.3 million in 2020, up from 27.8 million in 2000 (WTO, 2000a). Most of the tourists will be heading to South Africa. Tourist arrivals in South Africa will grow by 10.4 percent per annum and will increase to 36 million by 2020 up from 6 million in 2000. East Africa will be the other major growth region, with the number of arrivals increasing at 6.0 percent annually. This means that the estimated tourist arrivals will increase to 17 million in 2020. Table 5 shows the trend in tourism arrivals for 1996-2000. It should be noted that international tourist arrivals fell worldwide in 2001 by 1.3 percent, the first decline in international tourism arrivals since World War II (WTO, 2002a). Data suggests that Kenya's tourism industry will continue to play a vital role in JKIA efforts to establish itself as an international aviation hub in Eastern Africa. Further, a decline in tourist traffic would result in far fewer flight operations and could reduce air traffic to levels lower than those of Entebbe, Dar es Salaam and Addis Ababa (King, 1984; WTO, 2002b).

Table 5. African tourist arrivals, 1996-2000.

Country	Tourist Arrivals (in thousands)				
	1996	1997	1998	1999	2000
South Africa	5,186	5,170	5,,898	6,026	6,000
Tunisia	3,986	4,392	4,831	5,000	---
Egypt	3,896	3,961	3,454	4,489	5,506
Morocco	2,856	3,203	3,414	4,088	4,293
Zimbabwe	1,597	1,336	2,090	2,250	1,967
Kenya	1,003	1,001	894	969	1,037
Algeria	605	635	678	749	866
Botswana	656	765	940	1,051	---
Nigeria	1,230	1,292	1,357	1,425	1,492
Namibia	525	571	---	580	---

Source: World Tourism Organization. (2002): Compendium of Tourism Statistics. Madrid, Spain.

Growth of cargo traffic

Africa accounts for approximately 3.5 percent of the world's air cargo traffic in terms of tonnage and 4.4 percent in terms of tonne-kilometers. The total international flows of cargo moving into, within and out of Africa totaled approximately 961,000 tons in 2001, with Europe accounting for 65 percent of all African foreign air trade. Europe's dominance of market share can be explained by the region's proximity to Africa and long standing historical ties going back to the colonial days. While Europe once held parity in northbound and southbound tonnage, the market between the two regions is now slightly imbalanced as African air exports exceed air imports in total tonnage by a ratio of about 3 to 2.

African air exports—especially perishables—have made significant inroads in European market since the mid 1990s. The exports to Europe primarily consist of perishables such as fruits, vegetables, cut flowers and fish. Some textiles and express documents are also exported by air. African air imports from Europe primarily consist of specially manufactured goods, components and peripherals, express documents, machinery, transport equipment and spare parts. In Kenya, air exports have experienced a remarkable growth in the last ten or so years. Exports pf fresh horticultural products through JKIA have increased from 57,383 tons in 1992 to about 139,619 tons in 2000 (KAA, 2001, USAID/REDSO/ESA, 2001). An examination of Table 3 shows that there has been an increase in airfreight handled at JKIA during the study period.

Traffic forecast

Based on data obtained primarily from the Kenya Civil Aviation Authority offices, KAA and airlines operating into and out of Nairobi and interviews held with key informants in the Ministry of Transport, projections were made for departing visitors, aircraft movements, and passenger/cargo traffic through 2020. Index Numbers were used to show whether the volume of cargo throughout has been increasing at the airport or not. Time Series Analysis is used to reveal the future trend of aircraft numbers, passenger and cargo throughout in the next five to twenty years. A linear trend curve was used to forecast aircraft movements and volume of passenger and cargo traffic at JKIA. The nature of the trend curve used is determined by using the mathematical formula shown below:

$$Y = a + bT$$

Where: Y is volume of traffic (e.g., cargo)
T is number of years
a and b are constants representing the intercept and the slope respectively.

The trend curve assumes a constant annual increase in traffic level and decreasing rate of growth.

The trend curves reveal that growth in aircraft movements, passenger and cargo traffic have not been characterized by random fluctuations from year to year. It is apparent that as demand for air travel and air trade increased, so do the number of aircraft movements increase. Using the trend curves, projections for aircraft movements, passenger and cargo traffic were made for the period 2005-2020. Based on the trend curves, JKIA is likely to experience a major increase in the volume of passenger and cargo traffic leading to an increase in demand for more aircraft movements. Aircraft movements are expected to increase from 55,000 in 2005 to 78,000 in 2020 while passenger traffic will increase from 3.4 million in 2005 to slightly over 4.9 million in 2020. Cargo traffic is expected to see even greater increases as it nearly doubles from 160,000 tons to almost 280,000 tons in 2020. Consequently, the airport authorities have to expand and modernize JKIA if it is expected to handle efficiently such large volumes of traffic in the future. Any congestion at the airport would lead air operators to shift to other more efficient airports in the region.

CONCLUSION

Air transport in Kenya, like elsewhere in the developing countries, was introduced from outside. By the time the country attained independence in 1963, it was well linked with its former colonial master, through British Airways and several other foreign airlines operated into and out of Nairobi. EAAC, owed by the three East African states, provided regional services as well as international flights into and out of Nairobi. The rapid growth of air traffic in Kenya after independence has led to development of several major airports and numerous airstrips dotting the whole country. Many of the airstrips are found in National Parks and Game Reserves distributed throughout the country.

Today, Kenya possesses three international airports, the most important in terms of passenger and cargo traffic handled being JKIA. In 2003, JKIA was ranked 85th in size among world airports and 2nd in Africa after Johannesburg in terms of cargo traffic (Table 3). JKIA has grown into a major regional hub airport in Eastern Africa due to its geographical position and the large number of international airlines operating into and out of the airport.

As already discussed, most of the foreign visitors passing through JKIA are tourists. At present, the country continues to be one of the top destinations in Africa. Since the tourism industry is predicted to grow rapidly in East Africa in the next twenty years, the region is likely to witness a significant increase in tourist arrivals by 2020. JKIA has already exceeded its planned passenger handling capacity. The planned cargo capacity will also be soon exceeded. This will force airline operators to relocate to other airports in the region that are already expanding to cope with increasing passenger and cargo traffic. JKIA faces several additional problems that need to be addressed if the airport is to compete with other regional air hubs in Africa such as Entebbe, Addis Ababa and Johannesburg, namely aviation safety and security. If these issues and airport infrastructure are addressed, there is no doubt JKIA can become an aviation hub in eastern and central Africa.

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CORPORATE SOCIAL RESPONSIBILITY IN AVIATION

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ABSTRACT

The dialog within aviation management education regarding ethics is incomplete without a discussion of corporate social responsibility (CSR). CSR research requires discussion involving: (a) the current emphasis on CSR in business in general and aviation specifically; (b) business and educational theory that provide a basis for aviation companies to engage in socially responsible actions; (c) techniques used by aviation and aerospace companies to fulfill this responsibility; and (d) a glimpse of teaching approaches used in university aviation management classes. The summary of this research suggests educators explain CSR theory and practice to students in industry and collegiate aviation management programs. Doing so extends the discussion of ethical behavior and matches the current high level of interest and activity within the aviation industry toward CSR.

I think many people assume, wrongly, that a company exists simply to make money. …A group of people get together and exist as an institution that we call a company so that…they make a contribution to society, a phrase which sounds trite but is fundamental.

David Packard, cofounder of Hewitt Packard (Handy, 2003, p. 80).

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INTRODUCTION

CSR currently an important business topic

Corporate Social Responsibility (CSR) is a subject of much current interest within the managerial world. (CSR is also frequently described as *social responsibility* or *community relations*.) Last year corporations voluntarily contributed more than $3.6 billion to various social endeavors. The amount of charitable contributions has increased yearly since 1987 (Renz & Lawrence, 2005). A press release from the Center on Philanthropy (2005, February 25) states that American non-government donations to the Southeast Asia tsunami disaster totaled more than a billion dollars. A PricewaterhouseCoopers global survey indicates a priority of chief executives is “maintaining a high degree of corporate responsibility” (Verschoor, 2003, p. 20). In the last 24 months the *Harvard Business Review* produced 16 featured articles about CSR (Harvard Business Online, 2005, June 10). The *Economist* ran a special feature surveying CSR practices in January 2005 (Good company, 2005, January 22). The article states, “Big firms nowadays are called upon to be good corporate citizens, and they all want to show that they are” (p. 3). A search for *Wall Street Journal* articles containing *corporate social responsibility* in the last 12 months results in 78 articles (Wall Street Journal Online, 2006) and a weekly feature titled “Giving Back” was started April 1, 2005, because of the editors’ belief in the high level of reader interest in philanthropy (E. Bernstein, personal communication, June 13, 2005). The weekly articles discuss some aspect of social responsibility actions including the “Gift of the Week” (Bernstein, 2005, June).

Half the attendees of the January 2005 World Economic Forum in Davos, Switzerland, were from businesses including 500 Chairmen and CEOs (Stephens, 2005, January 31). Meeting sessions included CSR topics: “Does business have a noble purpose;” “How Responsible is Responsible Enough;” “Using private resources to deliver public good;” and “Is responsible investment about to payoff” (World Economic Forum, 2005). CSR is currently a key subject for business leaders!

CSR extends the ethics discussion

The Journal of Air Transportation published a series of four articles in the past three years discussing ethics in university aviation management programs in the US (Oderman, 2002, 2003a, 2003b, 2004). The 2002 article received the Sorenson Best Paper Award. This history suggests that ethics is an important issue in the aviation education community. The ethics discussion is incomplete without specifically including CSR.

A review of basic management texts demonstrates consistent introduction of CSR (or social responsibility) not as a singular subject but combined with ethics. Bateman and Snell (2004), Certo (2000), Daft and Marcic (2004), DuBrin and Ireland (1993), and Williams (2005), all have a chapter titled “Ethics and Corporate Responsibility” in their books. Jones, George, and Hill (2000) combine ethics, social responsibility and diversity in a single chapter. Griffin (1997) and Robbins and Decenzo (2004) combine ethics and social responsibility as a singular subject in chapters with other subjects. The two concepts, ethics and social responsibility are directly and closely linked.

Perspective

The focus of this research is on for-profit organizations in the aviation arena. Boeing, Lockheed, Hawaiian Airlines, and Northwest Airlines are examples. The corporate charter of these organizations creates an expectation that they obey the law and make a profit for owners.

Non-profit organizations also volunteer to assist society beyond the scope of their basic mission. Two examples include the women and men of one of the Navy Reserve air squadrons at the now defunct Glenview Naval Air Station, working with former Eastern Airline flight attendants, who for many years provided an annual Christmas flight for young children with severe diseases. Also, the Volunteer Pilots Association provides transportation for children needing medical attention. Other non-profit groups in the aviation community are the Association of Flight Attendants and Air Line Pilots Association and the Federal employees of the Air Traffic Control Center at Oberlin, Ohio. Members of these organizations may participate in voluntary community activity working on a union (and not a company) sponsored activity. Although these and other non-profit organizations might act in socially responsible ways beyond their basic purpose, they are not included in this project. The focus is on for-profit businesses.

The intended audience falls into two categories. First are educators, both in academia and industry. Students of these individuals may be college aviation management majors or new supervisors or foremen in a management skills class. The second category is individuals who are interested in the basic business of management in the aviation environment. The intent is to provide both groups with knowledge that improves their understanding of business practices and the philosophy behind those practices. Although business sponsored social responsibility activity occurs on a global basis, this research is limited to practices and policies within the United States aviation industry.

An in-depth review of the legal and political action aspects of CSR is purposefully omitted from this study. The legal history is traceable to a 1916 suit challenging Henry Ford's efforts to make his cars more affordable to the public at a detriment to corporate profit. The court found his actions improper. It was not until the 1950s that CSR efforts as practiced today became legal (Smith, 2003). Aviation companies and their unions have active political action committees. This is a form of social responsibility not often associated with CSR but deserves attention at a later time.

Definitions

The constructs e*thics* and CSR are difficult to define succinctly but are key terms of this article and therefore require a working definition between the readers and the author. The Oxford English Dictionary defines ethics as "relating to morals" and "the science of morals" (Oxford English Dictionary, 2006a), *Morality* is defined as "ethical wisdom, knowledge of moral science" (Oxford English Dictionary, 2006b.). The *Miriam-Webster OnLine* (2006a) uses *ethical* as a synonym for *moral*, and *moral* (2006b) as a synonym for <u>ethical</u>. It appears that in common usage the terms ethics and morals are interchangeable.

Oderman states "ethics deals with standards of conduct" (2002, p. 8). Daft and Marcic (2004) describe personal behavior (what people actually do) on a behavioral continuum. One end is guided by explicit law and regulation through which society has specifically defined acceptable conduct and the range of penalties if an individual does not comply. The other end of the continuum is freewill or free choice. Does it really matter if you choose to put grape jelly or orange marmalade on your peanut butter and jelly sandwich? In the middle of these extremes society relies on individuals deciding to act in a manner consistent with implicit social rules and judgments. Oderman's description of ethics fits this middle area of the continuum. Decisions and actions that fall between the law and freewill are evaluated by society's mostly implicit ethical standards.

Ethics is not what some individuals, often politicians, make it to be. Last year all Illinois state employees, including professors, were required to complete an online ethics training program. One of the key messages of the program is to obey the law. Breaking the law is not an ethical decision, or as described by Oderman, a decision determining a standard of conduct. Society took the decision out of the individual domain when the law or regulation was created. Not following the law is an issue of criminality, not ethics.

The definition used in this article is based on the above and is: *ethics is the philosophical process of deciding how to act and making moral judgments about the action taken.* Acting ethically, being ethical, refers to actions that the self and/or members of society find more acceptable than unacceptable.

CSR, like ethics, has no universal definition. Approaches include "a manager's duty or obligation to make decisions that nurture, protect, enhance and promote the welfare and well-being of stakeholders and society as a whole" (Jones, George, and Hill, 2000, p. 160). (The term *stakeholder* appears frequently in CSR literature and refers to shareholders, employees, customers, and society in general including both the human and physical environment.) Another description is "the obligation toward society assumed by business" (Bateman and Snell, 2004, p. 147). Since 2002 the International Standards Organization (ISO) has been working toward an ISO standard for CSR. The *ISO Bulletin* refers to CSR as "the values and standards by which business operates" (Spotlight, 2002, July, p. 7). Daft and Marcic suggest that CSR is "management's obligation to make choices and take actions that will contribute to the welfare and interests of society as well as the organization" (2004, p. 123). John Copeland, the Executive in Residence at the Soderquist Center for Leadership and Ethics (Soderquist Center, 2005) stated in an interview that CSR is "really defined more as corporate citizenship" (Maxwell, 2004, p. 5).

In this article the assumption is that an organization exists first for the economic benefit of the owners and employees. Helping society beyond that objective is considered a secondary responsibility. This leads to the definition: *CSR is both the philosophy and practice of for-profit organizations voluntarily acting to positively assist society in ways beyond that required to obtain profit objectives.*

Overview

Sections that follow include a theoretical grounding of social responsibility, CSR practices in aviation, and current academic teaching practices. Eight recommendations for classroom consideration are presented as a conclusion.

GROUNDING SOCIAL RESPONSIBILITY

Using the umbrella of grounded theory this section describes the roots of social responsibility from the perspective of business and education, offers reasons for and against social responsibility. Three tools are provided for review of CSR practices.

Business theory

Arguably the foremost management thinker of the past sixty years is Peter Drucker. He states that the institution of management has three tasks: (a) increase economic performance; (b) make the worker productive and efficient; and (c) manage social impacts and responsibilities (Drucker, 1954). He theorizes that institutions do not exist by themselves; they are an organ of society. The business enterprise must have "…concern for the quality of life, that is, for the physical, human, and social environment of modern man and modern community" (Drucker, 2001, p. 17).

This view is echoed more recently in the *Harvard Business Review* compilation of articles regarding CSR. Porter and Kramer state "companies do not function in isolation from society around them" (2003, p. 32). Handy, in the same series, explains that modern business depends more on employee time and talent than on stockholders' equity. He adds that successful companies depend on "a community with a purpose" and "not just making a profit but to make a profit in order to do something better" (2003, p. 66). He suggests that companies which forget the community and concentrate only on profits will die (the entropy principle of General Systems Theory).

CSR is based on ethical theory and morality. "A corporation can and should have a conscience," and "the language of ethics has a place in the vocabulary of an organization" (Goodpaster and Matthews 2003, p. 134). They describe both the complexity and benefit of this concept when suggesting that individuals guided by morality may not always agree on issues, but "at least have a basis for dialogue" (p. 138). In summary, management theory suggests profit making corporations are a part of and have the responsibility to support society beyond paying employees and making a profit for owners.

The role of education

Just as Drucker is a major voice in management theory, John Dewey has a major influence on educational theory. Dewey wrote in the *School Journal*, January 1897, that education is the "fundamental method of social progress and reform" (Boydston, 1972, p. 93) and that a teacher is responsible for the formation of the "proper social life" (p. 95). Those involved in aviation management education are preparing individuals to obtain jobs or improve performance in new or existing positions. Dewey indicates that, "An occupation is the only thing which balances the distinctive capacity of an individual with his social service" (Dewey, 1916, p. 308). There is a historical track of educators supporting Dewey's views. Recent support is offered by David Pierce. As the then President of the American Association of Community Colleges, he describes what society demands of higher education:

> To train a skilled, intelligent, creative, and responsible workforce. …To support a citizenry that participates responsibly in community affairs including public governance and cares about our country and the world. …To be a resource for people searching for ideas and information on

> solving social, economic, political, and scientific problems (1993).

The conclusion easily reached is that the purpose of the education process is to prepare students interested and capable of helping solve society's problems. A challenging task!

Social responsibility is a good thing

Benefits of social responsibility include the following.

1. It is a cost effective way for an organization to improve its competitive position through advertising the good deeds of the organization. A 2002 survey indicates 84% of Americans would likely switch to a brand associated with a good cause if price and quality were similar (Comiteau, 2003, p. 24).
2. Protecting the environment leads to more productive use of resources (Porter and Kramer, 2003).
3. Boosting social conditions, including education, leads to improved locations for company operations and potential creation of customers and skilled workers (Porter and Kramer, 2003).
4. Investors are drawn to socially responsible companies (Stock, 2003).
5. Individual professionals who perform charitable volunteer work are recognized and receive personal benefits for their efforts (Hall, 2003).

This list of reasons why CSR is a good thing includes tangible benefits for organizations and individuals. It does not rely on philosophical attitudes.

Social responsibility is a bad thing

Milton Friedman's *New York Times Magazine* article of September 13, 1970, remains the focus of the view against CSR. In it he argues that social responsibility is an individual and not an institutional responsibility and to suggest otherwise is socialism (Friedman, 1970). He suggests that executives who spend corporate dollars on social programs are unfairly taxing shareholders and customers by using their dollars without permission. The title of the piece eloquently summarizes his view, *The Social Responsibility of Business is to Increase Its Profits*. Such a view rules out any action that is not seen to directly lead toward profitability.

Another classic article of the 1970s is Levinson's *Management by Whose Objectives* (Levinson, 1970). He describes the frustration of an individual who on one hand is responsible to create profits but on the other must achieve other objectives which detract from bottom line performance. This is the quandary described by Friedman.

A January 2005 *Economist* article (apparently written by an editorial team) argues that another issue is questionable corporate commitment to social responsibility. They posit that CSR is cosmetic, that "the human face that CSR applies to capitalism goes on each morning, gets increasingly smeared by day and washes off at night" (Good company, 2005, p. 4).

Anecdotal evidence suggests that many students agree with this view. Classroom comments often suggest companies only do good things for selfish benefit and not for the purpose of doing good.

Our society includes conflicting views on essentially every subject. Many believe strongly that CSR is a bad thing. Their arguments have persuasive logic and deserve consideration before reaching an independent decision for or against CSR.

A visual hierarchy

Three options are offered as potentially helpful tools by which to view business activity. Each or all of these tools may be used to evaluate social actions of aviation companies. Figure 1 is Johnson's (2003) *Corporate Social Responsibility Continuum*. He suggests five levels of support. (The levels offered are Johnson's; the description is this author's synopsis of Johnson's discussion.)

Figure 1. Johnson's corporate social responsibility continuum

Level 5	**Social Advocacy**	A company should be good regardless of the financial consequences.
Level 4	**Strategic**	Consistently support positive social actions with a clear understanding of the financial benefits.
Level 3	**Fragmented**	A mixed and inconsistent approach to social responsiveness.
Level 2	**Compliant**	Minimal compliance with laws and regulations.
Level 1	**Illegal/irresponsible**	At least some if not consistent conscious violation of the law.

Source: Johnson, H. H. (2003). Does it pay to be good? Social responsibility and financial performance. Business Horizons, 46(6), p. 36

Figure 2 is an attempt to represent the continuum of behavior suggested by Daft and Marcic (2004; see *Definitions* section).

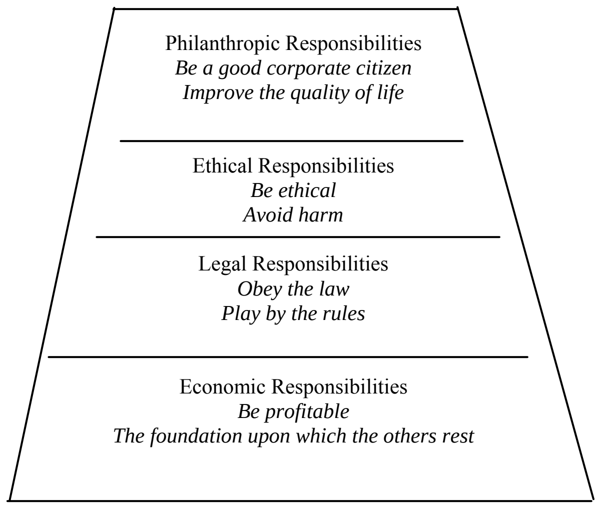
Figure 2 Daft and Marcic's behavior continuum

Domain of Codified Law	**Domain of Ethics**	**Domain of Free Choice**

Source: Daft, R. L and Marcic, D. (2004). Understanding management (4th edition). Mason, OH: South-Western, p. 113

Figure 3 represents Carroll's (1991) *Pyramid of Corporate Social Responsibility*. This approach recognizes the broad ranges of business responsibilities and also suggests a hierarchy of relation between ethics and social responsibility.

Figure 3. Carroll's pyramid of corporation social responsibility



Source: Carroll, A. B. (1991). The pyramid of corporate social responsibility; Toward the Moral Management of Organizational Stakeholders. Business Horizons, 34(4), p. 42

When evaluating a possible or actual behavior by an organization or individual one or all of these three tools may help to determine where the action falls on the spectrum of behavior. Is it criminal, ethical or does it really matter? Is the action based on a position of the organization already obeying the law and consistently attempting to act ethically? Is this part of a strategic process or real advocacy? Not all will agree on the answers, but the process of deciding may be helpful.

CSR PRACTICES IN AVIATION

The challenge is to find an aviation related business that does not have some type of social responsibility program! A search of CSR in the corporate information for the 104 member companies of the Aerospace Industries Association (AIA) and 21 members of the Air Transportation Association (ATA) most often leads to the company's charitable foundation and or activities to support the community. (*Community* or *community outreach* are synonyms frequently used by companies to describe CSR programs.)

Companies may place CSR programs or actions into categories. American Airlines' list includes six distinct types in three different groups (American Airlines, 2001). Category A is social outreach and recognition.

Category B is ethics. Category C includes environmental protection; training; health and safety; and diversity.

The different categories are offered for consideration and comparison with Carroll's pyramid. The majority of policies for the items in category C are covered by law and regulation. Examples include the Federal Aviation Regulations which prescribe the training requirements and records for pilots and flight attendants, the structural demands of cabin seats, and the aircraft's minimum equipment list, among other things. Many safety and training issues are covered by the Occupational Safety and Health Act and other regulations which require training employees regarding use of fire extinguishers; material safety data sheets (MSDS); and other equipment. Work conditions (health and safety) are covered by air quality and temperature standards. The Equal Pay Act (1963), Title VII of Civil Rights Act (1964), Age Discrimination in Employment Act (1967), and other legislation, all influence hiring and firing decisions which impacts diversity. The Clean Air Act (1990) influences environmental decisions. Actions taken by an organization to meet these legal requirements are mandatory and including them on a list of socially responsible actions is debatable. However, actions which exceed the letter and spirit of the law might be viewed as socially responsible actions.

Carroll's pyramid (Figure 3) suggests complying with the law (category C issues) must occur before an organization is viewed as ethical (category B on American's list). Many aviation/aerospace organizations have created specific ethics policies. Continental Airlines has a Code of Ethics for the company Directors (Continental Airlines, 2004). Boeing has a detailed Code of Ethics and Business Conduct Program (Boeing, 2005). AirTran includes the importance of ethics when discussing corporate governance (AirTran Airways, 2005a). The 3M Company lists Ethical Business Conduct Guidelines (3M, 2005). These ethics statements match the third level of Carroll's pyramid. Whether or not a company is acting in an ethical manner is determined by the court of public opinion. The legal courts determine if it is acting criminally.

Social outreach and recognition is category A on American's list, top of the Carroll pyramid and the key focus of this article. Earlier comments described the theory of *why* a company may behave in a socially responsible manner. The discussion of *what* they do starts now. Examples provided are grouped by various views or perspectives. These are the actions taken to *assist society in ways beyond that required to obtain profit objectives* (as described in the working definition of CSR). Some of what is described here is an ethnographic report of 29 years as an airline manager with both field and staff experience at varied airports and corporate headquarters. As appropriate, other source material is added.

All employees – United Way

A new employee of an aviation/aerospace company will learn in his or her first year that the company provides a platform for donating to the local United Way campaign. Delta reports employee donations of $3.4 million to United Way in 2003 (Delta Airlines, 2005) and FedEx donations were $12 million (FedEx, 2004). The United Airlines Foundation, founded in 1952, indicates United Way was its only national benefactor for many years (United Airlines Foundation, 2005a). An employee is told that he or she not only can but is encouraged to give to the local United Way through payroll deduction. The company promotes the campaign and provides the collection process including computer and other support. Managers are encouraged to have a high percentage of their employees participate. In addition, a company may donate a volunteer during the annual city or region campaign to aid with the administration of United Way's program.

A personal experience indicates the depth of corporate commitment. I was asked by a senior officer of my airline to use a professional association connection to gain access to the CEO of another local (non-aviation) company that did not participate in the United Way campaign. The purpose was to encourage participation in the annual campaign. It was another way my company was attempting to be supportive.

Employee volunteerism

The second thing an employee quickly learns is that there are many ways to volunteer to support a wide array of causes. The internal company communication system might advertise for volunteers to help with the upcoming 10K or half-marathon run sponsored by the company to support a local charity. Volunteers give up all or part of a day off to direct parking, pass out water to runners, or do whatever is needed. Thousands of FedEx employees and their families volunteer to support the March of Dimes annual fund-raiser walk. In 2004 they raised over $1 million (FedEx, 2005). United Airlines says more than 30,000 employees have volunteered for community service since 1996 (United, 2005). Have you ever watched the Jerry Lewis Telethon over Labor Day Weekend? The ushers in the Las Vegas location have been volunteer flight attendants. Many individuals answering the phones are volunteer airline employees of all classifications.

Perhaps through the leadership or sponsorship of a company officer a group of employees dedicate themselves to assist a group of young people learn about business. Using training and or conference rooms and volunteer employee time airlines/aerospace companies sponsor Junior Achievement groups (see http://www.ja.org if you are not familiar with the organization) and Scout Explorer Posts which offer aviation as one of the areas of concentration. Another type of approach involves more than 450 Southwest pilots annually offer themselves for adoption by fifth grade classes for a four-week learning program which features the importance of education (Southwest.com, 2005).

In October 2004 Miguel Arocho, an American San Juan based crew chief and Gladys Ruiz, a Miami based flight attendant for 16 years, were honored for their work on charitable missions in Central America (Someone special at American, 2004 October). Each month American describes employee volunteerism with a feature story on the AA Information page of the seat-back in-flight magazine *American Way*. Forty-eight United employees from around the entire system were brought to the Chicago headquarters in April 2004 to be honored by Chairman Glenn Tilton for their volunteerism. At the awards ceremony Tilton stated, “We must not only provide outstanding customer service, but also demonstrate outstanding corporate citizenship” (United NEWSREAL, personal communication, April 26, 2004).

It is impossible to list all the ways airline/aerospace employees help society through volunteer efforts. The public tends not to learn of, for example, flight attendants or others using their passes—with no employer involvement—to travel to Asia to pickup an adopted child and fly him or her to Los Angeles where the new mom and dad anxiously await. Nor does the public learn of the CEO who personally supports bringing busloads of middle school children from the inner-city to corporate headquarters, giving them a tour, buying their lunch and arranging for a paid junior high school summer intern all out of his own pocket. The public does not see the CEO carrying the lunch tray and sit next to the sixth-grader who has no real comprehension of the position of the person next to her. You can see in her wide eyes that she is learning about business and jobs in a way previously never imagined. (The CEO forbid the public relations department to promote his actions.) This list of laudatory efforts is essentially endless.

Employee/managerial initiatives

As an employee you may also initiate actions that benefit both society and your company. These are issues that go beyond legal requirements. Trash is an example! American Airlines permits their in-flight caterers LSG Sky Chef and Gate Gourmet to split the proceeds from recycling aluminum cans between themselves and the WINGS Foundation, an organization of American Flight Attendants that provides assistance to needy peers (Michael Saxton, personal communication, June 17, 2005). In the early 1990s United’s headquarters initiated a system to recycle all paper products. Some view these situations as helping the environment. The kitchen manager is reducing his or her trash bill and adding to revenue, WINGS has a gift revenue stream, and United reduced the annual headquarters’ garbage bill $200,000 a year. Yes, employees should feel good about recycling. Yes, managers should feel good both about recycling and about improving finances. It is a win-win situation.

The pilots and flight managers and company engineers responsible for energy conservation working together to taxi on one engine and use ground electric power in place of a jet fuel driven auxiliary power units have reduced air pollutants, but they have also reduced cost. Again, it is a win-win.

Company assistance for individual organizations

Rolls Royce provides facility, equipment, administrative support, and financial assistance to Embry-Riddle (Rolls Royce, 2005). Southwest Airlines, BF Goodrich and Mitchell Air recently donated $300,000 to Lewis University to aid repair of a 737 donated by United in 1999 (Alumni help fix Lewis University jumbo jet, 2005, June 10). Formal internship programs between an aviation company and a university are also a form of support for university programs.

CHRIS Kids, Inc., in Atlanta, Georgia, identified AirTran as a strong supporter of their program (AirTran Airways, 2005b). Delta uses the proceeds from recycling aluminum cans on Hartsfield arrival flights to support Habitat for Humanity (Aluminum cans build Habitat for Humanity homes, 2005). Northwest publicizes their charitable partners through in-flight announcements made by flight attendants (Northwest, 2005). The DePortola Middle School in San Diego has been adopted by CUBIC Corporation, an AIA member primarily involved in military aviation (CUBIC Corporation, 2005). The company provides the school consulting and technical assistance, computers, tours of CUBIC's facilities, career days, and other support. The Children's Hunger Alliance in Columbus, Ohio, which works to improve the quality of school meals, receives financial support from UPS (UPS, 2005). DHL is an active supporter of Operation Slugger, an effort to donate sports equipment to US military personnel in Iraq (DHL, 2005; Operation Slugger, 2005).

The general rule for all these examples is that the airline/aerospace company's primary interest is local. Support is provided to organizations where the company is based or has major operations.

Requests of the company from the public

An airline receives countless requests from members of the general public for free tickets to be used for fundraisers (e.g., the local church group and library board) or to support some other effort such as sending a deserving individual to a national conference. The common assumption is that the airlines have lots of empty seats and it will not cost them anything to provide a ticket. Almost all of these requests are denied. United states they do not provide transportation for fundraising events (United Airlines

Foundation, 2005b). US Airways lists restrictions, as do many companies, and provides a form to use when requesting assistance (Usairways.com, 2005).

Another type of request comes from organizations such as the Urban League and NAACP that develop a working relationship with the hometown airline. A large airline will have a small staff group designed to help promote diversity. One of the functions is to judiciously provide transportation and other support to appropriate groups. The Atlanta Urban League may call Delta and ask for roundtrip tickets for two officers to attend a national convention in San Francisco. Not every request is approved, but the airline will truly try to support the group.

Customer's view through frequent flyer miles

Customers' exposure to airline CSR is probably best viewed as an opportunity to donate accumulated miles to a particular charity. Northwest has a list of *AirCares Partners* a customer may choose. US Airways and Frontier both promote the Make-a-Wish Foundation as their national charity for donating miles (usairways.com, 2005). Frontier uses the title *Miles-4-Smiles* title for this program (Frontier Airlines, 2004). Hawaiian Airlines calls their program *Akamai Miles*. Akamai is a Hawaiian word meaning "smart" or "clever" (Hawaiian Dictionaries, 2005). A unique feature is a traveler can adopt a particular local school and donate miles, to which Hawaiian Air adds 10%. Or, the traveler can adopt a particular teacher to receive the miles which may be used to fly themselves and/or their students for educational purposes (Hawaiian Airlines, 2005).

Socially responsible or public relations?

Sports stadiums tend to have corporate names. The Baltimore Ravens play at FedEx Field, the Dallas Mavericks play at the American Airlines Center, Michael Jordan played basketball at the United (Airlines) Center. This is pure public relations. The airline has written a big check to have the facility feature their name. When there is high probability that the stadium will be built, a bidding war occurs to determine what name goes on it. Is American going to allow a United Center in Dallas? No. Is the repetition of the name American Center in Dallas a cost effective means of advertising compared to print, TV or billboards? American—and other companies—must think so.

In Atlanta you find the Delta Air Lines Assistant Concertmaster Chair endowment (Atlanta Symphony Orchestra, 2005). A recent Philadelphia Museum of Art exhibit featured works that Boeing helped underwrite (Philadelphia Museum of Art, 2005). Northrop Grumman and Southwest Airlines are two of the sponsors for the Long Beach, California, Annual Jazz Festival (All About Jazz, 2005). United is the official airline of the Chicago

Symphony Orchestra and a major sponsor of the annual Ravinia (outdoor summer) Music Festival. Is this support of the community and the arts public relations or an act of social responsibility? These events are not like the stadium that will probably be built anyway. In many, if not most, cases this activity does not occur without financial and other support of corporations. Johnson's Social Responsibility Continuum is an appropriate tool to view this type of corporate activity. At which level should these actions be placed: strategy; advocacy; perhaps a little of each?

Summary of airline/aerospace practices

This discussion provides only a brief overview of the many socially supportive activities conducted by members of these industries. Much of this work is accomplished through charitable foundations. America West, AMR/American Airlines, Boeing, Delta, and GE, among others, have created a corporate foundation to be the focus of any donations of goods and services (Foundation Center, 2005). The efforts are applauded by *Business Ethics: The magazine of corporate responsibility*. The list of 100 Best Corporate Citizens included AIA/ATA members 3M in 2004 and Southwest and FedEx for 2004 and 2005 (100 Best Corporate Citizens, 2005). This should not be interpreted as a mark against those excluded from the list but a validation of the high standards of CSR subscribed to by members of the airline and aerospace family.

Social responsibility is not something limited to big corporations in the aviation industry. Sparked by a student presentation about the management of an airport in a small local community (population less than 30,000 residents) the airport's fixed base operator (FBO) was asked about participation in any CSR or community service activity. The prompt reply was that they contributed to many community organizations and also worked closely with the local Easter Seals employment program. Easter Seals supports development and hiring of those with disabilities (Easter Seals, 2006). One of the 30 full-time employees at the FBO is a part of the Easter Seals program (Steve Coulson, personal communication, May 16, 2006). In some ways this response is more impressive than the press release from the large corporate public relations department touting the donation of an airplane.

TEACHING PRACTICES

A web search was used to develop an email list of list of about 190 faculty in the 56 US aviation management programs (Phillips, 2004). An email was sent to these faculty members asking them to take a six question mostly multiple-choice survey regarding teaching practices used to support CSR. Fifty-eight faculty members from 28 schools responded. Over 90% of those responding believe CSR is highly or of some importance. The intent of the survey is to provide a glimpse of teaching practices. No predictive claim is made regarding how all aviation faculty do or do not address CSR.

Responding faculty members indicate they teach a total of approximately 135 different courses. AVM 101 Introduction to Aviation is one (fictitious) class, regardless of how many sections are taught. Reports indicate that CSR is included in classroom lecture in about 90% of classes taught and a specific assignment regarding some aspect of CSR occurs in about 50% of classes taught.

Faculty members mentioned five teaching practices regarding CSR:

1. As one of several possible topics for an independent study class;
2. As part of the process when developing an aviation corporation;
3. As a subject for guest lecturers from industry to include in their remarks;
4. As a specific assignment to research and write about; and
5. As part of an airline simulation.

Two of the eight decisions students must make when participating in Smith and Golden's simulation are social performance budgeting and behavioral elements (2006). The web-based description of *Decisions to be Made* by students includes:

> There are 13 different mini-cases, one for each decision period. Teams must respond to each of these. They include social responsibility/business ethics issues, environmental forces, and the international environment. Each consists of a one page mini-case with multiple answers and teams must select the answer they think is most appropriate to the situation. If desired, these provide excellent class discussion topics.

These survey responses indicate that faculty members: (a) are familiar with CSR; (b) believe CSR is important; and (c) have (at least in some cases) trusted, successful techniques for including CSR in the curriculum.

Comments about classroom techniques show inclusion of the Environmental Protection Act and handling of aviation wastes, aviation liability, ethics, the harm of poor leadership, the government's role in aviation, critical thinking, aeronautical decision making, diversity and evaluating the effectiveness of a flight instructor. An instructor's classroom freedom allows wide diversity in how any subject is defined and approached. Using the tools provided by Johnson (2003), Carroll (1991) and Daft and Marcic (2004; see Figures 1, 2 and 3) position a subject such as diversity in a broad discussion of overall corporate responsibility, not just social responsibility.

CONCLUSION

This research leads to guidance for educators, those who teach aviation management students in industry and academia. Here are the key findings that should be considered for classroom discussion:

1. A business does not exist in society to only make a buck for the owners. It also exists to help make society a better place.
2. The purpose of the education process is to prepare students to make a positive impact in society.
3. Some companies and many individuals link legal requirements and ethics with social responsibility. That is not necessarily wrong, but it may cloud the issue of working toward CSR programs. The emphasis on CSR should be after and in addition to obeying the law and acting ethically in situations where the law is not specific.
4. Aviation companies and employees voluntarily do many things to help others.
5. In many cases an aviation/aerospace company's aggressive action to meet or exceed the requirement of the law helps both the company and society. It is a win-win situation.
6. What a company does is often not purely profit oriented or socially oriented. There is a continuum and much overlap.
7. The argument about whether or not a company should participate in social programs will and should continue. It is important for managers to know why they do what they do and argue against what they believe to be inappropriate policy.
8. There is personal benefit received through volunteerism at work.

One example of the last finding—one not previously discussed—is my own family (three girls, mom and dad) that has volunteered at company events. One event was helping put on a bicycle ride where riders earned pledged dollars for the laps they rode. My 12 year old daughter felt a part of the process by counting laps; and the family added to its traditions. Some of the most fun career related experiences are jointly working with other employees in a volunteer mode. Stories of the fund-raising powder puff softball games between flight attendants and local police departments are best described in another venue. Win-win is not only profit and environment; it is personally doing good and having a lot of fun.

As a final thought, reflect on the responsibility of the academic or industry educator. If our students do not have an appreciation for the history, importance and benefits of their organization and themselves acting in a socially responsible manner, who is to blame? Do not let the answer be the educator for failing to carry the message.

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THE COMPETITIVE EFFECTS OF AIRLINE MERGERS AND ACQUISITIONS: MORE CAPITAL MARKET EVIDENCE

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ABSTRACT

This study investigates the stock market effects of airline mergers and acquisitions that took place in the U.S. during the period 1985-2001 on rival domestic airlines. We document significant positive price reactions for the target firms, insignificant reactions for the bidders, and marginally significant negative effects for a portfolio of rival firms on the day of the merger announcement. Our empirical evidence further suggests that the bidder's market share relative to that of the rival, the bidder's pre-merger market position, and the change in the bidder's market share post-merger are determinants of the magnitude of the rival's stock price reaction.

INTRODUCTION

After deregulation of the U.S. airline industry in 1978, a large number of mergers and acquisitions have taken place. Airlines have strong motives to merge or acquire other airlines in order to increase their market power or market coverage, to enhance their operating efficiency, or to overcome regulatory entry barriers (Scherer & Ross, 1990). Mergers and acquisitions can change the industry's market structure. Thus, such strategic moves will affect all market participants, including the bidder, the target and the existing or potential rival firms. These impacts will be directly reflected in the firms' stock prices in an efficient market (Fama, 1970, 1991).

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While the effects of mergers and acquisitions on the firms directly involved have been subject to extensive research, there are relatively few studies that examine the impact of mergers and acquisitions on the market value of rivals firms. In the context of the airline industry, this question is of interest because mergers and acquisitions not only change the relative market positions of the industry players; they also have important policy ramifications. For example, if mergers and acquisitions result in excessive market power for a particular firm, to the extent of creating an effective monopoly, then the purpose of the Airlines Deregulation Act of 1978 (i.e., to foster market competition and thus enhance economic efficiency) will be defeated. Some prior research focus on examining the economic effects (e.g., airfares) of the airline deregulation (Borenstein, 1990; Morrison & Winston, 1986). Several other studies examine the stock price reactions of rival firms in challenged mergers (Eckbo, 1983, 1985; Eckbo & Wier, 1985; Stillman, 1983). They find that the announcement of mergers increased the market price of rival firms' stocks but they characterize this (weak) increase in rivals' stock price as an information effect; namely, rivals now become more likely to be takeover targets as a result of the mergers. Kim and Singal (1993) discuss these studies and conclude that tests based on stock market prices are at best indirect and probably weak.

More recently, Park, Park and Zhang (2003) examine the impact of the British Airways/USAir Alliance on rival firm value. They find that rival firms' share prices reacted negatively to news that increased the likelihood of the Alliance being consummated, and positively to news that decreased the likelihood of the Alliance being consummated. This indicates that rival firms were thought to suffer from (as in the competitive effect hypothesis), rather than benefit from (as in the collusive market hypothesis) the British Airways/USAir Alliance. Interestingly, Park et al. report that the effects on rival firms are not moderated by the degree of rivalry between the alliance partners and their rival firms. This appears to contradict the results in Hergott (1997), which indicate that mergers and acquisitions create airline dominance at the airport level and lead to market power. More specifically, Hergott, using an event study methodology similar to Park et al., finds highly significant positive abnormal returns for regional rivals of Northwest-Republic but not for major airline rivals. Hergott attributes this result to the possibility that the regional airlines competed with Northwest-Republic on a higher percentage of routes and thus their profits would be more positively sensitive to an increase in prices on routes served by Northwest and Republic than would those of the major airlines.[1] Both the Park et al. and Hergott

[1] Bamberger, Carlton and Neumann (2001) empirically investigate the effect of the Continental/America West and Northwest/Alaska alliances and find that both alliances caused average fares to fall and that the size of the fare effect was larger on

studies were restricted to one single merger case each. Therefore, their results are not generalizable and may explain the apparent discrepancy between their findings.

This paper aims to investigate the impact of airline mergers and acquisitions on the stock market value of bidders, targets and, in particular, their rivals. The study contributes to the literature in the following ways. First, the authors conduct a large-scale study that examines the possible competitive effects of airline mergers and acquisitions on their rivals. By virtue of its long sample period (1985-2001), the study extends the results in Echbo (1983, 1985) and others. Second, the authors go further to delineate the factors that are associated with the stock price reactions of rivals to the announcements of mergers and acquisitions. In doing so, it is hoped that the empirical evidence provided can inform the debate on the relative validity of the *market power* hypothesis versus the *competitive effect* hypothesis.

EFFECTS OF MERGERS ON BIDDERS, TARGETS, AND RIVALS

When two airlines merge or when one airline acquires another airline, a new entity is created that is usually more powerful than the combined power of the previously separate entities. The merger leads to potential synergies and possible market leader power (see Borenstein, 1990; Kim & Singal, 1993). Synergies may result from greater bargaining power vis-à-vis suppliers, or from enhanced operating efficiency, or from greater market coverage. A horizontal merger between two airlines may be motivated by the desire of one airline to take over a competitor and hence reduce competition, or it may occur because one airline wants to enlarge its market coverage by controlling another airline that provides a complimentary market network (see Hanlon, 1999; O'Connor, 1995). In both cases, the merger is regarded as contributing positively to the airlines concerned. For this reason, previous studies have found that the targets' stock prices normally react positively to the merger announcement, although the bidders' reactions are only marginally positive or close to zero on average (for a summary of these studies, see Panayides & Gong, 2003; Scherer & Ross, 1990). In the airline industry, Singal (1996) provides a linkage between the stock market and the product market. He found that abnormal returns in the stock market are correlated with profit changes in the product market resulting from mergers.

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those city pairs where the pre-alliance level of competition was relatively low. Kim and Singal (1993) found that routes affected by airline mergers showed significant increases in airfare and such increases are positively correlated with changes in concentration. Carlton, Landes and Posner (1980) find that airline mergers could provide substantial value to consumers. They were, however, unable to empirically estimate the possible adverse competitive effects of the North Central-Southern merger (the subject of their case study).

Zhang and Aldridge (1997) investigate the reaction of investors to news about merger and foreign alliance possibilities in the Canadian airline industry, and find that favorable news increasing the likelihood of mergers and acquisitions are accompanied by significant positive price reactions for the bidder and the target.

Depending on the market setting, rival firms may react either positively or negatively to the announcements of mergers and acquisitions. If the merger results in a stronger competitor, the rival firms may lose market share to the new and stronger competitor. The extent of such losses depends on the relative market positions of the firms concerned. In contrast with this competitive effect argument, a market power argument suggests that the rival firms are likely to benefit from the creation of a stronger competitor if the latter exploits its market power to raise prices (Eckbo, 1983; Scherer & Ross, 1990). Thus, the value of rival airlines may increase or decrease, depending on the relative strength of the competitive effect as opposed to the market power effect. The extent of this relative strength may vary from case to case, and this may explain the seeming discrepancy between the findings of Park et al. (2003) and those of Hergott (1997). The effects of industry or firm-specific news on industry rivals (called information transfers) have been well documented in the accounting and finance literature (see Firth, 1976; Foster, 1980; Laux, Starks and Yoon, 1998).

The authors hypothesize that one key determinant of the net effect of the mergers on rival firms is the market share of the newly created competitor relative to that of the existing rivals. This is because, if the newly created competitor is strong (i.e., has a larger market share) relative to the existing rival, then (as under the market power argument) it is more likely to exploit its market power and raise prices. If this happens, the rivals may benefit from a more collusive market environment and thus their share prices will react positively (see Eckbo, 1983). If the newly created competitor is relatively weak (i.e., has small market share) as compared with the existing rival, it is more likely to compete (through the merger or acquisition) more fiercely with the existing rivals and thus all parties will lose from the ensuing price wars. This leads to the following mutually exclusive hypotheses. The market power hypothesis states that the reaction of an existing rival to a merger between two competitor airlines is positively associated with the market share of the new competitor created from the merger relative to that of the existing rival. The competitive effect hypothesis states that the reaction of an existing rival to a merger between two competitor airlines is negatively associated with the market share of the new competitor created from the merger relative to that of the existing rival.

Apart from market share, myriad other factors may determine the price reaction of the rivals. For example, firm size, and the extent of network overlaps or similarity of routes and services provided may also help to explain the impact of a merger or acquisition on the market value of a rival firm (see Hergott, 1997; Eckel, Eckel & Singal, 1997).[2] Omitting these factors should not introduce any systematic bias and they are better left to a future study.

SAMPLE SELECTION AND TESTING METHODOLOGY

Our study investigates the price reactions of rival airlines to the first public announcement of mergers and acquisitions in the U.S. airline industry. The period examined is from 1985 to 2001. Mergers are defined as two firms merging into one single entity and acquisitions are defined as a company acquiring a relatively important percentage (an arbitrary 14%) of ownership in the target firms. For convenience, the word *merger* is used to refer to both cases.

Selection of bidders and targets

The instances of mergers are identified by searching the *Factiva* database for 'mergers' and 'airlines' in the period 1985 to 2001. This database covers a number of journals, magazines and newspapers including the *Wall Street Journal*, *Dow Jones News Service*, Reuters and PR Newswire. The announcement date is the date on which the merger or acquisition activity was first publicly released in the media. To be selected, the sample bidder and target firms must meet the following criteria.

1. The bidder and the target firms must conduct business in the United States.
2. The firms' main income is derived from passenger transportation.
3. The firms must be public-listed and daily stock returns must be available from the University of Chicago's Center for Research in Security Prices Daily Returns File in the 255 trading days before and 5 days after the announcement date. This enables the estimation of the market model parameters and for the computation of firms' abnormal returns around the mergers.
4. Firms must not have major corporate events occurring during the event window (5 days centered on the announcement date). This criterion is to rule out cases where confounding events occurred during the merger announcement period.

The final sample consists of 15 mergers. These are listed in Table 1.

[2] To a large extent, these alternative factors are likely to be highly correlated with market share (properly defined).

Table 1: Mergers and acquisitions in the U.S. airline industry 1985-2001

Case	Announcement Date	Bidder	Target (% acquisition in brackets)	Key Rival Airlines
1	2-Oct-85	Piedmont Airlines	Empire Airlines	Eastern Airlines, US Air
2	23-Jan-86	Northwest Airlines	Republic Airlines	United Airlines, American Airlines
3	24-Feb-86	Continental Airlines	Eastern Airlines	American Airlines, US Air
4	27-Feb-86	Trans World Airlines	Ozark Airlines	Southwest Airlines, Continental Airlines
5	23-May-86	Delta Airlines	Atlantic Southeast (20%)	Eastern Airlines, Republic Airlines
6	29-May-86	Delta Airlines	ComAir (20%)	Air Wisconsin, American Airlines
7	9-Sep-86	Delta Airlines	Western Airlines	Pan American World Airways, United Airlines
8	9-Mar-87	US Air	Piedmont Aviation	American Airlines, United Airlines
9	23-Jul-87	Alaska Airlines	Jet American Airlines	United Airlines, Delta Airlines
10	10-Dec-90	Northwest Airlines	Hawaiian Airlines (25%)	United Airlines, Continental Airlines
11	17-Sep-91	United Airlines	Air Wisconsin	American Airlines, Midway Airlines
12	16-Dec-97	Northwest Airlines	Continental Airlines (14%)	American Airlines, United Airlines
13	19-Nov-98	American Airlines	Reno Air	Alaska Airlines, Southwest Airlines
14	24-May-00	United Airlines	US Airways	American Airlines, Continental Airlines
15	8-Jan-01	American Airlines	Trans World Airlines	Northwest Airlines, Continental Airlines

Source: *Factiva*

Selection of rivals

Before the Airlines Deregulation of 1978, airlines provided point-to-point or city-pair services, so they were mainly competing on the point-to-point service. After the deregulation, however, there was a significant change in the routing and schedule patterns of airlines because of new entrants. Airlines increasingly structured their services via the hub-and-spoke network system. A hub is a central airport where passengers are collected from feeder flights, transferred to other flights on the same airline, and then carried to their ultimate destination. A spoke provides feeder services which transport passengers between different small points and the hub. Because hub-and-spoke network has the benefits of better connectivity for passengers, higher load factors and lower unit costs, more and more airlines tend to operate the hub-and-spoke system (Brueckner & Spiller, 1991). Usually, major airlines have multiple hubs because this enables them to serve small and widely spread markets. If two airlines operate a hub-and-spoke service in a similar geographical area, they are competing for the same customers. One of the reasons airlines engage in mergers is to reduce competition in the same hub or service areas, to increase their market power relative to competitors, or to expand their network and enhance the service level.

Therefore, rivals for each merger case are selected on two criteria: a) They conduct air passenger business in the same geographic market as the target and/or the bidder; or b) Their hubs are close to each other, so that their spokes may overlap. Based on these two criteria, rivals are identified from the *Factiva* news reports accompanying the merger announcements. Two key rivals for each merger event so identified are listed in the last column of Table 1.[3]

Market share of bidder, target, and rivals

The market power of a firm has been shown to be positively related to market share; larger firms generally wield greater market power. In the airline industry, an airline's market share is taken to be its output (measured in terms of revenue passenger kilometers or RPK) as a proportion of the total industry output in a particular geographical area or market. A competitive hub-and-spoke network is one that brings a large number of passengers on flights to airlines, and RPK is a good measurement of the average number of passengers on flights. Ideally, the market share of the airlines involved (bidder, target, and rival) should be measured in a narrowly defined market, for example, in the regional area for regional airlines or on the national level for majors. Since such narrowly defined market share data are not available to us, we measure an airline's market share as the ratio of its number of domestic RPK to the total industry RPK excluding international traffic (see Slovin, Sushka, and Hudson, 1991). The market share of each airline in the year prior to the merger announcement is computed from annual traffic statistics published by International Civil Aviation Organization and/or taken directly from the *Factiva* reports.[4].

Measuring abnormal price reaction around the merger announcements

To the extent that a merger is likely to change the future profitability of the companies involved (these include not only bidders and targets, but also

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[3] There is no theoretical reason why only two rivals are selected. In practice, however, most regional airline markets operate as a tight oligopoly with from two to four competing firms (see McCarthy, 2001).

[4] These news reports from which we identified the dates of the mergers, the firms involved, and the market share statistics are available from the authors on request.

rivals), the effects of the event will be rapidly reflected in the stock prices of the firms in an efficient capital market. Fama (1970, 1991) and Elton and Gruber (2003) provide extensive evidence in support of this. In line with existing studies, we adopt an event study methodology to measure firms' abnormal returns surrounding merger announcements. Brown and Warner (1980, 1985) provide details on the event study methodology.

Define the date of the announcement of a merger as event day 0. In the absence of the merger, the expected return to the *jth* stock at time *t*, R_{jt} is represented by the market model:

$$R_{jt} = \alpha_j + \beta_j R_{mt} + \in_{jt} \qquad (1.)$$

Where R_{mt} is the market return at time *t* and $\in$ is a zero-mean disturbance term. β_j is the sensitivity of the *jth* stock to the market and α_j measures the mean return to the stock when the market return is zero. Therefore, $\beta_j R_{mt}$ is the part of the returns explained by the normal relationship of the stock with the market index.

The market model parameters α_j and β_j are estimated via ordinary least squares regression using daily returns during the estimate window (-255,-6) relative to the event date. The abnormal returns of the *jth* stock at the time *t* is measured as the prediction error of the market model:

$$AR_{jt} = R_{jt} - \hat{\alpha}_j - \hat{\beta}_j R_{mt} \qquad (2.)$$

The sample average abnormal return at time *t* ($\overline{AR}_t$) is computed as

$$\overline{AR}_t = \frac{1}{N} \sum_{j=1}^{N} AR_{jt} \qquad (3.)$$

where N is the total number of firms in each group, i.e. the bidder, target, and rivals. The cumulative average abnormal return from event time *p* up to event time *q*, $CAR(p,q)$ is given by:

$$CAR(p,q) = \sum_{t=p}^{q} \overline{AR}_t \qquad (4.)$$

If the merger announcement does not affect the share prices at time *t*, the average abnormal returns of the related firms, $\overline{AR}_t$, should be statistically close to zero. The test statistics for $\overline{AR}_t$ and $CAR(p,q)$ are:

$$t(\overline{AR}_t) = \overline{AR}_t \,/\, \hat{S}(\overline{AR})$$
$$t(CAR) = CAR(p,q) / [\hat{S}(\overline{AR}) \times \sqrt{q-p+1}]$$

where:

$$\hat{S}(\overline{AR}) = \sqrt{\frac{\sum_{t=-255}^{-6} (\overline{AR}_t - \overline{\overline{AR}})^2}{249}}$$
$$\overline{\overline{AR}} = \frac{1}{250} \sum_{t=-255}^{-6} \overline{AR}_t$$

Where $\hat{S}(\overline{AR})$ is the standard deviation of the average abnormal returns estimated during the estimate window (-255, -6).

Theory as well as previous studies suggests that the reactions of bidders, targets and rivals are usually different. The price reaction of bidders is usually small, from slightly positive, to close-to-zero. This result is attributed to the fact that investors believe the acquiring firms often pay a full price for the target or, in some cases, overpay. Managerial or incentive problems may also cause short term price reactions, or even long term underperformance for the bidders (see Firth, 1991). In contrast, the target firms usually have high positive abnormal returns. This is because, apart from the premium paid to shareholders of the target firm, investors are generally also optimistic about the target's future performance after the merger. On this basis, the authors predict significant abnormal returns to the targets.

As discussed in Effects of Mergers section above, the reaction of the rivals depends on the market setting. If the market power effect dominates the competitive effect, then a horizontal merger may induce positive abnormal returns to the rivals. Negative abnormal returns to the rivals are consistent with a net competitive effect.

EMPIRICAL RESULTS

Abnormal returns of bidders, targets, and rivals around the merger acquisition date

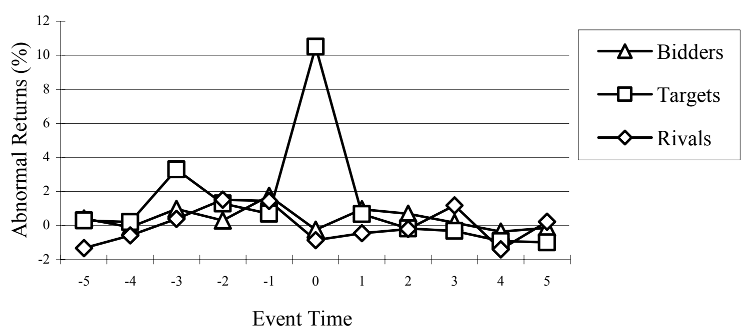
The mean returns and systematic risks (beta) of bidders, targets, and rivals computed during the estimation window are presented in Table 2. Of special interest is the mean beta for bidders, targets, and rivals, which are 1.19, 1.75 and 1.60, respectively. These are all numerically and statistically greater than unity, in contrast with earlier studies that documented a below-unity average beta for U.S. airlines (see Gong, Firth and Cullinane, 2006; Turner & Morrell, 2002).[5]

Table 2: Mean returns and systematic risks of bidders, targets, and rivals

Group	Number of obs.	Mean Return (standard deviation)	Beta (standard deviation)
Bidders	15	0.00092 (0.00099)	1.19 (0.647)
Targets	15	0.00115 (0.00185)	1.75 (0.445)
Rivals	30	0.00080 (0.00134)	1.60 (0.605)

The average abnormal returns to bidders, targets and rivals are listed in Table 3 and depicted in Figure 1. On the event day 0, the average abnormal return to bidders is slightly negative at -0.24% but is statistically insignificant. The cumulative abnormal return during day -1 and day 0 is marginally significant at 1.50% (Table 4). This indicates that the market expects the mergers to increase the bidders' future profitability, at least slightly.

Figure 1: Average abnormal returns of bidders, targets, and rivals around the merger announcement date



[5] Using a small sample of U.S. airlines, Flouris and Walker (2005) find that the systematic risks or beta coefficients of U.S. airlines increased considerably after 9/11. The average beta was below unity before 9/11 but was substantially greater than unity post-9/11. Estimation of beta for airlines warrants a separate study in its own right.

Table 3: Average Cumulative Abnormal Returns (CAR) of bidders, targets, and rivals

	Bidders		Targets		Rivals	
Event Day	CAR (%)	Z-stat	CAR (%)	Z-stat	CAR (%)	Z-stat
-5	0.42	0.60	0.31	0.42	-1.32	-1.60$
-4	-0.09	0.00	0.20	0.88	-0.57	-0.93
-3	0.97	1.96*	3.29	3.03**	0.40	0.95
-2	0.30	0.42	1.30	1.47$	1.51	2.20*
-1	1.75	2.84**	0.69	1.70*	1.45	2.83**
0	-0.24	-0.59	10.50	9.90***	-0.85	-1.30$
1	0.96	1.42$	0.68	0.77	-0.45	-0.32
2	0.69	1.09	-0.17	-0.22	-0.21	-0.70
3	0.18	0.38	-0.32	-0.41	1.18	1.66*
4	-0.35	-0.45	-0.92	-1.07	-1.40	-2.09*
5	-0.12	-0.35	-0.99	-0.89	0.23	0.06

$, *, **, *** Significant at the 0.1, 0.05, 0.01, 0.001 level, respectively.

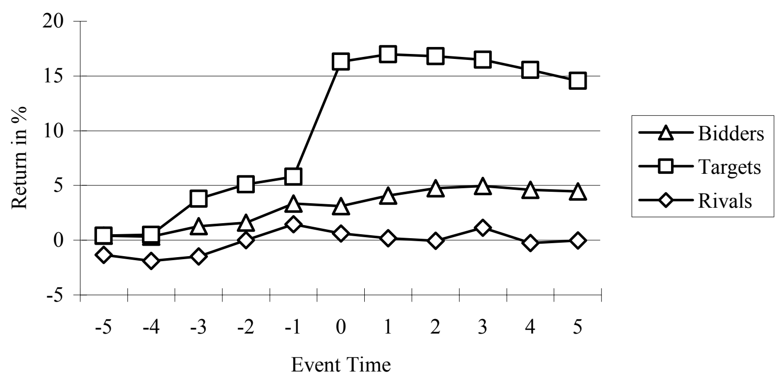
Table 4: Cumulative Average Abnormal Returns (CAR) of bidders, targets, and rivals

	Bidders		Targets		Rivals	
Event Day	CAR (%)	Z-stat	CAR (%)	Z-stat	CAR (%)	Z-stat
-5 to -2	1.59	1.49$	5.10	2.90**	0.01	0.31
-1 to 0	1.50	1.59$	11.18	8.20***	0.59	1.08
1 to 5	1.35	0.94	-1.72	-0.81	-0.64	-0.62

$, *, **, *** Significant at the 0.1, 0.05, 0.01, 0.001 level, respectively.

Target firms on average experienced a high and positive abnormal return of 10.5% on the first announcement of the mergers. The existence of positive abnormal returns beginning from three days before the actual announcement may reflect information leakage or market anticipation for the forthcoming merger. The magnitude of these abnormal returns are however much lower than that on the event day, indicating that the announcement itself conveys positive incremental information about the merger and its effects on the market value of the targets. Together with a cumulative abnormal return of 11.18% during the two days leading up to the announcement, the evidence is consistent with findings in previous studies that target firms are the greatest beneficiaries of a merger, partly because they are generally smaller than the bidders and partly because of the premium paid. It is noteworthy that both the bidders and the targets react rapidly and fully to the merger announcement, as abnormal price reactions do not last beyond the first announcement (Figure 2). This is consistent with the semi-strong form of the efficient market hypothesis (Fama, 1970).

Figure 2: Cumulative Average Abnormal Returns (CAR) of bidders, targets, and rivals around the merger announcement date



The focus of this study is the stock price effects of the merger announcement on the rival firms of the bidder and/or the target. For each merger case, two major rivals for the bidder and/or the target have been identified. The average effect of the merger announcement on the rivals is captured in the equally weighted returns to the portfolio of the two rivals' shares. Table 3 reveals that although the rival firms on average experienced significant abnormal returns during the few days centered on the announcement (i.e., day -2 to day 4), the sign of these abnormal returns does not reveal a clear pattern about the direction of the reaction for the rivals. On day -2 and day -1, the average abnormal returns were 1.51% and 1.45, respectively, and significant at the 5% level. However, the average abnormal return on the announcement day is -0.85%, and significant at the 10% level.

The cumulative average abnormal return to the rivals during day -1 to day 0 is 0.59%, which is insignificant at conventional levels (Table 4). The evidence also seems to suggest some type of semi-strong form inefficiency in that significant abnormal returns still exist in the post-event period. Post-announcement drifts of this sort are well documented in the accounting literature.

It should be emphasized that the above evidence reflects the *average* reaction of the rival firms. In reality, any two rivals corresponding with a merger case may experience reactions in different directions. For example, a closer rival may react positively to the creation of a much stronger or larger competitor, if the competitor is expected to result in a more collusive industry structure leading to higher output prices in the same geographical market. In comparison, a more distant rival may not benefit by as much, or may even lose from this new and stronger entrant, if the latter competes away customers from the more distant rival without raising its output prices. In the Effects of Mergers section above, the authors argue that the market share of the newly created entrant, either in absolute value or relative to the rival firm, may be used to test the empirical validity of the market power hypothesis and the competitive effect hypothesis. Next results of regressing the rival's abnormal returns against the target's market share are presented (alternatively, the combined market share of the bidder and the target). Scaling the rival's abnormal return by the bidder's abnormal return allows parsimonious models to be tested (Firth, 1996). This standardized measure also adjusts for the impact of the merger announcement on the bidder itself: The more the merger is expected to improve the bidder's market position (as reflected in positive abnormal returns), the greater is the potential of the merger to affect the rivals (either from the market power or from the competitive effect perspective). Using only the rival's abnormal returns as the dependent variable weakens the statistical results (not reported) but does not change the conclusions qualitatively.

Relation between market share and rival's price action

We first present the results when market share is measured as the market share for the bidder relative to that of the rival (Panel A, Table 5). The mean relative information transfer, RIT, which is measured as the ratio of the rivals' cumulative abnormal returns during day -1 and day 0 to the bidder's cumulative abnormal return in the same interval, is -0.40.[6] This means that, on average, the reactions of bidders and rivals are opposite in sign: if the bidder's stock price reacted positively to the merger announcement, its rival reacted negatively, and vice versa. This is consistent with the competitive

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[6] The results remain qualitatively the same when using alternative windows (-1, 1) and (-5, 5) and are thus not reported.

effect hypothesis: when one benefits from a merger, the other one suffers from it.

Table 5: Cross-Sectional Regression Results*

Panel A. Relative market share (RMS) measured as the bidder's market share relative to that of the rival

No. of obs.	Intercept (t-statistic)	RMS coefficient (t-statistic)
25	0.48 (0.15)	-0.65 (-4.22)

Mean value of dependent variable = -0.40
R-squared = 0.45

Panel B. Relative market share (RMS) measured as the combined market share of the bidder's and the rival's market shares relative to that of the rival

No. of obs.	Intercept (t-statistic)	RMS coefficient (t-statistic)
17	-0.72 (-0.15)	-0.68 (-3.38)

Mean value of dependent variable = -0.64
R-squared = 0.42

Panel C. Multiple regression results (t-statistic in brackets)

No. of obs.	RMS	Bidder's Market Share	Change in Bidder's Market Share
17	-0.46 (-2.91)	-0.19 (-1.76)	-0.14 (-1.29)

Mean value of dependent variable = -0.64
Adjusted R-squared = 0.55

*Dependent variable $RIT = Rival\_CAR_{(-1,0)} / Bidder\_CAR_{(-1,0)}$.

Five observations in Panel A do not have market share data, leaving 25 observations.
Eight other observations in Panel B and Panel C do not have market share data, leaving 17 observations.

The coefficient of relative market share is -0.65, which is significant at the 0.1% level. This indicates that the competitive effect of airline mergers on the rival firms is negatively related to the market share of the bidder relative to that of the rival. Intuitively, if the bidder is large relative to the rival (i.e., has a larger market share), the stock price reaction of the rival is more negative and thus opposite in sign to the bidder's stock price reaction. This indicates that when a large bidder acquires a target firm in the same geographical area as the rival, the rival tends to react in the opposite direction as the bidder firm itself: if the bidder experiences a positive price reaction, the rival experiences highly negative abnormal returns, which reflects the market's expectation that the rival will lose from the entry (via a merger) of a strong competitor. This is consistent with the competitive effect hypothesis, and is in line with the negative mean value of RIT. The R-squared is 0.45, which indicates that 45% of the total variance in RIT is explained by the regression model.

Panel B of Table 5 presents the results when relative market share is measured as the combined market share of the bidder and the target relative to the market share of the rival. The market share coefficient is -0.68, significant at the 0.1% level. The R-squared is 0.42 (p-value < 0.001), indicating that the model has strong explanatory power. Thus, the result in Panel B confirms and reinforces the result in Panel A and is supportive of the competitive effect hypothesis rather than the market power hypothesis.

Panel C of Table 5 differs from Panel B in that the bidder's pre-merger market share (average being 10.24%) and the percentage change in the bidder's market share after the merger (average being 4.2%) are added as additional explanatory variables.[7] Since a stronger bidder (as reflected in a large market share before the merger and a significant increase in its market share as a result of the merger) may be considered a market leader and/or induce stronger inter-firm competition,[8] both of these two additional explanatory variables are expected to be negatively associated with the abnormal returns of the rival under the competitive effect hypothesis. The coefficient of bidder's market share is -0.19, which marginally significant. The coefficient of the change in bidder's market share has the expected sign but is not significant at conventional levels. Note that the coefficient of relative market share has dropped to -0.46 but remains highly statistically significant. The adjusted R-squared is relatively high at 0.55, indicating reasonable goodness of fit.

Thus, the empirical evidence suggests that competitive effects of airline mergers dominate market power effects, and the bidder's market position and the change in its market share are determinants of the rival's stock price reaction. This makes intuitive sense because, if the creation of a strong competitor (through merger or acquisition) benefits rather than harms the existing rivals, the rivals to oppose to these strategic activities by their competitors will not be observed (Park et. al., 2003).

CONCLUSION

The authors investigate the competitive effects of airline mergers and acquisitions on the market value of rival airlines. Using 15 cases of mergers and acquisitions that took place in the U.S. airline industry during 1985 to 2001, it was found that bidders and targets react in a way consistent with findings in previous studies. Bidders in general experienced marginally positive abnormal returns, whereas targets experienced highly positive abnormal returns around the first public announcement of the mergers. Evidence on the average reaction of rival firms was mixed, with positive

[7] Regression diagnostics reveal no significant multicollinearity between these explanatory variables.

[8] Theoretically and as previously discussed, a collusive market structure may also result from the creation of a strong competitor. Such collusion will benefit the market participants and induce positive stock price reactions in the rivals. This empirical issue has to be determined empirically.

price reaction immediately prior to the announcement, negative reaction on the date of the announcement, and a mixture of negative and positive reactions in the post-merger period. Further cross-sectional regression analysis reveals that competitive effect is moderated by the bidder's market share relative to the rival's market share. The bidder's market position and its change in market share (pre-merger versus post-merger) also affect the stock price reaction of the rival firms. Thus, the larger or stronger the bidder is, the stronger (i.e., more negative) is the competitive effect associated with the mergers. Overall, the evidence in this study may be interpreted as supporting the competitive effect hypothesis rather than the market power hypothesis. Such evidence may be cited to justify industry opposition to strategic activities such as mergers that may hurt competitors, and to alleviate regulatory concern that mergers may lead to a more collusive industry structure.

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THE COMPETITIVE POSITION OF HUB AIRPORTS IN THE TRANSATLANTIC MARKET

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ABSTRACT

This article puts forward the argument that the measurement of connectivity in hub-and-spoke networks has to take into account the quality and quantity of both direct and indirect connections. The NETSCAN model, which has been applied in this study, quantifies indirect connectivity and scales it into a theoretical direct connection. NETSCAN allows researchers, airports, airlines, alliances and airport regions to analyse their competitive position in an integrated way. Using NETSCAN, the authors analysed the developments on the market between northwest Europe and the United States (US) between May 2003 and May 2005. One of the most striking developments has certainly been the impact of the Air France-KLM merger and the effects of the integration of KLM and Northwest into the SkyTeam alliance on the connectivity of Amsterdam Schiphol. Direct as well as indirect connectivity (via European and North American hubs) from Amsterdam to the US increased substantially. The main reason for this increase is the integration of the former Wings and SkyTeam networks via the respective hub airports. Moreover, the extended SkyTeam alliance raised frequencies between Amsterdam and the SkyTeam hubs (Atlanta, Houston, for example), opened new routes (Cincinnati) and boosted the network between Amsterdam and France. As a result of the new routes and frequencies, Amsterdam took over Heathrow's position as the third best-connected northwest European airport to the US.

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INTRODUCTION

Hub-and-spoke networks have been an essential feature of the operations of air carriers since the deregulation of the domestic American air transport market in 1978. Hub-and-spoke networks allow the hub airline to maximize the number of connected city pairs given a certain number of flights. Due to the consolidation of different origin-destination combinations on a limited number of routes, the hub airline may benefit from higher load factors, higher frequencies and the use of larger aircraft with lower unit costs (Dennis, 1994a, 1994b).

In a hub-and-spoke network, the carrier concentrates its network both spatially and temporally (Reynolds-Feighan, 2001). From a spatial point of view, the carrier organizes its network around one or a few central hub airports. At the hub, passengers transfer to their connecting flight. From a temporal perspective, the flight schedule at the hub is organised in a number of daily waves of incoming and outgoing flights, in which ideally all incoming flights connect to all outgoing flights (Bootsma, 1997). The wave system restricts the loss of passenger demand due to the additional transfer time of an indirect connection compared to a direct connection.

Also in Europe, the hub-and-spoke network has gained ground since the liberalisation of the internal European Union (EU) market (1988-1997). Already before the liberalisation of the EU market, the national airlines operated star-shaped networks, spatially concentrated around the national home bases. Yet, most of these carriers could not be characterised as hub-and-spoke airlines. The star-shaped networks were merely the result of the system of bilateral air service agreements that pinned down the designated carriers on their national home bases. Since the liberalisation of the market, many national and a few regional airlines built up their hub-and-spoke network by means of the intensification and adoption of wave systems (Burghouwt, 2005). However, since 2001 a shakeout on the hub market has taken place. Some hubs were torn down or rationalized by their home based carriers. British Airways dehubbed London Gatwick because the split-hub operation at Heathrow and Gatwick was not profitable. Iberia cancelled its hub operations at Miami because security measures at the airport had been tightened due to the events of September 11, 2001 (9/11), and connecting times had doubled. Air France rationalized the hub operation at Clermont-Ferrand after the take-over of Regional Airlines in 2000. The hub operation at Clermont-Ferrand (the former hub of Regional Airlines) duplicated substantially the hub operation of Air France at Lyon. Other hubs disappeared or were scaled down because of the bankruptcies of the hub carriers (Sabena at Brussels, Swissair and Zurich, Air Littoral at Nice, Crossair at Basle).

Global airline alliances are increasingly important for the future of hubs. The three global airline alliances (OneWorld, Star and SkyTeam) choose one or two hubs at each continent to function as primary intercontinental gateways. Other hubs fulfil secondary, regionally oriented roles (Dennis, 2005).

The growth of hub-and-spoke operations has changed the competition between airlines in a structural way. The competitive position of airlines and airports is usually expressed in terms of top ten lists. Airlines and airports are compared with respect to total passenger enplanements, number of aircraft movements or tonnes of freight. Although such indicators are valuable in itself, they do not give any information on the competitive position of airline networks and hub airports.

The gap in such analyses is the fact that, because of the rise of hub-and-spoke systems, competition between airlines takes place in both a direct and indirect way. On the one hand, airlines compete on direct routes (from A to B). On the other had, they compete indirectly with a transfer at a hub (from A to B via H). The passenger's choice for a certain route alternative will depend, among other things, on the ticket price and network quality. Especially in case of the availability of a direct route alternative, ticket price will be an important tool for an airline offering an indirect connection to compensate for lower network quality. Network quality is defined here as the frequency and associated travel times of a certain connection.

This paper discusses the competitive position between airports, airlines, alliances and their hubs on the market between northwest Europe and the US. The analysis is restricted to network quality. Reliable price data are scarce and, if available, hard to use because of the large number of quickly changing ticket prices on a single flight.

The paper is outlined as follows. The next section places this study in the context of earlier research on hub-and-spoke networks. The third section discusses the principles of hub-and-spoke systems in relation to network quality and connectivity. The fourth section deals with the NETSCAN model. The fifth and sixth sections discuss the empirical results of the research. The final section presents the conclusions of the research.

LITERATURE REVIEW

The rise of hub-and-spoke networks has been the subject of many academic studies. One branch of research deals with the advantages of hub-and-spoke networks in terms of economies of density and scope (Braeutigam 1999; Brueckner & Spiller, 1994; Caves, Christensen & Tretheway, 1984; Wojahn 2001), hub premiums, (Berry, Carnall & Spiller, 1996; Borenstein 1989; Leijsen, Rietveld & Nijkamp, 2000; Oum, Zhang & Zhang, 1995), entry deterrence (Zhang 1996) and the role of hub-and-spoke networks in airline alliances (Dresner & Windle, 1995; Oum, Park & Zhang, 2000; Pels, 2001). A second branch of research aims to optimize hub-and-spoke networks spatially by means of hub location-allocation models (Kuby & Gray 1993; O'Kelly & Miller, 1994; O'Kelly, 1998; O'Kelly & Bryan, 1998).

Another branch of research has studied the structure, performance and growth of hub-and-spoke networks from an empirical point of view. Most studies focus on the spatial dimension of hub-and-spoke networks: the level to which an airline has concentrated its network on a few key nodes in the network (Bania, Bauer & Zlatoper, 1998; Burghouwt, Hakfoort & Ritsema-Van Eck, 2003; Ivy, 1993; Shaw, 1993; Reynolds-Feighan, 2001; Wojahn, 2001). However, Bootsma (1997), Burghouwt (2005), Burghouwt and de Wit (2005); Dennis (1994a, 1994b), Reynolds-Feighan (2001) and Wojahn (2001) explicitly underline the temporal dimension or schedule structure as an essential element for the empirical study of the structure, performance and development of hub-and-spoke networks. Hub-and-spoke airlines offer consumers both direct and indirect travel opportunities (via their hub). To maximize indirect travel opportunities and to minimize passenger loss due to transfer time and detour time indirect travel opportunities need efficient schedule coordination in terms of a well developed wave system structure at the hub.

However, schedule coordination and the resulting hub performance are not captured by the traditional graph theoretical or spatial concentration measures. Only a few authors have included the level of schedule coordination in the measurement of the performance and structure of hub-and-spoke networks (for example, Bootsma, 1997; Burghouwt, 2005; Dennis, 1994b; Veldhuis, 1997). These studies include the possibility of making transfers from one flight to another, taking into account minimum and maximum connecting times and the quality of those connections. In this study, the NETSCAN model, developed by Veldhuis (1997) and owned by SEO Economic Research, has been applied to measure the performance of airline networks in the transatlantic market.

NETWORK QUALITY, HUB-AND-SPOKE SYSTEMS AND CONNECTIVITY

The extent to which airlines can play a role in the market between A and B depends on a number of factors. First, the size of the market is important. If the size of the origin-destination market is larger than a certain critical threshold, an airline may decide to serve that market directly. The critical threshold will also depend on the critical load factor, the size of the smallest airplane that can be operated on the route and the minimum desired weekly frequency. If the market size is below this threshold, the market can only be served indirectly. However, this does not mean that, if a direct travel opportunity is available all passengers will choose the direct travel alternative. In reality, traffic will be spread over direct and indirect travel opportunities, depending on ticket prices and the network quality of the indirect connection.

The quality of an indirect connection between A and B with a transfer at hub H is not equal to the quality of a direct connection between A and B. In other words, the passenger travelling indirectly will experience additional costs due to longer travel times, consisting of detour time and transfer time. The transfer time equals at least the minimum connecting time, or the minimum time needed to transfer between two flights at hub H.

Hence, the extent to which an airline is able to serve successfully an indirect market is, besides prices, mainly dependent on two things. First, the geographical location of the respective hub in relation to the main continental and intercontinental traffic flows. Second, the efficiency of the airline's schedule is crucial. If a carrier is able to coordinate its incoming and outgoing flights effectively so that all incoming flights connect to all outgoing flights, the quality loss of an indirect connection can be kept to a minimum.

Against the background of hub-and-spoke networks, this article distinguishes three types of connections:

1. Direct connections: flights between A and B without a hub transfer (e.g., from Amsterdam to Los Angeles)
2. Indirect connections: flights from A to B, but with a transfer at hub X (e.g., from Amsterdam to Los Angeles via Detroit)

Hub connections: connections via (with a transfer at) hub A between origin C and destination B (e.g., from Hamburg via Amsterdam to Los Angeles).

In fact, hub connections are equal to indirect connections. However, indirect connectivity is measured from the perspective of the originating airport and hub connectivity is measured from the perspective of the hub airport. The measurement of indirect connectivity is particularly important from the perspective of consumer welfare (e.g., how many direct and indirect connections are available to consumers between Amsterdam and Los Angeles). The concept of hub connectivity is particularly important for measuring the competitive position of airline hubs in a certain market (e.g., how does Amsterdam perform as a hub in the market between Hamburg and Los Angeles).

METHOD AND DATA

The NETSCAN model

As the authors argued earlier, the quality of an indirect connection is not equal to the quality of a direct connection. The NETSCAN model quantifies the quality of an indirect connection and scales it to the quality of a theoretical direct connection. The authors discuss briefly the methodology of the NETSCAN model in general terms. For a detailed discussion, refer to Veldhuis (1997) and IATA (2000).

NETSCAN assigns a quality index to every connection, ranging between 0 and 1. A direct, non-stop flight is given the maximum quality index of 1. The quality index of an indirect connection will always be lower than 1 since extra travel time is added due to transfer time and detour time of the flight. The same holds true for a direct multi-stop connection: passenger face a lower network quality because of en-route stops compared to a non-stop direct connection.

If the additional travel time of an indirect connection exceeds a certain threshold, the quality index of the connection equals 0. The threshold of a certain indirect connection between two airports depends on the travel time of a theoretical direct connection between these two airports. In other words, the longer the theoretical direct travel time between two airports, the longer the maximum indirect travel time can be. For example, a maximum indirect travel time of three hours belongs to a direct flight of one hour, while the maximum indirect travel time of a 12-hour flight equals 24 hours. The travel time of a theoretical direct connection is determined by the geographical coordinates of origin and destination airport and assumptions on flight speed and time needed for take-off and landing. By taking the product of the quality index and the frequency of the connection per time unit (day, week, and year), the total number of connections or connectivity units (CNUs), can be derived. Summarizing the following model has been applied for each individual (direct, indirect or hub) connection:

$$\text{MAXT} = (3 - 0.075 * \text{NST}) * \text{NST} \quad (1)$$

$$\text{PTT} = \text{FLY} + (3 * \text{TRF}) \quad (2)$$

$$\text{QUAL} = 1 - ((\text{PTT} - \text{NST})/(\text{MAXT} - \text{NST})) \quad (3)$$

$$\text{CNU} = \text{QUAL} * \text{FREQ} \quad (4)$$

Where MAXT is the maximum perceived travel time, NST is the non-stop travel time, PTT is the perceived travel time, FLY is the flying time, TRF is the transfer time, QUAL is the quality index of an individual connection and CNU is the number of connectivity units.

Table 1 illustrates the NETSCAN model. Consider the example of the connectivity between Amsterdam and Cincinnati. The SkyTeam alliance operates a daily direct connection to Cincinnati in May 2005. The direct flight has a quality index of 1 since no transfer time or detour time is involved. Hence, the number of CNUs per week equals the frequency per week. Besides a direct connection, SkyTeam, and to a lesser extent the Star alliance, offers indirect connections via other American and European hubs. In this respect, Detroit is the most important hub. In theory, the number of viable connections (quality index > 0) via Detroit is 89 per week. However, as a result of transfer time and detour time, the average quality index equals 0,32. This results in a total number of weighted CNUs of 28,7. Because NETSCAN scales the indirect connection to a theoretical direct connection, the CNUs via Detroit can be read as follows: between Amsterdam and Cincinnati 89 indirect flights per week are offered by SkyTeam via Detroit. These 89 flights are comparable to 28,7 direct flights from Amsterdam to Cincinnati.

Table 1. Quality indices, frequency per week and connectivity units (CNU's), Amsterdam-Cincinnati, 3rd week of May 2005

Origin	Hub	Destination	Alliance	Average Quality Index	Frequency per Week	CNU/week
Amsterdam	--	Cincinnati	SkyTeam	1,00	7	7,0
Amsterdam	Atlanta	Cincinnati	SkyTeam	0,42	14	5,9
	Boston		SkyTeam	0,49	7	3,4
	Paris CDG		SkyTeam	0,35	47	16,6
	Detroit		SkyTeam	0,32	89	28,7
	New York Newark		SkyTeam	0,40	46	18,2
	Rome FCO		SkyTeam	0,38	7	2,6
	Frankfurt		SkyTeam	0,47	7	3,3
	Washington Dulles		SkyTeam	0,46	14	6,4
	Houston		SkyTeam	0,35	7	2,4
	New York JFK		SkyTeam	0,37	28	10,5
	Memphis		SkyTeam	0,19	7	1,4
	Minneapolis		SkyTeam	0,30	41	12,1
	Chicago O'Hare		SkyTeam	0,39	14	5,4
			Star	0,31	7	2,2
	Philadelphia		Star	0,30	6	1,8
	Montreal Dorval		SkyTeam	0,58	7	4,1
	Toronto		SkyTeam	0,41	6	2,5
TOTAL				**0,37**	**361,00**	**134,50**

Source: OAG (2005); own calculations

Data and classifications

The authors used OAG flight schedules in the third week of May in 2003, 2004 and 2005 (OAG 2005). Direct connections are directly available from the OAG database. Indirect connections have been constructed using an algorithm, which identifies for each incoming flight at an airport the number of outgoing flights that connect to it. The algorithm takes into account minimum connection times and puts a limit on the maximum connecting time and routing factor. Next, the NETSCAN model assigns to each direct and indirect connection a quality index, ranging between 0 and 1.

Within the NETSCAN model, only online connections are considered as viable connections. In other words, the transfer between two flights has to take place between flights of the same airline or global airline alliance. For the years 2004 and 2005, we distinguish three global airline alliances: OneWorld, SkyTeam and Star. For the year 2003, the authors distinguish an additional alliance, Wings (KLM/Northwest), which submerged into SkyTeam in 2004.

The analysis considers the connectivity between airports in northwest Europe and airports in the US. Northwest Europe is defined as Belgium, the Netherlands, and Luxemburg (Benelux), the UK, Ireland, France and Germany. Only westbound connections (from northwest Europe to the US) have been taken into account. The return connections have not been considered in the analysis. It is important to note that the total market between northwest Europe and the US has been analysed. This means that indirect connections in this market can be provided by hubs within the geographical boundaries of this market (Amsterdam and Frankfurt, for example) but also by hubs located outside the geographical boundaries of this market (Madrid, for example).

Furthermore, we make a distinction between primary, secondary and tertiary airports. European primary airports are the four largest airports: London Heathrow, Paris CDG, Frankfurt and Amsterdam. The American primary airports are the major gateways: Chicago O'Hare, Atlanta, Los Angeles and New York JFK. Secondary airports are all those airports having a direct connection from northwest Europe to the US in May 2005 (Munich, Minneapolis, for example). Tertiary airports are all other airports.

DIRECT AND INDIRECT CONNECTIVITY

Recovery and stabilisation

The total number of direct flights between northwest Europe and the US increased about 21 percent between May 2003 and May 2005 (Table 2). For a large part, this growth took place between 2003 and 2004 (+17%). This period can be considered as a recovering period from the downturn after 9/11 and the economic recession. The period between 2004 and 2005 demonstrates lower growth rates (+4%), which is much closer to the long-term growth rates in international air transport. The same holds true for indirect connectivity (with a transfer at a hub). The number of indirect connections increased at a higher rate between 2003 and 2005 (+41%) than direct connectivity.

The highest growth percentages can be found at the only primary airport in the Benelux (Schiphol), both with respect to direct and indirect connectivity. The authors later show that this has been largely the consequence of the integration of KLM into the SkyTeam alliance after the Air France-KLM merger. The primary airport of the UK and Ireland region (London Heathrow) experienced modest growth levels in terms of the number of direct frequencies. This is partly the result of the capacity shortages at the airport. The crisis in the global air transport sector and the orientation of Heathrow towards North America had eased the capacity shortages at the airport. Not surprisingly, the number of flights increased between 2003 and 2004. Between 2004 and 2005, the growth percentages were again reduced to zero. No more flights could be accommodated at the airport. The growth in the number of indirect connections was mainly due to better/more connections via other hubs to the US.

In addition, Table 2 demonstrates the demand threshold, which airlines need in order to serve transatlantic routes. Only between primary/secondary European airports on the one hand and primary/secondary American airports on the other, demand levels are sufficiently large to justify direct connections. Tertiary European airports depend on European hub airports for their connections to the US.

Table 2. Direct and indirect connectivity units (CNU) from primary, secondary and tertiary airports in northwest Europe to the US, 2003-2005[1]

		CNU		% growth					
		2003	**2003**	**2003-2004**		**2004-2005**		**2003-2005**	
Initial origin	Type of origin	Direct	Indirect	Direct	Indirect	Direct	Indirect	Direct	Indirect
Benelux	primary (AMS)	185	2790	14	78	8	17	24	109
	secondary	43	1296	10	10	1	6	11	17
	tertiary	.	150		39		28		78
UK and Ireland	primary (LHR)	501	3698	14	37	0	1	14	38
	secondary	354	7245	17	30	9	10	28	43
	tertiary	.	605		21		8		30
France	primary (CDG)	257	4662	18	30	3	5	22	36
	secondary	9	1324	-19	12	0	16	-19	29
	tertiary	.	501		10		19		31
Germany	primary (FRA)	267	5144	18	28	1	3	20	32
	secondary	81	4819	36	33	7	-1	46	31
	tertiary	.	1355		7		12		19
Total		**1696**	**33590**	**17**	**32**	**4**	**7**	**21**	**41**

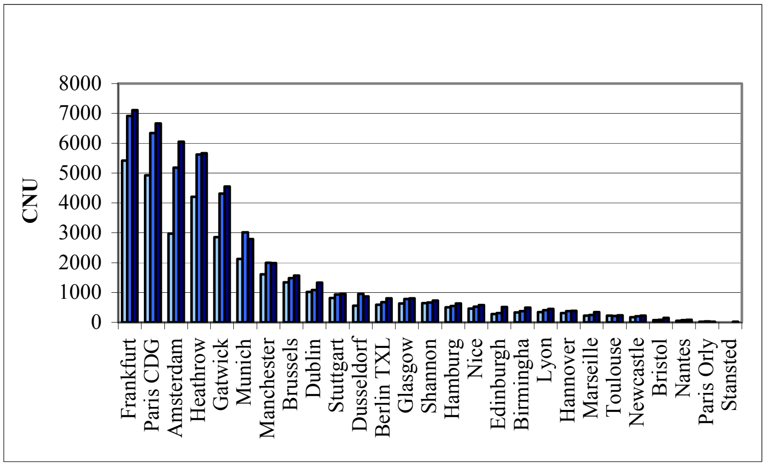
Source: OAG (2005); own calculations

Changing connectivity levels of European Airports

To what extent did the position of individual European airports change with respect direct and indirect connectivity levels? Figure 1 shows some remarkable changes between 2003 and 2005.

First, the primary and secondary airports show a recovery of the industry crisis between 2003 and 2004 (see also the previous section). Yet, at most of the European airports, growth rates were considerably lower between 2004 and 2005. Some airports even demonstrated negative growth rates, such as Munich, Manchester and Düsseldorf.

Figure 1. Total connectivity (direct + indirect) from primary and secondary NW-European airports, 2003-2005



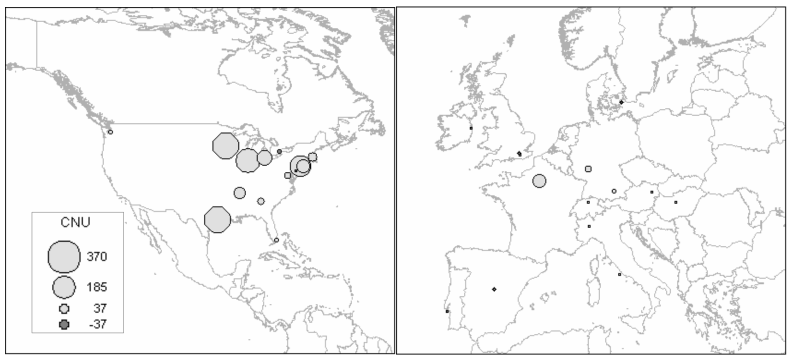
Source: OAG (2005); own calculations

Secondly, Amsterdam Schiphol is an exception to the more modest growth rates in the 2004-2005 period. How can we understand the continued growth at Schiphol? The explanation for this observation can be found in the Air France-KLM merger and the entry of KLM to the SkyTeam alliance. In 2003, KLM was still part of the Wings alliance (KLM/Northwest). Indirect connections to the US were primarily generated by the Wings alliance via the Northwest hubs in the US (Detroit, Minneapolis and Memphis) and to a lesser extent by other alliances. Our NETSCAN model did not consider connections between, for example, KLM and Delta as viable connections since both carriers did not belong to the same alliance in 2003.

The entry of Northwest and KLM to the SkyTeam alliance resulted in an integration of the Wings and SkyTeam networks. From 2004 on, the NETSCAN model considers the connections between, for example, the KLM and Delta flights at Schiphol, as online, viable connections. As Figure 2a illustrates for Amsterdam, the impact of the network integration between 2003 and 2004 is substantial. A good example is Houston. In 2003, the KLM flights to Houston did not connect to the domestic flights of Continental. From 2004 on (due to the Air France-KLM merger and the integration of KLM into SkyTeam) the NETSCAN model considers these connections as online and thus viable connections. As a result, the number of connections from Amsterdam via Houston to the rest of the US increased substantially.

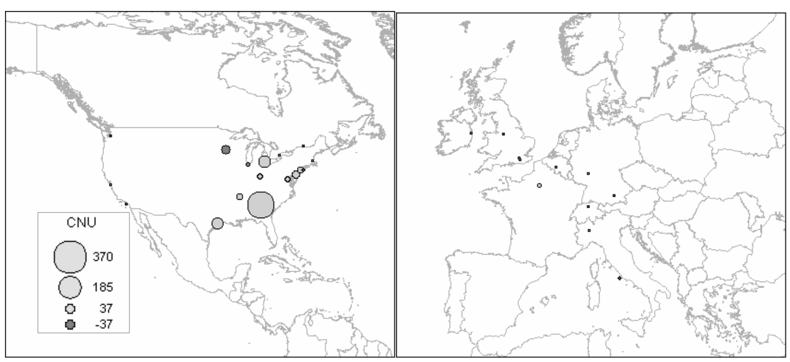
In addition, new services and frequencies between the US and Amsterdam were added against the background of the SkyTeam extension and the Air France-KLM merger. Delta Airlines, for example, started to operate a daily frequency between its Cincinnati hub and the new SkyTeam hub in Amsterdam during the period 2003 and 2004. The same holds true for the growth in frequencies between Amsterdam and Atlanta in 2005. KLM started a daily frequency to Atlanta in 2005, which brought the total SkyTeam frequency to a twice-daily level. Figure 2b shows that, as a result of the additional daily frequency, the indirect connectivity between Amsterdam and the US via Atlanta was boosted.

Figure 2a. Absolute growth of indirect connectivity (CNU) from Amsterdam via North-American and European hubs to the US, 2003-2004



Source: OAG (2005); own calculations

Figure 2b. Absolute growth of indirect connectivity (CNU) from Amsterdam via North-American and European hubs to the US, 2004-2005



Source: OAG (2005); own calculations

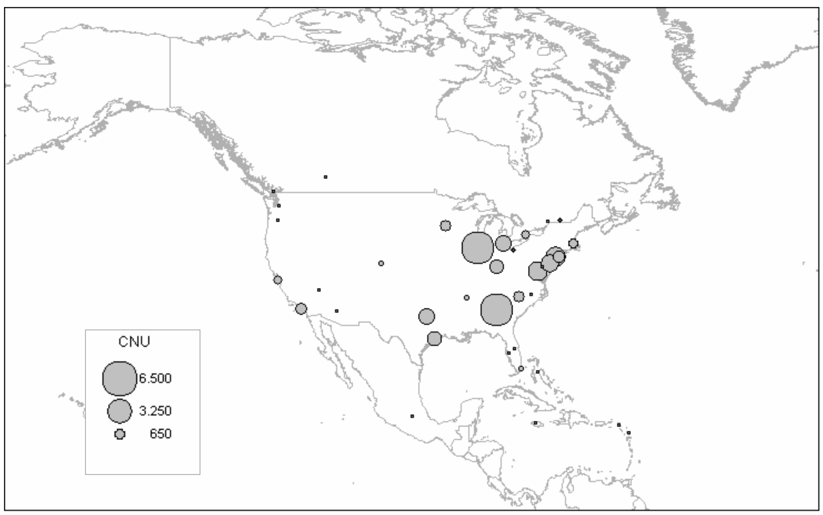
Finally, London Heathrow lost its third position to Amsterdam in the ranking of best-connected airports to the US (Figure 1). Whereas Amsterdam benefited from the integration of KLM into the Air France and SkyTeam network, Heathrow suffered from its capacity limitations. The capacity problems at Heathrow make it extremely difficult for the OneWorld and other alliances to increase frequencies or add new routes.

HUB CONNECTIVITY

The dominance of American hubs

Until now, we have only considered direct and indirect connectivity. These measures give a good indication of the direct and indirect service levels available at the respective airports to the consumers. However, they do not measure the competitive position of an airport in the connecting market. Hence, we have analysed the hub connectivity of airports in the transatlantic market.

Figure 3a. Hub connectivity on the market between NW-Europe and the US per hub in 2005, North-American hubs



Source: OAG (2005); own calculations

Figure 3b. Hub connectivity on the market between NW-Europe and the USA per hub in 2005, European hubs

Source: OAG (2005); own calculations

With regard to hub connectivity on the market between northwest Europe and the US, American airports have a dominant position (Figures 3a & b). Moreover, they have further strengthened their position between 2003 and 2005. In 2003, almost 65% of the hub connections were generated at American airports. In 2005, this percentage had increased to 69%. The share of northwest European airports in total hub connectivity decreased from 30% in 2003 to 27% in 2005. The dominance of American hubs is largely the consequence of the difference in market size between the US and northwest Europe. The number of tertiary airports in the US is much higher than the number of tertiary airports in northwest Europe. Since tertiary American airports are only served by American hubs and not by European airports, the hub connectivity of American airports is essentially larger than the hub connectivity of northwest European airports.

Chicago O'Hare and Atlanta can be considered as superhubs. The two hubs offered more hub connections than all northwest European hubs together. Both airports are the main home bases of large hub-and-spoke carriers and their alliance: Chicago for both American (OneWorld) and United (Star), Atlanta for Delta (SkyTeam). In addition to the superhubs, a group of second tier hubs can be identified, on both the European and

American side. In Europe, the primary airports London Heathrow, Frankfurt, Paris CDG and Amsterdam belong to this group of second tier airports. Further down the hierarchy, the only European airport that plays a substantial role in the connecting market is Lufthansa's secondary hub Munich. Other airports have too little direct flights to the US or are too decentrally located in a geographical sense (such as Madrid or Milan Malpensa) to be competitive in the hub market. London Gatwick was an important hub to the US during the nineties, but lost its position after British Airways decided to dehub Gatwick (Burghouwt, 2005).

On the American side, the number of second tier airports is larger. In particular, the airports that are a hub for SkyTeam are important second tier airports (Newark, Detroit, Cincinnati, and Houston). In addition, the Dallas DFW (OneWorld) and Washington Dulles and Philadelphia (Star) can be considered as second tier airports. The fact that the SkyTeam hubs seem to dominate the hub market is in line with the development of alliance market shares, which will be discussed in the next section.

Changing alliance patterns

The global airline alliances fully dominated the connecting market between northwest Europe and the US during the period of analysis. Only 1% of the hub connectivity was generated by airlines not belonging to a global airline alliance. SkyTeam had the largest share in the number of hub connections (CNUs) in 2004 and 2005, followed by Star and OneWorld. In addition, the share of SkyTeam increased from 30% in 2003 to 46% in 2005, because of the integration of the Wings networks (KLM/Northwest) into SkyTeam. Because of the integration, Star lost its first position in the hub market to SkyTeam. Because of the synergy effects due to network integration, the share of SkyTeam in 2004 (44%) was substantially larger than the sum of the market shares of Wings (9%) and SkyTeam (30%) in 2003.

American hubs dominate the market in all alliances. Within SkyTeam, the share of American hubs was 73% in 2005. Within the networks of all of the alliances, the share of European hubs decreased and the share of American hubs increased. The same holds true for all other alliances. A small percentage of the hub connectivity of the alliances is generated at hubs outside northwest Europe or the US. Examples of such hubs are Madrid (Oneworld), Mexico (SkyTeam) and Toronto Lester (Star).

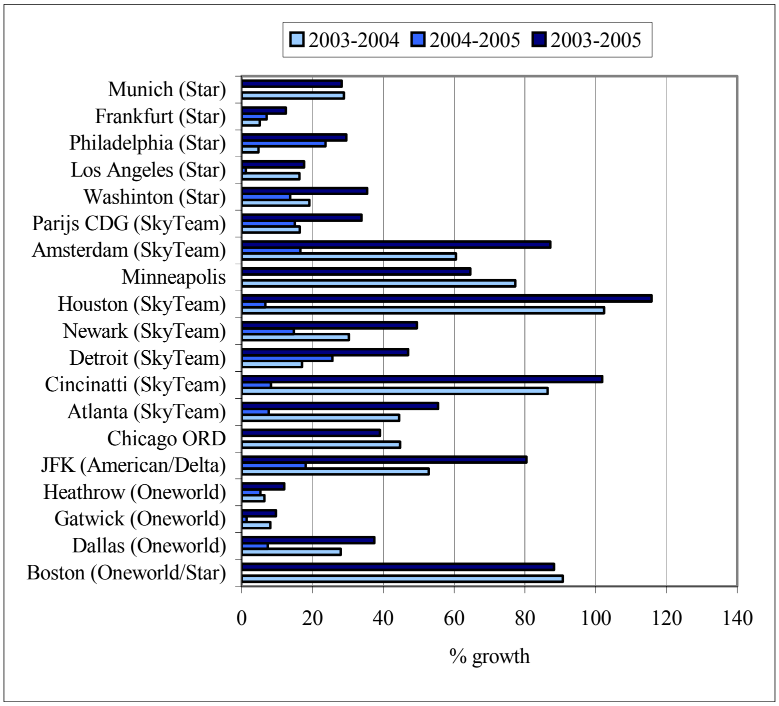
Table 3. Share of regions in total hub connectivity of alliance and share of alliance in total hub-connectivity, 2003-2005

			2003	2004	2005
% in total alliance	ONEWORLD	NW-Europe	34	30	31
		US	57	62	62
		Rest of the world	9	8	8
% in grand total			**23**	**21**	**20**
% in total alliance	SKY TEAM	NW-Europe	19	21	22
		US	74	73	73
		Rest of the world	7	6	5
% in grand total			**30**	**44**	**46**
% in total alliance	STAR	NW-Europe	30	27	28
		US	59	64	63
		Rest of the world	11	9	10
% in grand total			**36**	**34**	**33**
% in total alliance	WINGS	NW-Europe	34	--	--
		US	61	--	--
		Rest of the world	5	--	--
% in grand total			**9**	--	--
% in total alliance	NON-ALLIANCE	NW-Europe	0	0	0
		US	0	0	0
		Rest of the world	100	100	100
% in grand total			**1**	**1**	**1**

Source: OAG (2005); own calculations

Not surprisingly, the growth of European hubs has been on average lower than the growth of American hubs (Figure 4). In the US, Cincinnati, Houston, New York JFK, Minneapolis and Boston demonstrated high growth rates in particular. In Europe, only Amsterdam Schiphol experienced growth levels comparable to its American counterparts. In contrast to Frankfurt, Munich and Heathrow, this growth continued in between 2004 and 2005.

Figure 4. Percent growth in hub-connectivity, NW-Europe to US for selected airports, 2003-2005

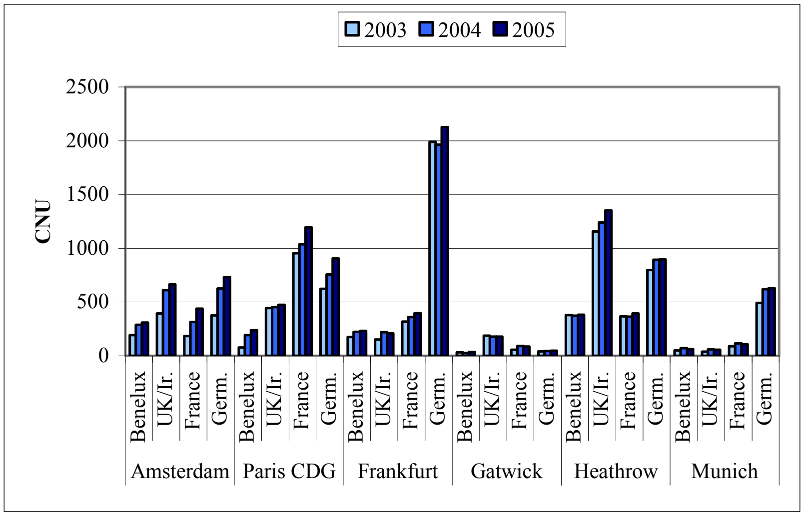


Source: OAG (2005); own calculations

Developments within alliances

As the authors showed earlier, growth at the SkyTeam hubs can be attributed largely to extension of the SkyTeam alliance and the growth of transatlantic frequencies to the European hubs Amsterdam Schiphol and Paris CDG. In addition, Air France-KLM increased feeder frequencies between Schiphol and the French hinterland. Paris CDG is more orientated towards France and Germany for attracting transfer passengers. There is a clear distinction in geographical market segmentation between the two hubs. Paris CDG's feeder network in northwest Europe is primarily located in France, whereas the feeder network of Amsterdam is more focused on the UK and has in general less CNUs per feeder airport (Figure 5 and Appendix).

Figure 5 Connectivity units between NW-European regions and the US via selected European hubs, 2003-2005



Source: OAG (2005); own calculations

Within the SkyTeam alliance, Minneapolis (Northwest) seems to start to play a less important role. Although the number of frequencies between European origins remained equal between 2004 and 2005, the hub connectivity of Minneapolis decreased because of fewer frequencies to the American domestic market. This conclusion is in line with the strategy of Northwest to convert Detroit into the primary intercontinental hub and to give Minneapolis a secondary, continental role. After the large-scale expansion of Detroit Metro, the airport is much better equipped to facilitate and the hub system of Northwest, which requires high peak-hour capacity and short connecting times.

The Star alliance has two primary European hubs for the market between northwest Europe and the US: Frankfurt and Munich. The secondary hub of Star, Copenhagen, only plays a marginal role for the market under consideration. At Frankfurt, growth percentages were moderate due to severe capacity restrictions at the airport. In contrast to Amsterdam, Paris CDG and Heathrow, both hubs are largely orientated towards the large German domestic market for attracting feeder traffic (see Appendix). In 2005, the percentage of hub connections with a German origin was 72% at Frankfurt and 74% at Munich. In comparison, for Amsterdam, the percentage of hub connections originating in Benelux was only 14%, for Paris CDG (French origins) 43% and for Heathrow (UK/Ireland origins)

45% (see Appendix). Outside Germany, there are not many airports in northwest Europe used as feeder airports by Frankfurt and Munich.

Finally, OneWorld has little opportunities to grow on the northern part of the transatlantic market as far as London Heathrow is concerned. Heathrow is capacity restricted while the Gatwick hub strategy did not prove to be a success at the end of the 1990s. As the Appendix shows, connectivity is mostly generated at the large British and European airports. On the American side, Chicago O'Hare saw its position as a hub decline to some extent between 2004 and 2005. Chicago is a dual hub of both American (OneWorld) and United (Star). Possibly, the implementation of the rolling hub concept by American may be the cause of the slightly declining hub position between 2004 and 2005. American depeaked its hub operation in order to ease congestion problems at the airport. Depeaking might have had a negative impact on connectivity levels at O'Hare.

Some first evidence on concentration levels after the Air France/KLM merger

Until now, the impact of the Air France-KLM merger and the integration of Wings into SkyTeam seem to have had only positive network impacts. But what about the impact of these developments on market concentration levels at the transatlantic market? The number of global airline alliances decreased from four to three.

Although market concentration is somewhat outside the scope of the paper, the results of our model allow us to compute average market concentration levels in terms of the Hirschman-Herfindahl Index[1] (HHI) at the route level. Figure 6 shows the average HHI between 2003 and 2005 for a selection of European airports. The HHI was defined at the airport-pair level. Input for the HHI is the share of an alliance in the total number of direct and indirect connectivity units per airport pair.

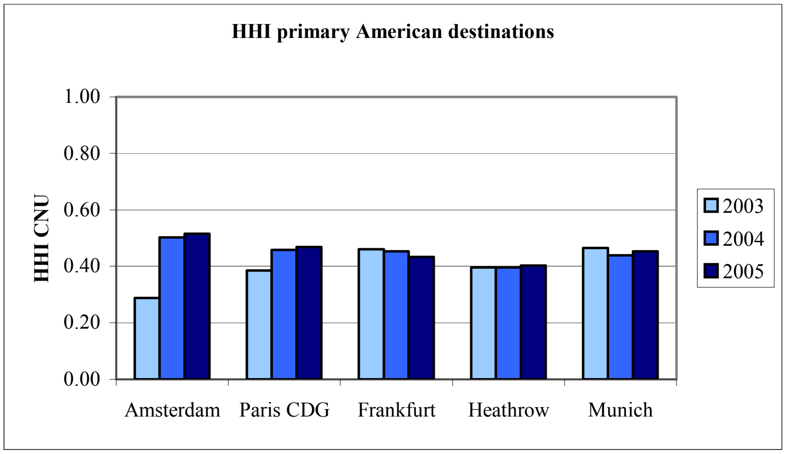
The Air France-KLM merger and the integration of Wings into SkyTeam have had a market concentration increasing impact. Both at Amsterdam and Paris CDG, concentration levels increased substantially. This conclusion holds for all route types, but is stronger for primary and secondary American destinations than for tertiary destinations. However, concentration levels at the (thin) tertiary destinations were already high in 2003. In addition, the concentration increasing effects are larger for Amsterdam than for Paris CDG. At the same time, concentration levels at three other major northwest European airports remained virtually stable between 2003 and 2005.

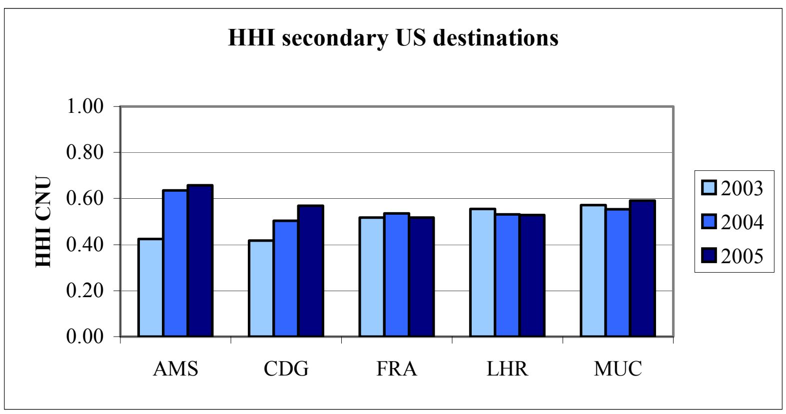
Increasing concentration levels generally allow airlines to set higher fares (see for example, Borenstein, 1992). Hence, evaluation of the consumer

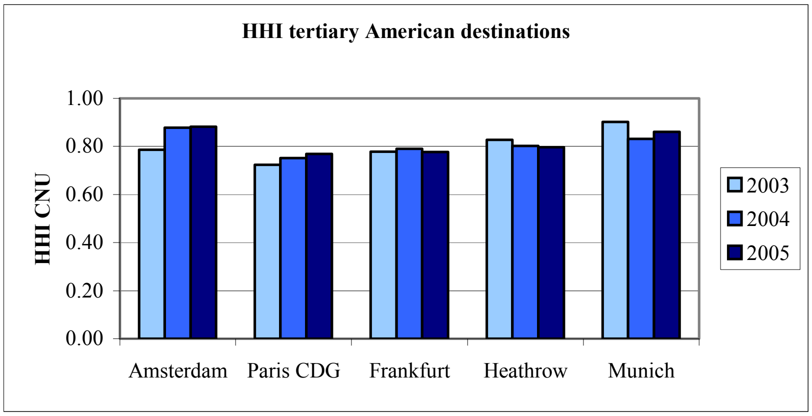
[1] Sum of squared market shares.

welfare impacts of the Air France-KLM will have to take into account both the positive impacts of the enlargement of the network scope as well as potential impacts on airfares. Yet, this issue is outside the scope of this paper and should be dealt with in future research.

Figure 6. Average Hirschman-Herfindahl Index (HHI) per airport pair between selected European airports and primary, secondary and tertiary US destinations, 2003-2005







Source: OAG (2005); own calculations

CONCLUSIONS

In this paper, the authors argued that the measurement of network performance in hub-and-spoke systems should take into account the quantity and quality of both direct and indirect connections. The NETSCAN model quantifies the potential direct and indirect connectivity and scales the quality of these connections to the quality of a theoretical direct connection. As a result, direct and indirect connections (via hubs) are additive and can be compared. NETSCAN allows for an integrated analysis of the competitive position of airline/alliance networks, airports and regions.

The authors applied NETSCAN to the network between northwest Europe and the US between 2003 and 2005. One of the most striking developments has certainly been the impact of the Air France-KLM merger on the competitive position of Amsterdam Schiphol and the SkyTeam alliance in general. Both the number of direct and indirect travel opportunities for the passengers travelling from and via Schiphol increased at a higher rate than at the neighbouring European hub airports. On the one hand, the integration of Wings into SkyTeam resulted in a substantial increase in connecting opportunities at the hubs of the extended SkyTeam alliance. On the other hand, frequencies between Amsterdam and the new SkyTeam hubs as well as French secondary airports were increased and new services were initiated.

Yet, the paper has also demonstrated some first signs of the potential impact of the Air France-KLM merger and the integration of Wings into SkyTeam on concentration levels in the transatlantic market. In particular, at the routes between Amsterdam/Paris and the primary and secondary American destinations, average concentration levels increased substantially.

In contrast, concentration levels between some other large European airports and the US remained virtually unchanged. Increasing concentration levels might eventually result in higher airfares for consumers. The positive welfare effects of the Air France-KLM merger in terms of a large network scope will have to be evaluated against potential upward effects on fare levels. Yet, this issue will have to be addressed in future research.

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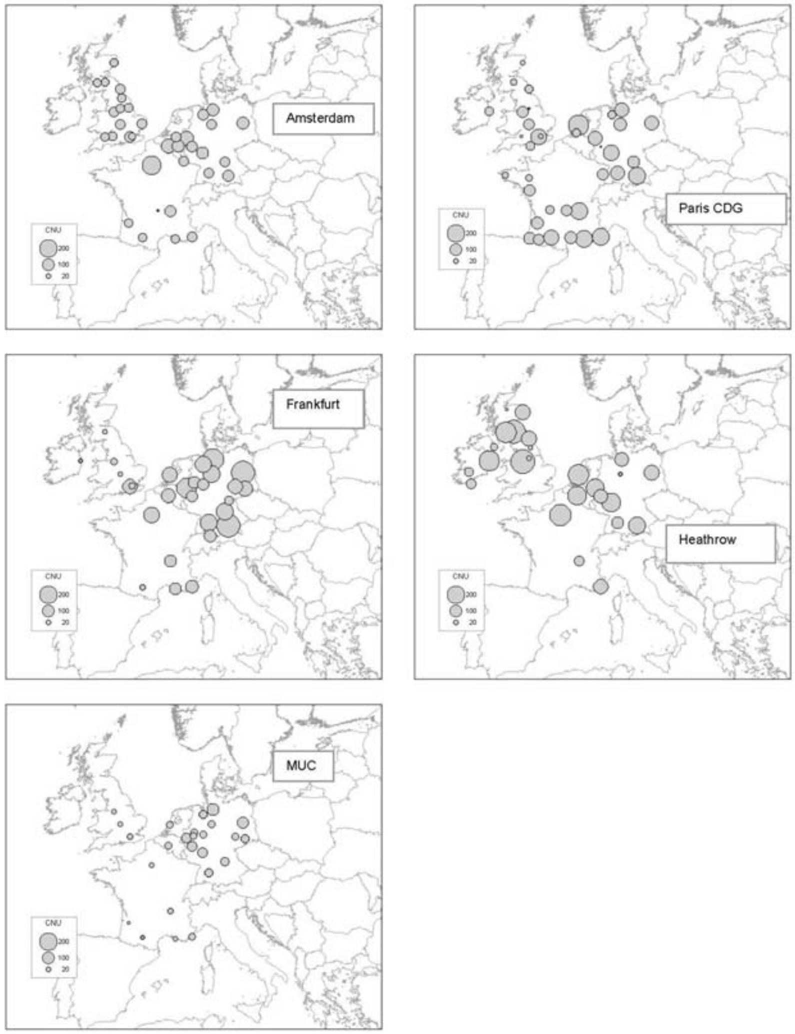
APPENDIX

Annex A Indirect connectivity (CNU per week) of Northwest-European airports via selected, major European airports, 2005



Source: OAG (2005); own calculations

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