FORMULATION OF A METHOD TO ASSESS TECHNOLOGIES FOR THE IMPROVEMENT OF AIRPORT CAPACITY

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ABSTRACT

Commercial air transportation growth and airline deregulation in recent years have resulted in traffic volume beyond the capacity of existing airports and air traffic control. This excess traffic often results in delays and the subsequent revenue loss for airline operators. Therefore, a number of initiatives to improve airport capacity and throughput have been proposed. These initiatives include a wide variety of technologies ranging from runway independent vehicles to vortex sensing systems. However, in order to assess the impact of these technologies on commercial air traffic one must move beyond the vehicle to a system-of-systems point of view.

The technologies proposed for the improvement of airport capacity require a modeling and simulation environment that can account for an airline's flight network as well as a fleet composed of various aircraft types. The Aviation Systems Analysis Capability (ASAC) model, developed by the Logistics Management Institute under a NASA contract, may be viewed as the foundation for such an environment.

However, a complete technology evaluation environment must not stop at a fleet analysis, other aspects of technology infusion must also be addressed. First, the impact of these technologies on the aircraft performance must be assessed. Second, the ability to calculate the cost of implementing the technologies, both within the aircraft cockpit and in ground facilities, must be developed. In addition, the effect of these technologies, and the resulting timesavings, on the airline's indirect cost will be of utmost interest. Finally, the impact on the safety of the flight environment deserves careful analysis.

This paper identifies the different models that may be used for a comprehensive, systematic evaluation of aircraft, fleet, safety and cost, as well as the issues involved in their integration. Furthermore, an outline of a probabilistic technology evaluation methodology is presented as a potential approach to the problem at hand once a complete model of the airspace system has been developed.

The goal of this methodology, currently under development, is to analyze an entire aircraft fleet from a probabilistic point of view, taking into account safety and cost issues, as well as allowing for the infusion of new technologies. This will ultimately result in a dynamic what-if environment to aid decision-makers, as well as a means to quantify the risk and uncertainty associated with the application of new technologies including technology readiness levels, and other factors beyond the designers control.

INTRODUCTION

Air traffic demand has been growing at a steady pace in recent years. The current fleet is three times larger than it was twenty years ago, and it is expected to continue expanding in order to accommodate the forecasted 5% annual growth in passenger demand. Unfortunately, the infrastructure required to support the commercial air system is being outpaced by the current market growth with the subsequent degradation in on-time performance. The tendency to use smaller aircraft to provide a larger selection of departure times only contributes to strain capacity further resulting in some of the worst delays since the eighties. In the near future, the ability of air carriers to meet demand, and avoid lost revenues will be severely limited by the adequacy of airports and air traffic management [1, 2].

Several approaches have been proposed to increase the capacity of the air space system. Airlines, for instance, could change operating procedures, moving away from hub-and-spoke systems and concentrated departures at two or three times in the day. Regulation changes could also be proposed allowing pilots to maintain their own safety separation with other aircraft in proposed free-flight environments. Other potential remedies include decision support tools which are being developed to ease controller workloads both en-route and at airports, as well as new high capacity and runway independent aircraft which are now on the drawing board. All of these approaches show promise for significant benefits, but due to the risks involved, are in need of credible, quantitative (if possible) models to analyze aircraft and forecast technology impacts from a fleet perspective, including performance, economics and safety. This paper is intended to describe the issues involved in the development of such a model, as well as the methodology to support it.

APPROACH

In order to model the effect of aircraft and infrastructure technologies on throughput and capacity, four major modeling areas must be addressed: First, the aircraft performance including fuel burn, flight speeds, optimal cruise altitudes, etc… Second, the infrastructure and existing fleet since the aircraft will have to operate within this environment and the impacts of certain technologies will only be fully realized through this type of analysis. Third, the costs incurred by aircraft manufacturers, air carriers, airports, and everyone else involved. This is particularly important in accounting for the potential financial drawbacks of proposed technologies. And finally, safety which is of utmost concern and is becoming the most significant driver in decision making. A quantitative assessment of safety will be especially challenging when considering transitions to new air traffic management approaches, and in analyzing fleets with partial technology penetration.

Integration of the four modeling areas mentioned above is also essential since they are not mutually independent although they are often treated as such. The aircraft performance directly affects cost through fuel burn rates, number of passengers carried and distance flown. The fleet and the aircraft are deeply intertwined. The aircraft must adapt to the existing infrastructure which in turn is dependent on the aircraft of which it is composed. The limitation of airspace capacity combined with a growing fleet can have a marked impact on costs through accumulated delays. Furthermore, safety is often compromised when airport capacities are exceeded, and it is of course directly linked to the aircraft performance. Safety, costs and delays directly affect air travel demand, and indirectly the need for new aircraft. All of these effects must be considered jointly in the model to be created due to their interactions.

Furthermore, the analysis carried out once this model is fully developed must be of a probabilistic nature. This need for a probabilistic approach is prompted by the uncertainty inherent in the operating conditions encountered, as well as assumptions made in the technology effects, and in the fidelity of the constituent codes employed. Only such an analysis would capture the risk associated with the technologies proposed. This imposes additional requirements on the model developed such as ease of automation, streamlined calculations, transparency, and an efficient exchange of information.

Aircraft Performance Model

An aircraft sizing and synthesis code can be used to generate basic data on the performance of a particular design. This will enable the modeling of existing, derivative and new designs as well as the effects of certain technologies on aircraft operation and affordability. The code chosen for this purpose must have the ability to calculate certain parameters beyond basic aircraft performance. Since, emphasis is being placed on the integration of this aircraft within the existing fleet and infrastructure, a detailed take-off and landing analysis, and a means to analyze noise footprint concerns are necessary.

One of the potential codes for this purpose is FLOPS (FLight OPtimization System)[3]. This government owned “public domain” code originally developed by NASA is the premier sizing and synthesis code in existence today in the US. The code is capable of “scaling”, sizing a given configuration in terms of geometry, weights and propulsion requirements for a specified mission. It also employs a take-off and landing module that accounts for all pertinent system-level FAA imposed requirements for certification. A noise footprint module also exists to account for the concerns of communities in the vicinity of busy airports. Furthermore, FLOPS has been modified at the Aerospace Systems Design Laboratory in order to model technology effects at the conceptual design level through the use of technology dials referred to as “Kappa factors”. These Kappa factors represent a percent increase or decrease in a particular performance measure, enabling the decision-maker to create a generic technology impact forecasting environment. This environment may be used either as a means to model a particular technology, or as a reverse engineering method. In the latter case, the necessary performance levels are specified and technologies that may cause these desired effects are sought based on a dynamic “what-if” environment which allows for rapid evaluation of performance and economic attributes as a function of the technology dials. In both cases due consideration must be given to the fact that these technologies are often not fully proven when they are first implemented, therefore their effects are often charged with uncertainty warranting a probabilistic methodology. This formulation and approach are based on a probabilistic technology modeling methodology called Technology Identification, Evaluation and Selection (TIES). This method is described in numerous publications [4, 5, 6, 7 & 8] and is briefly presented in the methodology section below for completeness sake.

Sizing codes have been found to be self-sufficient for modeling and forecasting the impact of aircraft related technologies on system performance. However, cases have been encountered where infrastructure or operations related technologies were proposed which, when modeled this way, had negligible or even adverse effects on the system. This is due to the fact that the potential benefits from these technologies affect attributes not captured by these models. In order for these effects to be measured and traded-off a system-of-systems viewpoint must be taken.

Fleet and Airspace Model

A model of the fleet and airspace is essential when investigating potential technologies from a system-of-systems point of view. The airspace represents the environment the aircraft will have to operate within. Therefore, although a technology may have a beneficial impact on aircraft performance it may cause problems when air traffic operations are considered, diminishing its returns or even rendering the technology unacceptable. For example, consider a very large aircraft, a new concept that can itself be considered a 'technology'. This aircraft may offer great returns to the airline operating it due to its large capacity, but it may not be compatible with the existing infrastructure at a busy airport where the capacity was needed. Alternatively, an aircraft technology may be proposed that impacts aircraft performance adversely through increased weight or costs, but that may make bad weather landing operations possible. Such a technology will not receive due consideration unless a fleet perspective is taken.

In order to remedy the ever-growing delays at congested airports, infrastructure technologies are also under consideration. Whether they aim to aid controllers in their decisions, or to transfer safety responsibilities to the pilots, these technologies cannot be analyzed without a reliable model of the fleet and airspace. A means to calculate metrics such as air travel demand in terms of Revenue Passenger Miles (RPM), fleet size, or expected delays is necessary.

Ongoing work at the Logistics Management Institute (LMI), under a contract by NASA, has resulted in a number of models, grouped under the name of ASAC (Air System Capability Analysis), that aim to represent the U. S. national airspace. ASAC approaches fleet modeling in a number of different ways. The Air Carrier Investment Model attempts to balance airline costs and passenger demand to determine the number of new aircraft that will be required to meet demand within budget limitations. It further projects the impact that these new aircraft orders will have on the U.S. economy [9]. The LMI Net models the entire airspace, both at the airports and en-route to estimate the effects of certain controller support decision tools on overall delays [10]. The Flight Segment Cost model links delays to airline costs on a rudimentary level and considers the effect of winds aloft on aircraft required to follow controller defined paths [11]. This is particularly useful when considering the potential cost/time savings of a free flight environment. A number of these models can also be connected to each other through the Executive Assistant also developed by LMI [12]. The LMI models consider the uncertainty associated with some of their required inputs by considering both a mean value and a standard deviation. However, a number of other inputs such as fuel price or labor rates could also be treated probabilistically since their values are market driven. Furthermore, the responses calculated by these models are deterministic, a single value is provided, rather than attaching a probability or a tolerance margin to each result produced. Probabilistic outputs would be more realistic when accounting for the variability of the inputs and the approximations required to build the model. Currently the ASAC models do not have a strong link to the aircraft being flown, and cannot model the effect air traffic management technologies could have on the aircraft utilizing that environment. Furthermore, the costs of implementing airspace technologies cannot be completely quantified with the LMI models, and only a portion of the benefits can be accurately reflected. This prompts the development and/or linking of additional cost models.

Cost Models

Affordability has come to the forefront of aerospace research in recent years due to budget cuts and an increasingly competitive market. It is the economic impact of growing delays that has prompted a closer look at fleet oriented technologies, and it will be the investment required to implement these technologies that ultimately determines their success. Thus, a thorough economic analysis is an integral part of a technology assessment, whether that technology is intended to improve aircraft performance, or airspace system effectiveness.

An aircraft life cycle cost or total ownership cost approach is necessary when dealing with the aircraft and its operational environment. Development and production costs will be affected by any technology that is placed in a new aircraft. Retrofitting costs will involve not only the cost of the new equipment, but also the revenue lost while the aircraft is grounded to install the new equipment. On the other hand, delays are very costly to the airline, not only due to additional labor and fuel costs, but also in terms of customer satisfaction; therefore, the savings in this area thanks to new technologies may offset the increased costs elsewhere.

ALCCA (aircraft Life Cycle Cost Analysis), originally developed at NASA and later modified at the Aerospace Systems Design Laboratory, contains a number of capabilities that make it a candidate for technology modeling [13, 14]. The original RDT&E costs within this model have been enhanced with a detailed module that breaks down the activities involved in an RDT&E program and calculated costs for each activity independently. This detailed module also has the capability of calculating software engineering costs which will be of particular importance when considering avionics technologies. Another feature that makes ALCCA particularly attractive for a system-of-systems analysis is the revenue loss module developed at ASDL [15]. This module based on airline data calculates the costs of a delay including flight and hotel vouchers as the delays exceed certain lengths, furthermore, this module can estimate the revenue lost while an aircraft is grounded for retrofitting of equipment or major overhauls.

Another aspect to be considered when taking a fleet perspective is the costs related to the infrastructure. The authors are currently researching available data for the creation of such a model which would be essential if all the potential benefits and drawbacks of technology implementation are to be assessed. Metrics such as controller labor or runway enhancement costs would be of interest. It should be noted that these infrastructure costs affect the airports and air traffic control, whereas the economical benefits mainly impact the airlines whose delays are diminished. However, costs and delays are not the only concern with overcrowded airports and overtaxed controllers. Safety may be compromised by such situations prompting the use of certain technologies in spite of their economic drawbacks. Therefore, a model of the airspace system would not be complete without a safety assessment.

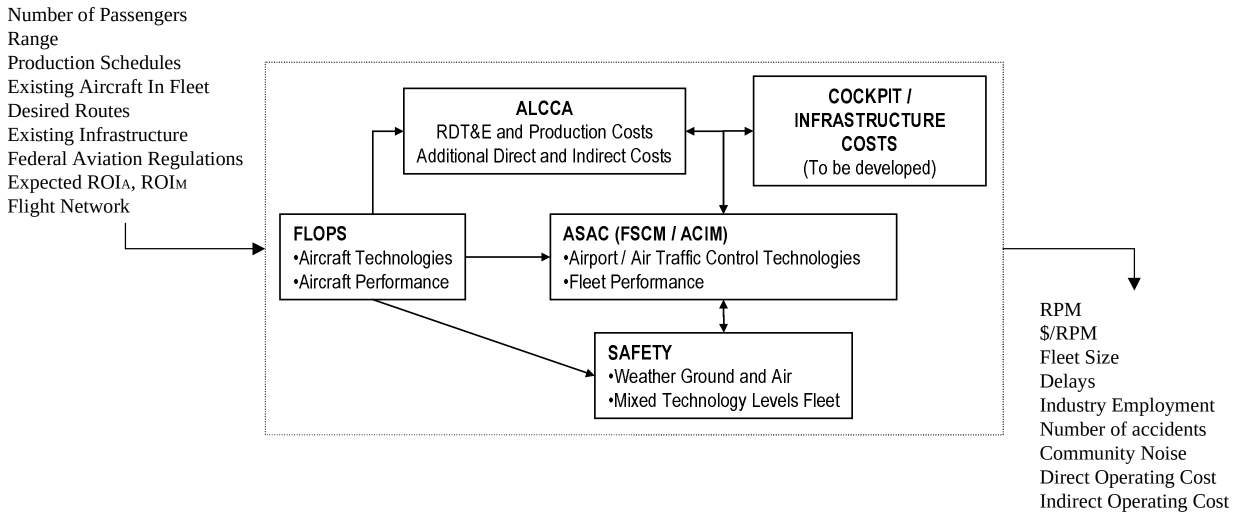
Safety

NASA and the FAA have been working jointly on the development of several technologies to improve safety in low visibility situations and to determine what is a safe separation between landing/departing aircraft under the Terminal Area Productivity Program. LMI has developed a model to capture the effects of certain technologies. And a model based on fuzzy logic which includes a pilot in the loop is currently in use at ASDL. However, further development and validation efforts must be accomplished in this area in order to obtain a reliable forecast of accident rates.

MODEL DEVELOPMENT

The airspace system has a number of components that need to be considered, namely: The aircraft, the fleet/infrastructure, costs and safety. Potential models have been identified for each of these fields; however, these models cannot be treated independently. The numerous interactions between these models must be identified and implemented. Figure 1 shows a schematic of the relationship between the models, and a description how these models relate to each other follows.

Figure 1: Proposed System Infrastructure



The need for a link between the aircraft performance and the life cycle cost of the aircraft has been recognized for quite some time now and a direct link between FLOPS and ALCCA has been implemented at ASDL. This link allows for the transfer of information such as number of passengers, fuel required, cruise speed, mission segment specifics and altitude, as well as aircraft component weights from FLOPS to ALCCA.

A translator between the FLOPS output and the ASAC Flight Segment Cost Model has been generated following the procedure outlined in reference 11. This link involves searching the FLOPS output file for the fuel burn rates at the different phases of flight, cruise altitude and speed, gross weight and empty weight and generating an input file in the proper units for the Flight Segment Cost Model (FCSM). The FSCM then uses this data to calculate the time and fuel spent due to delays at the airport, and due to the predominant winds along the route flown.

The link between the cost model and the fleet model is slightly more complex. ALCCA has the capability of calculating production costs given certain assumptions about the number of aircraft to be produced. These costs are then directly related to how many aircraft the airlines will be able to purchase given the demand for air travel and the ticket revenues obtained. Thus, a more expensive aircraft may result in fewer aircraft being purchased, air travel demand not being met, revenue being lost by the airline and even fewer aircraft being purchased. If the demand for new aircraft is reduced to the extreme, the manufacturer may be forced to recur to layoffs affecting the economy, which directly affects air travel demand. Thus, the link between manufacturer costs, aircraft needed to meet air travel demand (as forecasted by ASAC's Air Carrier Investment Module), and airline revenues is essential. Furthermore, the delays in terms of time and fuel calculated within ASAC's LMI Net and Flight Segment Cost Model can be translated to costs not only through the ASAC Cost Translator, but also with the use of the Revenue Loss module within ALCCA.

The link between the safety model and the aircraft performance is obvious from the point of view that the aircraft configuration will determine both its maneuverability, and the safety distance that other aircraft must observe with respect to it. This safety module also has a direct influence on the ASAC delay estimates since these are greatly affected by aircraft separation distances and the limitation on arrivals and departures during low visibility operations.

These links could be implemented either in a direct fashion where the models are linked together at the code level, or through an integration environment such as IMAGE (Integration Modeling and Analysis Graphical Environment) [17]. Alternatively, if a faster high level analysis is required these models can be replaced by Response Surface Equations (RSE's)[18], quadratic polynomial approximations of the form

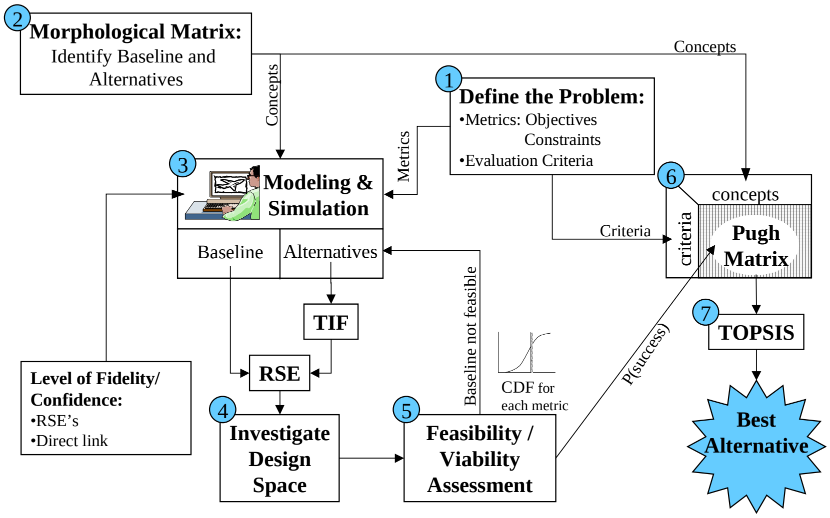
$$Metric = b_0 + \sum_{i=1}^{n} b_i x_i + \sum_{i=1}^{n} b_{ii} x_i^2 + \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} b_{ij} x_i x_j$$

These RSE's can then be used in conjunction with a Monte Carlo simulation to generate probability distributions for the metrics of interest according to the uncertainties associated with the parameters considered [19]. For a more in depth analysis where all potential sources of uncertainty must be addressed, fast probability integration techniques such as those available within FPI [20] can be used to generate an approximation of the metric probability distributions using the models directly.

PROBABILISTIC TECHNOLOGY ANALYSIS METHODOLOGY

The development of a suitable airspace/fleet modeling and simulation environment is only the first step toward analyzing the potential of certain technologies to solve the delay problem that is presenting itself due to lack of airport capacity. A methodology to identify and evaluate these potential technologies in a structured manner is also necessary. The proposed technique is similar to the TIES methodology described in references 4, 5, 6, 7, & 8 and outlined in Figure 2.

Figure 2: Technology Identification, Evaluation and Selection (TIES) Methodology [5]



The first step would involve defining the problem in terms of identifying the responses of interest and the most influential factors for them. The responses will ultimately determine whether the design or technology is worthwhile. The factors will guide us in identifying those technologies that would most impact these input parameters and the resulting responses. In this case potential responses would be total block time and fuel including delays, manufacturer production costs, fleet size, airline operating costs, number of arrivals and departures possible within a certain margin of safety, accident rates, and the ability of the aircraft to perform its intended mission in terms of payload and range. The identification of a baseline (no technology) and potential technology alternatives that will result in fewer delays would be the next step, the technologies to be considered involve a mix of aircraft, airport and air traffic control technologies, and their mutual compatibilities must be investigated. The third step denominated modeling and simulation involves the development of a credible model that can represent the benefits and drawback of all technologies to be considered in a probabilistic manner. An approach to create such a model for the airspace system is described in the previous sections of this paper. These first three steps set up the problem and a means to analyze it, and have received considerable thought thus far. The next four steps involve detailed analysis and rely on the availability of a model; thus, they have not been addressed yet.

As an example, the steps in this methodology will be notionally applied to one of the models within ASAC, the Flight Segment Cost Model (FCSM).

Step 1: Define the problem

This step involves understanding what limitations and expectations a potential customer would impose on the system being studied. These desires and requirements are then translated into metrics that will measure the customer satisfaction and targets and constraints that must be met.

In this case metrics such as Revenue Passenger Miles (RPM), total block time and fuel for a flight segment, the delays accumulated, and the resulting costs and revenues might capture the interests of a given airline. Furthermore, limits might be placed on the length of a delay in order to avoid customer dissatisfaction, and the costs due to delays that are acceptable before the airline is forced to cancel operations must be determined.

Step 2: Identify baseline and alternatives

The baseline in this case would be the current situation at a particular airport. Potential alternatives would include a vortex sensing system to set safety buffer zones that are no larger than the vortices shed require, a synthetic vision cockpit for low visibility operations, and a surface movement decision support tool for controllers, or a combination thereof. These would have to be translated into potential benefits and drawbacks. For example, the vortex sensing system would reduce the distance needed between approaching aircraft, which is one of the inputs for the FCSM. However, it will also have a negative impact in airline costs through the additional cost of enabling the aircraft to operate with such a system. Additionally, technologies related to the aircraft such as improved engines or drag reducing techniques can be considered in terms of their effects on fuel consumption and flight speed.

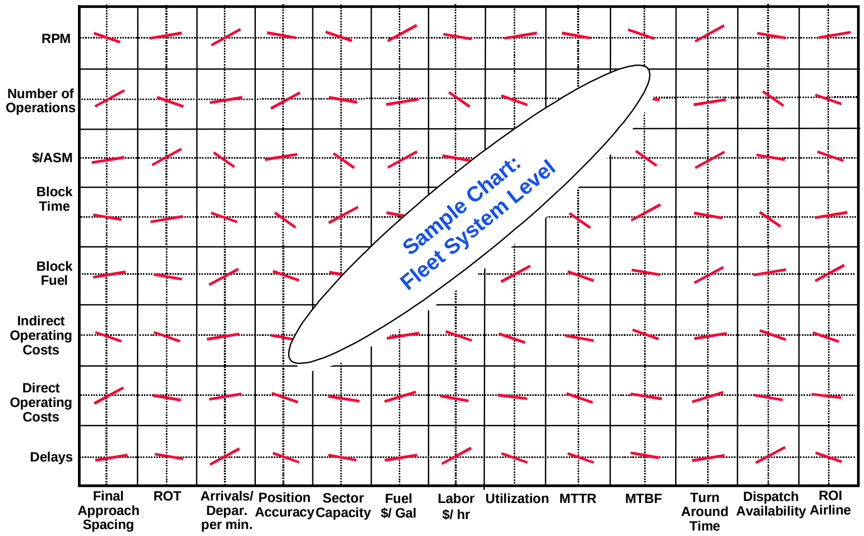
Step 3: Modeling and Simulation

The FCSM model has the ability to calculate the desired metrics and the technology effects being considered insofar as it considers the type of aircraft being flown and the environment that surrounds it at origin and destination airports. Therefore, this model combined with statistical techniques such as Response Surfaces and Monte Carlo simulation, to allow for probabilistic inputs and outputs could make up the modeling and simulation environment. Alternatively, if the decision-maker desires a more in depth analysis tracking all potential sources of uncertainty, fast probability integration techniques, such as those implemented in FPI [20], can be used to approximate the metric probability distributions.

Step 4: Design Space Exploration

This step involves the creation of a metamodel of the FSCM. This metamodel is obtained by varying the most influential inputs to the model according to a design of experiments and analyzing the results through Analysis of Variance. If the number of inputs to the model is too large and the expertise to identify the most influential factors is not immediately available, a screening test also employing design of experiments and ANOVA techniques can be used to identify the main factors [18, 19]. This analysis results in a quadratic approximation of the metrics chosen that will change parametrically as the inputs vary. A dynamic what-if environment, called a prediction profile, can then be created using the statistical package JMP [21]. This environment represents the sensitivity of the model to the inputs chosen, see Figure 3 for a notional example of such an environment.

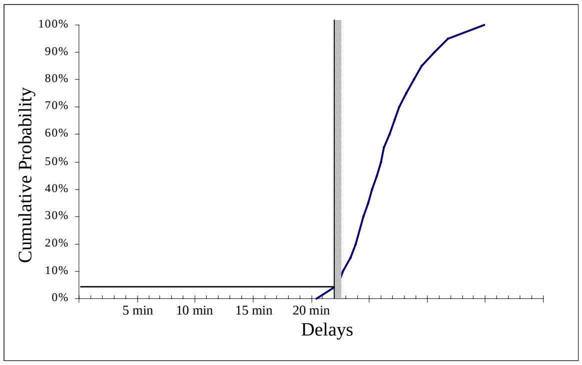
Figure 3: Notional system prediction profile



Step 5: System Feasibility and Viability

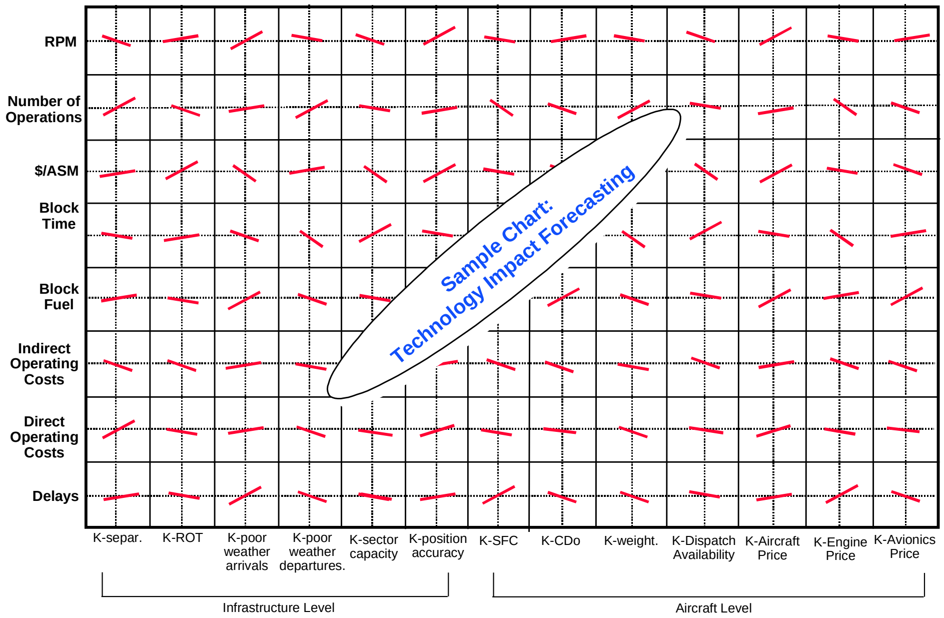
Once a metamodel of the design space has been created, a Monte Carlo simulation can be run using a package such as Crystal Ball [22]. This will use a random number generator to produce varying inputs according to a specified probability distribution. The output for each set of inputs is collected and a histogram of the results is created. This yields a probability distribution for each metric under consideration. If the metrics will not meet the targets or constraints defined in step 1 with a high degree of probability, technology infusion is warranted. Figure 4 portrays such a situation where a desired target is not met with high confidence.

Figure 4: Metric and not-achieved target



If technology infusion is required, the expected impacts of each technology must be determined. A similar procedure is carried out, but in this case the inputs are fixed, and it is a series of kappa factors which represent technology impacts that are changing. Once again a series of prediction profiles is created which can also be used for reverse engineering. The k-factors can be changed until the desired metric values are achieved. These k-factor values represent the target changes that must be addressed through technology infusion. Figure 5 depicts an example of such a prediction profile.

Figure 5: Technology Impact Forecasting



Once this metamodel has been created a Monte Carlo simulation is run to assess the impact of each technology. Due to technology readiness issues, technological impacts are often not known with full certainty, therefore the expected impacts of each technology or technology combination are modeled as a probability distribution. The result, as before, is a probability distribution for each metric.

Step 6: Technology Evaluation

The cumulative probability distributions generated in the previous step are used to estimate the confidence of meeting the set targets each alternative will yield. This information is tabulated for each metric and each technology combination. The information collected can then be used to select the most promising technologies.

Step 7: Technology Selection

A multi-attribute decision-making technique can now be used to determine which technologies meet all desired targets with the highest degree of probability. A weighting of the different metrics according to their importance to the customer may also be useful.

CONCLUSIONS

The growing air travel market and limited airport capacity are causing increasing delays with the subsequent lost revenues and safety concerns. Technologies are being proposed to remedy this situation, however, a means to estimate their potential effects and associated risks is necessary. This paper introduces a technology evaluation methodology that takes into account uncertainty and risk. This methodology however relies on an integral model of the airspace system, the aircraft within it, the costs associated with its operation and the safety of the flying public. An approach and some candidate models for this task are discussed.

Additional work is required in the linking of the various models under consideration, and in creating a reliable estimate of infrastructure costs for the airport and air traffic control. Furthermore, the probabilistic methodology presented has been applied successfully at the aircraft level, but unforeseen issues may arise when applying it at the system of systems level.

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BIOGRAPHICAL SKETCH

Biographical Sketch for Elena Garcia

Ms. Garcia was born and raised in Madrid, Spain. In 1992 she came to the United States to study Aerospace Engineering seeking an environment more oriented to practical application than that existing in the Spanish university system. She graduated in 1996 from the University of Virginia with a B.S. in Aerospace Engineering. In the fall of 1996 she entered the aerospace engineering graduate program at the Georgia Institute of Technology and joined the Aerospace Systems Design Lab. In December of 1997 she received a M.S. degree in Aerospace Engineering and joined the Ph.D. program under the supervision of Dr. Dimitri Mavris. Her graduate research is focused in the cost estimation area as it relates to aircraft affordability. Her current research is approaching the affordability of commercial aircraft and applicable emerging technologies from a system-of-systems point of view.

Biographical Sketch for Dr. Dimitri Mavris

Education:

Georgia Institute of Technology	Aerospace Engineering	B.S. 1984
Georgia Institute of Technology	Aerospace Engineering	M.S. 1985
Georgia Institute of Technology	Aerospace Engineering	Ph.D., 1988
Georgia Institute of Technology	Design Methods/Advanced Concepts	Post Doctoral 1989-1992

Appointments:

- AIAA Aircraft Design Technical Committee Chair (2000 to 2002)

- Boeing Chair in Advanced Aerospace Systems Analysis, School of Aerospace Engineering, Georgia Institute of Technology (Appointed January 2000)
- Director, Aerospace Systems Design Laboratory, School of Aerospace Engineering, Georgia Institute of Technology (1998 to Present)
- Boeing A. D. Welliver Faculty Fellow, The Boeing Company (Summer 1998)
- Assistant Professor, School of Aerospace Engineering, Georgia Institute of Technology (1996 to Present)
- Editor, Journal of Parametrics (1996 to Present)
- Visiting Professor, School of Aerospace Engineering, Georgia Institute of Technology (1995 to 1996)
- Associate Director & Manager, Aerospace Systems Design Laboratory, School of Aerospace Engineering, Georgia Institute of Technology (1992 to 1998)
- Research Engineer II, School of Aerospace Engineering, Georgia Institute of Technology (1992 to 1995)
- Post Doctoral Fellow, School of Aerospace Engineering, Georgia Institute of Technology (1989 to 1992)

Research Activities:

1. Dr. Mavris has made several significant accomplishments in the area of multi-disciplinary design, particularly in advanced probabilistic design methodology. He is the developer of Robust Design Simulation which is focused on finding ways to account for uncertainty in the design process and to produce robust designs that are insensitive to changes in the design and/or operational environment.
2. Dr. Mavris has made significant contributions in the area of technology assessment. He has developed the Technology Impact Forecasting (TIF) methodology in collaboration with and response to industry and government needs. This method provides designers with the ability to infuse new technologies into the design process and evaluate their impact in terms of benefit, cost, and risk even before the time and expense of developing and maturing the technology is complete.
3. Dr. Mavris has made significant contributions in the area of decision making for complex system design. He has developed the Technology Identification, Evaluation & Selection (TIES) methodology, in collaboration with and response to industry and government needs, to provide a comprehensive, structured and robust methodology for decision making in the early phases of design. This includes his work on a joint probabilistic approach to multi-attribute decision-making.
4. Dr. Mavris has helped bring a new perspective to the teaching of design and a dedication to introducing students to real world aspects of engineering design. He has sponsored numerous undergraduate and graduate design teams in industry and government sponsored competitions including first place entrants in the 1995 and 1997 AIAA Air Breathing Propulsion competition and the 1999 AIAA Missile Design competition as well as a fourth place entrant in the 1999 AIAA Design-Build-Fly competition. He has created a Design for Life Cycle Cost course, an Engine Design course, a Fixed-Wing Aircraft Design sequence and helped secure Design Methodologies and Design Performance as areas for doctoral qualification exams in the School of Aerospace Engineering.
5. Service on national boards and committees including: Chair of the AIAA's Aircraft Design Technical Committee, Editor of the International Society of Parametric Analysts Journal of Parametrics, Member of AIAA's Air Transportation and Operation Technology Committee and Missile Systems Technical Committee. His service and dedication have earned him accolades with an NSF CAREER Award (March 1998 to February 2002), the 2000 Ralph Teeter Educator of the Year Award, as a 1998 Boeing A.D. Welliver Faculty Fellow and 1997 Georgia Tech Outstanding Leadership in the Development of Graduate Research Students Award.