The Federal Air Marshal Service

Using Value Focused Thinking to Optimize Field Office Allocations

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***Abstract*— The Federal Air Marshal Service's (FAMS) mission is to promote confidence in the nation's civil aviation system through effective deployment of Federal Air Marshals (FAMs) to detect, deter, and defeat hostile acts targeting United States air carriers, airports, passengers, and crews. To accomplish this mission, the FAMS has established field offices across the United States and assigned marshals to these offices. As with all of government, the FAMS continues to work to operate efficiently as well as effectively. To this end, they seek to determine the best field office and marshal assignment set to maximize risk coverage at the minimum cost.**

In this work, we take a two-phased approach to solve this problem: risk assessment and field office allocation. In the first phase, we use Value Focused Thinking (VFT) to formulate a detailed risk profile for each flight. In the second phase, we iteratively apply a separate application of VFT in a heuristic manner to determine the best from a set of assignment/field office alternatives until we achieve a near-optimal solution. Then, we use cost benefit analysis to decide among the final candidate solutions.

The results provided in this study will be used by the FAMS to realign their field offices and the marshal allocation as well as provide the analytic rigor to defend their future budget submissions to Congress. Due to the sensitive nature of the assignment information, our presentation will focus on our approach and use derived vice actual data to obtain a solution set.

Keywords—Federal Air Marshal Service; Value Focused Thinking

I. INTRODUCTION

This project is in coordination with the Federal Air Marshal Service (FAMS) to increase their effectiveness and efficiency of Federal Air Marshal (FAM) deployment at a time of increased budget scrutiny across the government. Many projects approach this type of problem with rigorous programming analytics. We approach the problem based on the principles of Value Focused Thinking (VFT) within the Systems Decision Process (SDP) in order to reach a less rigorous, yet very effective solution to the problem.

This report is written ahead of the completion of the project. However, we provide a detailed discussion of our approach and a plan to timely reach the solution to the problem.

II. PROBLEM BACKGROUND

The FAMS is a last line defense to threats onboard United States carrier flights. The Department of Homeland Security offers several approaches to mitigate the risks aboard flights within the Transportation Security Administration, but the FAMS is the only reactive countermeasure to flight threats short of scrambling military aircraft. The FAMS's mission is to promote confidence in the nation's civil aviation system through effective deployment of FAMs to detect, deter, and defeat hostile acts targeting American air carriers, airports, passengers, and crews. The government aligned the FAMS in the early 1960s to combat an increase in airline hijackings. Since then, the terrorist attacks on American centers of gravity on 11 September 2001 have especially spurred a heavy increase in the role of the FAMS [1]. Under its current alignment, the FAMS employs less than 10,000 active FAMs allocated to over 20 field offices across the United States needing to cover over 25,000 potential flights per day [2].

The initial problem statement for this study was to optimize coverage of the FAMs on high risk flights while minimizing program costs in order to better reach the FAMS's goal of promoting confidence in the American civil aviation system. In order to fully understand the depth of this project, it is important to grasp the concepts behind the FAMS's operations ranging from risk assessment and risk management to scheduling programs and resource allocation. The following will discuss some major insights on these topics.

There are not enough FAMs to cover every United States carrier flight per day. Therefore, understanding risk is important to the FAMS's operations, because they want to assign their available FAMs to flights with the highest risk. In general, risk is calculated as the product of consequence and probability, or alternatively, the product of consequence, threat, and vulnerability. When applying these equations to the given problem, it is permissible to combine threat and vulnerability to allude to the probability of an attack [3]. The probability is the chance of a terrorist using an airline flight as a weapon, and the consequence would be the damage caused by a successful attack.

However, it is impractical to model flight risk after these general equations. This is because flight attacks are much like Black Swan Events. Black Swan Events are highly improbable and unpredictable, and they have enormous effects. They are at the limit of statistics, thus general mathematical risk assessment methods should not be used to model them. Descriptive characteristics are the best tool in assessing the risk of Black Swan Events [4]. Furthermore, these descriptive characteristics should focus on the consequences of a successful terrorist attack [5].

For example, there is a significant social amplification or ripple effect from a successful terrorist attack. Ripple effects are greater in high population density areas, thus population density is an important metric to consider when assessing flight risk [6]. Risk research concluded to focus on other characteristics such as flight fuel load and departure time. Insurance underwriters for the World Trade Center and aviation were contacted to help validate these metrics.

Intelligent Randomization in Scheduling (IRIS) is a current multi-year project working to optimize the FAMs' schedule [7]. This project is focusing on a separate, but related problem. We implement flight assignment rather than flight scheduling in order to simplify some of the analysis. Also, focusing on field office allocation is critical in the project rather than trying to solve allocation and scheduling at once [8]. This report later addresses further scheduling research in context.

A. Stakeholder Analysis

The client and the decision maker is the Studies, Research, and Analysis Office of Flight Operations within the FAMS. They would like a desired outcome of a field office allocation recommendation. That office minimized access to much of the FAMS's procedures in order to maximize the ingenuity of this study. The underlying need of the project is to provide the FAMS with a field office allocation plan that is effective for their mission, thus maximizing FAM coverage of high risk flights. At the same time, the plan must be efficient; meaning the cost of the best field office allocation set is of high priority.

B. Redefined Problem Statement

The objective of this project is to determine the best field office allocation set that meets the FAMS' needs by assessing the risk of flights and assigning FAMs to flights to maximize risk coverage. The project deliverables will include a recommendation for the field office allocation set, consisting of the number of field offices, the location of each field office, and the number of FAMs assigned to each field office, that best meets the FAMS' needs of effective and efficient FAM deployment.

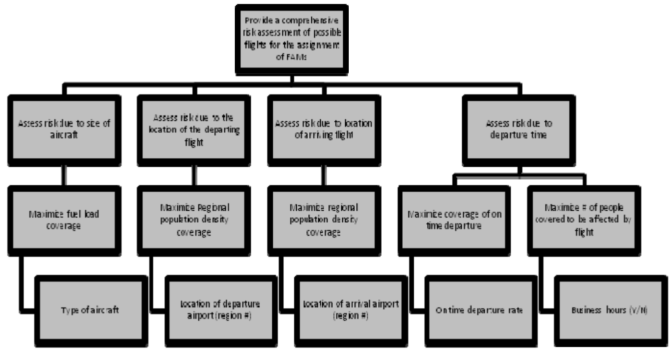
III. Approach

This project implements a two phase approach to solve the FAMS's problem. The two phases are consecutive steps to solving the problem based on the two distinct parts of the redefined problem statement. The two phases are Phase I – risk assessment and Phase II – field office allocation.

A. Phase I

Risk assessment is an intricate part of this project and an important step to reaching conclusions. For this project, the risk assessment is predicated around the methodology of VFT. VFT uses a clear understanding of values to drive the creation of alternatives [9]. VFT implements various tools and analyses to help narrow focus and generate alternatives for which flights are of the greatest risk. A value hierarchy, value functions, and swing weight matrices are three important tools used to find conclusions about which flights are risky. The first step in reaching a risk assessment requires the use of a value hierarchy as depicted in Figure 1.

Figure 1. Risk Assessment Value Hierarchy



The value hierarchy is broken down into four levels. Each level—from top to bottom—provides a deeper understanding of the problem, resulting in a visual representation of the risk assessment. The fundamental objective is at the top level. The fundamental objective provides a description of the outcome for Phase I. Functions are one level below the fundamental objective. The functions describe how to accomplish the fundamental objective. Objectives are the next level below the functions. The objectives are the goals for each function. Lastly, the value measures are the measurements or units associated with each objective. The value measures listed are the best proposed metrics to accurately assess flight risk. The purpose of the value function is to assign varying levels of value to a flight depending on its characteristics corresponding to each value measure.

Next, a swing weight matrix—as illustrated in Table 1—helps weight each value measure in order to reach a total value score or risk profile for each flight.

Table 1. Risk Assessment Swing Weight Matrix

		Level of importance of the value measure								
		Very Important	Swt	Mwt	Important	Swt	Mwt	Less Important	Swt	Mwt
Variation in measure range	High	Departure Airport Region	100	0.290	Arrival Airport Region	80	0.232	Departure Time Flight	25	0.072
		Type of Aircraft	90	0.261						
	Medium									
	Low				On Time Departure Rate	50	0.145			

Swing weights measure the raw importance of each value measure and generally decrease in value from the top left to bottom right of the swing weight matrix. Background research and stakeholder analysis are the main inputs into these weights. Measure weights are the relative importance of each value measure compared to one another and are calculated using Equation 1 [9]. Finally, we assess the flight data to reach a flight risk profile using Equation 2 [9].

$$w_i = \frac{f_i}{\sum_{i=1} f_i} \quad (1)$$

$$v(x) = \sum_{i=1} w_i v_i(x_i) \quad (2)$$

B. Phase II

Phase II is the heart of our problem, and its outcome will answer our redefined problem statement. Similar to Phase I, Phase II conducts VFT analysis. This phase is still in progress.

1) Value Hierarchy

The value hierarchy is near complete for Phase II, but we cannot publish it due to uncertainties from other incomplete parts of the project. Tentatively, the fundamental objective is to provide an effective and efficient field office allocation policy. Most likely, our value measures for field office allocation are total risk coverage, average distance of the field office set to Washington DC, the number of new field offices, the average distance between field offices, the average cost of living, and the number of FAMs that are hired, the number of FAMs that are fired, and the number of FAMs that are displaced.

2) FAM Flight Assignment

FAM flight assignment refers to the total risk coverage value measure in the field office allocation value hierarchy. FAM flight assignment helps connect the work of both Phase I and Phase II through risk. The goal of this subset is to optimally assign FAMs to the given flight data by maximizing their total risk coverage of flights subject to their scheduling constraints. Phase II utilizes FAM flight assignment as an input to its total risk coverage value measure.

Furthermore, FAM flight assignment is a NP-hard problem and a difficult, complex problem when trying to solve optimally. In the interest of the scope of this project, we chose to model FAM flight assignment in the most simple and effective manner to reach a near optimal solution. By using greedy heuristics and additional constraints to the FAM schedule, we are in current production of a solution for FAM flight assignment in generic Excel and Visual Basic (VBA). Given the flight data and respective risk assessments, the VBA algorithm will output the near optimal assignments for every FAM within each field office.

There are several assumptions and constraints we must make in our assignment algorithm based on the FAMS operating procedures and the mass complexity of the problem:

- FAMs are scheduled in two day intervals.
- On any given day, half of a field office's FAMs are off duty (not covering flights), and the other half is on duty (covering flights).
- The maximum duty day for a FAM is 10 hours, of which 90 minutes for pre-flight and 15 minutes for post-flight are required for each flight covered.
- A FAM starting a tour from their field office must cover a flight from their field office departing between 0600 and 1200 hours.
- A FAM ending a tour at their field office must cover a flight to their field office arriving between 1800 and 2400 hours.
- Finally, any given flight cannot be covered by a FAM more than once.

3) Candidate Solutions

We defined our initial candidate solutions by choosing a logical variation of the number of field offices and FAMs and determined field office location by the ranking of the departure airports for the highest risk flights. So our initial candidate solution set is 25 different solutions with the number of field offices ranging 30, 20, 10, 5, and 1 and the number of FAMs ranging 20,000, 15,000, 10,000, 5,000, and 2,000.

Sensitivity analysis is key to refining Phase II. Once the FAM flight assignment algorithm is complete, we can start testing candidate solutions and conduct sensitivity analysis. Analysis outcomes will include verifying the value measures of the field office allocation value hierarchy, verifying the measure weights of the corresponding swing weight matrix, and most importantly, variations to the candidate solution set in order to reach the near optimal solution.

The completion of the FAM flight assignment algorithm will help solidify the field office allocation value hierarchy and lead to the scoring of the final candidate solutions. The candidate solutions will comprise of field office allocation sets, which will include the number of field offices, the location of each field office, and the number of FAMs assigned to each field office. This project will make a final recommendation based on VFT to best meet the FAMS' needs of effective and efficient FAM deployment.

IV. Conclusion

With Phase I's completion, we successfully determined a risk profile for each flight in our data set. Finalizing our FAM flight assignment algorithm will allow us to further develop our candidate solutions to the problem. We are confident that once the cost benefit analysis of our final candidate solutions is complete, we will find the best field office allocation solution set for the FAMS assess risk and allocate their resources effectively and efficiently.

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