Air Force Operations Center Scheduling (AFOCS)

OR 680 / SYST 798
Capstone Project Literature Review Report

Prepared for: Dr. Kathryn Laskey

Prepared by: Scott Genberg

Rebecca McCrabb

Ashley Rock

Amar Zabarah

Sponsors: Brian Collins (Kepler Research, Inc)

Matt Prebble (Kepler Research, Inc)

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1 INTRODUCTION

U.S. Air Force operations require staffing an operation center with trained and certified personnel. Scheduling the staffing of this operation center is a time consuming manual process. Scheduling includes not only staffing the operation center, but also scheduling the training, training resources, and trainers necessary to maintain current certification. The goal of this literature review is to analyze the approach and validation of an optimization scheduling algorithm that will enable the automation of the scheduling tasks for a USAF group-level organization (Group). This is the literature review for similar models and algorithms. This document will include tools to be analyzed as well as any possible algorithms, models, or code will be considered by Team AFOCS for reuse.

1.1 Background

The operations center requires two functional positions: Commander and Deputy Commander. The shifts are 24 hours long (7 a.m. to 7 a.m.).

1.2 Personnel

Personnel are categorized according to their functional roles. The four functional roles are:

1. Personnel
2. Instructor
3. Evaluator
4. Flight Commander

Personnel are the individuals whose primary function is to perform operations center duty. Each shift requires one commander and one deputy commander. Pairing the same commander with the same deputy commander aids shift efficiency. Maintaining a shift efficiency level of 80%, that is 80% of the time each person is assigned to a shift or training they are paired with the same partner, is a high priority for the organization. Personnel can pull up to a maximum of 8 shifts in a calendar month. All commanders can pull duty as a deputy commander if necessary.

The other three sets of individuals, in addition to their role as instructor, evaluator or flight commander can also be qualified as either commander or deputy commander. These individuals are required to pull two shifts per calendar month.

1.3 Required Training

Individuals are required to participate in mandatory monthly training events to maintain current certifications to perform duty. Additionally, there is an annual evaluation requirement. There is a maximum of 45 days between performing duty in the op center.

1.4 Down Time

The day immediately following a shift is an Off day ("O"day) for the personnel who performed duty during the shift. Additionally, all personnel are required to have nothing scheduled during the twelve hours immediately preceding the shift. Sundays and federal holidays are normally training holidays with no scheduled training, however shifts are still scheduled

1.5 Training Resources

The group has two simulators and numerous classrooms available to conduct the monthly required training. Simulator availability is dependent upon the operations tempo (op temp) for the group. The simulators are available in four 4-hour blocks from 7 a.m. to 11 p.m. during regular op tempo or in five 4-hours blocks from 6 a.m. to 2 a.m during increased op tempo. Simulator availability and classroom availability will each be constraints as the number of simulators and simulator slot times are limited as well as the number of available seats in each classroom.

2 TEAM AFOCS ALGORITHM APPROACH

2.1 Technical Approach

A standard Systems Engineering vee-design approach was applied to this project. Due to the very short period of performance, some of the activities occurred concurrently. The project was completed in five overlapping phases. The phases were:

- Requirements Development
- Research and Analysis
- Algorithm Development
- Test and Evaluation
- Delivery

Figure 1 shows the customized Systems Engineering approach to this project.

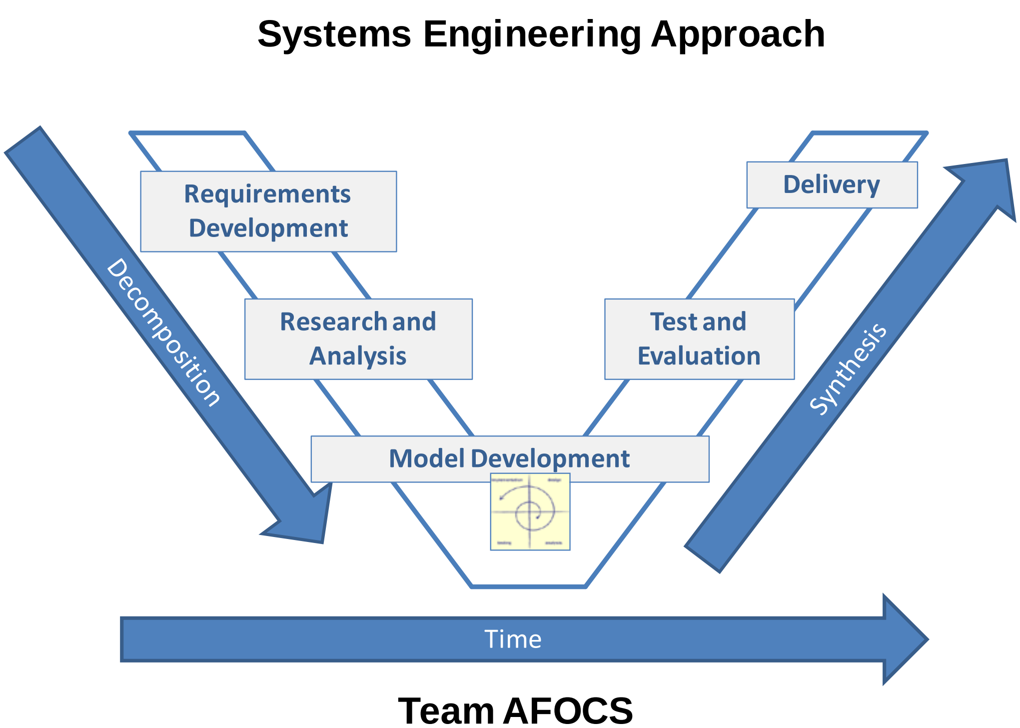


Figure 1: Team AFOCS Technical Approach

2.2 Algorithm Development

Design and development of the optimization algorithm, the model, was conducted through an iterative approach. The model was developed using Linear Programming and Integer Programming techniques. And to satisfy the technical requirements team AFOCS used AIMMS v3.11 as the primary software tool (www.aimms.com).

The optimization produces monthly schedules for personnel in four phases. The first phase focuses on scheduling the shifts for the op centers, as fulfilling shift demand is the top priority. After shifts are scheduled, the model's second phase focuses on scheduling training events for each person to meet the monthly training requirements. The training events require the coordination of (1) personnel to complete the training, (2) INSTs to perform the training, and (3) simulators or classrooms to serve as the platform for training, with each component having limited availability and scheduling conflicts. The third phase entails scheduling the backup crew for each day, which consists of one CDR and one DEP who are not scheduled for shift or training on that day. The fourth phase performs the assignment of students, INSTs, and EVALs to simulator slots for the TR and AE simulation events.

After creation of the monthly original schedule for personnel, the last portion of the model development was to create the capability to reschedule mid-month due to an absence of one or more personnel. The model has two different methods to address personnel unavailability mid-month: a heuristic approach for 1-2 personnel becoming unavailable and a dynamic approach for more than 2 people becoming unavailable on a single problem day. The heuristic approach utilizes the backup crew to fill-in for a person who becomes unavailable, and then schedules another person for the backup crew to fill-in for the backup CW now assigned to a shift. The dynamic portion of the model modifies the schedule from the problem day to the end of the month and reassigns personnel to shifts and training to meet demand while minimizing deviation from the original schedule.

3 SOLUTION METHODS

An optimization algorithm needs to be developed for automatic scheduling for operations centers to improve efficiency and performance of the existing scheduling process. The AFOCS team needs to develop a dynamic algorithm to handle daily changes and produce a re-optimized solution while still adhering to all the scheduling concerns. Since the publication of "Traffic delays at toll booth's" in 1954, the shift scheduling problem has been researched and documented especially the integer programming approach (Titiyevska, 5). This section will document how each approach documented is similar and how it varies from each other.

In order to create a schedule of shifts, a process must be followed. The most common process involves the following three steps:

- Forecasting load/demand: "This entails crating a forecast regarding the amount of incoming work during different times of the week/day." (Wasserkrug, 245)
- Staffing requirements calculations: "This involves translating the amount of forecast work into the number of people (and skills) required at each point in time in order to meet a predetermined service level." (Wasserkrug, 245)
- Schedule creation: "This process creates the actual operational schedule, while ensuring that the right number of people (and skills) is available at each point in time and that employee's personal preferences and labour rules/regulations are satisfied." (Wasserkrug, 245)

The ultimate goal is to apply "an analytical scheduling solution to reduce the manpower costs associated with providing the IT support." (Wasserkrug, 255) The following two approaches are often taken when trying to address the issue of staff scheduling:

1. Scheduling planning which is "[c]alculating the long-term minimum team size required to provide the support while maintaining the service-level constraints" (Wasserkrug, 255).
2. Operational planning which is "[g]enerating the optimal operational schedule to ensure that the service-level constraint is met using the existing team size." (Wasserkrug, 255)

3.1 Scheduling Tools

The following section will give a short summary of information gathered about scheduling tools available on the market. Due to proprietary information, commercially available tools do not reveal the algorithms used in their scheduling software/tools/applications. The following tools were evaluated due to availability of white papers about the product, being listed on TopTenReviews.com, and a product by Kepler Research:

- TimePiece by Kepler Research

Kepler Research offers a product called TimePiece which "is an automated web-based scheduling and management tool for crtical business or mission operations" (Kepler Research). The web-based interface makes the tool accessible via a web-browser anytime, anywhere. It has a "flexible configuration capability [that] allows for any scheduling method, over various time frames (day, week, month), training requirements and other certification requirements" (Kepler Research). This flexibility lends the tool to allow users to view the schedule in calendar view by location or personnel based off the rules and requirements created by the user. TimePiece can be exported to Microsoft Excel, Microsoft Word, Adobe Reader via PDF and Apple's iCal software.

- StaffLogic by Webmedia

Webmedia offers a product called StaffLogic which "enables automation of the work time planning process and is as easy and intuitive to use as a spreadsheet program." (Webmedia) The tool "can be used both as a desktop or a web application. Core functions are realized in the desktop application [… and the] web application enables employees to view existing work schedules, changes personal contact data and submit applications concerning holidays, illnesses and other issues, as well as monitor their status." (Webmedia). StaffLogic utilizes the Ant Colony Optimization algorithm to find the optimal schedule.

- Schedule24 by Intellicate

Intellicate developed a product (Schedule24) that works in fives steps: start the schedule, automate the shift patterns, add additional information to the pattern/schedule, analyze the schedule and publishing the schedule. The tool "provides the user with a heuristic scheduling environment […and] can be contrasted with managing scheduling as an optimization problem This requires the user to define what is feasible and what an optimum schedule is, usually by applying constraints" (Intellicate Limited, 3). Schedule24 can be exported to Microsoft Word, Microsoft Access, Microsoft Excel, HTML and Adobe Readier via PDF.

- WhenToWork

WhenToWork, Inc. created an online scheduling software tool that allows employees to be notified of schedule releases/changes, indicates options for if someone calls in for a day off as well as confirms that employees have received their schedule. The tool provides users with schedule formats that include a calendar, graphical and or list format. The application is designed to be flexible by using time off requirements to update the schedule. (WhenToWork.com)

- Schedule It

ScheduleIt is a desktop scheduling tool with an online scheduling service that offers the following six views: navigation, week, day/resource, new event, Gantt and schedule. The tool has the ability to "[s]et event requirements and resource skills to get recommendations on the available resources that best suit the task" (ScheduleIt) that can be used as filters. Additional features of the tool include reminders, warnings, and alerts pertaining to the developed schedule. The schedule can be exported to the following formats: DOC, PDF, JPG, TXT, CSV, BMP and vCalendar. (ScheduleIt)

- Employee Scheduling Partner

espSoftware created a scheduler to automatically schedule employees without pencils. Employee Scheduling Partner is a software tool that can "[a]ssign a skill level to each employee and job/station" (espSoftware). Additionally, the tool offers a manual override option as well as schedule positions and stations such as cashiers to multiple registers.

3.2 Derived Algorithm Solutions

The need to optimize a shift schedule pertains to more than just Team AFOCS but to oil refineries, third-level IT support, network operations and management centers as well as multiple activities.

Hesham Alfares wrote, "Scheduling Laboratory Technicians at an Oil Refinery" which details a laboratory that "is composed of three sections: (1) General Lab, (2) Gas Lab, and (3) Water Lab" that employ the same sets of employees. One of the focuses of the paper is to determine "the optimum workforce size required to efficiently operate the laboratory by qualified employees". Alfares collected and analyzed data to include various test schedules, monthly shift schedules and company policies regarding work schedules. From this, "the mathematical programming model of the lab technicians' tour scheduling problem [was] formulated" (3) can be found below:

$$\text{Minimize } Z = \sum_{j=1}^{J} c_j x_j \quad (3)$$

Subject to

$$\sum_{j=1}^{J} a_{isj} x_j \geq r_{i,s}, \quad i = 1, \ldots, 7, s = 1, \ldots, 3 \quad (4)$$

$$x_j \geq 0 \text{ and integer}, \quad j = 1, \ldots, J \quad (5)$$

where

c_j = annual cost of assigning one technician to tour j, ($21,900 for 5/2 schedule tours, and $27,100 for 7/2-7/2-7/3 schedule tours),

x_j = number of technicians assigned to tour j,

$$a_{isj} = \begin{cases} 1 & \text{if shift } s \text{ on day } i \text{ is a work day for tour } j \\ 0 & \text{otherwise} \end{cases}$$

After inputting the relevant parameters, the optimum solution of the "integer programming model [was] obtained by Excel Solver.

The research titled "Creating operational shift schedules for third-level IT support: challenges, models and case study" discusses the ticket handling process as follows:

1. First Task: "The amount of work required on this ticket before being transferred to a party other than the team being scheduled. Task 1 does not include the time the ticket awaits in the queue before work on it has begun." (251)

2. Second Task: "The total amount of time the ticket is assigned either to the customer or to an additional service provider. This includes the time the ticket spends waiting for the customer or service provider." (251)

3. Third Task: "The total amount of time the ticket is assigned to another team from the same service provider. This includes the time the ticket spends waiting for this team." (251)

4. Fourth Task: "Once the ticket is routed back to the team being scheduled (i.e. the same team that carried out the work in the [first] phase), this is the remaining amount of work required on this ticket." (251)

"Once the staffing requirements [were] determined from the forecasted demand and the service-level constraints, the actual operational schedules were generated using mixed integer programming." (254) The research outlined that it was assumed that there would be two shifts and ten personnel resources on the team. Each personnel resources is represented by "a binary variable X_{ij} that is 1 if [...] i is assigned to shift j and 0 otherwise" (254). The conditions for the third level IT support is represented by $\forall i,\ X_{i1} \leq S_1$, $S_2 \leq \sum_{i=1}^{10} X_{i2}$, $S_1 \leq S_2$ (254). The first equation guarantees that a personnel resource is assigned to the first shift (S_1=1). The second equation guarantees that a personnel resource is assigned to the second shift (S_2=1). The third equation is to "ensure that if S_1 is 1, then so is S_2." (255) These formulas were used to determine the size of each shift needed to continue operations.

The research "Optimal Staffing Level of Network Operations and Management Centers" discusses the following input parameters utilize to develop the mathematical model: types of tasks, types of workers, task categories for each type of worker, labor cost for each worker type, maximum number of workers and minimum number of tasks (2). From these inputs, the following mathematical model was produced:

$$\text{Min } Z = \sum_{i=1}^{n}\sum_{j=1}^{m} c_{ij} X_{ij}$$

s.t. (subject to)

$$\frac{X_{ij}}{\sum_{i=1}^{n} X_{ij}} \geq L_{ij} \text{ for each } i \text{ and } j \text{(Max \# of Each Task)}$$

$$\frac{X_{ij}}{\sum_{i=1}^{n} X_{ij}} \leq U_{ij} \text{ for each } i \text{ and } j \text{(Min \# of Each Task)}$$

$$\sum_{i=1}^{n} X_{ij} \leq b_j \text{ for each } j \text{(Max \# of Each Type of Worker)}$$

$$\sum_{j=1}^{m} a_{ij} X_{ij} \geq TL_i \text{ for each } i$$

(Min # of Each Task for Each Worker Type)

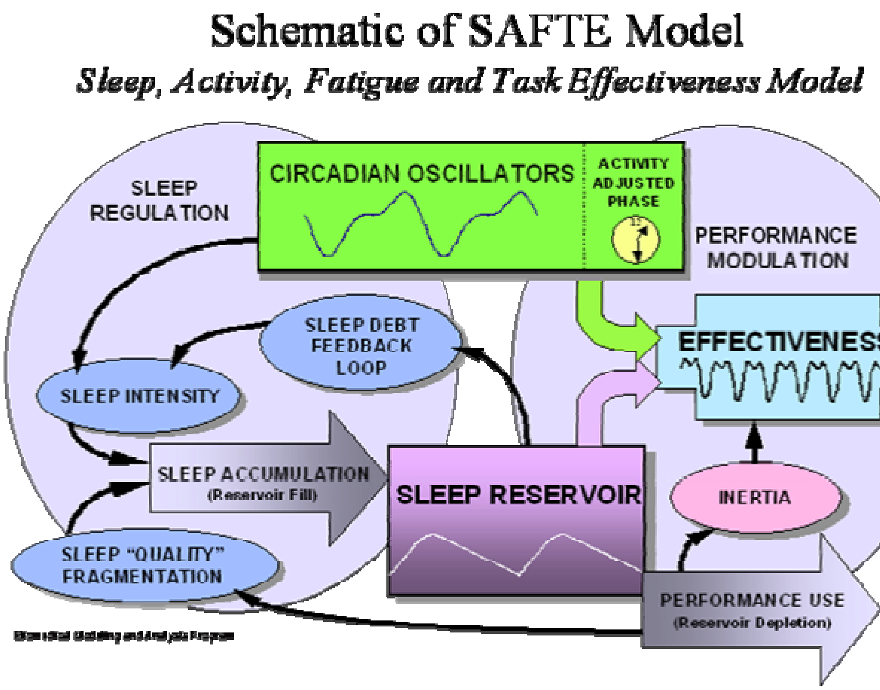
All $X_{ij}'s \geq 0$.

The objective function (Z) is linear which indicates that the mathematical model uses the linear programming technique. With the use of Excel, the optimal staffing level is achieved for the network operations and management center using the above formula. (3) The documentation of the formula indicates that with it being generic, the mathematical model can be expanded to more than just shift schedules at network operations and management centers.

4 VALIDATION AND TESTING APPROACH

The optimization algorithm will be tested iteratively throughout the model development. Final testing will be accomplished with simulated data to ensure the functional requirements are met. Testing and evaluation process will be documented and further described in the Test Plan.

Todd Dart described the Sleep, Activity, Fatigue and Task Effectiveness (SAFTE) Model as a means of validating a shift schedule, which is the method of choice for the United States Department of Defense, in his paper on the “Application of Shift Work Scheduling Principles and Tools for Optimizing Console Based Operations”. (4)



The SAFTE model is designed to minimize fatigue, minimize operational issues and ensure that the principles of shift work scheduling are followed.

5 CONCLUSION

In this paper Team AFOCS analyzes algorithms in order to optimize scheduling shifts that will enable the automation of the scheduling tasks for the United States Air Force operations center. The team also summarized several commercial products designed to schedule shifts of personnel. Finally, Team AFOCS analyzed different approaches to test and validation of the shift schedules to ensure that optimization has been achieved. The purpose of this was to reduce the amount of time involved in the manual process of creating the schedule for staffing for the United States Air Force.

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