MANPOWER OPTIMIZATION OF USAF FACILITY AND INFRASTRUCTURE SUPPORT REQUIREMENTS AT SEMI-PERMANENT BASE

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ABSTRACT

This paper presents a case study of a Civil Engineering Operation's flight manpower requirements for a base initially established through expeditionary materials and deployment kits and has transitioned to semi-permanent and permanent construction over the last 10 years. Actual levels of service were determined using an asset management philosophy, which then drove the goal-programming optimization methodology to determine labor requirements. Data are collected from a maintenance management system and used to compare the current manpower predictor, Unit Type Codes (UTCs), to actual requirements. Initial results show significant disparities indicating differences of skill sets required between initial and semi-permanent base requirements. Additionally provided are categories of work recommendations along with the weighting criteria for determined goals.

BACKGROUND

As the Global War on Terrorism progresses, demands for manpower continue to surge for support troops [5]. After the initial surge of requirements due to a conflict, the flying mission requirements plateau in contrast to the support requirements that continue to grow as the conflict continues. This difference shows the continued high state of reliance on expeditionary support personnel during all phases of the conflict.

Expeditionary bases are now transitioning to enduring bases, a move which shifts the construction from temporary fabric structures and deployment kits to semi-permanent and permanent structures. The facilities and infrastructures at these bases are designed to last longer, operate at higher efficiencies, while lowering overall maintenance cost and labor. However, labor requirements to support base facilities and infrastructure continue at an all time high. This requirement has led directly to increased deployment tempo. It has also created a shortage of available resources for other ongoing and future operations. The objective of this research is to explore opportunities to save man-hours throughout all enduring bases in the Central Command Area of Responsibility.

CURRENT CONDITIONS

Currently civil engineers deploy to bases that have been in operation for several years under the Unit Type Codes (UTCs) organizational structure designed to support initial deployment requirements. Over the course of the past 10 years, increases are continually approved to the UTC organizational structure. This gradual creep of requirements has created a cumulative effect of overages in each of the respective shops in comparison to the specified UTC.

The main requirements for support manpower are based on personnel beddown, base threat level and number of missions supported [3]. As each one of these functions increases, the total support manpower increases. The manpower prediction model, shown in Figure 1, provides a rough estimate of the number of support manpower needed to conduct operations.

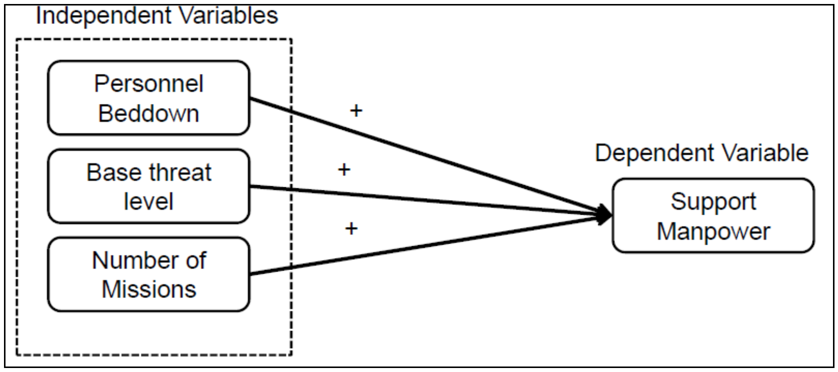

FIGURE 1 - Unit Type Codes Total Manpower Requirement

Expeditionary bases are transitioning to enduring bases with no evaluation of the changing labor requirements for facilities and infrastructure support. This leads to utilizing the same UTC manpower model to determine manning requirements, resulting in some skill sets being over tasked while others are underutilized.

RESEARCH

This paper examines the data of the Air Force Interim Work Information Management Systems (IWIMS) maintenance records. The IWIMS is a specific type of Maintenance Management System (MMS) designed for the Air Force [4]. Craftsmen record the number of hours spent on each type of maintenance work into five categories (Emergency, Urgent, Routine, Other or Indirect Work) providing a baseline level of service (LOS).

Data were collected for approximately 29,000 work orders spanning a period of one year from Jan 1, 2009 to Dec 31, 2009. Data collected from seven shops, Power Production, Heating Ventilation and Air Conditioning (HVAC), Electric, Pavements (Heavy), Pest Management, Structures, and Utilities, provide an accurate snapshot of the Operation’s flight labor, time, and cost requirements.

The data contain the following attributes:

- The shop the work order was assigned
- The title of the work order
- The labor utilization code (LUC)
- The facility number
- The total cost of the work order
- The total man-hours expended on the work order
- The work order status
- The work order number
- The date the work order was opened
- The date the work order was closed

From the data gathered, a category of work is created to account for the inefficiencies associated with facility and infrastructure maintenance. This work category is called indirect work and can be thought of as all the other tasks that have to be accomplished but are not otherwise accounted. A typical industry standard for indirect work is 78% [2].

This efficiency rate indicates that one hour of work really requires 1 hour and 17 minutes to complete. The higher the efficiency rate, the closer the time to complete the work approaches the actual time recorded. Air Force Civil Engineer leadership validated a 70% efficiency rate as a good estimate to allow for additional surge capability [1]. This means that for every 1 hour of recorded data the indirect work time will add an additional 26 minutes.

Many types of mathematical models attempt to forecast labor requirements. Models such as the Markov models, renewal models, and optimization models are examples of mathematical models used for forecasting labor requirements. "Optimization models may be particularly useful to organizations with strictly formulated goals and restrictions. Such applications are typical within the defense industry" [6]. Military organizational constructs use optimization models to analyze data and forecast manpower requirements.

Specifically the data are inserted into an optimization equation to produce a new manpower level providing the same level of service. Holding the LOS constant the optimization equation attempts to right-size manpower levels. A comparison of current manning to UTC levels is used to suggest adjustments. Further manpower reductions may be appropriate if reductions below the current LOS are considered.

OPTIMIZATION

Goal programming optimization requires goals be set for a group of variables that allow trade-offs to reach an optimal solution. It enables decision makers flexibility as goals are adjusted to explore other optimal options. This asset management approach to manpower allows the "what if" exploration to determine gaps between actual and desired level of service. It also allows for a clear articulation of impacts to level of services for different goals. Deciding on the criteria to optimize is a key aspect in providing the best solution to the fundamental asset management problem, in this case balancing manpower and LOS. Equation 1 is the objective function used in this case with the various criteria defined and weighted. Because all units are in terms of man-hours, there is no requirement to normalize the function.

$$F(w_1(X_1)+w_2(X_2)+w_3(\sum_{J=1}^{12} d_{R_J}^{+})+w_4(\sum_{J=1}^{12} d_{R_J}^{-})+w_5(\sum_{J=1}^{12} d_{O_J}^{+})+w_6(\sum_{J=1}^{12} d_{O_J}^{-})+w_7(\sum_{J=1}^{12} d_{I_J}^{+})+w_8(\sum_{J=1}^{12} d_{I_J}^{-})) \quad (1)$$

Where:

X_i: Decision Variable for number of man-hours of i=1…5

E_J: Total number of Emergency man-hours required for each month J=1…12

U_J: Total number of Urgent man-hours required for each month J=1…12

R_J: Total number of Routine man-hours required for each month J=1…12

O_J: Total number of All-Other man-hours required for each month J=1…12

I_J: Total number of Indirect work man-hours required for each month J=1…12

d^+_i: Positive deviational variable for the i-th goal, $d^+_i: \geq 0$

d^-_i: Negative deviational variable for the i-th goal, $d^-_i: \geq 0$

w_i: The weighted factor to indicate importance of meeting that factor, i=1…8

Deviational variables allow the decision variable to move either "over" or "under" the goal specified. The value of the deviational variable is the difference between the goal and the decision variable for that month. Weighting of the variables allows for the decision makers to identify criteria as more important than others.

From an asset management perspective, this weighting equates to the prioritizing of essential criteria to enable a quantification of impact to the level of service. Weighting provides the trade-offs codified in the objective function. The possible outcomes vary as the weights change. Table 1 provides the weights that are associated with each variable in the objective function. Because the objective function is minimized, the higher the weight the more effect it has on the function.

W_1	Emergency	10
W_2	Urgent	10
W_4	Routine Under	3
W_3	Routine Over	1
W_6	Other Under	3
W_5	Other Over	1
W_8	Indirect Under	1
W_7	Indirect Over	1

TABLE 1 – Weights for Objective Function

Although Emergency and Urgent are currently hard constraints that must be satisfied, they have been assigned weights to allow for the possibility for future work to deviate from the current LOS. In this case, weighting emphasizes the importance of meeting the goal by associating a penalty of three against any value under the goal. This means that if maintenance has to be deferred, there is three times as much time somewhere else in the cycle to accomplish the deferred maintenance. A neutral stance is taken on indirect work, because the implications of weighting this criterion would unintentionally cut the desired surge capability or increase the amount of indirect work specified.

Equations 2 and 3 list the hard constraints for this goal-programming optimization problem. It provides assurance that the manpower provided for both Emergency and Urgent types of work will be greater or equal to the amount actually required every month. The hard constraints give decision makers confidence that the core mission requirements will be met. Hard constraints have the ability to become soft constraints by simply utilizing a deviational and allowing the actual number to vary from the goal. This future research can utilize the weighting values discussed in Table 1.

$$X_1 \geq E_J ; J = 1...12 \qquad (2)$$

$$X_2 \geq U_J ; J = 1...12 \qquad (3)$$

Equations 4, 5 and 6 list the soft constraints for this optimization problem. The soft constraints allow a deviation to occur either over or under the required amount of provided manpower. This deviation is then minimized in the objective function. Weights are attached to the deviations based on preferences provided by the decision makers. The soft constraints allow a holistic look at resources across the entire period. This flexibility means that work can be deferred to another month.

$$X_3 - d^+_{R_J} + d^-_{R_J} = R_J; J = 1...12 \quad (4)$$

$$X_4 - d^+_{O_J} + d^-_{O_J} = O_J; J = 1...12 \quad (5)$$

$$X_5 - d^+_{I_J} + d^-_{I_J} = I_J; J = 1...12 \quad (6)$$

The weights listed in Table 1 results in priority slanted towards "over" rather than "under" the required number of man-hours. This weighting is applied to both the Routine work requirement as well as the Other category of work. For the Indirect category of work we allow the deviational to vary to either side of the goal without penalty.

INTIAL FINDINGS

The initial findings indicate man-hours currently allocated are in excess of what is needed to support the LOS required for each category of work, Emergency, Urgent, Routine, Other, and Indirect Work (E, U, R, O & IW). Figure 5 shows the overall Operations Flight man-hour requirements for the 2009 calendar year in contrast to the man-hours provided. It shows the recorded number of hours the flight is required to complete does not match the hours that the flight has available. It also shows the bulk of the Operation flight's work is required for routine and all other work categories.

Figure 2 shows an aggregated analysis of the entire Operation's flight, which combines seven different shops. Table 2 shows the result for each shop.

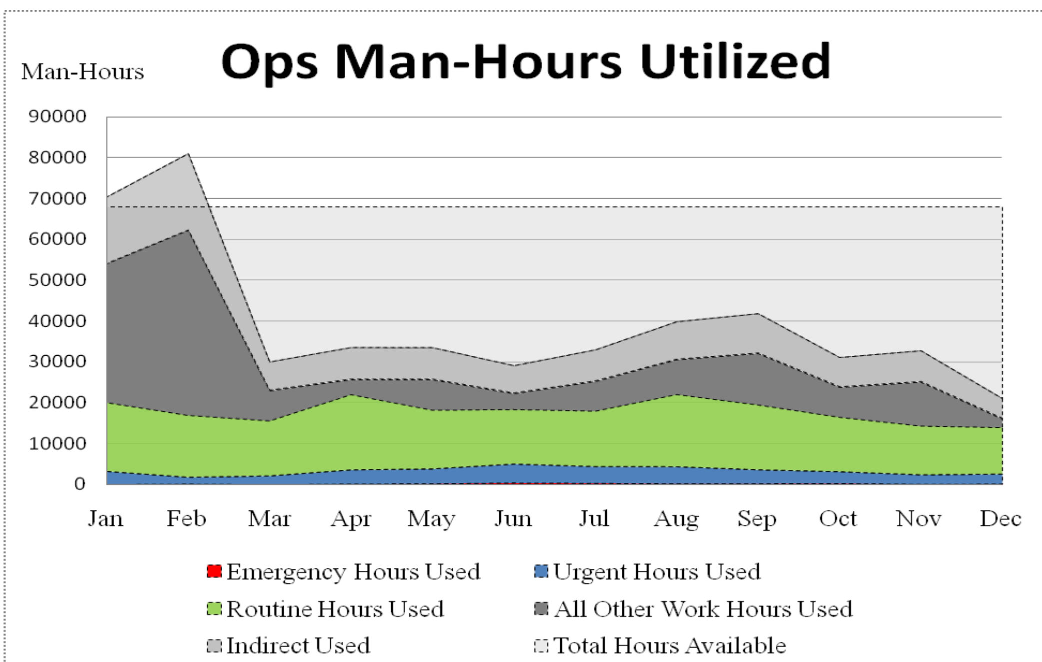

FIGURE 2 - Civil Engineer Operation Flight Man-Hours Utilized Jan-Dec 2009

Using the goal programming methodology to determine the optimal man-hours for a constant LOS. Table 2 displays how much reduction in manpower can be achieved with goal programming optimization for each shop.

Shop	Electric	Heavy	HVAC	Pest Mgt	Power Pro	Structures	Utilities	Totals
Manpower Decrease (Airmen)	9	2	25	3	6	8	34	87

TABLE 2 - Man-hour Levels for Shops at Al Udeid Air Base

Initial results show extra manpower availability and the potential to reduce overall manning levels to accomplish work at the current LOS. The results also show a discrepancy between the UTC levels and the actual requirements for several shops. Keep in mind, UTC levels consider base post attack recovery and initial beddown requirements, which are not presented for security reasons. These discrepancies illustrate the shift in requirements from expeditionary type construction of tents and other temporary construction to enduring type construction of semi-permanent facilities and infrastructures. The optimized level is higher than the UTC manpower level for Electric & Heating Ventilation Air Conditioning (HVAC). The optimized level for Pest Management, Power Production, & Utilities are substantially lower than the UTC manpower levels. Utilizing the optimized values for each shop will reduce manpower by 87 personnel for each deployment time period, resulting in a total manpower savings of 174 troops annually.

IMPLICATIONS

The current manpower level provides more available man-hours than required to achieve the same LOS. This excess capability drives the use of manpower resources to accomplish non-essential or "pet" tasks. Table 3 provides the total man-hour requirement for each category of work for the Operation's flight. It shows that the *Other* category of work accounts for nearly 40% of the entire workload required.

Work Category	Emergency	Urgent	Routine	Other
Man-Hours	3700	38000	175900	150000

TABLE 3 - Total Categorical Man-hour Requirements

The *other* category should be examined to determine the type of work and the validity of the work that the Operation flight is being requested to complete to ensure that pet projects are highlighted and identified. Leaders need to balance manpower availability with readiness requirements and deployment operation tempos and this category of work would be the prime area of interest to assist in the balancing effort.

To further evaluate this issue we recommend data managers reclassify this work into the following six categories; emergency, urgent, routine, In-house Work Program, Recurring Work Program, and non-productive time. By classifying work into these six categories, management can identify if there are disparities between required and actual work.

As the largest Operation's flight, the over staffing of Al Udeid directly impacts other U.S. Central Command Area of Responsibility bases as they pull from a finite pool of resources which means that every resource utilized by one location cannot be utilized by another.

LIMITATIONS

This research involves examinations of previous recorded maintenance data. The use of Collection Work Orders (CWOs), which are utilized to group work together over extended periods, causes a skew in the data, masks "pet projects," and creates uncertainties in the analysis, as it is not possible to determine when the actual work occurred. In many cases this is done intentionally to hide non-mission related work generated by senior leadership.

FUTURE RESEARCH

This is the first time since the Korean War that military bases are transitioning to semi-permanent construction type. This provides a unique opportunity to collect and analyze data from this transition period. This research provides insights and starting points for other potential research efforts. An examination of the *other* work category has the potential to yield dividends. Dissecting this category yields an understanding of what work is legitimate to mission success and what work is creating inefficiencies for manpower.

An exploration of changing the hard constraints into soft constraints and incorporating that data into the overall level of service can yield great insight as well. Soft constraints in these categories of work can provide flexibility of interaction between all the categories. The interaction created allows trade-offs throughout the entire system instead of limited to a portion.

CONCLUSIONS

This paper provides Air Force Civil Engineers with a further understanding of labor requirements at enduring bases. It enables the optimization of labor by providing an asset management tool that looks holistically at enduring locations to ensure the right sized skill set is available to maintain, repair, and operate the facilities and infrastructures.

It also provides insight into the long term planning of a base's manning requirements and allows for better articulation by deployed commanders of the LOS they can provide for the base. This articulation allows an understanding that prioritization of work accomplishment is needed to ensure the efficient and effective use of a finite manpower resource.

This paper presents a methodology to optimize manpower levels across all the operations flight located in the US Central Command Area of Responsibility. A clear understanding of requirements for the Civil Engineering community enables better projections of training, staffing, and equipment needs in enduring locations.

This paper also applies to the wider audience of commercial contractors by giving a better understanding for bidding on base operation and maintenance contracts. Providing a clearer understanding of the actual workloads required at these types of facilities. Contractors can have more accurate bids and provide higher levels of service at lower cost. It provides insight to expected quantities and response capabilities that contractors would need to possess to adequately compete for and obtain facility and infrastructure maintenance contracts at such locations.

The research into the Operation's flight data provides an asset management framework for decision-making. This research provides the backbone of the data that should be collected along with how this data can be utilized to make meaningful decisions.

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