A POST-DISASTER CONSTRUCTION PORTFOLIO OPTIMIZATION FRAMEWORK FOR TYNDALL AFB REBUILD POST HURRICANE MICHAEL

THESIS

André J. May, Captain, USAF

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André J. May

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Abstract

Natural disasters such as hurricanes, earthquakes, tsunamis, and extreme flooding cause severe social and economic disruptions. Restoration of social and revenue-generating services often requires extensive reconstruction, from the facility to the campus scale. For multi-facility portfolios, decision-makers must prioritize post-disaster reconstruction activities appropriately to ensure facilities and infrastructure are restored. In addition, any expansion or new construction initiatives are ideally completed in order of decision-maker and community preference. Most post-disaster optimization and decision framework research consider a single stakeholder as guiding decisions related to a project portfolio. However, these portfolio prioritization frameworks ignore the effect of multiple stakeholders and competing priorities, as well as project complexity, as it relates to project risk. This research incorporates stakeholder priority and risk mitigation objectives in an optimization framework that targets the efficient prioritization or ordering of projects in a complex portfolio. Here a mixed-integer linear programming (MILP) optimization framework is proposed that prioritizes a project portfolio through complexity index-based risk mitigation and multi-stakeholder priority objectives, subject to an iteratively relaxed budget constraint. The relaxation of the budget constraint reveals the order in which projects should be done and the degree to which the solution—number and sequence of projects—are stable under budget changes. The results reveal that low cost, high mission impact projects are preferred over high cost, low mission impact projects. While this result is expected, the model and framework can facilitate recovery and new-mission bed down in the face of future natural disasters, contingency operations, or mission expansion, where competing priorities are many and complexity is high. While the mission priorities of the Air Force are used to create the optimized project sequences, the preferences can be transformed to meet a variety of stakeholder needs in the public sector, higher education, or healthcare sector.

Dedication

This work is dedicated to my compatriots, forefathers, family, and community. Thank you for inspiring creativity, modeling tenacity, and providing accountability.

Acknowledgments

I would like to thank my faculty advisor, Lt Col Justin Delorit, for his insight and mentorship in completing this thesis. I would also like to thank my committee members, Col Peter Feng and Maj Brigham Moore, for taking their time in assisting me with revisions, perspective, and technical assistance throughout the research process.

André J. May

Table of Contents

List of Figures

Page

List of Tables

Page

A POST-DISASTER CONSTRUCTION PORTFOLIO OPTIMIZATION FRAMEWORK FOR TYNDALL AFB REBUILT POST HURRICANE MICHAEL

I. Introduction

Natural disasters such as hurricanes, earthquakes, tsunamis, and extreme flooding cause severe social and economic disruptions. Restoration of social and revenue-generating services often requires extensive reconstruction of facilities and infrastructure at municipal and regional scales. Multi-facility reconstruction portfolios must be executed in a sequence that ensures facilities and infrastructure are rebuilt in a way that restores social and revenue-generating services, is consistent with community priorities and meets budgetary constraints.

The Department of Defense (DoD) and the United States Air Force (USAF) own vast installations of community-like facilities and infrastructure, and many are positioned such that they are exposed to the risks of natural disasters. For example, four extreme natural events have caused approximately $7 Billion in cumulative facility damage to USAF installations: Hurricane Andrew's impact on Homestead Air Force Base (AFB) in 1992 (Grudo, 2017); Hurricane Katrina's impact on Keesler AFB in 2005 (Jenifer, 2006); Hurricane Michael's impact on Tyndall AFB, FL in 2018 (Shapiro, 2019); and flooding at Offutt AFB in 2019 (Losey, 2020). Post-disaster installation reconstruction projects are typically managed by an Air Force Program Management Office (PMO), as was the case for Keesler AFB (Hood, 2006), Tyndall AFB (Koopman, 2019), and Offutt AFB (Heard, 2019).

In the wake of the devastation brought by Hurricane Michael, Tyndall AFB experienced nearly complete mission degradation. As a result, the reduction in mission capabilities posed an increased risk to national security, through halted airframe training, civil engineer expeditionary training, and through degradation of other unique missions. In a first-of-its-kind effort, the DoD chose to rebuild the installation to restore lost mission capabilities and used the opportunity to simultaneously bed down a new airframe and associated mission and support facilities.

In deciding to undertake a rebuild and mission expansion, the USAF presented the Tyndall PMO with two competing priorities, for which a large group of stakeholders sought the opportunity to influence the phasing of the installation's reconstruction and new construction. Differences in stakeholder perspective create conflict (Eid & El-adaway, 2017), and as such some mechanism is required to determine the efficient order in which projects should be executed, to balance restoration of enduring mission capabilities, establishment of new capabilities, and the restoration of community support services. The primary conflict, with respect to Tyndall, exists between the strategic stakeholder— the Major Command (MAJCOM)—which is primarily concerned with the new mission bed down, and local leaders who are most concerned with the restoration of the installation's traditional mission and community support functions. This primary conflict leads to the following research question:

How can a diverse and complex portfolio of projects be optimized to meet the competing objectives of meeting stakeholders' priorities and achieving risk mitigation with a constrained budget?

This thesis explores these relationships and produces a multi-objective optimization framework that creates a single reconstruction and new mission bed down portfolio which limits mission risk, balances stakeholder priorities, and operates within the project management capacity constraints of Tyndall's PMO.

While this thesis provides the Tyndall PMO with a range of data-driven portfolio sequences that illustrate the tradeoffs between stakeholder priorities and risk mitigation, the basic optimization framework is applicable to any multi-stakeholder project portfolio—disaster or non-disaster driven. The installation of the future (IoTF) construct, by which Tyndall is being rebuilt and adapted, is the template for the DoD's installation modernization plan (AFIMSC, 2022). Optimization of construction portfolios, like the one undertaken in this research, will have wide-reaching utility for the DoD; while the mission priorities of the Air Force are used to create optimized project sequences, the preferences can be changed to meet a variety of stakeholder needs in the public sector, higher education, healthcare sector, or any industry that manages portfolios of facilities.

Significance and Motivation

The National Defense Strategy (NDS) and the National Defense Authorization Act (NDAA) provide the DoD and the USAF with the strategic guidance, authorization, and resources to engage in military operations. Furthermore, these two documents justify the Tyndall Air Force base rebuild efforts, the F-35 airframe beddown, and the IoTF construct. Relating the 2018 NDS to the Tyndall rebuild, focus is drawn to DoD's objective, "…establishing an unmatched twenty-first century National Security Innovation Base that effectively supports Department operations and sustains security and solvency". The NDS intends to meet these objectives through three lines of efforts, with the most relevant to this research being "rebuilding military readiness as we build a more lethal joint force" (Inhofe and Reed 2019). Therefore, to meet these objectives and lines of efforts, the Department of Defense and the Air Force decided, after the Hurricane Michael disaster, to rebuild Tyndall Air Force to meet existing mission capabilities.

Additionally, Tyndall Air Force Base, like most installations, was built in the period during and immediately after World War II. Hurricane Michael's destruction of Tyndall provides an opportunity for the DoD to update the installation's built environment to reflect its IoTF objectives. Moreover, the Fiscal Year 2020 NDAA identifies Tyndall as a good candidate for the F-35 Joint Strike Fighter's new mission beddown. In support of building a more modern lethal force, sustaining or regaining the United States' comparative combat advantage and ensuring peacetime deterrence, the Fiscal Year 2020 NDAA "$10 billion to procure 94 Joint Strike Fighter aircraft…60 of which would be for the Air Force" (Inhofe & Reed, 2019). As such, the Air Force requires a modern and sophisticated installation from which to accommodate and project fifth-generation airframes.

The cumulative effect of the NDS's push toward sustainable and robust installations, and the NDAA's drive for force modernization makes Tyndall the perfect candidate for an IoTF test case. However, the complexity of managing a rebuild and a new mission bed down requires engineers and planners to work together to manage construction projects in a way that satisfies multiple, competing objectives, balances risks and illustrates the tradeoffs of selecting one project over another.

Research Objectives

This research explores (1) the development of a metric capable of expressing project risk mitigation through facility connectedness to mission, duration, and project complexity; (2) the development of a stakeholder prioritization metric that captures stakeholders' inputs and preferences for various rebuild and mission expansion projects; and (3) the incorporation of the risk mitigation metric and stakeholder prioritization metric in a multi-objective optimization framework that leverages real-world budgetary constraints to determine which projects gets done, and in which order, depending on the stakeholder prioritization.

II. Literature Review

Before constructing the prioritization optimization model, it is necessary to explore the factors associated with project prioritization and selection and specifically how these factors are related to a post-disaster construction environment. The factors that are investigated include: (1) current optimization models used to prioritize project portfolios and limitations; (2) prioritization metrics; and (3) stakeholder interactions.

Project Portfolio Optimization and Selection Techniques

The importance of prioritized post-disaster construction activities and recovery objectives has led to an intersection between optimization methods and construction project portfolio development. Selecting the appropriate project portfolio execution method is crucial to achieving a risk-minimized solution. There are six project portfolio selection categories identified widely in literature: benefiting measurement methods, mathematical programming models, cognitive emulation models, simulation and heuristics models, real options models, and hybrid techniques (Elbok & Berrado, 2017). Among these six models, mathematical programming, such as linear programming and integer programming, and hybrid techniques like multi-criteria decision analysis (MCDA), are widely used in project portfolio management (Elbok & Berrado, 2017).

Several studies investigate reconstruction portfolio optimization for post-disaster environments. One such effort uses the analytical hierarchy process (AHP), an MCDA method, to prioritize portfolio projects (Ghannad et al., 2020); it proposes a new post-disaster recovery prioritization framework that evaluates optimal recovery priorities for damaged facilities, and maximizes the long-term socioeconomic benefits for affected residents. To account for how infrastructures relate to socio-economic benefits, infrastructure reconstruction is categorized into two parts: buildings as social infrastructure, e.g., houses, public buildings, schools, and commercial buildings; and other critical infrastructure, e.g., water and power supplies, transportation, and communication infrastructure (Ghannad et al., 2020). Another model, utilizing both the user equilibrium algorithm and multi-objective genetic algorithm approaches, generates an optimal resource allocation solution. The model aims to minimize disruption for networks, e.g., transportation, and cost by optimizing resource allocations (Orabi et al., 2009).

Linear programming is another optimization technique used to prioritize post-disaster construction portfolios. This section focuses on two examples to illustrate the utility and flexibility of this simple, yet effective approach. The first is a multi-objective linear programming model that simultaneously maximizes temporary housing safety and minimizes public expenditures for various temporary housing alternatives (El-Anwar et al., 2010). The optimization model consists of two underlying models: a safety model that measures temporary housing safety when exposed to various types of potential disasters; and a cost model that aims to evaluate and minimize total public expenditure on post-disaster temporary housing (El-Anwar et al., 2010). The second model uses a variation of linear programming, known as mixed-integer linear programming (MILP), to optimize a post-disaster transportation construction portfolio through minimizing cost and traffic disruption Omar El-Anwar et al. (2016). Both approaches, though numerically different, highlight the fact that competing priorities in construction decision management can be handled by linear programming approaches, though both are limited in that they do not address project complexity, and seek to order projects given multiple stakeholder influences.

All optimization approaches have limitations, and generally, the more complicated the approach, the more complex the limitations. For example, AHP is limited by a phenomenon known as rank reversal, which occurs when the alternative rankings change with either the addition or removal of an alternative (Yuen, 2009; (Adam & Humphreys, 2008). Genetic algorithms are computationally complicated, and not effective at finding solutions to complex problems (Saeed, 2013). Also, formulating a genetic algorithm objective function is complicated for even simple problems, and the final answer is not guaranteed to be efficient (Serani et al., 2014; Beg & Islam, 2016). Even linear programming, which is generally accepted as the least complex of optimization techniques, is limited by its inability to consider nonlinear effects, the high-dimensionality risk, and the inability to consider a problem's temporality (Urbanucci, 2018). However, linear programming and its variants, such as the MILP, are advantageous and widely used in the field of optimization because they tend to produce highly reliable global optimality, and results are generally easy to interpret as compared with other more complex optimization alternatives (Urbanucci, 2018). Given the scope of the problem addressed by this research, both AHP and Genetic Algorithms are likely overly complicated, and a linear approach is likely to produce results that are highly useful for project planners looking to determine the order in which projects should be completed to minimize portfolio risk and balance stakeholder prioritization (Kaliyamurthi, 2017; Nefeslioglu et al., 2013; Saeed, 2013).

Prioritization Metrics

Post disaster construction delivery methods present decision-makers with problems beyond steady-state construction delivery. Projects require inspection, retrofit and reconstruction to ensure health and safety, but under recovery, projects also need to be prioritized to determine which services must be restored, in which order. The lack of prioritization is a post disaster environment increases recovery time and extends the return of vital services. Construction activity acceleration methods mitigate recovery time and disruption to services (Martins et al., 2019), as illustrated by the development of a conceptual model for accelerated prioritization of transportation infrastructure projects after a natural disaster. The optimization model presented by Martins et al. maximizes recovery efforts through a recovery index. Project cost and duration are the two objectives, and the model maximizes the recovery index through minimizing both project cost and duration. The model is subjected to three constraints: total investment, no repeating projects, and a portfolio recovery index score greater than or equal to a desired threshold. In a separate effort, a similar group of authors develops a list of eighteen prioritization metrics, and distribute a questionnaire to gather criteria weights from stakeholders, to determine the infrastructure that should be accelerated and the acceleration method to be utilized (Moreu et al., 2019). The two aforementioned efforts, when considered together, highlight the potential to combine analytical methods (recovery indices) and deliberative processes (focused-stakeholder engagement), to achieve a balanced approach to project prioritization.

Stakeholder Interaction

Exploring how stakeholders interact in a dynamic and chaotic post-disaster recovery environment is important to consider, as misaligned objectives can further compound the challenges of recovery. There are few stakeholder interactions and decision models that discuss how stakeholders interact in the wake of disasters. The project portfolio management (PPM) system is a planning and controlling approach used mostly by project management offices or dedicated role-players in the project organization, to achieve strategic alignment with multiple stakeholders. A poor structural and strategic alignment between stakeholders, multiple PMOs, and the upper echelon of the company or internal stakeholders can result in project or portfolio failure (Kaiser et al., 2015). AHP, together with multi-attribute utility theory (MAUT) is a prioritization and decision-making tool used to drive environmental restoration decisions involving multiple stakeholders. What separates MAUT from other multi-attribute methodologies is the emphasis on using *deliberations* to achieve consensus among the objectives and preferences, and is useful once an AHP model produces an optimized list of projects (Karydas & Gifun, 2006). That is, the AHP culls non-critical projects, and the MAUT helps stakeholders prioritize the optimized remainder. This hybrid analytic-deliberative process is appropriate for construction environments involving multiple stakeholders (Apostolakis & Pickett, 1998).

In a decision-making situation, stakeholders possess their own decision actions, strategies, and objectives; and multiple stakeholders results in competition for resources. Agent-based modelling (ABM) strives to take these competing objectives and align them to an overall goal and outcome (Eid & El-adaway, 2017). ABM is advantageous in that the concept models complex system-of-systems where the contribution of a multiple stakeholders contributes to the collective welfare of the system. The technique evaluates system performance by taking into account agent interaction (Eid & El-adaway, 2017). ABMs are more challenging to construct than other modelling methods as the model's limitations lie in the defining the system and sub-system boundaries (Chhatwal & He, 2015).

In a post-disaster construction environment, the project prioritization framework that is most likely to be implemented by the USAF is one that is not overly complex (for the problem), user friendly, and adaptable to other problems or across PMOs. In addition, the framework also needs to incorporate stakeholder priorities and mitigate risk of delay, cost overruns and construction complexity. From the literature review it has been shown that multiple post-disaster construction studies have considered both risk mitigation and stakeholder influence independently. However, there is a gap in the body of knowledge of studies that combine risk mitigation and stakeholder prioritization into a single optimization framework that is efficient, non-complex, and addresses the research question posed earlier.

III. Case Study and Data

The literature review topics discussed is applied to Tyndall AFB to develop a single framework that efficiently combines risk mitigation and stakeholder prioritization. The Tyndall PMO has a project portfolio of 56 projects consisting of a combination new beddown projects (not related to hurricane damage) and enduring mission projects (related to hurricane damage) under the Military Construction (MILCON) program as well as other enduring mission projects under the Facilities Sustainment, Restoration and Modernization (FSRM) program. The Tyndall PMO manages the needs of four different stakeholder groups—Beddown, Fighter Wing Flying Operations, Fighter Wing Mission Support, and Others—that possess equity in the prioritization of recovery and mission beddown efforts. This section discusses using Tyndall AFB as a case study and focuses on: (1) how to formulate the project risk mitigation using facility-level data; and (2) how to formulate stakeholder prioritization, given the groups of stakeholders present at Tyndall AFB. Ultimately, these areas will reveal the parameters required to populate a project risk mitigation index (RMI) and stakeholder prioritization index (SPI) that will form the basis of the multi-objective optimization.

The Tyndall PMO supplies most data for this research and provides a project portfolio organized based on functional use and funding type. Using these functional and funding types the data is further organized into four stakeholder categories (Table 1) where the Beddown stakeholder group is represented by orange; the Fighter Wing Flying Operations stakeholder group is represented by gray; the Fighter Wing Mission Support stakeholder group is represented by green; and the Others stakeholder group, consisting of tenant units and FSRM projects, is represented by blue.

Table 1 Project Portfolio Organized by Stakeholder Groups. Orange: Beddown; Gray: Fighter Wing Flying Operations; Green: Fighter Wing Mission Support; Blue: Others

Stakeholder Group	Description of Project Portfolio Functional Areas	Number of Projects
Beddown	F-35	13
Fighter Wing Flying Operations	Flight line Operations, Airfield Drainage, MSA (Flight line)	6
Fighter Wing Mission Support	Infrastructure, Industrial, Administration, MWR, Lodging, Dorms, Community Commons	19
Others (Tenants)	WEG, Silver Flag, FSRM	18

Mission Dependency Index (MDI)

The US Air Force Installation and Mission Support Center (AFIMSC) developed the Mission Dependency Index (MDI) as a 0 to 100 metric to measure the relative importance of an installation's facilities and infrastructure with respect to organizational missions (DePalmer et al., 2021). Furthermore, the MDI plays a critical role in project prioritization and funding. For these reasons, MDI can be viewed through the lens of risk, i.e., answering the question: *Which facilities pose the risk to mission failure if not restored?*

The US Air Force adapted its MDI methodology from the US Navy with the purpose of linking facilities and infrastructure to missions and supporting risk-based decision-making (Weniger, 2018). The MDI applies the risk management concepts of the probability of failure and the consequence of failure. To investigate the mission's reliance on an installation's facilities and infrastructure, the Air Force adopts the terms interruptability and replicability, respectively. Interruptability is time-based and measures how fast an organization's mission would be impacted if the facility's function is interrupted. Replicability is based on capability and measures how hard it would be to relocate, replicate or reconstitute the facility's function (DePalmer, 2021). The MDI is a measure of the mission's importance, and the higher the MDI value, the more difficult it is to replicate the function and the faster the response time needs to be if the facility is interrupted. Therefore, the model needs to penalize projects with higher MDIs and reward projects with lower MDIs to maximize risk mitigation.

Project Duration Index (PDI)

The Project Duration Index (PDI) is a single value bounded between 0 and 1. First the project duration is calculated and defined as the difference between the notice to proceed (NTP) date and the beneficial occupancy date (BOD) for each project, both of which are obtained from each project's Form 1391. To maximize risk mitigation, the model is constructed to reward projects with shorter durations and penalize projects with longer durations, as shorter projects are generally believed to be less complex and risky, viewed from a cost and schedule overrun perspective. Therefore, to achieve this outcome, each project's relative duration is expressed as the difference between the project with the longest duration in the portfolio and that project's duration. This decision ensures that shorter project durations follow the logic of rewarding risk mitigation.

Project Complexity Index (PCI)

The Project Complexity Index (PCI) is a single value bounded between 0 and 1 and is borrowed from a companion project, *Human Resourcing via Project Complexity for Post-Disaster Construction Management,* which uses Analytical Hierarchy Method (AHP) and Multi-Attribute Utility Theory (MAUT), to develop the PCI values. The PCI values use the same project data from the Tyndall Air Force Base PMO to ensure consistency in this research effort. The methods developed by Vidal, Marle, and Bocquet (2011) form the foundation for the AHP criteria and sub-criteria developed in the aforementioned work. However, the criteria and sub-criteria are later tailored to address post-disaster construction management. The PCI values are developed using four criteria and six sub-criteria (Fig. 1). The four criteria are size, variety, interdependence, and conflict. The size criterion considers the sub-criteria of the project's programmed amount (cost) and period of performance (duration). The variety criterion accounts for the number of project stakeholders on a given project and the project's construction type, which might be vertical construction, horizontal construction, or specialty construction such as a sensitive compartmented information facility (SCIF). The interdependence criterion highlights the number of phases any given project needs as well as the type of systems it involves. For instance, a system might involve standard systems such as fire, communication, or utility systems, no standard systems, or smart technology systems. Finally, the model accounts for the project's context, which determines if the project is executed in a post-disaster environment/contingency environment or a typical, steady-state environment.

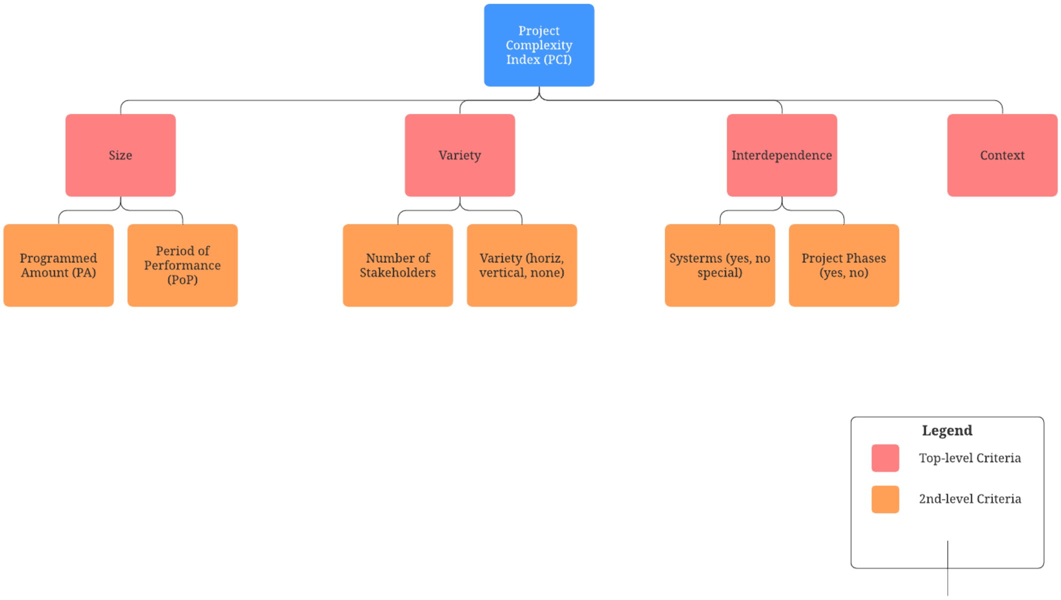


Figure 1 Project Complexity Index Hierarchy

The PCI produces low values to indicate a less complex project and high values to indicate a more complex project. However, for this research, the project complexity scores are transformed to ensure that the project complexity index values align with the RMI objective of favoring projects that are less complex. For each project, this transformation involves taking the difference between 1 and the project complexity score before the transformation.

Data

The project complexity index is a derived value (Fig. 2d), and the Tyndall PMO provides cost (Fig. 2a), MDI (Fig. 2b), and project duration (Fig. 2c) data. The y-axis shows the number of projects. Each has a different unit of measure, and to ensure equity in the model, both the MDI and project duration are min-max normalized (0,1]. The total project portfolio is valued at $2.9 Billion (maximum, $279 Million; minimum, $3.5 Million; mean, $52 Million) and 40 of the 56 projects have a programmed amount (cost) between $3.5 Million and $50 Million. The MDI statistics for the project portfolio are maximum, 100; minimum, 7; mean, 62. In addition, most projects are in the moderate to high MDI categories with 16 projects having MDI values between 40 and 60 and 19 projects having MDI values between 80 and 100. The project dates, both NTP and BOD, are used to calculate the duration, and the project portfolio has a maximum, 1620 days; minimum, 601 days; mean, 1001 days with most projects—16 – having durations between 600 and 800 days. However, the project complexity data before transformation is from a companion project and the statistics are maximum, 0.71; minimum, 0.23; mean, 0.49 with half of the projects having a complexity score between 0.4 and 0.5 (Figure 2d).

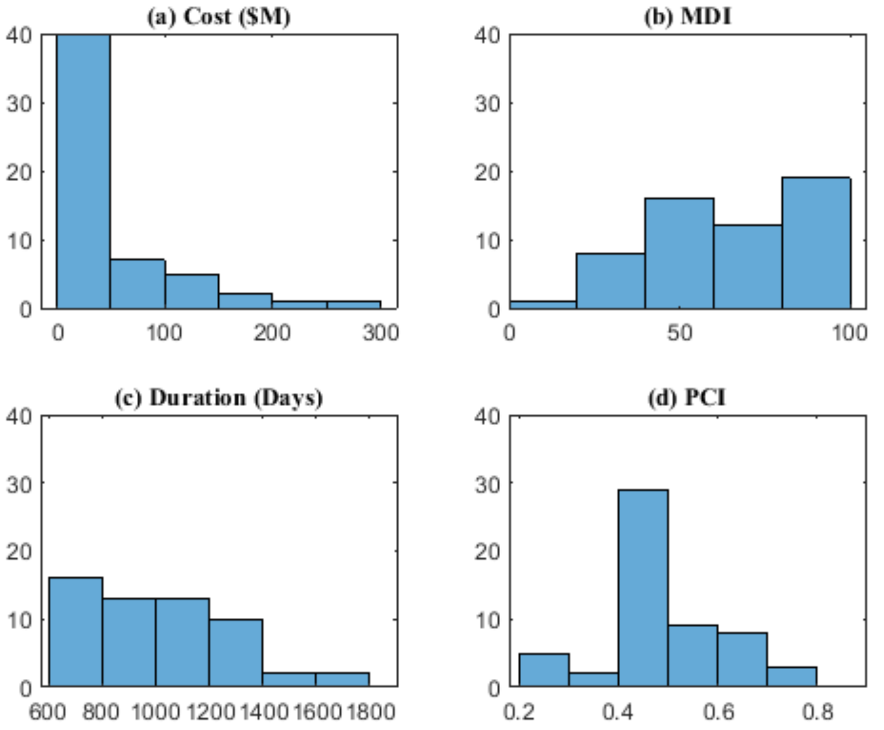


Figure 2 Distribution of Data

V. Methodology

Objective

This section presents the development of (1) a "local" decision model that investigates the optimal combination of relative weights, i.e., it produces the RMI; and (2) a "global" optimization model that can maximize project portfolio prioritization efforts in a post-disaster environment based on RMI and SPI. The local and global models form a two-stage approach to solving the problem of project prioritization (discussed below). This research uses Tyndall AFB PMO data to test and showcase the utility of the model in balancing stakeholder priorities and risk mitigation.

Overview

Addressing the research question involves the development of a two-factor sensitivity analysis, where the project selection and order are sensitive to different weights applied to a RMI and SPI as well as a budget allocation constraint (Figure 3). The research consists of a project portfolio of both new mission beddown and enduring mission projects and the research goal is to determine the projects' order and priorities through a maximization of both RMI and SPI. The first step is to develop a RMI, comprised of a parameterized PDI, PCI, and the affected facility's MDI. Next, a local optimization model determines the optimal combination of relative parameter weights that maximizes RMI. The RMI is combined with an SPI to perform a global optimization to determine final project prioritization given a weight assigned to SPI and RMI, and a budget constraint (f). The global optimization model is a variation of the classical knapsack optimization problem, where the objective is to determine how many projects fit into a "bin." Here, the bin size is f, which is arbitrary. Comparing model outputs across relaxations of f reveals the order in which project should be completed. The remainder of this chapter focuses on the development and discussion of the local and global optimization models executed to produce project portfolio prioritization.

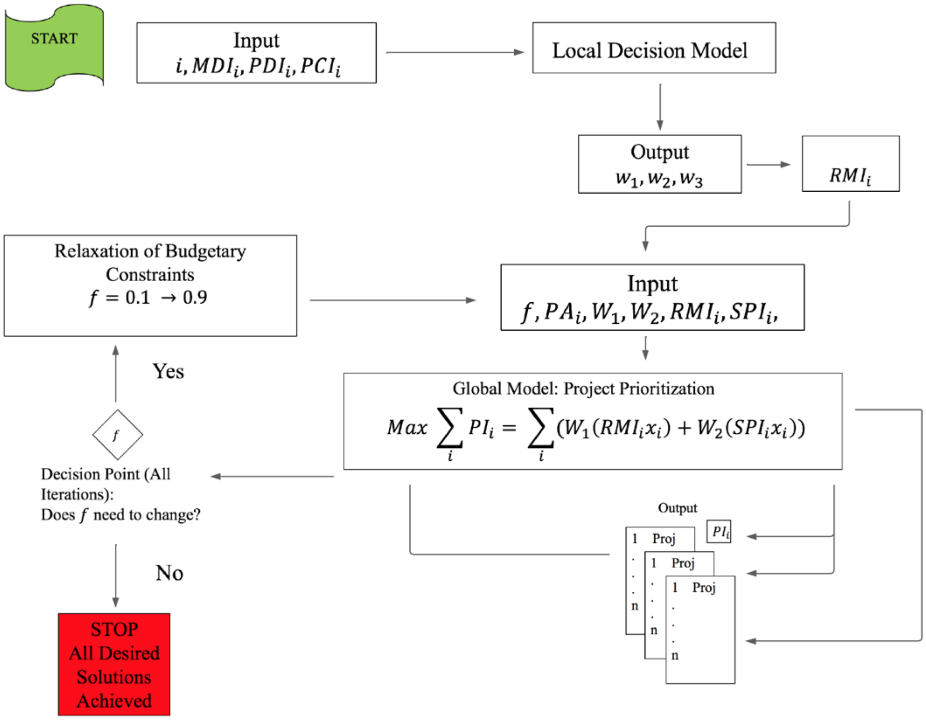


Figure 3. Conceptual design of local and global project prioritization framework

A Local Decision Model - Determination the Optimal Combination of Relative Weights for RMI

The local decisions model's objective is to determine the optimal values for w_1, w_2, and w_3 across the portfolio that minimizes the overall risk. The modeler can adjust the weighting constraint to define the level of risk to investigate. The decision model has three components (discussed in Section 3): MDI, PDI, and PCI and follows a standard linear optimization format (Equation 1):

$$\text{Max} \qquad \sum_i (MDI_i w_1 + PDI_i w_2 + PCI_i w_3) \tag{1}$$

$$\text{Subject to:} \qquad 0.25 \le w_1, w_2, w_3 \le 0.75 \tag{2}$$

Equation (1) models the appropriate distribution of parameters to produce a better risk mitigation measure. Each project (*i)* has parameter values for MDI_i, PDI_i, and PCI_i, that contribute to the calibration of weights ($w_1 \rightarrow MDI_i, w_2 \rightarrow PDI_i, w_3 \rightarrow PCI_i$), where the weights must sum to one. Constraint (2) sets lower and upper bounds so each parameter gets some amount of weighting. This simple constraint produces an MDI-dominated solution. Iteratively testing different constraints values further reveals MDI to be the most important parameter in the local decision model. This MDI-dominant solution is due to the fact that the coefficient in front of the w_1 parameter – the sum of project MDIs – is the largest of the three coefficients. Therefore, relying on this method of determining the weights leads to a MDI-centric RMI value.

To reflect the reality of multi-dimensional risk in project selection and management, the modeler uses good engineering judgement to allocate some weight to each parameter and set the weights between 0.25 and 0.75. These values are arbitrary and could be examined in future work.

A Global Model – Portfolio Optimization Framework for Post-Disaster Project Prioritization

To select and prioritize projects across multiple portfolios in a post-disaster environment requires the development of a multi-objective optimization model. This model is a multi-objective framework that utilizes a prioritization index (PI) to determine which project to complete and in what order subject to a budgetary constraint. The objective is to maximize the parameters, RMI and SPI.

Stakeholder Priority Index (SPI)

The SPI is a single value bounded between 0 and 1. Prioritizing both new mission beddown and enduring mission project require input from the various stakeholders involved with the Tyndall post-disaster reconstruction program. The SPI metric captures the users' input and measures how much a stakeholder or decision-maker values a project. For this work, a stakeholder is defined as the Installation Commander and organizational mission owners, both local and tenant units. Furthermore, for this research there are four different stakeholder groups: Beddown, Fighter Wing Flying Operations, Fighter Wing Mission Support, and Others. The Beddown stakeholders are solely interested in F-35 new mission projects. Both the Fighter Wing Flying Operations and Fighter Wing Mission Support stakeholders are interested in the installation's enduring mission projects. The Others stakeholders consist of tenant units and other projects under the FSRM program. Not included here are state, county, and local government agency or private utility company stakeholders, however, the framework could easily be expanded to account for these groups. Maximization of the SPI is desired, as larger values denote higher priorities (Equation 3) and all values are normalized on a 0 to 1 scale.

$$SPI_i = \left\| \frac{(n+1)-s_i}{n} \right\| \tag{3}$$

Equation (3) is the formulation of the normalized stakeholders' preference for each project (i). The integer (n) is the total number of projects within the portfolio and (s_i) is the project's ranking score between 1 and n.

The SPI and RMI metrics are given a weighted value between 0.1 and 0.9 in 0.1 increments, such that the PI is not only maximized, but also considers decision-makers' preferences when determining the optimal portfolio framework for post-disaster project prioritization (Equation 4). Furthermore, the multi-objective optimization model is subject to a budgetary constraint (f) available to the PMO, and this constraint is expressed as a percent of the total programmed value of the portfolio. The budget constraint is progressively relaxed across many simulations of the optimization model to reveal: (1) which projects are most important given a constrained budget; and (2) whether project recommendations across budget and SPI and RMI sensitives remain consistent, i.e., testing model result stability to changes in funding and preferences. Below is a formulation of the global multi-objective optimization model (Equation 4).

$$\text{Max} \quad \sum_i [W_1(RMI_i x_i) + W_2(SPI_i x_i)] \tag{4}$$

$$\text{Subject to:} \quad \sum_i PA_i x_i \leq f(PA_{total}) \tag{5}$$

$$x_i \in \{0,1\} \tag{6}$$

Equation (4) represents an objective function that mitigates the most amount of risk (*RMI$_i$*) and appeases stakeholders' priority (*SPI$_i$*) based on given weights (W_1, W_2) that sums to one. Constraint (5) is a budgetary restriction where all the included project cost (PA_i) have to be less than the stated budgetary allocation factor (f) of the project portfolio's total cost (PA_{total}). (f) ranges from 0.1 (10%) to 0.9 (90%); and (PA_{total}) is the total cost for all 56 projects. Finally, constraint (6) is a binary restriction on the decision variable (x_i), where (x_i) indicates whether a particular project is selected or not selected.

The Relaxation of Budgetary Constraint and Weighting Criteria

The global optimization model consists of nine different budgetary constraint scenarios and nine different weight criteria combinations of SPI and RMI, which produces a total of 81 unique portfolio realizations. The global model is a variation of classical knapsack problem. The iteration of relaxing the budgetary constraint simulates different knapsack sizes, and the model determines which projects and how many are added. The budget allocation factor is a single value between 0.1 and 0.9, in 0.1 increments, and represents the percent of the budget available to the PMO to execute projects. If the budget allocation factor was either 0 or 1 the model would recommend either no projects or all the projects. For instance, 0.3 represents that thirty percent of the overall portfolio budget is available to complete projects.

The SPI and RMI weighting factors are single values between 0.1 and 0.9 that represent the decision-makers' tendency to mitigate project risk or favor project portfolio ranking. For the weighting factors, 0 and 1 are not included as the model is considering both objectives at all times in the computational phase. For instance, a 0.1 weight value represents a slight preference for the objective to which it is assigned, 0.5 a moderate preference, and 0.9 a very strong preference. The RMI and SPI weighting factors are formulated as inverses of each other to model decision-making tradeoffs. An RMI weight value of 0.1 results in a SPI weight value of 0.9 and indicates that the decision-makers strongly prefer project portfolio ranking over project risk mitigation. An RMI weight value of 0.5 and subsequent SPI value of 0.5 indicates that the decision-makers value risk mitigation and project portfolio ranking equally. An RMI weight value of 0.9 and SPI value of 0.1 represents that the decision-makers strongly prefer project risk mitigation over project portfolio. Finally, the iteration of the RMI and SPI weights ensure that the model investigates the full spectrum of decision-making tradeoffs and the effect on project selection and project prioritization.

VI. Results

RMI Weights

Running eight iterations for the RMI optimization model reveals that the MDI is the dominant variable and the project complexity and project duration weights default to the boundary condition's lower limit value. Using the selected boundary condition of 0.25 and 0.75 (discussed in Section 5), the optimal RMI weights are as follows: w_1= 0.5, w_2= 0.25, and w_3= 0.25.

Portfolio Optimization Output

The global model results are a binary value with 1 indicating the project is recommended for construction and 0 indicating the project is not recommended for construction. Each project's individual objective value (PI_i) is a measure of that project's relative priority amongst the other projects and falls between 0 and 1; the higher the value, the higher the project's prioritization amongst the other 56 projects. The optimization model is sensitive to both the RMI and SPI weights and the available budgetary constraint. Simulating across the budget allocation factor (f) and the RMI and SPI weights (W_1, W_2) and pairing up the results, the model produces a 56 by 81 matrix of prioritized projects. Readers can refer to Appendix A for the global model's complete output across all scenarios. However, the analysis focuses on the five areas of interests (Figure 4) to investigate the effects of what happens to project prioritization as both the RMI and SPI weights and budget allocation factor changes in the extreme. Mode 1, the blue top left point, considers values at (RMI = 0.9, SPI = 0.1, f = 10%). Mode 2, the purple bottom left point, considers values at (RMI = 0.1, SPI = 0.9, f = 10%). Mode 3, the orange top right point, considers values at (RMI = 0.9, SPI = 0.1, f = 70%). Mode 4, the gray lower right point, considers values at (RMI = 0.1, SPI = 0.9, f = 70%) and Mode 5, the green central point, considers values at (RMI = 0.5, SPI = 0.5, f = 50%). The budgetary level of f = 0.7 is selected for Modes 3 and 4 because the maximum value of f = 0.9 does not provide any great insight into project prioritization and selection.

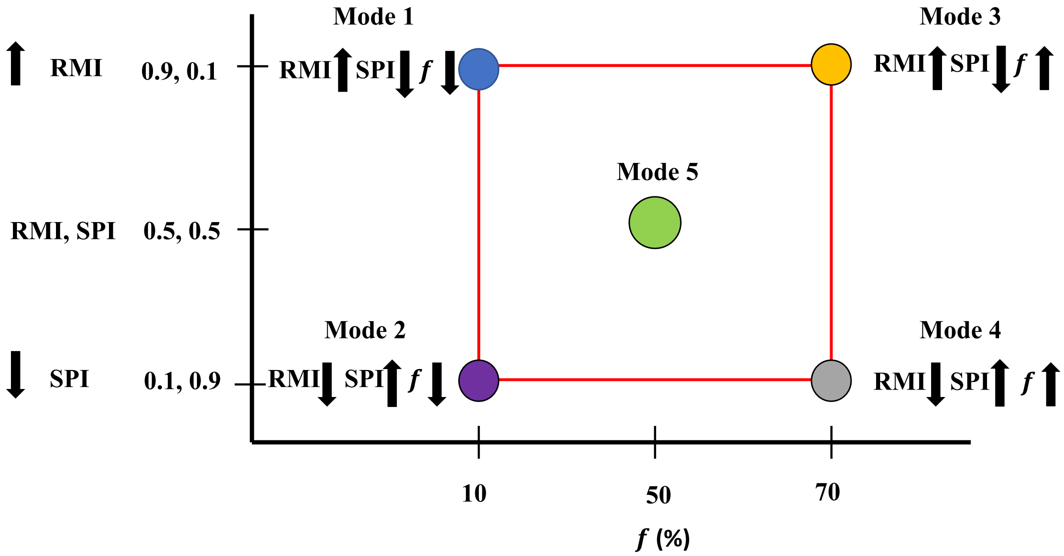


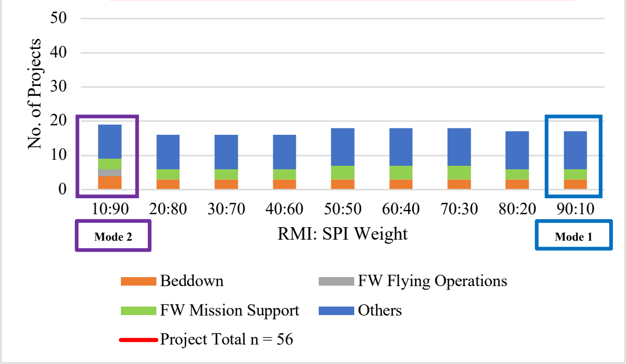
Figure 4. Notional Representation of the Global Model Output Analysis

In general, the global model prioritizes projects with an MDI between 40 and 100 and a low project cost between $3 and $25 Million and it is relatively agnostic to beddown mission and enduring mission, i.e., SPI does not impact project selection. When MDI is high (80-100) and project cost is low, the model mainly recommends F-35 beddown mission projects. When MDI is moderate (40-69) and the cost is low, the model mainly prefers enduring mission projects. The high and moderate MDI, low-cost projects are economical and provide huge payoff for stakeholders. However, the MDI is the dominant model feature, given that cost is low or moderate; as cost rises, MDI begins to have greater influence. For relatively low MDI values (40-50), low-cost projects are first recommended by the model at $f = 40\%$, and more expensive projects (> \$100 Million) are only recommended when $f > 70\%$. Across the nine different budgetary constraint scenarios, a few projects are generally not recommended for execution. For example, the Small Arms Range is the lowest MDI value project and one of the lowest cost projects, and even in instances when the Small Arms Range is considered for execution ($f > 50\%$), the project is only recommended when the model is weighted more heavily toward RMI. In summary, low-cost, high mission impact projects are generally preferred over high cost, low mission value projects.

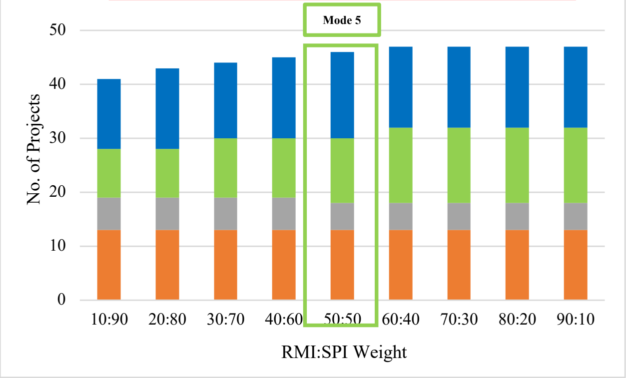
Figure 5 summarizes the recommended stakeholder groups projects at the $f = 10\%$ (Fig. 5a), $f = 50\%$ (Fig. 5b) and $f = 70\%$ (Fig. 5c) and highlights the outcomes at the five Modes represented in Figure 4. The results reveal that as RMI increases and the SPI decreases, there is a relative increase in the total number of projects completed as each stakeholder group comprises a mixture of moderate to high MDI (40-100) and low to moderate cost projects (≤ \$100 Million). In addition, there is a relative increase in the number of recommended Others stakeholder projects; relative stability in the number of the recommended Beddown and FW Flying Operations projects; and a slight fluctuation in number of recommended FW Mission Support projects, particularly at $f = 70\%$. This suggests that the Others stakeholder projects are susceptible to changes in RMI, and decision-makers, being more risk averse, favor low to moderate cost projects. Beddown and FW Flying Operation projects are unaffected by changes in the RMI and SPI as decision-makers favor high MDI projects. Both the Beddown and FW Flying Operation stakeholder groups have the two smallest portions of the total portfolio and consist of mainly high-MDI projects. FW Mission Support projects remain relatively stable. However, as the budget increases and decision-makers become more risk averse, there is "zone of indecisiveness" when RMI is between 30 and 50. At this point decision-makers are torn between prioritizing their own projects and mitigating risk. Across the five Modes, the stakeholder groups remain relatively stable, and the model recommends at least one project from each of the four projects except Mode 1. Furthermore, at the 10% budget scenario Mode 2 is the only scenario where the model recommends FW Flying Operation projects. The FW Flying operations have mostly moderate-MDI projects with the exception of two high-MDI projects (> 90), and this outcome suggests that the model recommends high-MDI projects when risk mitigation is low i.e., the decision-maker is very risk tolerant.

As the available budget increases the Beddown, Fighter Wing (FW) Flying Operations and Others stakeholder groups receive 50% of their respective projects at low budget scenarios ($f \leq 30\%$), while the Fighter Wing (FW) Mission Support groups receives 50% of their projects at $f > 30\%$ (Figure 5). Furthermore, at the 10% budget scenario, the model recommends on average mostly Others project group with 11 projects (61% of the group's total projects); followed by four Beddown group projects (60% of the group's total projects); two FW Flying Operations projects (30% of the group's total projects); and three FW Mission Support projects (18% of the group's total projects). At the 50% budget scenario the model recommends all Beddown group projects with 13 projects and mostly all FW Flying Operation projects with six projects, both 100% of their respective group's total projects. Next, the model recommends 15 Others projects (83% of the group's total projects) and nine FW Mission Support projects (53% of the group's total projects). At the 70% budget scenario the model recommends 16 Others projects (89% of the group's total projects) and 15 FW Mission Support projects (88% of the group's total projects).

(a) Stakeholder Projects Recommended at f = 10%



(b) Stakeholder Projects Recommended at f = 50%



(c) Stakeholder Projects Recommended at f = 70%

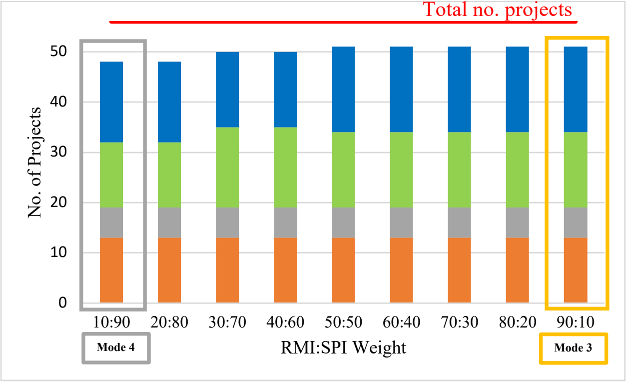


Figure 5. Stakeholder Project Recommendation at Different Funding Scenarios

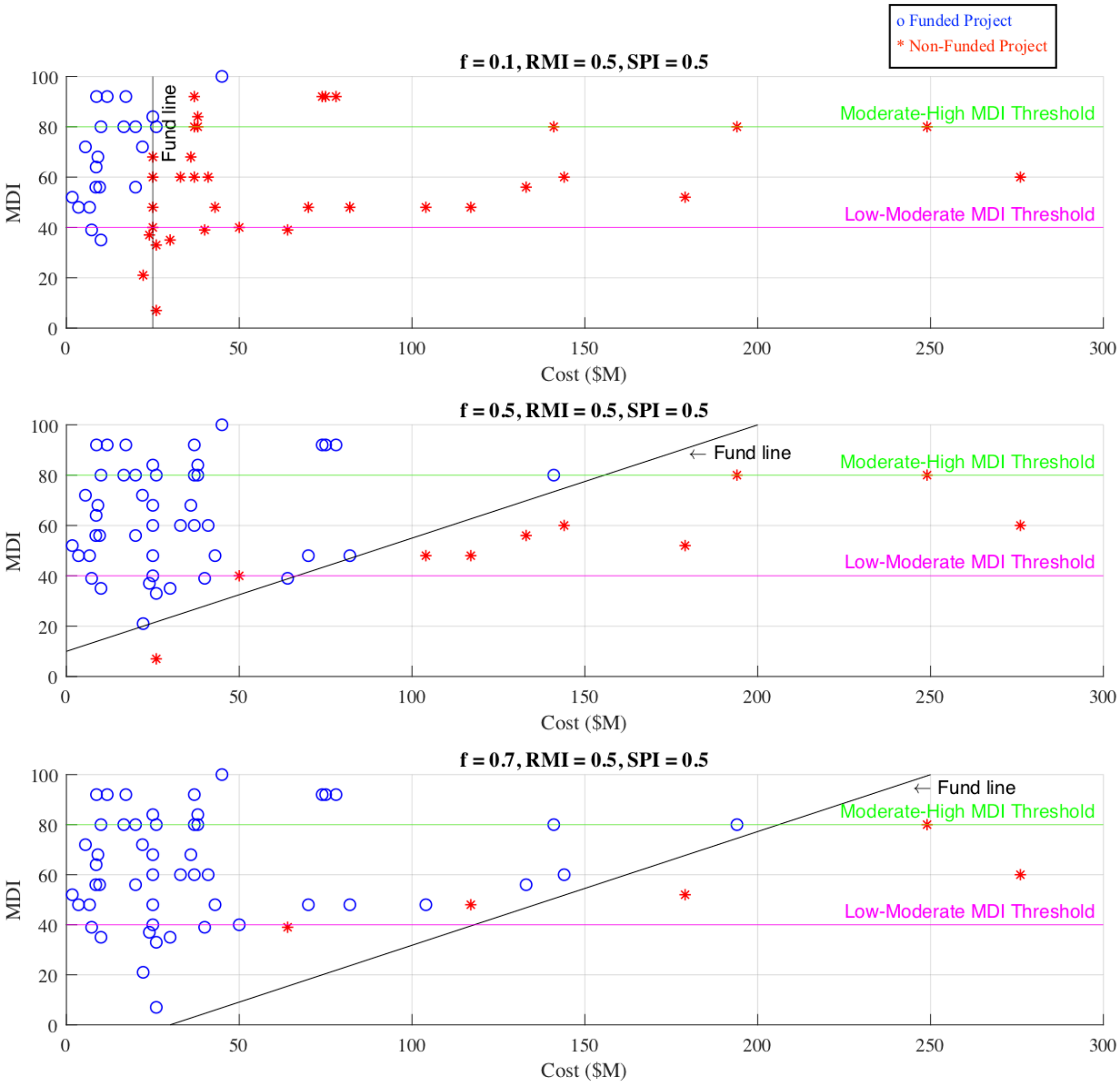


Figure 6 Funded and Non-Funded Projects at Different Funding Scenarios

Figure 6 summarizes the funded and non-funded projects with respect to the cost and MDI at various values of f, RMI and SPI. Fig. 6a considers values at (RMI = 0.5, SPI = 0.5, f = 10%). Fig 6b. considers values at (RMI = 0.5, SPI = 0.5, f = 50%). Fig. 6c considers values at (RMI = 0.5, SPI = 0.5, f = 70%). Furthermore, the pink, horizontal line delineates low and moderate MDI values and the green horizontal line delineates moderate and high MDI values.

Each figure highlights a “tension zone” between funded and non-funded projects delineated by a “fund-don’t fund” line. At $f = 10\%$, there is a vertical “fund-don’t fund” line where the majority of the funded projects are moderate to high MDI projects (40-100) and between \$3 and \$25 Million. As the budget allocation factor increases to $f = 50\%$, the fund-don’t fund line’s slope decreases and selects the remaining low MDI projects, except for the Small-Arms Range project (MDI = 7, cost = \$27 Million), and a few moderate MDI projects, except for the Gate Complex project (MDI = 40, cost = \$50 Million). Finally, at $f = 70\%$, the fund-don’t line rotates and translates and recommends more expensive projects (> \$100 Million). In addition, the model recommends the Small-Arms Range project, the Utilities Demo Phase 2 project (MDI = 80, cost = \$141 Million) but not the Utilities Demo Phase 1 project (MDI = 80, cost = \$194). Decision-makers would not accept this recommendation because the recommendation violates scheduling logic. Therefore, there needs to be a deliberative period. The suggested course of action from the deliberations would be to wait until $f = 70\%$ to complete both Utilities Demo phases and at the $f = 50\%$ reallocate some of the budget towards other projects such as the Gate Complex project.

Categorizing Project Behaviors

When looking at the prioritization model's output at each of the nine different budgetary constraint scenarios, the projects begin to appear in Regimes. A Regime is a behavior that projects exhibit due to their sensitivity to decision-makers favoring RMI or SPI. Considering a given budgetary constraint scenario and investigating the trend across all nine RMI and SPI weighting scenarios within that given budgetary constraint level, projects exhibit five Regimes: (1) the project is always selected, (2) never selected, (3) is selected and then not selected across weighting scenarios, (4) is not selected and then is selected across weighting scenarios (opposite of 3), and (5) others. These Regime values, n_{R_1} through n_{R_5} , are divided by the total number of portfolio projects and then expressed as percentages. Figure 7 shows a notional representation of the various Regimes at a given budgetary scenario, f, in percentage.

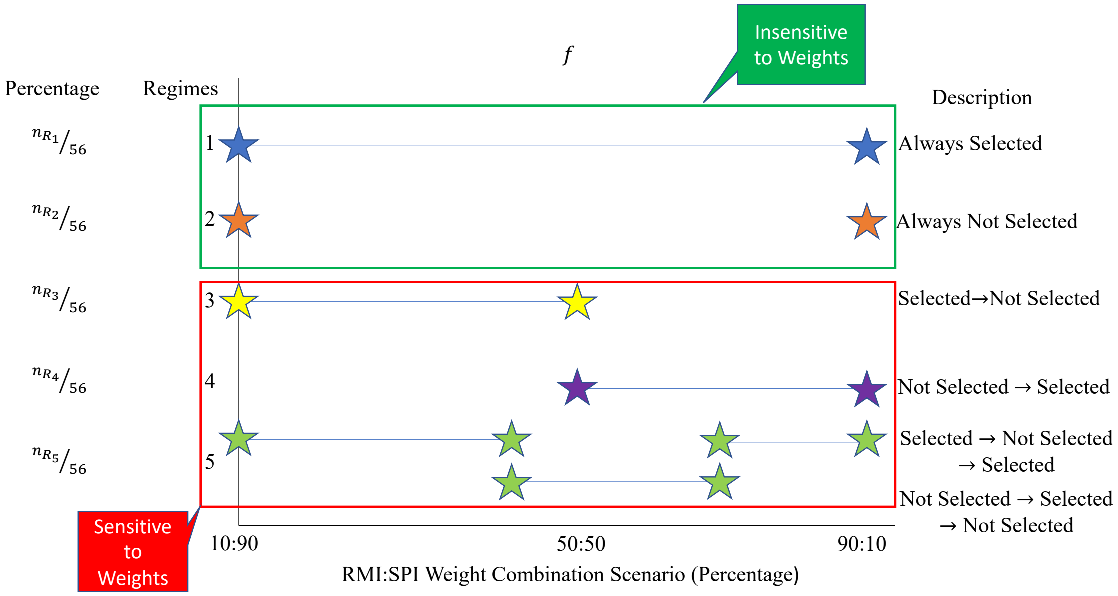


Figure 7. Notional Representation of Project Regimes

In Figure 8 each budget allocation level considers all nine RMI and SPI weight combination (Fig. 6). Furthermore, Figure 7 reveals that for any budget allocation, many projects fall in Regime 1 or Regime 2. This outcome suggests that the model is relatively stable to changes in RMI and SPI, i.e., the project either is or is not selected in any budget allocation scenario and projects are moderate to high-cost projects. In addition, there is an uptick in the number of projects in Regime 5 around the zone of indecisiveness. That uptick suggests that decision-makers are unsure of what they want, and Section 5 illustrates this phenomenon. Regimes 3 and 4 remain relatively stable throughout.

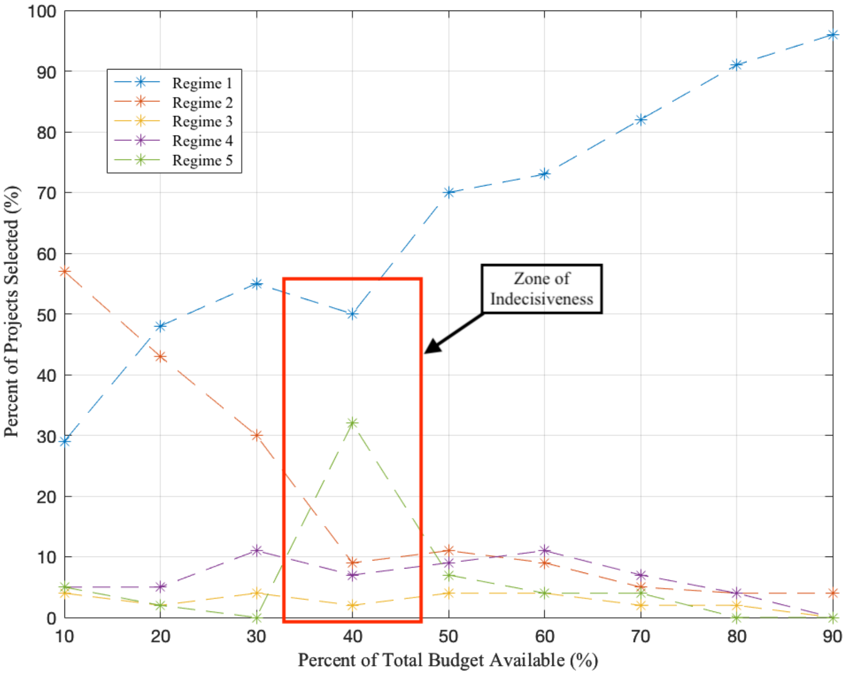


Figure 8 Summary of Model Outputs Using Regimes

V. Discussion

The literature review concludes that multiple post-disaster studies have considered both risk mitigation and stakeholder influence separately. The research's novel contribution is that the prioritization model combines both risk mitigation and stakeholder prioritization into a user-friendly, duplicable, and efficient model. Furthermore, in historical post-disaster construction events, as discussed earlier, the USAF PMO's main objective was to regenerate the enduring mission. However, Tyndall AFB presents a more complex challenge with the introduction of simultaneously bedding down a new mission. This model addresses this complexity by incorporating not only risk mitigation activities but also accounting for the challenges posed by multiple stakeholders. The model reveals the possibility of linking both risk mitigation and stakeholder prioritization, while considering tradeoffs through the RMI and SPI weights. Inadequate stakeholder interactions or none at all creates risk, and the model needs to account for stakeholder interactions (Eid & El-adaway, 2017). Therefore, maximizing both stakeholder prioritization and risk mitigation improves overall risk management, project portfolio management, and project prioritization (Ghannad et al., 2021). The project prioritization model results demonstrate its preference for low cost, high mission impact projects over high-cost, low mission impact projects. The model also reveals that as the RMI weight increases and decision-makers favor risk mitigation over their individual project preference, more overall projects are recommended.

The Small Arms Range project is one of the lowest cost, lowest MDI projects in the portfolio. Outside of this model, decision-makers would likely recommend this project at the 10% budget scenario. However, the model does not reliably recommend this project until 70% of the budget is available. Based on the funding documents approved by the US Congress, the PMO plans to execute the Small Arms Range; however, it is probably better not to execute this project. The model does not favor this project because of the low mission benefit for stakeholders; the model only recommends the project at higher budget levels when decision-makers value risk mitigation over project preference. Designing the Small Arms Range to a lower standard lowers the cost and might make the project a more likely candidate for this optimization model. In addition, if decision-makers use this model for adapting infrastructure pre-disaster, they would not recommend the Small Arms Range for adaptation because they can find alternatives and afford to lose the project in the case of a disaster.

In addition, this research expects to produce a portfolio planning tool that reduces cost overruns, schedule overruns, and complexity while also improving efficiency and effectiveness. While the process of solving for the RMI objective reveals that the MDI is the most important parameter, the inclusion of the PCI and PDI are integral to addressing the research question and mitigating the effects of schedule overruns and project complexity. Therefore, the overall construction of the RMI is important to the model and is illustrated below in the following example.

The AFCEC Facilities and Gate project is the second most expensive project in the portfolio with a high MDI and complexity (PCI < 0.35). However, the project duration is less risky at 500 days, approximately 120 days (4 months) below the average. The model does not recommend this project until 90% of the budget is available. Based on the funding documents approved by the US Congress, the PMO plans on executing this AFCEC project. The project is complex because it involves the construction of multiple laboratory facilities, which are themselves complex. The model does not favor this project mainly because of the cost as the project is 9% of the overall portfolio budget. The model would favor this project if it were divided into multiple phases as long as those phases do not violate USAF project-splitting programming rules. This division will lower the project's cost and duration and ensure that the AFCEC project is a more likely candidate for this optimization model.

The model presents a diverse array of projects considering multiple stakeholders. As discussed earlier, there are four stakeholder groups, and the model illustrates that the RMI and SPI weights influence the type of projects that are completed. A majority of Beddown and FW Flying Operation stakeholder group projects are high-MDI projects and are recommended in low-RMI scenarios, such as the Aircraft Parking Apron and the Flight line Fire Station. The FW Mission Support and Other stakeholder groups consist of low to high MDI projects. When the decision-maker is risk-tolerant (low RMI), the model selects FW Mission Support and Others stakeholder projects that are also moderate to high MDI such as Fire Station #2 and the Emergency Management Facility. When

RMI is high and decision-makers are more risk-averse (high SPI), decision-makers will tend to prefer their own respective stakeholder projects versus low to moderate MDI projects.

Regimes

The notional Regimes representation (Figure 7) and the summary of model outputs (Figure 8) illustrate that Regime 1 projects are the most important projects as they are always on, Regime 2 projects are the least important projects, Regime 3 projects are important to some extent but stop becoming a priority at some point, Regime 4 projects eventually become important but are still less important than Regimes 3 projects and Regime 5 projects require further investigation. There are examples of Regimes 3 and 4 projects, albeit a few, across the different budget scenarios. This behavior seems to be the case because projects like the Small Arms Range, a Regime 4 project, do not get much stakeholder support. However, as risk mitigation increases, the model recommends this project. This outcome indicates that projects like the Small Arms Range are only recommended at both higher budget scenarios and risk mitigation scenarios. For Regime 3 projects decision-makers value project preference over risk mitigation to some degree. At low budget scenarios, such as $f = 10\%$, projects such as the OSS/RADR project and the CE Maintenance Shops are Regime 3 projects that have low costs and high MDIs. Decision-makers behave in this manner because while the projects are high pay off projects, decision-makers tend to become more risk-averse (high RMI) and stay away from these high mission value projects and focus on low-cost, lower MDI projects to meet the budgetary constraint. For Regime 4 projects decision-makers value project preference over risk mitigation to some degree. At low-budget scenarios, such as $f = 10\%$, projects such as the Special Purpose Vehicle Maintenance Shop and F-35 Weapons Load Training Hangar are Regime 4 projects that have low costs and moderate MDIs. Decision-makers behave in this manner because while the project is a low-hanging fruit, decision-makers tend to prefer low-cost, high-impact projects. However, as risk mitigation becomes more prevalent decision-makers tend to abandon their preferences and focus on these low-cost, moderate-MDI projects to meet the budgetary constraint.

At low budget scenarios such as $f = 10\%$, decision-makers behave in a manner that prioritize mission importance (MDI) over cost and focus mainly on selecting as many "low-hanging" and "must do" projects i.e., low-cost, high-MDI and low-cost, moderate-MDI projects. The 29% of Regime 1 projects are mainly Others stakeholder projects such as the ABM Simulator Facility, while the 57% of Regime 2 projects at f = 10% are moderate to expensive projects (> \$25 Million). For instance, at a ten percent budget allocation, valued at \$293 Million, decision-makers would never consider the selecting the Utilities Demo Phase 1 project, a high-impact (MDI = 80) and expensive (> \$100 Million) project. This one project uses up 66% of the allocated budget and diminished the decision-makers ability to capitalize on as many "low-hanging fruit" projects.

As the budget constraint is relaxed, more money becomes available and the percentage of Regime 1 projects increases, but not proportionally to the budget constraint relaxation. At the budget scenario level ($f = 40\%$) there is a notable "inflection point" in the number of Regime 1 projects between $f = 30\%$ and $f = 50\%$ (Figure 8). In addition, the number of Regime 5 projects, the next highest percentage of selected projects at 32%, experience an uptick in the number of projects recommended. The uncertainty at budget scenario level ($f = 40\%$) and the significant increase in Regime 5 projects represents a "period of indecisiveness," and a shift in the decision-makers behaviors. By the time budget scenario level ($f = 30\%$) is complete, the model recommends 100% of the Beddown group projects and 83% of all the FW Flying Operations projects. Also of note is that all the recommended F35 and FW Flying Operation projects are high-impact, Regime 1 projects. With the majority of high-impact projects already selected, decision-makers are now left with prioritizing the remaining stakeholder projects, which are multiple combinations of low to expensive projects and low to high impact projects. Decision-makers are left wondering what to do from here; continue focusing on high-impact, "must-do" project or begin focusing on low-cost, "nice-to-have" projects. The Regime 5 projects are the prioritization model's way of displaying the decision-makers "indecisiveness" behaviors and suggests that the model is relatively sensitive to changes in RMI and SPI. For instance, at ($f = 40\%$) the CES Shops and Maintenance Complex project (cost > $26 Million, MDI = 80) is a Regime 5 project that is not selected when RMI < 30, selected at RMI $= 30$ and then not selected again at RMI > 30. As decision-makers become more risk-averse at the RMI $= 30$ and more money is available they select this high-impact project for one moment. However, as they become more risk averse and consider high-mission impact projects, they defaulted back to non-selection and chose the MWR facilities and Recreation Fields project, This project is another Regime 5 project that mirrors the CES Shops and Maintenance Complex project and is a cheap, low-impact and "nice to have" project.

At budget scenario ($f = 70\%$), 82% of Regime 1 projects are selected. However, the Regimes of interest are the 5% of Regime 2 projects and 4% of Regime 5 projects still remaining. The remaining 5% of Regime 3 projects are the first, second and fourth most expensive projects in the portfolio. The remaining 4% of Regime 5 projects are the WEG Hangar project, an Others stakeholder project, at (cost > $100 Million, MDI between 40-60) and the Community Commons project, a FW Mission Support project, at (cost 50-70, MDI 30-40). Both these projects are a tradeoff of each other as decision-makers select the Community Commons project at (RMI = 30 and RMI = 40) while simultaneously not selecting the WEG Hangar project at the same RMI levels.

Assumptions and Limitations

Several assumptions are utilized in the formulation of this proposed methodology: (1) the projects had no interdependency with each other; (2) Project acceleration methods such as schedule crashing or resource allocation are not applied to these PMO portfolio projects; (3) Temporary structures are not considered as alternatives for mission redundancy and; (4) Demolition projects are not considered portfolio projects.

Two primary limitations exist that presents opportunities for future improvements to the prioritization model and framework. The first limitation is the use of fictitious stakeholder data. With the time commitment and challenges involved with conducting human subject research and surveys, the researcher synthetically generated the stakeholder's project ranking scores (s_i). This decision results in the development and employment of fictitious SPI inputs that eventually limits the optimization model. The project ranking scores are generated on the assumption that stakeholders have a neutral preference on project selection, which limits the different behavior types stakeholders can exhibit and the introduction of a "rouge" or different-minded stakeholder group can shift the project prioritization model's results significantly. To combat this limitation, future research can involve the use of a Delphi study with focus groups or develop and distribute surveys to get the project preferences directly from the stakeholder. These survey results can be used to develop a distribution of stakeholder priorities and decision-making preferences. In addition, the ABM model (discussed in Section 2) can model stakeholder interactions and remove the "fictitious" nature of stakeholder assumptions. The ABM model's goal is to take competing objectives of multiple stakeholders and align them with an overall goal. While challenging to construct, the ABM model will result in a more accurate representation of stakeholder priorities and reduces the prioritization model's limitation.

The second limitation is the number of parameters use in the formulation of the RMI. While the MDI, PDI and PCI sufficiently addresses the research question and tailors the problem to the USAF, the model can incorporate other post-disaster risk factors such as; safety, asset damage cost, economic impact, regulation and sustainability to name a few (Moreu et al., 2019). Future researchers can employ multiple linear regression to test for interdependency as new risk parameters are considered. Readers can refer to Moreu et. al (2019) for a comprehensive list of criteria.

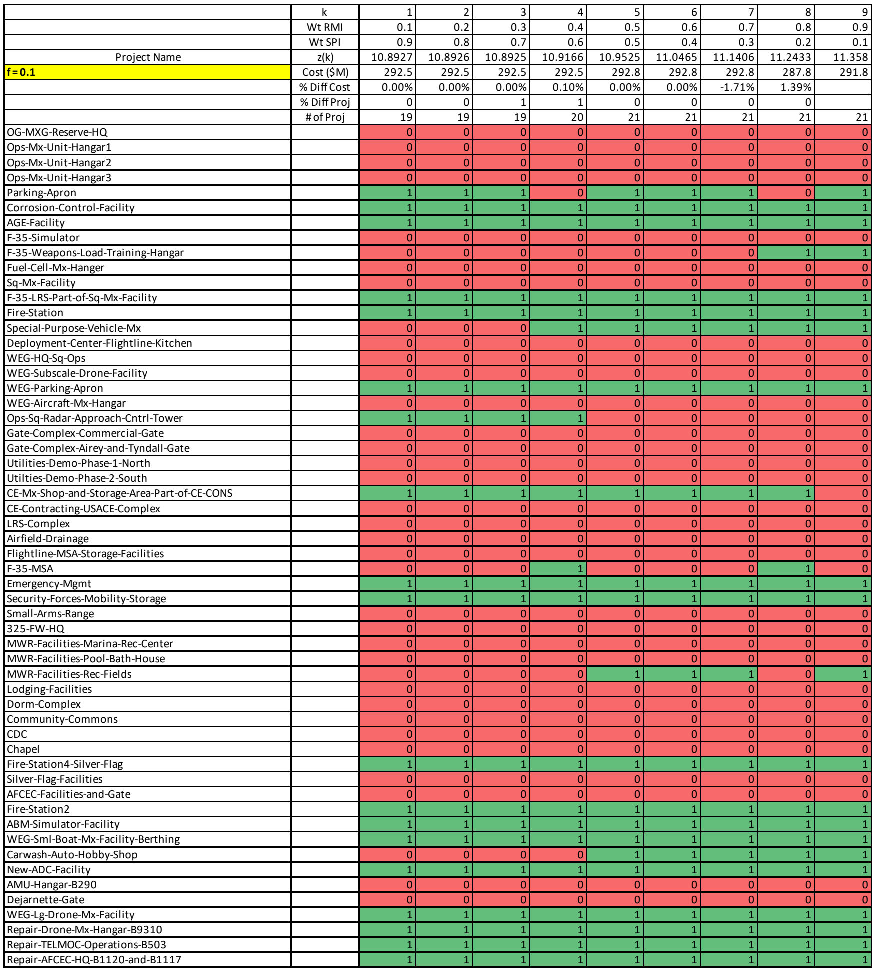
VI. Conclusion

In the aftermath of natural disasters, decision-makers are faced with multiple challenges in the natural and built environments. They must provide services and infrastructure that return society and the economy to an adapted standard-one that protects against recurrence. Private and public sector decision-makers normally focus post-disaster efforts on a piecemeal rebuild. The rebuilding effort may involve activities such as rebuilding key infrastructure, utility systems, roadways, and housing. However, rebuild and new construction efforts in a post-storm environment are rarely comprehensively planned, as facility owners and developers scramble to absorb construction capacity in the local economy (Ghannad et al., 2020; Orabi et al., 2009). The result is a suboptimal construction process and one that results in suboptimal quality and return of essential services. This global model uses risk mitigation and stakeholder priorities as a mechanism to give decision-makers prioritize rebuild projects in a post-disaster environment while under a budgetary constraint.

The global model is flexible and allows for the addition of other objectives and criteria to explore prioritizing complex, post-disaster construction projects. For the local model the solution was MDI-dominant and the weights are selected using good engineering judgment. However future research needs to be done to better improve the model. Researchers can use AHP and pairwise comparison to investigate which one of three categories, MDI, PDI, PCI, is most appropriate or if equal weighting is the better option. With the weights substantiated by the AHP and pairwise comparison, the results are then validated using Delphi study or developed survey from a polled audience. -In addition, the model can experiment with project interdependency and investigate how connected projects influence the selection and prioritization.

This research provides the Tyndall PMO with a range of data-driven portfolio sequences that illustrate the tradeoffs between risk mitigation and stakeholder priorities. The installation of the future (IoTF) construct by which Tyndall is being rebuilt and adapted is the template for the DoD's installation modernization plan. Optimization of construction portfolios, like the one undertaken in this research, have wide-reaching utility for the Department of Defense. Furthermore, for organizations outside the USAF and DoD, having decided on a measure of facility importance, construction complexity, project duration, the number of stakeholders, and the level of influence the stakeholders, can implement this model and framework as planning tool for future natural disasters or contingency operations involving competing stakeholders and priorities. State and municipality governments can utilize this model to improve the robustness of their post-disaster plans. In a non-post disaster situation, the private sector could benefit from this research. For example, hospitals and universities/colleges with multiple campuses and/or mix-use campuses can use the research from this body of work to inform their multi-stakeholder construction portfolios.

Appendix A: Project Prioritization Model Output



	k	1	2	3	4	5	6	7	8	9
	Wt RMI	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
	Wt SPI	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1
Project Name	z(k)	10.8927	10.8926	10.8925	10.9166	10.9525	11.0465	11.1406	11.2433	11.358
f = 0.1	Cost ($M)	292.5	292.5	292.5	292.5	292.8	292.8	292.8	287.8	291.8
	% Diff Cost	0.00%	0.00%	0.00%	0.10%	0.00%	0.00%	-1.71%	1.39%	
	% Diff Proj	0	0	1	1	0	0	0	0	
	# of Proj	19	19	19	20	21	21	21	21	21
OG-MXG-Reserve-HQ		0	0	0	0	0	0	0	0	0
Ops-Mx-Unit-Hangar1		0	0	0	0	0	0	0	0	0
Ops-Mx-Unit-Hangar2		0	0	0	0	0	0	0	0	0
Ops-Mx-Unit-Hangar3		0	0	0	0	0	0	0	0	0
Parking-Apron		1	1	1	0	1	1	1	0	1
Corrosion-Control-Facility		1	1	1	1	1	1	1	1	1
AGE-Facility		1	1	1	1	1	1	1	1	1
F-35-Simulator		0	0	0	0	0	0	0	0	0
F-35-Weapons-Load-Training-Hangar		0	0	0	0	0	0	0	1	1
Fuel-Cell-Mx-Hanger		0	0	0	0	0	0	0	0	0
Sq-Mx-Facility		0	0	0	0	0	0	0	0	0
F-35-LRS-Part-of-Sq-Mx-Facility		1	1	1	1	1	1	1	1	1
Fire-Station		1	1	1	1	1	1	1	1	1
Special-Purpose-Vehicle-Mx		0	0	0	1	1	1	1	1	1
Deployment-Center-Flightline-Kitchen		0	0	0	0	0	0	0	0	0
WEG-HQ-Sq-Ops		0	0	0	0	0	0	0	0	0
WEG-Subscale-Drone-Facility		0	0	0	0	0	0	0	0	0
WEG-Parking-Apron		1	1	1	1	1	1	1	1	1
WEG-Aircraft-Mx-Hangar		0	0	0	0	0	0	0	0	0
Ops-Sq-Radar-Approach-Cntrl-Tower		1	1	1	1	0	0	0	0	0
Gate-Complex-Commercial-Gate		0	0	0	0	0	0	0	0	0
Gate-Complex-Airey-and-Tyndall-Gate		0	0	0	0	0	0	0	0	0
Utilities-Demo-Phase-1-North		0	0	0	0	0	0	0	0	0
Utilties-Demo-Phase-2-South		0	0	0	0	0	0	0	0	0
CE-Mx-Shop-and-Storage-Area-Part-of-CE-CONS		1	1	1	1	1	1	1	1	0
CE-Contracting-USACE-Complex		0	0	0	0	0	0	0	0	0
LRS-Complex		0	0	0	0	0	0	0	0	0
Airfield-Drainage		0	0	0	0	0	0	0	0	0
Flightline-MSA-Storage-Facilities		0	0	0	0	0	0	0	0	0
F-35-MSA		0	0	0	1	0	0	0	1	0
Emergency-Mgmt		1	1	1	1	1	1	1	1	1
Security-Forces-Mobility-Storage		1	1	1	1	1	1	1	1	1
Small-Arms-Range		0	0	0	0	0	0	0	0	0
325-FW-HQ		0	0	0	0	0	0	0	0	0
MWR-Facilities-Marina-Rec-Center		0	0	0	0	0	0	0	0	0
MWR-Facilities-Pool-Bath-House		0	0	0	0	0	0	0	0	0
MWR-Facilities-Rec-Fields		0	0	0	0	1	1	1	0	1
Lodging-Facilities		0	0	0	0	0	0	0	0	0
Dorm-Complex		0	0	0	0	0	0	0	0	0
Community-Commons		0	0	0	0	0	0	0	0	0
CDC		0	0	0	0	0	0	0	0	0
Chapel		0	0	0	0	0	0	0	0	0
Fire-Station4-Silver-Flag		1	1	1	1	1	1	1	1	1
Silver-Flag-Facilities		0	0	0	0	0	0	0	0	0
AFCEC-Facilities-and-Gate		0	0	0	0	0	0	0	0	0
Fire-Station2		1	1	1	1	1	1	1	1	1
ABM-Simulator-Facility		1	1	1	1	1	1	1	1	1
WEG-Sml-Boat-Mx-Facility-Berthing		1	1	1	1	1	1	1	1	1
Carwash-Auto-Hobby-Shop		0	0	0	0	1	1	1	1	1
New-ADC-Facility		1	1	1	1	1	1	1	1	1
AMU-Hangar-B290		0	0	0	0	0	0	0	0	0
Dejarnette-Gate		0	0	0	0	0	0	0	0	0
WEG-Lg-Drone-Mx-Facility		1	1	1	1	1	1	1	1	1
Repair-Drone-Mx-Hangar-B9310		1	1	1	1	1	1	1	1	1
Repair-TELMOC-Operations-B503		1	1	1	1	1	1	1	1	1
Repair-AFCEC-HQ-B1120-and-B1117		1	1	1	1	1	1	1	1	1

			k	1	2	3	4	5	6	7	8	9
			Wt RMI	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
			Wt SPI	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1
Proj #	Project Name		z(k)	15.7305	15.7608	15.8385	15.9454	16.0523	16.1591	16.266	16.3729	16.4798
	f = 0.2		Cost ($M)	585.5	581.5	585.8	585.8	585.8	585.8	585.8	585.8	585.8
			% Diff Cost	-0.68%	0.74%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
			% Diff Proj	0	2	0	0	0	0	0	0	
			# of Proj	28	28	30	30	30	30	30	30	30
1	OG-MXG-Reserve-HQ			0	0	1	1	1	1	1	1	1
2	Ops-Mx-Unit-Hangar1			0	0	0	0	0	0	0	0	0
3	Ops-Mx-Unit-Hangar2			0	0	0	0	0	0	0	0	0
4	Ops-Mx-Unit-Hangar3			0	0	0	0	0	0	0	0	0
5	Parking-Apron			1	1	1	1	1	1	1	1	1
6	Corrosion-Control-Facility			1	1	1	1	1	1	1	1	1
7	AGE-Facility			1	1	1	1	1	1	1	1	1
8	F-35-Simulator			1	1	1	1	1	1	1	1	1
9	F-35-Weapons-Load-Training-Hangar			1	1	1	1	1	1	1	1	1
10	Fuel-Cell-Mx-Hanger			1	1	1	1	1	1	1	1	1
11	Sq-Mx-Facility			0	1	0	0	0	0	0	0	0
12	F-35-LRS-Part-of-Sq-Mx-Facility			1	1	1	1	1	1	1	1	1
13	Fire-Station			1	1	1	1	1	1	1	1	1
14	Special-Purpose-Vehicle-Mx			1	1	1	1	1	1	1	1	1
15	Deployment-Center-Flightline-Kitchen			0	0	0	0	0	0	0	0	0
16	WEG-HQ-Sq-Ops			0	0	0	0	0	0	0	0	0
17	WEG-Subscale-Drone-Facility			0	0	0	0	0	0	0	0	0
18	WEG-Parking-Apron			1	1	1	1	1	1	1	1	1
19	WEG-Aircraft-Mx-Hangar			0	0	0	0	0	0	0	0	0
20	Ops-Sq-Radar-Approach-Cntrl-Tower			1	1	1	1	1	1	1	1	1
21	Gate-Complex-Commercial-Gate			0	0	0	0	0	0	0	0	0
22	Gate-Complex-Airey-and-Tyndall-Gate			0	0	0	0	0	0	0	0	0
23	Utilities-Demo-Phase-1-North			0	0	0	0	0	0	0	0	0
24	Utilties-Demo-Phase-2-South			0	0	0	0	0	0	0	0	0
25	CE-Mx-Shop-and-Storage-Area-Part-of-CE-CONS			1	1	1	1	1	1	1	1	1
26	CE-Contracting-USACE-Complex			0	0	0	0	0	0	0	0	0
27	LRS-Complex			0	0	0	0	0	0	0	0	0
28	Airfield-Drainage			0	0	0	0	0	0	0	0	0
29	Flightline-MSA-Storage-Facilities			1	1	1	1	1	1	1	1	1
30	F-35-MSA			1	1	1	1	1	1	1	1	1
31	Emergency-Mgmt			1	1	1	1	1	1	1	1	1
32	Security-Forces-Mobility-Storage			1	1	1	1	1	1	1	1	1
33	Small-Arms-Range			0	0	0	0	0	0	0	0	0
34	325-FW-HQ			1	1	1	1	1	1	1	1	1
35	MWR-Facilities-Marina-Rec-Center			0	0	0	0	0	0	0	0	0
36	MWR-Facilities-Pool-Bath-House			0	0	0	0	0	0	0	0	0
37	MWR-Facilities-Rec-Fields			0	0	1	1	1	1	1	1	1
38	Lodging-Facilities			0	0	0	0	0	0	0	0	0
39	Dorm-Complex			0	0	0	0	0	0	0	0	0
40	Community-Commons			0	0	0	0	0	0	0	0	0
41	CDC			1	0	0	0	0	0	0	0	0
42	Chapel			0	0	0	0	0	0	0	0	0
43	Fire-Station4-Silver-Flag			1	1	1	1	1	1	1	1	1
44	Silver-Flag-Facilities			1	1	1	1	1	1	1	1	1
45	AFCEC-Facilities-and-Gate			0	0	0	0	0	0	0	0	0
46	Fire-Station2			1	1	1	1	1	1	1	1	1
47	ABM-Simulator-Facility			1	1	1	1	1	1	1	1	1
48	WEG-Sml-Boat-Mx-Facility-Berthing			1	1	1	1	1	1	1	1	1
49	Carwash-Auto-Hobby-Shop			0	0	1	1	1	1	1	1	1
50	New-ADC-Facility			1	1	1	1	1	1	1	1	1
51	AMU-Hangar-B290			0	0	0	0	0	0	0	0	0
52	Dejarnette-Gate			0	0	0	0	0	0	0	0	0
53	WEG-Lg-Drone-Mx-Facility			1	1	1	1	1	1	1	1	1
54	Repair-Drone-Mx-Hangar-B9310			1	1	1	1	1	1	1	1	1
55	Repair-TELMOC-Operations-B503			1	1	1	1	1	1	1	1	1
56	Repair-AFCEC-HQ-B1120-and-B1117			1	1	1	1	1	1	1	1	1

		k	1	2	3	4	5	6	7	8	9
		Wt RMI	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
		Wt SPI	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1
Proj #	Project Name	z(k)	19.1316	19.1204	19.1847	19.2641	19.3436	19.423	19.5403	19.7119	19.8835
	f=0.3	Cost ($M)	874.5	874.5	874.8	874.8	874.8	874.8	877.8	877.8	877.8
		% Diff Cost	0.00%	0.03%	0.00%	0.00%	0.00%	0.34%	0.00%	0.00%	
		% Diff Proj	0	2	0	0	0	2	0	0	
		# of Proj	33	33	35	35	35	35	37	37	37
1	OG-MXG-Reserve-HQ		0	0	1	1	1	1	1	1	1
2	Ops-Mx-Unit-Hangar1		1	1	1	1	1	1	0	0	0
3	Ops-Mx-Unit-Hangar2		1	1	1	1	1	1	1	1	1
4	Ops-Mx-Unit-Hangar3		1	1	1	1	1	1	1	1	1
5	Parking-Apron		1	1	1	1	1	1	1	1	1
6	Corrosion-Control-Facility		1	1	1	1	1	1	1	1	1
7	AGE-Facility		1	1	1	1	1	1	1	1	1
8	F-35-Simulator		1	1	1	1	1	1	1	1	1
9	F-35-Weapons-Load-Training-Hangar		1	1	1	1	1	1	1	1	1
10	Fuel-Cell-Mx-Hanger		1	1	1	1	1	1	1	1	1
11	Sq-Mx-Facility		1	1	1	1	1	1	1	1	1
12	F-35-LRS-Part-of-Sq-Mx-Facility		1	1	1	1	1	1	1	1	1
13	Fire-Station		1	1	1	1	1	1	1	1	1
14	Special-Purpose-Vehicle-Mx		1	1	1	1	1	1	1	1	1
15	Deployment-Center-Flightline-Kitchen		0	0	0	0	0	0	0	0	0
16	WEG-HQ-Sq-Ops		0	0	0	0	0	0	0	0	0
17	WEG-Subscale-Drone-Facility		0	0	0	0	0	0	0	0	0
18	WEG-Parking-Apron		1	1	1	1	1	1	1	1	1
19	WEG-Aircraft-Mx-Hangar		0	0	0	0	0	0	0	0	0
20	Ops-Sq-Radar-Approach-Cntrl-Tower		1	1	1	1	1	1	1	1	1
21	Gate-Complex-Commercial-Gate		1	1	1	1	1	1	1	1	1
22	Gate-Complex-Airey-and-Tyndall-Gate		0	0	0	0	0	0	0	0	0
23	Utilities-Demo-Phase-1-North		0	0	0	0	0	0	0	0	0
24	Utilties-Demo-Phase-2-South		0	0	0	0	0	0	0	0	0
25	CE-Mx-Shop-and-Storage-Area-Part-of-CE-CONS		1	1	1	1	1	1	1	1	1
26	CE-Contracting-USACE-Complex		0	0	0	0	0	0	0	0	0
27	LRS-Complex		0	0	0	0	0	0	0	0	0
28	Airfield-Drainage		0	0	0	0	0	0	0	0	0
29	Flightline-MSA-Storage-Facilities		1	1	1	1	1	1	1	1	1
30	F-35-MSA		1	1	1	1	1	1	1	1	1
31	Emergency-Mgmt		1	1	1	1	1	1	1	1	1
32	Security-Forces-Mobility-Storage		1	1	1	1	1	1	1	1	1
33	Small-Arms-Range		0	0	0	0	0	0	0	0	0
34	325-FW-HQ		1	1	1	1	1	1	1	1	1
35	MWR-Facilities-Marina-Rec-Center		0	0	0	0	0	0	0	0	0
36	MWR-Facilities-Pool-Bath-House		0	0	0	0	0	0	1	1	1
37	MWR-Facilities-Rec-Fields		0	0	1	1	1	1	1	1	1
38	Lodging-Facilities		0	0	0	0	0	0	0	0	0
39	Dorm-Complex		0	0	0	0	0	0	0	0	0
40	Community-Commons		0	0	0	0	0	0	0	0	0
41	CDC		1	1	0	0	0	0	0	0	0
42	Chapel		0	0	0	0	0	0	1	1	1
43	Fire-Station4-Silver-Flag		1	1	1	1	1	1	1	1	1
44	Silver-Flag-Facilities		1	1	1	1	1	1	1	1	1
45	AFCEC-Facilities-and-Gate		0	0	0	0	0	0	0	0	0
46	Fire-Station2		1	1	1	1	1	1	1	1	1
47	ABM-Simulator-Facility		1	1	1	1	1	1	1	1	1
48	WEG-Sml-Boat-Mx-Facility-Berthing		1	1	1	1	1	1	1	1	1
49	Carwash-Auto-Hobby-Shop		0	0	1	1	1	1	1	1	1
50	New-ADC-Facility		1	1	1	1	1	1	1	1	1
51	AMU-Hangar-B290		0	0	0	0	0	0	0	0	0
52	Dejarnette-Gate		0	0	0	0	0	0	1	1	1
53	WEG-Lg-Drone-Mx-Facility		1	1	1	1	1	1	1	1	1
54	Repair-Drone-Mx-Hangar-B9310		1	1	1	1	1	1	1	1	1
55	Repair-TELMOC-Operations-B503		1	1	1	1	1	1	1	1	1
56	Repair-AFCEC-HQ-B1120-and-B1117		1	1	1	1	1	1	1	1	1

		k	1	2	3	4	5	6	7	8	9
		Wt RMI	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
		Wt SPI	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1
Proj #	Project Name	z(k)	20.9884	21.0951	21.223	21.3795	21.586	21.7925	21.999	22.2055	22.412
	f=0.4	Cost ($M)	1170.8	1164.8	1164.8	1172	1172	1172	1172	1172	1172
		% Diff Cost	-0.51%	0.00%	0.62%	0.00%	0.00%	0.00%	0.00%	0.00%	
		% Diff Proj	1	0	3	0	0	0	0	0	
		# of Proj	39	40	40	43	43	43	43	43	43
1	OG-MXG-Reserve-HQ		0	1	1	1	1	1	1	1	1
2	Ops-Mx-Unit-Hangar1		1	1	1	1	1	1	1	1	1
3	Ops-Mx-Unit-Hangar2		1	1	1	1	1	1	1	1	1
4	Ops-Mx-Unit-Hangar3		1	1	1	1	1	1	1	1	1
5	Parking-Apron		1	1	1	1	1	1	1	1	1
6	Corrosion-Control-Facility		1	1	1	1	1	1	1	1	1
7	AGE-Facility		1	1	1	1	1	1	1	1	1
8	F-35-Simulator		1	1	1	1	1	1	1	1	1
9	F-35-Weapons-Load-Training-Hangar		1	1	1	1	1	1	1	1	1
10	Fuel-Cell-Mx-Hanger		1	1	1	1	1	1	1	1	1
11	Sq-Mx-Facility		1	1	1	1	1	1	1	1	1
12	F-35-LRS-Part-of-Sq-Mx-Facility		1	1	1	1	1	1	1	1	1
13	Fire-Station		1	1	1	1	1	1	1	1	1
14	Special-Purpose-Vehicle-Mx		1	1	1	1	1	1	1	1	1
15	Deployment-Center-Flightline-Kitchen		1	1	0	1	1	1	1	1	1
16	WEG-HQ-Sq-Ops		1	0	0	1	1	1	1	1	1
17	WEG-Subscale-Drone-Facility		0	0	1	0	0	0	0	0	0
18	WEG-Parking-Apron		1	1	0	1	1	1	1	1	1
19	WEG-Aircraft-Mx-Hangar		0	0	1	0	0	0	0	0	0
20	Ops-Sq-Radar-Approach-Cntrl-Tower		1	1	1	1	1	1	1	1	1
21	Gate-Complex-Commercial-Gate		1	1	0	1	1	1	1	1	1
22	Gate-Complex-Airey-and-Tyndall-Gate		0	0	0	0	0	0	0	0	0
23	Utilities-Demo-Phase-1-North		0	0	1	0	0	0	0	0	0
24	Utilties-Demo-Phase-2-South		1	1	1	0	0	0	0	0	0
25	CE-Mx-Shop-and-Storage-Area-Part-of-CE-CONS		1	1	0	1	1	1	1	1	1
26	CE-Contracting-USACE-Complex		0	0	0	0	0	0	0	0	0
27	LRS-Complex		0	0	0	0	0	0	0	0	0
28	Airfield-Drainage		0	0	1	0	0	0	0	0	0
29	Flightline-MSA-Storage-Facilities		1	1	1	1	1	1	1	1	1
30	F-35-MSA		1	1	1	1	1	1	1	1	1
31	Emergency-Mgmt		1	1	1	1	1	1	1	1	1
32	Security-Forces-Mobility-Storage		1	1	0	1	1	1	1	1	1
33	Small-Arms-Range		0	0	1	0	0	0	0	0	0
34	325-FW-HQ		1	1	1	1	1	1	1	1	1
35	MWR-Facilities-Marina-Rec-Center		0	1	0	1	1	1	1	1	1
36	MWR-Facilities-Pool-Bath-House		0	0	1	1	1	1	1	1	1
37	MWR-Facilities-Rec-Fields		1	1	0	1	1	1	1	1	1
38	Lodging-Facilities		0	0	0	0	0	0	0	0	0
39	Dorm-Complex		0	0	0	0	0	0	0	0	0
40	Community-Commons		0	0	1	0	0	0	0	0	0
41	CDC		1	1	0	1	1	1	1	1	1
42	Chapel		0	0	1	1	1	1	1	1	1
43	Fire-Station4-Silver-Flag		1	1	1	1	1	1	1	1	1
44	Silver-Flag-Facilities		1	1	0	1	1	1	1	1	1
45	AFCEC-Facilities-and-Gate		0	0	1	0	0	0	0	0	0
46	Fire-Station2		1	1	1	1	1	1	1	1	1
47	ABM-Simulator-Facility		1	1	1	1	1	1	1	1	1
48	WEG-Sml-Boat-Mx-Facility-Berthing		1	1	1	1	1	1	1	1	1
49	Carwash-Auto-Hobby-Shop		1	1	1	1	1	1	1	1	1
50	New-ADC-Facility		1	1	0	1	1	1	1	1	1
51	AMU-Hangar-B290		0	0	1	1	1	1	1	1	1
52	Dejarnette-Gate		1	1	1	1	1	1	1	1	1
53	WEG-Lg-Drone-Mx-Facility		1	1	1	1	1	1	1	1	1
54	Repair-Drone-Mx-Hangar-B9310		1	1	1	1	1	1	1	1	1
55	Repair-TELMOC-Operations-B503		1	1	1	1	1	1	1	1	1
56	Repair-AFCEC-HQ-B1120-and-B1117		1	1	1	1	1	1	1	1	1

		k	1	2	3	4	5	6	7	8	9
		Wt RMI	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
		Wt SPI	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1
Proj #	Project Name	z(k)	22.5165	22.635	22.7588	22.9351	23.1523	23.382	23.6242	23.8665	24.1087
	f=0.5	Cost ($M)	1462.8	1460.8	1458.8	1457	1459	1465	1465	1465	1465
		% Diff Cost	-0.14%	-0.14%	-0.12%	0.14%	0.41%	0.00%	0.00%	0.00%	
		% Diff Proj	2	1	1	1	1	0	0	0	
		# of Proj	41	43	44	45	46	47	47	47	47
1	OG-MXG-Reserve-HQ		1	1	1	1	1	1	1	1	1
2	Ops-Mx-Unit-Hangar1		1	1	1	1	1	1	1	1	1
3	Ops-Mx-Unit-Hangar2		1	1	1	1	1	1	1	1	1
4	Ops-Mx-Unit-Hangar3		1	1	1	1	1	1	1	1	1
5	Parking-Apron		1	1	1	1	1	1	1	1	1
6	Corrosion-Control-Facility		1	1	1	1	1	1	1	1	1
7	AGE-Facility		1	1	1	1	1	1	1	1	1
8	F-35-Simulator		1	1	1	1	1	1	1	1	1
9	F-35-Weapons-Load-Training-Hangar		1	1	1	1	1	1	1	1	1
10	Fuel-Cell-Mx-Hanger		1	1	1	1	1	1	1	1	1
11	Sq-Mx-Facility		1	1	1	1	1	1	1	1	1
12	F-35-LRS-Part-of-Sq-Mx-Facility		1	1	1	1	1	1	1	1	1
13	Fire-Station		1	1	1	1	1	1	1	1	1
14	Special-Purpose-Vehicle-Mx		1	1	1	1	1	1	1	1	1
15	Deployment-Center-Flightline-Kitchen		1	1	1	1	1	1	1	1	1
16	WEG-HQ-Sq-Ops		0	1	1	1	1	0	0	0	0
17	WEG-Subscale-Drone-Facility		0	1	0	0	1	1	1	1	1
18	WEG-Parking-Apron		1	1	1	1	1	1	1	1	1
19	WEG-Aircraft-Mx-Hangar		0	0	0	0	0	0	0	0	0
20	Ops-Sq-Radar-Approach-Cntrl-Tower		1	1	1	1	1	1	1	1	1
21	Gate-Complex-Commercial-Gate		1	1	1	1	1	1	1	1	1
22	Gate-Complex-Airey-and-Tyndall-Gate		0	0	1	0	0	1	1	1	1
23	Utilities-Demo-Phase-1-North		1	0	0	0	0	0	0	0	0
24	Utilties-Demo-Phase-2-South		1	1	1	1	1	1	1	1	1
25	CE-Mx-Shop-and-Storage-Area-Part-of-CE-CONS		1	1	1	1	1	1	1	1	1
26	CE-Contracting-USACE-Complex		0	0	0	0	0	0	0	0	0
27	LRS-Complex		0	0	0	0	0	0	0	0	0
28	Airfield-Drainage		1	1	1	1	0	0	0	0	0
29	Flightline-MSA-Storage-Facilities		1	1	1	1	1	1	1	1	1
30	F-35-MSA		1	1	1	1	1	1	1	1	1
31	Emergency-Mgmt		1	1	1	1	1	1	1	1	1
32	Security-Forces-Mobility-Storage		1	1	1	1	1	1	1	1	1
33	Small-Arms-Range		0	0	0	0	0	1	1	1	1
34	325-FW-HQ		1	1	1	1	1	1	1	1	1
35	MWR-Facilities-Marina-Rec-Center		0	1	1	1	1	1	1	1	1
36	MWR-Facilities-Pool-Bath-House		0	0	1	1	1	1	1	1	1
37	MWR-Facilities-Rec-Fields		1	1	1	1	1	1	1	1	1
38	Lodging-Facilities		0	0	0	0	0	0	0	0	0
39	Dorm-Complex		0	0	0	0	0	0	0	0	0
40	Community-Commons		0	0	0	0	1	1	1	1	1
41	CDC		1	1	1	1	1	1	1	1	1
42	Chapel		0	0	0	1	1	1	1	1	1
43	Fire-Station4-Silver-Flag		1	1	1	1	1	1	1	1	1
44	Silver-Flag-Facilities		1	1	1	1	1	1	1	1	1
45	AFCEC-Facilities-and-Gate		0	0	0	0	0	0	0	0	0
46	Fire-Station2		1	1	1	1	1	1	1	1	1
47	ABM-Simulator-Facility		1	1	1	1	1	1	1	1	1
48	WEG-Sml-Boat-Mx-Facility-Berthing		1	1	1	1	1	1	1	1	1
49	Carwash-Auto-Hobby-Shop		1	1	1	1	1	1	1	1	1
50	New-ADC-Facility		1	1	1	1	1	1	1	1	1
51	AMU-Hangar-B290		0	0	0	1	1	1	1	1	1
52	Dejarnette-Gate		1	1	1	1	1	1	1	1	1
53	WEG-Lg-Drone-Mx-Facility		1	1	1	1	1	1	1	1	1
54	Repair-Drone-Mx-Hangar-B9310		1	1	1	1	1	1	1	1	1
55	Repair-TELMOC-Operations-B503		1	1	1	1	1	1	1	1	1
56	Repair-AFCEC-HQ-B1120-and-B1117		1	1	1	1	1	1	1	1	1

		k	1	2	3	4	5	6	7	8	9
		Wt RMI	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
		Wt SPI	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1
Proj #	Project Name	z(k)	23.9535	24.0577	24.2082	24.4255	24.6435	24.8615	25.0795	25.2975	25.5155
	f = 0.6	Cost ($M)	1747.8	1756.8	1757	1757	1757	1757	1757	1757	1757
		% Diff Cost	0.51%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
		% Diff Proj	2	1	2	0	0	0	0	0	
		# of Proj	44	46	47	49	49	49	49	49	49
1	OG-MXG-Reserve-HQ		1	1	1	1	1	1	1	1	1
2	Ops-Mx-Unit-Hangar1		1	1	1	1	1	1	1	1	1
3	Ops-Mx-Unit-Hangar2		1	1	1	1	1	1	1	1	1
4	Ops-Mx-Unit-Hangar3		1	1	1	1	1	1	1	1	1
5	Parking-Apron		1	1	1	1	1	1	1	1	1
6	Corrosion-Control-Facility		1	1	1	1	1	1	1	1	1
7	AGE-Facility		1	1	1	1	1	1	1	1	1
8	F-35-Simulator		1	1	1	1	1	1	1	1	1
9	F-35-Weapons-Load-Training-Hangar		1	1	1	1	1	1	1	1	1
10	Fuel-Cell-Mx-Hanger		1	1	1	1	1	1	1	1	1
11	Sq-Mx-Facility		1	1	1	1	1	1	1	1	1
12	F-35-LRS-Part-of-Sq-Mx-Facility		1	1	1	1	1	1	1	1	1
13	Fire-Station		1	1	1	1	1	1	1	1	1
14	Special-Purpose-Vehicle-Mx		1	1	1	1	1	1	1	1	1
15	Deployment-Center-Flightline-Kitchen		1	1	1	1	1	1	1	1	1
16	WEG-HQ-Sq-Ops		1	1	1	1	1	1	1	1	1
17	WEG-Subscale-Drone-Facility		1	0	1	1	1	1	1	1	1
18	WEG-Parking-Apron		1	1	1	1	1	1	1	1	1
19	WEG-Aircraft-Mx-Hangar		1	0	0	0	0	0	0	0	0
20	Ops-Sq-Radar-Approach-Cntrl-Tower		1	1	1	1	1	1	1	1	1
21	Gate-Complex-Commercial-Gate		1	1	1	1	1	1	1	1	1
22	Gate-Complex-Airey-and-Tyndall-Gate		0	1	1	1	1	1	1	1	1
23	Utilities-Demo-Phase-1-North		1	1	1	0	0	0	0	0	0
24	Utilties-Demo-Phase-2-South		1	1	1	1	1	1	1	1	1
25	CE-Mx-Shop-and-Storage-Area-Part-of-CE-CONS		1	1	1	1	1	1	1	1	1
26	CE-Contracting-USACE-Complex		0	1	0	1	1	1	1	1	1
27	LRS-Complex		0	0	0	0	0	0	0	0	0
28	Airfield-Drainage		1	1	1	1	1	1	1	1	1
29	Flightline-MSA-Storage-Facilities		1	1	1	1	1	1	1	1	1
30	F-35-MSA		1	1	1	1	1	1	1	1	1
31	Emergency-Mgmt		1	1	1	1	1	1	1	1	1
32	Security-Forces-Mobility-Storage		1	1	1	1	1	1	1	1	1
33	Small-Arms-Range		0	0	0	0	0	0	0	0	0
34	325-FW-HQ		1	1	1	1	1	1	1	1	1
35	MWR-Facilities-Marina-Rec-Center		0	1	1	1	1	1	1	1	1
36	MWR-Facilities-Pool-Bath-House		0	1	1	1	1	1	1	1	1
37	MWR-Facilities-Rec-Fields		1	1	1	1	1	1	1	1	1
38	Lodging-Facilities		0	0	0	0	0	0	0	0	0
39	Dorm-Complex		0	0	0	0	0	0	0	0	0
40	Community-Commons		0	0	0	1	1	1	1	1	1
41	CDC		1	1	1	1	1	1	1	1	1
42	Chapel		0	0	0	1	1	1	1	1	1
43	Fire-Station4-Silver-Flag		1	1	1	1	1	1	1	1	1
44	Silver-Flag-Facilities		1	1	1	1	1	1	1	1	1
45	AFCEC-Facilities-and-Gate		0	0	0	0	0	0	0	0	0
46	Fire-Station2		1	1	1	1	1	1	1	1	1
47	ABM-Simulator-Facility		1	1	1	1	1	1	1	1	1
48	WEG-Sml-Boat-Mx-Facility-Berthing		1	1	1	1	1	1	1	1	1
49	Carwash-Auto-Hobby-Shop		1	1	1	1	1	1	1	1	1
50	New-ADC-Facility		1	1	1	1	1	1	1	1	1
51	AMU-Hangar-B290		0	0	1	1	1	1	1	1	1
52	Dejarnette-Gate		1	1	1	1	1	1	1	1	1
53	WEG-Lg-Drone-Mx-Facility		1	1	1	1	1	1	1	1	1
54	Repair-Drone-Mx-Hangar-B9310		1	1	1	1	1	1	1	1	1
55	Repair-TELMOC-Operations-B503		1	1	1	1	1	1	1	1	1
56	Repair-AFCEC-HQ-B1120-and-B1117		1	1	1	1	1	1	1	1	1

		k	1	2	3	4	5	6	7	8	9
		Wt RMI	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
		Wt SPI	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1
Proj #	Project Name	z(k)	25.3381	25.4262	25.5562	25.7298	25.9094	26.0913	26.2732	26.4551	26.637
	f=0.7	Cost ($M)	2048.8	2048.8	2045.8	2045.8	2046	2046	2046	2046	2046
		% Diff Cost	0.00%	-0.15%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	
		% Diff Proj	0	2	0	1	0	0	0	0	
		# of Proj	48	48	50	50	51	51	51	51	51
1	OG-MXG-Reserve-HQ		1	1	1	1	1	1	1	1	1
2	Ops-Mx-Unit-Hangar1		1	1	1	1	1	1	1	1	1
3	Ops-Mx-Unit-Hangar2		1	1	1	1	1	1	1	1	1
4	Ops-Mx-Unit-Hangar3		1	1	1	1	1	1	1	1	1
5	Parking-Apron		1	1	1	1	1	1	1	1	1
6	Corrosion-Control-Facility		1	1	1	1	1	1	1	1	1
7	AGE-Facility		1	1	1	1	1	1	1	1	1
8	F-35-Simulator		1	1	1	1	1	1	1	1	1
9	F-35-Weapons-Load-Training-Hangar		1	1	1	1	1	1	1	1	1
10	Fuel-Cell-Mx-Hanger		1	1	1	1	1	1	1	1	1
11	Sq-Mx-Facility		1	1	1	1	1	1	1	1	1
12	F-35-LRS-Part-of-Sq-Mx-Facility		1	1	1	1	1	1	1	1	1
13	Fire-Station		1	1	1	1	1	1	1	1	1
14	Special-Purpose-Vehicle-Mx		1	1	1	1	1	1	1	1	1
15	Deployment-Center-Flightline-Kitchen		1	1	1	1	1	1	1	1	1
16	WEG-HQ-Sq-Ops		1	1	1	1	1	1	1	1	1
17	WEG-Subscale-Drone-Facility		1	1	1	1	1	1	1	1	1
18	WEG-Parking-Apron		1	1	1	1	1	1	1	1	1
19	WEG-Aircraft-Mx-Hangar		1	1	0	0	1	1	1	1	1
20	Ops-Sq-Radar-Approach-Cntrl-Tower		1	1	1	1	1	1	1	1	1
21	Gate-Complex-Commercial-Gate		1	1	1	1	1	1	1	1	1
22	Gate-Complex-Airey-and-Tyndall-Gate		1	1	1	1	1	1	1	1	1
23	Utilities-Demo-Phase-1-North		1	1	1	1	1	1	1	1	1
24	Utilties-Demo-Phase-2-South		1	1	1	1	1	1	1	1	1
25	CE-Mx-Shop-and-Storage-Area-Part-of-CE-CONS		1	1	1	1	1	1	1	1	1
26	CE-Contracting-USACE-Complex		1	1	1	1	1	1	1	1	1
27	LRS-Complex		1	1	1	1	0	0	0	0	0
28	Airfield-Drainage		1	1	1	1	1	1	1	1	1
29	Flightline-MSA-Storage-Facilities		1	1	1	1	1	1	1	1	1
30	F-35-MSA		1	1	1	1	1	1	1	1	1
31	Emergency-Mgmt		1	1	1	1	1	1	1	1	1
32	Security-Forces-Mobility-Storage		1	1	1	1	1	1	1	1	1
33	Small-Arms-Range		0	0	0	0	1	1	1	1	1
34	325-FW-HQ		1	1	1	1	1	1	1	1	1
35	MWR-Facilities-Marina-Rec-Center		0	0	1	1	1	1	1	1	1
36	MWR-Facilities-Pool-Bath-House		1	1	1	1	1	1	1	1	1
37	MWR-Facilities-Rec-Fields		1	1	1	1	1	1	1	1	1
38	Lodging-Facilities		0	0	0	0	0	0	0	0	0
39	Dorm-Complex		0	0	0	0	0	0	0	0	0
40	Community-Commons		0	0	1	1	0	0	0	0	0
41	CDC		1	1	1	1	1	1	1	1	1
42	Chapel		0	0	1	1	1	1	1	1	1
43	Fire-Station4-Silver-Flag		1	1	1	1	1	1	1	1	1
44	Silver-Flag-Facilities		1	1	1	1	1	1	1	1	1
45	AFCEC-Facilities-and-Gate		0	0	0	0	0	0	0	0	0
46	Fire-Station2		1	1	1	1	1	1	1	1	1
47	ABM-Simulator-Facility		1	1	1	1	1	1	1	1	1
48	WEG-Sml-Boat-Mx-Facility-Berthing		1	1	1	1	1	1	1	1	1
49	Carwash-Auto-Hobby-Shop		1	1	1	1	1	1	1	1	1
50	New-ADC-Facility		1	1	1	1	1	1	1	1	1
51	AMU-Hangar-B290		0	0	0	0	1	1	1	1	1
52	Dejarnette-Gate		1	1	1	1	1	1	1	1	1
53	WEG-Lg-Drone-Mx-Facility		1	1	1	1	1	1	1	1	1
54	Repair-Drone-Mx-Hangar-B9310		1	1	1	1	1	1	1	1	1
55	Repair-TELMOC-Operations-B503		1	1	1	1	1	1	1	1	1
56	Repair-AFCEC-HQ-B1120-and-B1117		1	1	1	1	1	1	1	1	1

		k	1	2	3	4	5	6	7	8	9
		Wt RMI	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
		Wt SPI	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1
Proj #	Project Name	z(k)	26.5005	26.5188	26.5372	26.5556	26.5739	26.5923	26.6106	26.629	26.6473
	f=0.8	Cost ($M)	2376.7	2376.7	2376.7	2376.7	2376.7	2376.7	2376.7	2376.7	2376.7
		% Diff Cost	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
		% Diff Proj	0	2	0	0	0	0	0	0	
		# of Proj	51	51	53	53	53	53	53	53	53
1	OG-MXG-Reserve-HQ		1	1	1	1	1	1	1	1	1
2	Ops-Mx-Unit-Hangar1		1	1	1	1	1	1	1	1	1
3	Ops-Mx-Unit-Hangar2		1	1	1	1	1	1	1	1	1
4	Ops-Mx-Unit-Hangar3		1	1	1	1	1	1	1	1	1
5	Parking-Apron		1	1	1	1	1	1	1	1	1
6	Corrosion-Control-Facility		1	1	1	1	1	1	1	1	1
7	AGE-Facility		1	1	1	1	1	1	1	1	1
8	F-35-Simulator		1	1	1	1	1	1	1	1	1
9	F-35-Weapons-Load-Training-Hangar		1	1	1	1	1	1	1	1	1
10	Fuel-Cell-Mx-Hanger		1	1	1	1	1	1	1	1	1
11	Sq-Mx-Facility		1	1	1	1	1	1	1	1	1
12	F-35-LRS-Part-of-Sq-Mx-Facility		1	1	1	1	1	1	1	1	1
13	Fire-Station		1	1	1	1	1	1	1	1	1
14	Special-Purpose-Vehicle-Mx		1	1	1	1	1	1	1	1	1
15	Deployment-Center-Flightline-Kitchen		1	1	1	1	1	1	1	1	1
16	WEG-HQ-Sq-Ops		1	1	1	1	1	1	1	1	1
17	WEG-Subscale-Drone-Facility		1	1	1	1	1	1	1	1	1
18	WEG-Parking-Apron		1	1	1	1	1	1	1	1	1
19	WEG-Aircraft-Mx-Hangar		1	1	1	1	1	1	1	1	1
20	Ops-Sq-Radar-Approach-Cntrl-Tower		1	1	1	1	1	1	1	1	1
21	Gate-Complex-Commercial-Gate		1	1	1	1	1	1	1	1	1
22	Gate-Complex-Airey-and-Tyndall-Gate		1	1	1	1	1	1	1	1	1
23	Utilities-Demo-Phase-1-North		1	1	1	1	1	1	1	1	1
24	Utilties-Demo-Phase-2-South		1	1	1	1	1	1	1	1	1
25	CE-Mx-Shop-and-Storage-Area-Part-of-CE-CONS		1	1	1	1	1	1	1	1	1
26	CE-Contracting-USACE-Complex		1	1	1	1	1	1	1	1	1
27	LRS-Complex		1	1	1	1	1	1	1	1	1
28	Airfield-Drainage		1	1	1	1	1	1	1	1	1
29	Flightline-MSA-Storage-Facilities		1	1	1	1	1	1	1	1	1
30	F-35-MSA		1	1	1	1	1	1	1	1	1
31	Emergency-Mgmt		1	1	1	1	1	1	1	1	1
32	Security-Forces-Mobility-Storage		1	1	1	1	1	1	1	1	1
33	Small-Arms-Range		0	0	1	1	1	1	1	1	1
34	325-FW-HQ		1	1	1	1	1	1	1	1	1
35	MWR-Facilities-Marina-Rec-Center		1	1	1	1	1	1	1	1	1
36	MWR-Facilities-Pool-Bath-House		1	1	1	1	1	1	1	1	1
37	MWR-Facilities-Rec-Fields		1	1	1	1	1	1	1	1	1
38	Lodging-Facilities		1	1	1	1	1	1	1	1	1
39	Dorm-Complex		0	0	0	0	0	0	0	0	0
40	Community-Commons		1	1	0	0	0	0	0	0	0
41	CDC		1	1	1	1	1	1	1	1	1
42	Chapel		0	0	1	1	1	1	1	1	1
43	Fire-Station4-Silver-Flag		1	1	1	1	1	1	1	1	1
44	Silver-Flag-Facilities		1	1	1	1	1	1	1	1	1
45	AFCEC-Facilities-and-Gate		0	0	0	0	0	0	0	0	0
46	Fire-Station2		1	1	1	1	1	1	1	1	1
47	ABM-Simulator-Facility		1	1	1	1	1	1	1	1	1
48	WEG-Sml-Boat-Mx-Facility-Berthing		1	1	1	1	1	1	1	1	1
49	Carwash-Auto-Hobby-Shop		1	1	1	1	1	1	1	1	1
50	New-ADC-Facility		1	1	1	1	1	1	1	1	1
51	AMU-Hangar-B290		0	0	1	1	1	1	1	1	1
52	Dejarnette-Gate		1	1	1	1	1	1	1	1	1
53	WEG-Lg-Drone-Mx-Facility		1	1	1	1	1	1	1	1	1
54	Repair-Drone-Mx-Hangar-B9310		1	1	1	1	1	1	1	1	1
55	Repair-TELMOC-Operations-B503		1	1	1	1	1	1	1	1	1
56	Repair-AFCEC-HQ-B1120-and-B1117		1	1	1	1	1	1	1	1	1

		k	1	2	3	4	5	6	7	8	9
		Wt RMI	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
		Wt SPI	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1
Proj #	Project Name	z(k)	27.6228	27.7278	27.8328	27.9378	28.0427	28.1477	28.2527	28.3577	28.4627
	f=0.9	Cost ($M)	2629	2629	2629	2629	2629	2629	2629	2629	2629
		% Diff Cost	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
		% Diff Proj	0	0	0	0	0	0	0	0	
		# of Proj	54	54	54	54	54	54	54	54	54
1	OG-MXG-Reserve-HQ		1	1	1	1	1	1	1	1	1
2	Ops-Mx-Unit-Hangar1		1	1	1	1	1	1	1	1	1
3	Ops-Mx-Unit-Hangar2		1	1	1	1	1	1	1	1	1
4	Ops-Mx-Unit-Hangar3		1	1	1	1	1	1	1	1	1
5	Parking-Apron		1	1	1	1	1	1	1	1	1
6	Corrosion-Control-Facility		1	1	1	1	1	1	1	1	1
7	AGE-Facility		1	1	1	1	1	1	1	1	1
8	F-35-Simulator		1	1	1	1	1	1	1	1	1
9	F-35-Weapons-Load-Training-Hangar		1	1	1	1	1	1	1	1	1
10	Fuel-Cell-Mx-Hanger		1	1	1	1	1	1	1	1	1
11	Sq-Mx-Facility		1	1	1	1	1	1	1	1	1
12	F-35-LRS-Part-of-Sq-Mx-Facility		1	1	1	1	1	1	1	1	1
13	Fire-Station		1	1	1	1	1	1	1	1	1
14	Special-Purpose-Vehicle-Mx		1	1	1	1	1	1	1	1	1
15	Deployment-Center-Flightline-Kitchen		1	1	1	1	1	1	1	1	1
16	WEG-HQ-Sq-Ops		1	1	1	1	1	1	1	1	1
17	WEG-Subscale-Drone-Facility		1	1	1	1	1	1	1	1	1
18	WEG-Parking-Apron		1	1	1	1	1	1	1	1	1
19	WEG-Aircraft-Mx-Hangar		1	1	1	1	1	1	1	1	1
20	Ops-Sq-Radar-Approach-Cntrl-Tower		1	1	1	1	1	1	1	1	1
21	Gate-Complex-Commercial-Gate		1	1	1	1	1	1	1	1	1
22	Gate-Complex-Airey-and-Tyndall-Gate		1	1	1	1	1	1	1	1	1
23	Utilities-Demo-Phase-1-North		1	1	1	1	1	1	1	1	1
24	Utilties-Demo-Phase-2-South		1	1	1	1	1	1	1	1	1
25	CE-Mx-Shop-and-Storage-Area-Part-of-CE-CONS		1	1	1	1	1	1	1	1	1
26	CE-Contracting-USACE-Complex		1	1	1	1	1	1	1	1	1
27	LRS-Complex		1	1	1	1	1	1	1	1	1
28	Airfield-Drainage		1	1	1	1	1	1	1	1	1
29	Flightline-MSA-Storage-Facilities		1	1	1	1	1	1	1	1	1
30	F-35-MSA		1	1	1	1	1	1	1	1	1
31	Emergency-Mgmt		1	1	1	1	1	1	1	1	1
32	Security-Forces-Mobility-Storage		1	1	1	1	1	1	1	1	1
33	Small-Arms-Range		0	0	0	0	0	0	0	0	0
34	325-FW-HQ		1	1	1	1	1	1	1	1	1
35	MWR-Facilities-Marina-Rec-Center		1	1	1	1	1	1	1	1	1
36	MWR-Facilities-Pool-Bath-House		1	1	1	1	1	1	1	1	1
37	MWR-Facilities-Rec-Fields		1	1	1	1	1	1	1	1	1
38	Lodging-Facilities		1	1	1	1	1	1	1	1	1
39	Dorm-Complex		0	0	0	0	0	0	0	0	0
40	Community-Commons		1	1	1	1	1	1	1	1	1
41	CDC		1	1	1	1	1	1	1	1	1
42	Chapel		1	1	1	1	1	1	1	1	1
43	Fire-Station4-Silver-Flag		1	1	1	1	1	1	1	1	1
44	Silver-Flag-Facilities		1	1	1	1	1	1	1	1	1
45	AFCEC-Facilities-and-Gate		1	1	1	1	1	1	1	1	1
46	Fire-Station2		1	1	1	1	1	1	1	1	1
47	ABM-Simulator-Facility		1	1	1	1	1	1	1	1	1
48	WEG-Sml-Boat-Mx-Facility-Berthing		1	1	1	1	1	1	1	1	1
49	Carwash-Auto-Hobby-Shop		1	1	1	1	1	1	1	1	1
50	New-ADC-Facility		1	1	1	1	1	1	1	1	1
51	AMU-Hangar-B290		1	1	1	1	1	1	1	1	1
52	Dejarnette-Gate		1	1	1	1	1	1	1	1	1
53	WEG-Lg-Drone-Mx-Facility		1	1	1	1	1	1	1	1	1
54	Repair-Drone-Mx-Hangar-B9310		1	1	1	1	1	1	1	1	1
55	Repair-TELMOC-Operations-B503		1	1	1	1	1	1	1	1	1
56	Repair-AFCEC-HQ-B1120-and-B1117		1	1	1	1	1	1	1	1	1

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14. ABSTRACT

Natural disasters such as hurricanes, earthquakes, tsunamis and extreme flooding cause severe social and economic disruptions. Restoration of social and revenue generating services often requires extensive reconstruction spanning individual facilities to enterprise or municipal campuses. For multi-facility portfolios, post-disaster reconstruction must be properly prioritized to ensure facilities and infrastructure are restored, and any expansion or new construction initiatives are completed, in order of precedence, as defined by decision-maker and community needs. Many post-disaster optimization and decision frameworks consider a portfolio project with one main stakeholder. However, these portfolio prioritization frameworks ignore the effect of multiple stakeholders competing priorities. This research incorporates stakeholder priority as an objective in the optimization framework. Here a multi-integer linear programming (MILP) optimization framework is proposed that prioritizes a project portfolio through maximizing risk mitigation and stakeholder priorities subject to a budgetary constraint. The projects are grouped into 4 stakeholder projects group and regardless of decision-makers preferences or the specific budget scenario high mission impact projects tend to dominate the solution space up to a point. Furthermore, low cost, high mission impact projects are preferred over high cost, low mission impact projects. This model may be expanded to include other risk mitigation as data collection and computational time allows. Furthermore, this model and framework serves as a planning tool for future natural disasters or contingency operations involving competing stakeholders and priorities. While the mission priorities of the Air Force are used to create the optimized project sequences, the preferences can be transferred to meet a variety of stakeholder needs in the public sector, higher education or healthcare sector.

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