A Predictive and Scalable Capital Investment Risk Model (CIRM) for the Department of Veterans Affairs

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Author Note: The authors of this report are completing an engineering capstone project at the United States Military Academy at West Point. We appreciate the Department of Veterans Affairs (VA) for providing an in-depth, real-world problem to put into practice the engineering tools we have built over the past 4 years. Through the Department of Veterans Affairs and their funding, we have explored the different nuances of capital reinvestment into facilities and visited a Medical Center in Charleston, South Carolina. The views expressed herein are those of the authors and do not reflect the position of the United States Military Academy, the Department of the Army, or the Department of Defense.

Abstract: The Department of Veterans Affairs (VA), Office of Construction and Facilities Management, is working towards providing a data-driven, risk-informed, capital investment information model to aid VA stakeholders in the allocation of funds and resources across the VA medical facility portfolio. The novel research methodology presented uses ArcGIS to provide a layered risk visual of the country using a unique multi-criteria additive risk model and compares the risk score against veteran satisfaction and facility condition assessments to understand the investment trade space. This output is the distinctive Capital Investment Risk Model (CIRM). Three main risk factors behind a county specific risk priority number metric include environmental risk, veteran demand, and resource allocations. The findings include insights into how the VA enterprise, and regional VA leaders might consider the next fiscal investment, understand its sensitivity, and predict future trends in the risk profile of each healthcare provider's ability to serve its veterans.

Keywords: Risk Priority Number (RPN), ArcGIS, Risk Criteria

1. Introduction

1.1 Background

The Department of Veterans Affairs mission statement is "To fulfill President Lincoln's promise to care for those who have served in our nation's military and for their families, caregivers, and survivors," (U.S. Department of Veterans Affairs). With this mission statement the VA provides millions of veterans and veteran families in our country with medical services that most normally could not afford. To help inform the decisions made within the VA, this research aims to help high-level decision makers within the Department of Veterans Affairs make informed decisions about resource allocations. The Office of Construction and Facilities Management (CFM) within the VA named key decision criteria that contribute to distributing funds to different facilities and new projects aimed at bolstering accessibility and quality of care for the veteran population. These decision criteria focus on the environmental risk factors and the effect on VA operations, veteran migration patterns and usage of the facilities, and VA hospital allocations. The research objective also aimed to ensure implementation of these new data-driven insights in ArcGIS. ArcGIS is a geospatial information system application that enables users to import, analyze, and visualize data linked to physical locations on Earth. Transforming the decision criteria into risk priority numbers, this research output aligned them with their respective areas within the ArcGIS model, pinpointing regions that demand the highest attention from investment decision makers. The research and its prototype model illuminate the current disposition of VA Medical Centers and provide information to planners on where to best allocate their next dollar to maximize benefit to the user.

1.2 Literature Review

To provide the millions of veterans and their families proper care, the Department of Veterans Affairs must identify additional hospitals, care centers, and various locations where there is demand. According to VA executives, their current method of determining demand is often politically driven, and with minimal qualitative data. With the CIRM model, the executives would be able to qualitatively compare regions and decide where the next VA centers should be based off the quantitative measurement CIRM provides. The model will provide a risk priority number to each county and state, based off a few factors including environmental, veteran care demand, and VA hospital supply. Using ArcGIS, the CIRM model will be able to visually display the risk factor variables across counties, allowing for the VA executives to see areas in the state that have an elevated risk for veteran care demand with not enough VA care supplies.

The first topic addressed was the environmental risk factors each region of the United States must prepare for and deal with, including hurricanes, severe storms, blizzards, flooding and more. Currently, to address environmental issues, the VA is working to integrate latest ideas with existing building standards, as well as a new program that will focus on the potential environmental threats to the VA and their facilities, known as the Climate Resilience Adaptation Program or the Program (McDonough, 2021). The VA has started innovative programs and determined the factors their VA centers must deal with, and what the center requires to protect them from weather storms. Through this planning it is apparent that accounting for these risk factors in the planning phase will allow for decision makers to more accurately invest into facilities and areas that will need to meet these requirements or require specific attention based on the risk factors associated with their areas. It will be vital to consider how different regions of the country experience different environmental risks, allowing for informed investment into mitigation measures. With the risk assessment that the CIRM model will provide VA facilities in their respective areas, they could deliver adequate care to the veteran population.

The research team conducted analysis to help find the current demand of veteran services at each potential VA care center by investigating the locations of veterans' populations and the impact of the demand in the area. After large events wars like WWI, WWII, Vietnam War, War on Terror, and post 9/11 veterans would migrate to new locations as they finished their military service (Cowper, Longino, et al., 2000). Currently, collected data helps to analyze changes in past migration patterns and predict how future veterans—and current service members—are likely to migrate. There seems to be a national trend to move away from rural areas and into urban areas near cities. This trend may lead to those urban regions increasing in numbers, but there is a possibility of the rural regions decreasing to a minimal amount (Amaral et al., 2018).

As environmental factors are considered along with an understanding of veteran migration, the proposed model will assess where the VA will allocate its resources or implement a new facility. The market assessments completed by the VA show that the majority of the seven strategic priorities need to be adjusted for the changing demographic of the veteran population. These factors will provide an added benefit which will allow the VA to increase its ability to provide the best care for the veteran population. Another factor that will help the model is the connectivity of the VA to its Veterans. The decision criterion for hospital allocation is if it maximizes the connectivity to veterans in its associated catchment area.

2. Methodology

2.1 Qualitative and Quantitative Predictive Risk Modeling

The overall risk equation relies on three main risk criteria depicted in Figure 1, and the weighted values associated with them to result in a total risk score. The risk criteria for this equation are environmental risk, veteran demand risk, and hospital resource allocation. The following figure is a qualitative value model that displays the breakdown of the different risk criteria and how they contribute to the overall quantitative risk priority number.

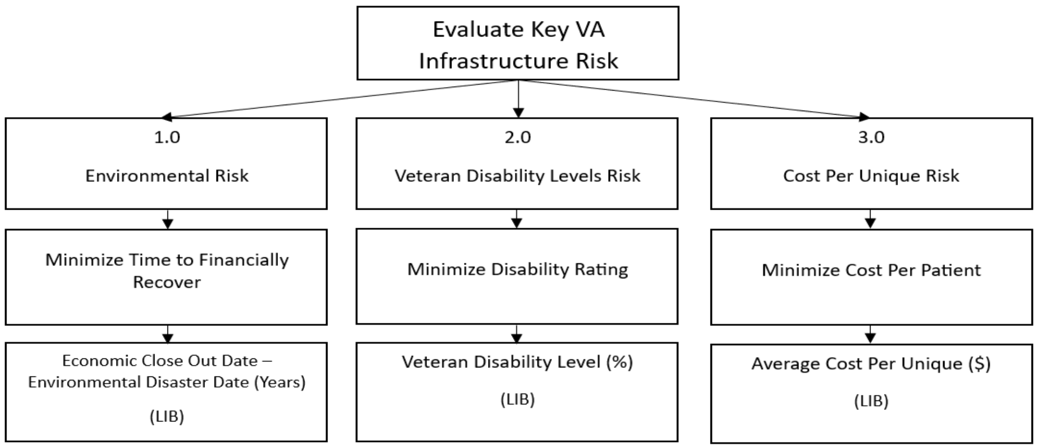

Figure 1: Value Model For CIRM

The total risk for each county in ArcGIS is found by Equation 1, which is a weighted scoring equation. This equation is based upon weights of each of the risk factors determined by the decision makers, while a risk priority number (RPN) is determined by the manipulation of data by the project group (Driscoll et al., 2002).

$$Total\ County\ Risk = .30(EnvironmentalRisk) + .50(VeteranDisability) + .20(Cost\ Per\ Unique) \tag{1}$$

This total risk equation is unique to each modeled county, as its variables reflect location-specific changes and individual risk priority numbers from each risk assessment method.

The equation to find the RPN for environmental risk is determined by finding the probability of occurrence of each environmental disaster in each county, as seen in Equation 2, to be used as the weights. Equation 2 is an example of determining the weight of flood declarations in a county.

$$Weight\ of\ Flood\ Declarations = \frac{\#\ of\ Flood\ Declarations\ in\ County\ X}{\#\ of\ Total\ Disaster\ Declarations\ in\ County\ X} \tag{2}$$

To determine the magnitudes used in environmental risk, we calculate the average duration of each disaster type in the county—from the declaration date to the date of economic reconciliation—as shown in Equation 3. Equation 3 is an example of finding the magnitude of flood declarations in a county.

$$Years\ to\ Economically\ Reconcile = \frac{\sum \frac{Disaster\ Closeout\ Date - Disaster\ Declaration\ Date}{365.25}}{\#\ of\ Type\ of\ Floods\ in\ County} \tag{3}$$

Using these values for weights and magnitudes, the RPN of a county or other location can be determined using Equation 4, which is a sum product of the probability of a specific declaration occurring and the average time it takes to economically recover within that county from the disaster.

$$Environmental\ Risk\ Priority\ Number = Flood\ \%(Flood\ Years) + Hurricane\ \%(Hurricane\ Years) + Tornado\ \%(Tornado\ Years) + Severe\ Storm\ \%\ (Severe\ Storm\ Years) \ldots \tag{4}$$

The equation to find the RPN for veteran demand risk is found by first determining the predicted number of veteran compensations by disability rating levels per county. From there the summation of the compensation levels multiplied by swing weight, produced the RPN. Equation 5 is an example of the veterans' disability risk in a certain year i.

$$Veteran's\ Risk_{in\ year\ i} = \sum(Weight * Predicted\ compensation\ in\ year\ i) \tag{5}$$

The research team determined the swing weights based on the expected reliance on the VA Medical Center. The team assigned a low swing weight to veterans with a disability level between 0% and 20%, while a 100% disabled veteran received a higher score. These numbers were then normalized across the nation, to enable the factor to be added to the total risk score.

To assess the capacities and capabilities of VA medical facilities, we created RPN values to determine which country the VA was spending the most on for unique patients. A unique patient is an enrolled veteran who has received care from the VA at least one time in their time. Equation 5 is what is used in the first step to figure out the cost per county.

$$Total\ Unique\ RPN = \frac{Total\ Expenditure\ (County)}{\#\ of\ Uniques\ (County)} \tag{6}$$

Once the expenditure per county was found, the next step was using Equation 6, to normalize all the expenditures per county and attach a numerical value. This equation created a value from 0 to 1 which will be used to find where the VA can spend money and where the VA is already investing.

$$Normalized\ RPN = \frac{Expenditure\ (County) - Min\ Expenditure\ (County)}{Max\ Expenditure\ (County) - Min\ Expenditure\ (County)} \tag{7}$$

To ensure that the priority numbers are applicable and weighted equally across all counties and states, all RPNs were normalized using equation 7 prior to being imported into the ArcGIS Pro. To find the RPN for resource allocation, we first determine the total expenditure cost for the VA in each county. Using the total expenditure, the team calculated average expenditures per unique patient by dividing the total expenditure by the number of unique patients in the county.

2.2 Implementation into ArcGIS Pro

The Department of Veteran Affairs set the scope of this project to their seven strategic priorities and VISN 6 (Veteran Integrated Service Network). Polygon features were created to display counties within their state boundaries. Instead of creating hundreds of distinctive features individually, the researchers used ArcGIS Online and the living atlas to import current county polygon features created by ESRI using data from the US Census Bureau. This base layer is the backbone of the model's ability to display the various priority numbers created and will allow for future analysis on the data. This allowed the addition of new fields to the attribute table of the different states.

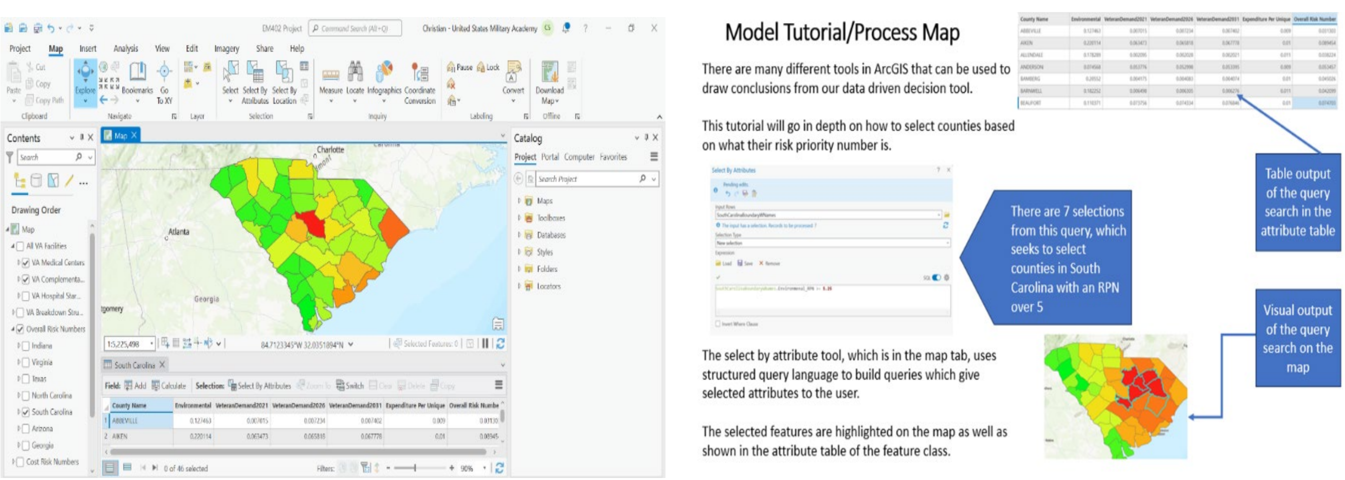

Figure 2: Screen Capture of Final Model & Tutorial

These new fields were environmental, veteran demand, and hospital resource allocation numbers. After adjusting all the county records to include the risk priority numbers from the three different fields, a user could toggle each field on and off for display. While there are many different techniques for symbology, the model is currently set at one standard deviation interval. This model uses the data collected by the VA to build a visual that shows risk per county.

County Name	Environmental	Veteran Demand 2021	Veteran Demand 2026	Veteran Demand 2031	Expenditure Per Unique	Overall Risk Number
Apache County	0.447	0.020	0.018	0.017	0.009	0.104
Cochise County	0.375	0.085	0.081	0.079	0.011	0.136
Coconino County	0.312	0.031	0.032	0.032	0.010	0.085

Figure 3: Attribute Table in ArcGIS Pro for the state of North Arizona.

3. Findings

3.1 Sensitivity Analysis

One factor of CIRM that the Department of Veterans Affairs requested was to determine a recommendation for the swing weights associated with each factor in model. These swing weights are adjustable and directly affect the RPN values of each county when updated based on the VA's priorities. After a meeting with the VA, they are focusing more on the veterans and the care that they need versus environmental or expenditure factors. The research team conducted a sensitivity analysis to determine how factor weights affect scores, varying one global weight at a time as shown in Figure 4 below.

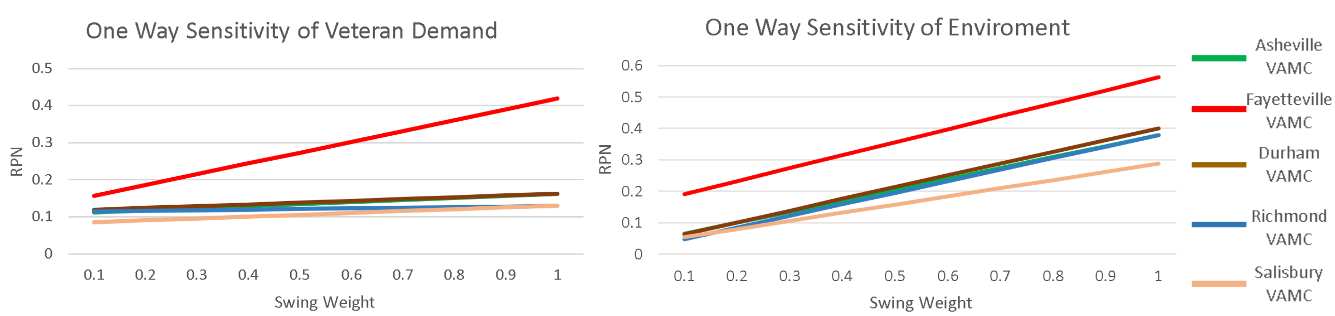

Figure 4: VISN 6 Sensitivity Analysis of Swing Weights

Fayetteville's VAMC is the dominate choice in this analysis. The RPN value is sensitive to the change in veteran demand and environmental swing weights when focusing on the other VAMCs. When the sensitivity analysis is applied at a larger scale—such as nationwide or within another VISN—the prioritization of VAMCs becomes sensitive to the swing weights used in the risk model. The expenditure factor seems to not be sensitive to the change in the swing weights. For the recommendation of how each factor is weighted; veteran demand should stay at a 50% swing weight, the environmental should have a swing weight of 30-40% depending on VA preferences, and the expenditure factor should stay at a low weight of 10-20% as the RPN values are not as sensitive.

4. Conclusion and Future Work

This model, which displays VISN 6 and the 7 strategic priorities, accurately encapsulates the environmental, veteran demand and cost risk that each county has historically experienced, allowing planners to visually depict the various risks of not investing capital into different counties. Using the risk score, star ratings from polled veterans, and facility condition assessments provided by the VA, a generated targeted risk matrix prioritized which VAMCs in VISN 6 had the greatest capital needs.

The quad chart in Figure 6 provides a visual to the decision maker by comparing the VA's assessment of their facility and its physical capabilities to the perceived care received by veterans in their reported star ratings. Both are compared to the aggregate risk score of the county or city in which the facility is located. This chart can be used to see the variances between the VA's internal assessment of their VAMCs and how those VAMCs are effective at giving positive care experiences to veterans. This comparison highlights the strengths and weaknesses of each facility by evaluating their VAMC values against those of other facilities on the chart. Additionally, the incorporation of risk into this chart helps decision makers to distribute resources accurately to lower the potential risk effects or improve their performance metrics of star rating or FCA.

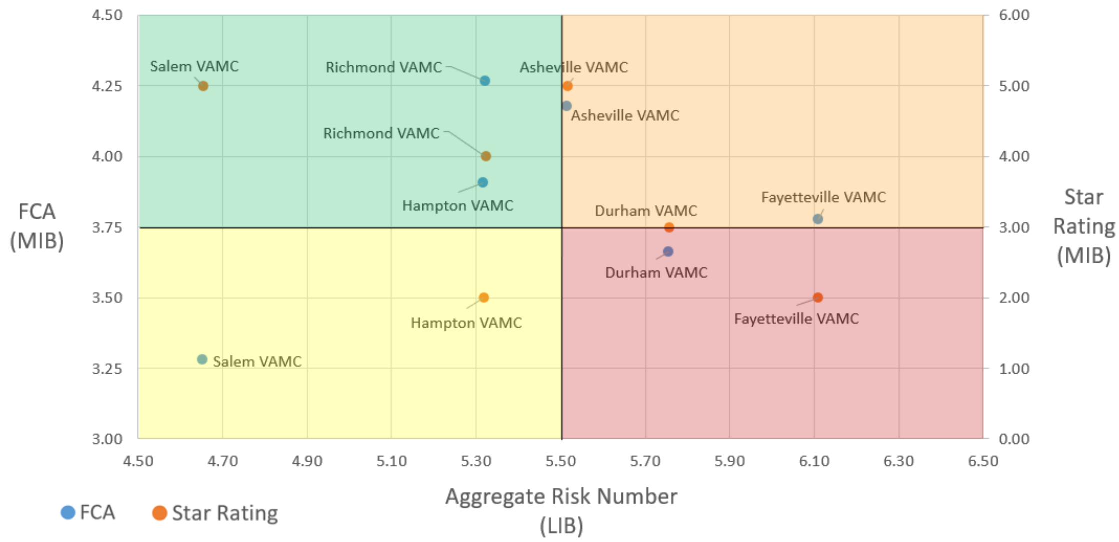

Figure 5: Capital Investment Target Matrix

The system usability scale is being employed to gather data about the validation of the model. Current feedback shows a desire for the end-user to interact with the weights and symbology of the model easier. This would make the model more versatile and allow different users to query different information. For future work, risk values can be aggregated into more useful groupings than counties for the VA. For example, the aggregation of risk values into the respective catchment areas for medical centers and other facilities in the Veterans Affairs healthcare system would allow decision makers at a lower level to understand the risks for their area. This would push the model to be highly scalable. Catchment areas, which typically work on a driving time radius depending on the VA medical facility's capability, are an example of data that would provide more in-depth detail for the ArcGIS Model. For example, the catchment area of a VA Medical Center (VAMC) is an hour drive time radius. The VAMCs tend to conduct feasibility studies which will confirm our determined catchment areas and/or improve the accuracy of the true catchment of the VAMC and its underlying facilities. After assessing the reach of each catchment area, we will tailor the risk priority numbers for the remaining risks and associate them with these areas to support informed decision-making.

5. Citations and References

Amaral, Ernesto F. L., Pollard, Michael S., Mendelsohn, Johnson, & Cefalu, Matthew. (2018) "Current and Future Demographics of the Veteran Population, 2014–2024." Population Review, vol. 57, no. 1, https://doi.org/10.1353/prv.2018.0002.

Cowper, D. C., Longino, C. F., Kubal, J. D., Manheim, L. M., Dienstfrey, S. J., & Palmer, J. M. (2000). The retirement migration of U.S. veterans, 1960, 1970, 1980, and 1990. Journal of Applied Gerontology, 19(2), 123–137. https://doi.org/10.1177/073346480001900201

ChatGPT. Assistance given to the author, AI. ChatGPT aided in review to make sure it was clear and concise and was not repetitive, making sure it was in a scholarly tone. All content and analysis is original. West Point, NY, 11OCT2024.

Driscoll, P. J., Parnell, G. S., & Henderson, D. L. (2022). *Decision Making in Systems Engineering and Management* . Wiley.

McDonough, Denis. "United States Department of Veteran's Affairs Climate Action Plan; August 2021." U.S. Department of Veterans Affairs. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.sustainability.gov/pdfs/va-2021-cap.pdf.

U.S. Department of Veterans Affairs. About the department - U.S. Department of Veterans Affairs. https://department.va.gov/about/.