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Joint Military Value Analysis of U.S. Military Bases

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Abstract: The Department of Defense (DoD) uses a Joint Military Value Analysis (JMVA) model in strategic joint-stationing and realignment studies for the Army, Navy, and Air Force. This additive Multi-Attribute Decision Analysis (MADA) model provides information to help make decisions about realigning possible bases in a joint context. The model is composed of twenty-seven attributes, each with a value function that corresponds to the data measurements of the attributes, and their weights are based on their importance and value to the U.S joint military. The attributes and weights in the model are derived from the Base Realignment and Closure (BRAC) 2005 Military Value Analysis models from each DoD branch. The JMVA provides a single source for Services to conduct separate joint analysis or possible joint BRAC.

Keywords: Base Realignment and Closure, Military Value Analysis, Optimization, Multi-Attribute Model, Additive Model

1. Introduction

Joint military value analysis (JMVA) models are used to optimize strategic joint stationing studies. This research developed a model and delivered an Excel implementation that will help decide and develop possible changes of Department of Defense (DoD) installations in stationing scenarios. Additionally, it would impact each DoD branch's separate future Base Realignment and Closure (BRAC) studies. This model brings together all Services' installation requirements. Military value modeling is only one portion of the BRAC; however, installation military value greatly impacts decisions on base realignment or closure. Therefore, we strive to bring a JMVA study to enhance all installation analyses in a constantly developing Military.

BRAC 2005 documents were studied in order to develop this model, specifically the Military Value sections. Each Service's attributes were brought together along with their respective weights to analyze the impact of each attribute on a base. This increased the understanding of each Service's needs, wants, and desires to derive the new JMVA attributes. Each service was represented equally, and similar needs were combined to lessen the number of attributes. The attributes were then screened by each Service's stakeholders to ensure each Service's needs, wants, and desires were met. Finally, the Multi-Attribute Decision Analysis model was built using a value hierarchy, value functions, and a swing weight matrix. With past literature, stakeholders, and Multi-Attribute Decision Analysis the JMVA model provides a basis for Congress and Military leaders to analyze installations for future goals, needs, and protection of the United states of America.

1.1 2005 Base Realignment and Closure (BRAC) and European Infrastructure Consolidation (EIC): Military Value Approach

The purpose behind using the previous realignments and consolidations was to build a strong and effective joint service model that optimize military value of a possible joint base. The process began by reviewing the 2005 BRAC for Army, Navy, Air Force, and Joint Cross-Service Group and the European Infrastructure Consolidation for Army and Air force. Based upon the information obtained in the reviews, a new set of attributes were recommended and established for a joint model. Then, new attributes were defined and weighted based on the combinations of previous sources' weights and definitions of their attributes. Finally, an additive model was created to assess the joint military value.

1.2 Value Modeling

Value modeling methodology has two stages, qualitative and quantitative modeling. The qualitative modeling consists of a value hierarchy with four levels, fundamental objective, functions, objectives, and value measures. The hierarchy assists to identify objectives and attributes essential to the system. The quantitative model stage is comprised of the development of value functions, that are based on data and corresponding distribution, and a swing weight matrix. The values are based on data and corresponding distribution, which are then weighted based on the swing weight matrix, for our research, the weight assignment process takes the weights developed from the swing weight matrices of previous BRACs and re-adjust them to reflect the updated stakeholder needs and new model requirements. The application of these weights to the value function returns a single, overall value to the system.

Our research was conducted in accordance with the Systems Decision Process (SDP) utilized by the United States Military Academy's Systems Engineering Department. While the SDP has four distinct, progressive stages - Problem Definition, Solution Design, Decision Making and Solution Implementation - The scope of our problem required a value model as the final product, which corresponds to the first stage of the SDP. This value model is intended serve as the first stage product for the larger, DoD-wide BRAC. Hence, the final product will be a value model that is implemented in Excel.

2. Joint Military Value Modeling

The purpose of joint military value modeling is to create universal model for a potential joint military base or for any one military branch base realignment and closure. This section will cover the qualitative and quantitative analysis done to create a mathematical model for a joint military value model.

2.1 Qualitative Analysis

Qualitative analysis was an essential part of the process of developing attributes for joint bases. In this section, we will discuss the hierarchical diagram of the attributes derived in the qualitative analysis process, the assessment of those attributes, and the results from stakeholder interviews.

2.1.1 Attribute Assessment

In the initial qualitative model, there were more than sixty attributes that were determined to be essential to a joint facility based on the 2005 BRAC research and initial meeting with our client. After deriving the attributes, we completed multiple revisions to check for redundancy among attributes as well as each attribute's relative importance to a joint facility. Once complete with revising, we were able to decrease the number of attributes to twenty-seven. The attributes that were deemed redundant were grouped to form one new attribute. The original attributes values measures were also grouped into the new attributes value. For example, in Figure 2 the attribute Ranges (2.3) was the result of the combination between Range Sustainability (2.3.1), Small Arms Ranges (2.3.2), and Live Fire Ranges (2.3.3). Prior to grouping these were separate attributes gathered from research that were determined to be closely related and have more of an impact on the outcome grouped than separate.

2.1.2 Stakeholder Interviews

The interview process was vital in our understanding of how previous military value analysis was conducted, what modifications to add, and specific problems concerning each branch of the Department of Defense. The needs of the Army, Navy, and Air Force bases were different, so we conducted interviews with personnel who worked on BRAC or had experience in the processes that used Military Value Analysis for bases. These discussions helped refine the attributes and measures of our model. From the Army, we interviewed the assistant to the Deputy Assistant Secretary of the Army (Installations, Housing, and Partnerships) for Infrastructure Analysis & Basing, Kurt Weaver, and other experts to gather information about the needs of the Army. Their main concerns focused on secure communications and Information Technology (IT) network, recruiting and retention considerations, ranges, and training area. The secure communications and IT network measures the network security of the base and the processes inside the base. Recruiting and retention is affected by its proximity to recreational activities, including but not limited to major urban areas. The range and training areas are essential to the development of the warfighting function of the Army, for if there is nowhere to train, there is nowhere for the Army to improve. For Air Force, we interviewed Colonel Scott Bryant and Timothy Brennan, both of whom worked with Air Force to gather considerations for JMVA, for information regarding the needs of the Air Force. From their interview, it

reassured our initial belief that the primary war fighting function for the Air Force is its air assets and its airfield. Providing facilities that supply an adequate amount of airfield space and space for rest and recovery for the aviators is critical for joint basing. For the Navy, the personnel we interviewed, their requirements focused on the necessity of waterborne operations. The proximity to water access includes port space, dredging, and ship maintenance facilities. The warfighting function of the Navy is its ships, and their access to oceans is the critical factor in determining if a base is suitable. They operate from the ship and the more the base can accommodate the ship, the better the base is for the ship. For joint considerations, all the services expressed concerns with the allocation of funding and differing requirements between the services, but they recognized there were some functions the branches could do as a joint function. These functions include supplying chaplain, medical, and security facilities. The interviewees also elaborated on the proximity of the two bases as a benefit to their integration. Joint bases may create an extra burden on the services, but it cuts down on unnecessary spending.

2.1.3 Hierarchical Diagram

The following twenty-seven attributes in Figure 1 will serve as the basis for screening and comparing one military installation to another and determine the joint military value. These attributes were derived from the 2005 BRAC, EIC, and the stakeholder interviews. On the top of Figure 1 are the objectives and corresponding attributes; the bottom shows attributes that were creating by grouping sub-attributes.

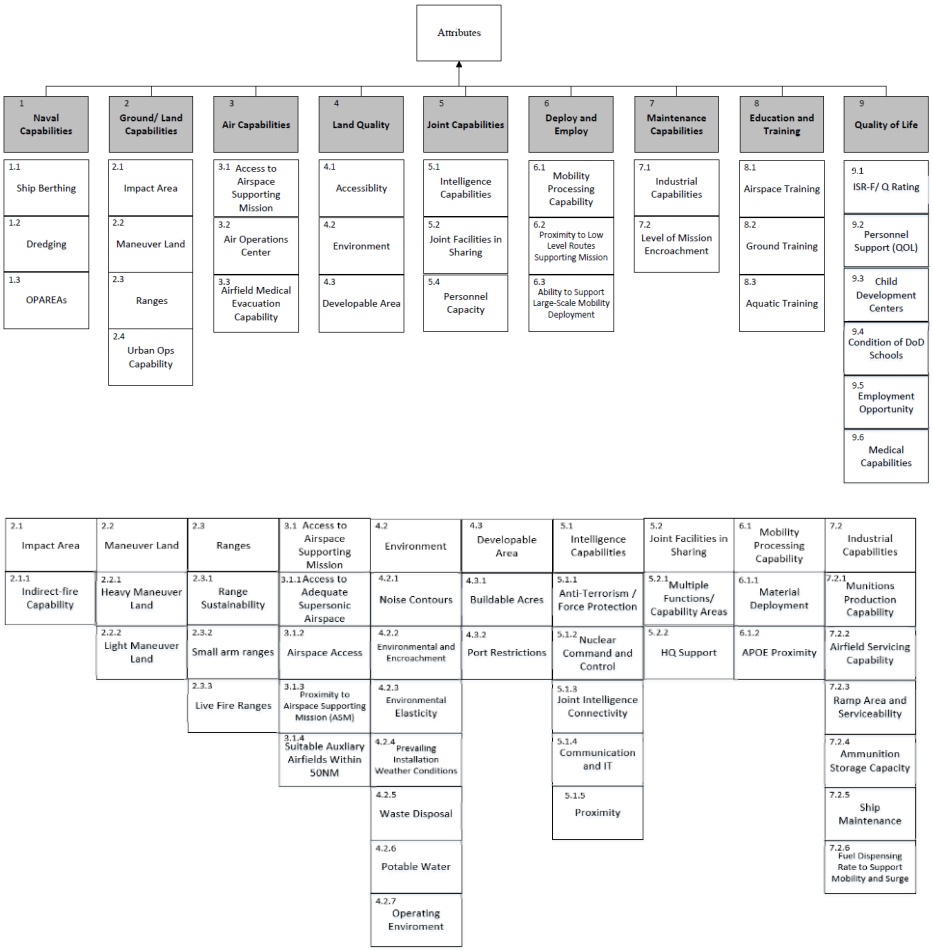

Figure 1. Joint Military Value Analysis Hierarchical Diagram

2.2 Quantitative Analysis

We use quantitative analysis to understand how we can quantify the needs and wants of the DoD in its bases. By quantifying the results of the qualitative analysis, we can compare the importance of each base along with the effective use that each base has in its qualitative analysis. The two parts of our quantitative analysis are value function development and weight assignment. Value function development assigns a distribution to each attribute based on the measurement that is used for the attribute and how the value changes with respect to change in the measurement. The weight assignment reflects the relative importance of an attribute in comparison to another. The higher-level objectives which consist of a set of attributes were also assigned weights to reflect the importance in terms of the joint military value rather than service-specific military value. Through the application of value functions and weights on the attributes, the overall joint military value of a base can be expressed in terms of a score ranging from 0 to 100.

2.2.1 Value Function Development

The value functions for each attribute differ mainly based on the type of value measures. There were three types of value measures for our model: natural, binary, and constructed.

For natural scale value measures, the minimum acceptable and most desirable values, determined based on data and stakeholder input, will be assigned values 0 and 10, respectively. Distributions of appropriate choosing were applied for intermediate values. Most often the distribution was linear. Logistic and log functions were also used for attributes that have a rate of increase in value that diminishes on both sides or towards the upper bound. For binary scale value measures, a uniform value of 10 was assigned to responses that indicate positive results. The intent is to use the swing weight matrix to scale the values. For constructed scale value measures, it has been noted that these cases were all two dimensional cases. The two dimensions were mapped in a table that assigns a label for each pair of the constructed scale value and the corresponding values of the other dimension, as seen in Figure 2.

Accessibility 4.1				
How many major DoD installations and major civilian airports are within 60 miles or less, 120 miles or less, and 180 or less?				
Distance from Airports (AP) and Installation (IN) in miles	**1 IN**	**1 AP or 2 IN**	**1 IN AND 1AP**	**≥2 IN and ≥1 AP or ≥2 AP and ≥1 IN**
≤180 miles	0	0.9	2.7	5.4
≤120 miles	1.8	3.6	6.3	8.1
≤60 miles	4.5	7.2	9	10

Figure 2. Example of a Constructed Two-Dimensional Value Matrix for the Attribute Land Quality: Accessibility (4.1)

2.2.2 Weight Assignments

The weight assignment for our Joint Military Value Model was done in two steps. Given the fact that nearly all attributes of the models were originally from initial BRACs, we first consolidated and the weights of each attribute from its original BRAC MV model. The weights for Attributes that had sub-attributes were simply the sum of the sub-attributes. For attributes that appeared in multiple BRACs, we used the average weight unless there was a significant discrepancy – if there existed a significant discrepancy, the weight was decided on a case-by-case basis by considering stakeholder input and the overall structure of the qualitative model. The initial weight for each attribute in the model was obtained as a result.

Then, each objective was assigned a final weight. Stakeholder input as well as previous BRAC MV models were used to determine the weight of the objectives. The sum of the weights for all objectives equal 100. The final weight for attributes were determined using Formula 1.

$$Final\ Attribute\ Weight = \frac{Initial\ Attribute\ Weight}{\sum_{i \in objective} Initial\ Attribute\ Weight_i} \times Objective\ Weight \quad (1)$$

This formula allows the weight to capture the significance of an attribute for not only the separate services but also the joint military value. Figure 3 shows the weight assignment process done for Objective 4, Land Quality.

Land Quality (8%)					
Accessibility [4.1]	$\frac{2.72}{24.03} \times 8 = 0.9056$	**Environment [4.2]**	$\frac{10.46}{24.03} \times 8 = 3.482$	**Developable Area [4.3]**	$\frac{10.85}{24.03} \times 8 = 3.612$
		Noise Contours [4.2.1]	$\frac{0.54}{24.03} \times 8 = 0.180$	Port Restrictions [4.3.1]	$\frac{4}{24.03} \times 8 = 0.919$
		Waste Disposal [4.2.2]	$\frac{0.6}{24.03} \times 8 = 0.633$	Buildable Acres [4.3.2]	$\frac{4.9}{24.03} \times 8 = 1.362$
		Prevailing Installation Weather Condition [4.2.3]	$\frac{5.52}{24.03} \times 8 = 1.838$	Ability to support additional populace [4.3.3]	$\frac{2.76}{24.03} \times 8 = 1.332$
		Environmental Elasticity [4.2.4]	$\frac{1.9}{24.03} \times 8 = 0.200$		
		Potable Water [4.2.5]	$\frac{1.9}{24.03} \times 8 = 0.633$		

Figure 3. Weight Assignment Process for Land Quality (4) and its Attributes (4.1, 4.2, 4.3)

3. Final Product

The final product is an Excel file that takes the data from military bases that are relevant to the model and return the overall joint military value for the base. Figure 4 shows the summary page of the product for an example military base with hypothetical data. Future work will require collection of data from military bases to compare the actual values and conduct additional analysis such as sensitivity analysis.

12%		20%		20%		8%		10%		12%		13%		5%	
Naval Capabilities 1	1.5	**Ground/Land Capabilities 2**	15.84	**Air Capabilities 3**	16.2	**Land Quality 4**	6.23	**Joint Capabilities 5**	8	**Deploy and Employ 6**	9	**Maintenance Capabilities 7**	10.5	**Quality of Life 8**	3.8
Ship Berthing 1.1	0	Impact Area 2.1	5	Access to Airspace Supporting Mission 3.1	15.1	Accessibility 4.1	0.65	Intelligence Capailities 5.1	3.1	Mobility Processing Capability 6.1	1.4	Industrial Capabilities 7.2	8.8	ISR-F/Q Rating 8.1	0.7
Dredging 1.2	0	Maeuver Land 2.2	10.25	Air Operations Center 3.2	0.5	Environment 4.2	2.56	Joint Facilities in Sharing 5.2	2.8	Proximity to Low Level Routes Supporting Mission 6.2	6.3	Level of Mission Encroachment 7.1	1.7	Personnel Support 8.2	1.5
OPAREAs 1.3	1.5	Ranges 2.3	0.09	Airfield Medical Evacuation Capability 3.3	0.6	Developable Area 4.3	3.02	Personnel Capacity 5.3	2.1	Ability to Support Large Scale Mobility Deployment 6.3	1.4			Child Development Centers 8.3	0
		Urban Ops Capability 2.4	0.5											Conditions of DoD School 8.4	0.32
				Total Value=	71.0306									Employment Opportunity 8.5	0.27
														Medical Capabilities 8.6	1.01

Figure 4. Weight Assignment Process for Land Quality (4) and its Attributes (4.1, 4.2, 4.3)

4. Conclusion

Joint Military Value Analysis through Qualitative and Quantitative analysis allows an assessment of a military base in terms of both service-specific military value and joint military value. The resulting product of our study is tailored to address the problem definition requirements of the Systems Decision Process – as such, the model that was produced will serve as a resource for decision makers in the event of a future BRAC. Our model accounts for the updated stakeholder needs and desires across the different services. This is reflected in the inclusion of attributes such as Communications and IT, Joint Capabilities, etc. The quantitative analysis process captures the significance of attributes not only for service-specific military bases but also joint military bases. At the same time, our model was developed by referencing past BRACs and EICs which used obsolete data. While our model provides a qualitative framework for joint military value, the quantitative analysis process should be complemented with updated data from military bases in future works.

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5. References

Abell, Charles S. Chairman, Educations and Training Joint Cross Service Group. Education and Training Joint Cross-Service Group Base Closure and Realignment Report (Volume VI).

Brennan, T., & Scott, B. (2019, February 5). Air Force JMVA Considerations [Telephone interview].

Department of the Air Force, Secretary of the Air Force. (2005). Department of the Air Force Analysis and Recommendations BRAC 2005 (Vol. V).

Department of the Army, Secretary of the Army. (2005). Analysis and Recommendations BRAC 2005 (Vol. V).

Department of the Navy, Secretary of the Navy. (2005). Analysis and Recommendations BRAC 2005 (Vol. V).

Harlow, H. (1983). Fundamentals for preparing psychology journal articles. *Journal of Comparative and Physiological Psychology, 55*, 893-896.

Department of the Navy. Supplemental Information to Volume IV of DoD Base Closure Report.Henry, W. I. (1990, April 21). Making the grade in today's schools. *Time, 135*, pp. 28-31.

Devitt, T. (2001, August 2). Technical Joint Cross Service Group. (2005). Technical Joint Cross Service Group Analyses and Recommendations (Volume XII).

Ewing, P., Tarantino, W., & Parnell, G. S. (Eds.). (n.d.). Army Base Realignment and Closure (BRAC) 2005 Military Value Analysis (Department of the Army, Secretary of the Army).

Haave, Carol A, Chairman, Intelligence Joint Cross Service Group. Report to the Defense Base Closure and Realignment Commission, Intelligence Joint Cross- Service Group (Volume IX).

Harmeyer, R. (2019, February 28). Navy JMVA Considerations [Telephone interview].

Taylor, George P. Lieutenant General, USAF, MC, CFS Chairman. Medical Joint Cross Service Group 2005 Base Closure and REalignment Report (Volume X).

Tison, Donald C, Chairman, Headquarters and Support Activities Joint Cross Service Group. Headquarters and Support Activities Joint Cross Service Group Final BRAC 2005 Report (Volume VII).

Weaver, K. A. (2019, January 23). Army JMVA Considerations 1 [Telephone interview].

Wynne, Michael, Chairman,Industrial Joint Cross Service Group. Industrial Joint Cross Service Group Final Report (Volume VIII).