Multi-Criteria Decision Making Model for Higher Education

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Abstract: -
The Department of Civil & Mechanical Engineering at the United States Military Academy faced significant strain on program resources which impact the Department's ability to effectively conduct senior year independent study projects. Accordingly, the program made a strategic decision to reduce the number of independent study projects offered. To do so, the Department implemented a Multi-Criteria Decision Model. The focus of this paper is the process of exploring, developing, and evaluating that mode. The stakeholders and parameters used in the development of our Multi-Criteria Decision Model are detailed in this report. The model was evaluated relative to multiple years of department records of prior authorized independent study projects and has now been applied in the evaluation (pre- and post-performance) of four independent study project terms. The results of this decision modeling development process are likely to be of interest to engineering educators charged with the process of making curriculum decisions, particularly those decisions in which the influence of multiple stakeholders and parameters must be considered.

Key-Words: - Process, Selection, Independent Study, Factors

1. Background

The Department of Civil & Mechanical Engineering (D-C&ME), at the United States Military Academy (USMA), consists of two ABET accredited programs of engineering. The Civil Engineering Division includes 18 faculty members (civilian and military) and graduates approximately 45 cadets per year. All cadets are required to take a core curriculum consisting of 31 courses in science, English, mathematics, history, information technology, and behavioural and social sciences. Civil engineering is one of the 22 academic majors available at USMA and one of seven ABET accredited engineering programs (computer science, electrical engineering, civil engineering, mechanical engineering, systems engineering, and environmental engineering). Cadets majoring in civil engineering take a total of 43 courses. Upon graduation from USMA, cadets receive a Bachelor of Science degree in their chosen field of study and are commissioned as second lieutenants in the United States Army. In exchange, graduates serve a minimum of five years as a United States Army officer.

Independent study projects have been a part of the civil engineering curriculum at USMA for more than 35 years [1-3]. Broadly, those independent study projects are categorized within three areas: service, competition, or research. Over the years, the number of independent study projects offered and performed has fluctuated as a result of such factors as department enrollment, available faculty, and interest-level on the part of the cadets (students). In general, there has never been a lack of "good ideas" in the pool of available independent study projects. Yet, the process by which these ideas are evaluated and rejected, tabled, or approved has varied and has largely been at the discretion of the course director who oversees the independent study program.

The D-C&ME continuously labors to balance the influence and concerns of various stakeholders (e.g. current cadets, alumni, faculty, etc.). This balance is particularly critical when evaluating future course offerings and instructor workloads. Independent study projects have historically represented a significant strain on that balance. The D-C&ME has recently completed several changes in the program's curriculum [4]. These changes include an increase in the number of senior year engineering electives offered and a reduction in the number of independent study projects. Independent study projects serve as a technical elective in the civil engineering curriculum, are offered during the fall and/or spring terms, and are separate from the required senior capstone project. The USMA course catalog defines the scope of the independent study course as:

> *The cadet, on an individual or small group basis, pursues advanced study of a research or design topic in civil*

engineering. The scope of the course is tailored to the needs of the project and desires of the cadet, in consultation with the Faculty Advisor. The cadet is required to define and analyze the problem, study the fundamentals involved, organize an approach, determine a procedure, perform research and/or achieve a solution, submit a written report, and give a formal briefing.[5]

Further, the course objectives are:

- Apply the engineering thought process to solve a complex, real-world problem.
- Develop a creative solution to a complex, real-world problem.
- Acquire information and learn new concepts in order to solve a complex, real-world problem.
- Write a clear, well-organized report.
- Deliver a clear, well-organized presentation. [6]

In an effort to reduce the demands on the faculty advising independent study projects and to encourage increased cadet enrollment in engineering electives, the D-C&ME has chosen to deliberately reduce the number of independent study project offerings. The D-C&ME opted to evaluate its current methods for authorizing or rejecting potential projects and develop a decision model for judging perspective independent study projects. The research question employed in this study was, "Can a decision model be developed and evaluated that considers the applicable parameters and stakeholders and helps us select the best independent study projects?"

2. Literature Review

The literature review presented in the following paragraphs begins with an investigation of prior application of decision models to independent study projects and explores project evaluation criteria. Further, the literature review includes a discussion of two of those reported criteria: students and faculty. The application of decision modeling beyond academics is briefly discussed. Finally, various types of decision models are presented.

An extensive volume of literature has been published on the subject of independent study in the engineering curriculum [1-3, 7-11]. However, an extensive search led to little information on the process of selecting appropriate independent study projects. Rather than utilizing a formal evaluation and decision process, most of the identified resources simply provided justifications for performance of independent study projects. These justifications typically included important considerations, which, when summarized, hold the potential to be utilized as selection criteria for such projects. The following list summarizes the common considerations noted within several prior independent study publications:

• Does the potential project have a well defined scope?

• Is there a detailed timeline for benchmarks and deliverables (contract)?

• Does the project offer a unique learning experience?

• Is the project challenging but reasonable for undergraduate level students?

• Will students have freedom with respect to research methods and solution approaches?

• Are faculty interested and willing to apply the effort required to make it successful?

• Are the project requirements feasible/manageable given time and resources?

• Is the project perceived as authentic and valuable?

• Will the project result in a product (object or report) that will be used subsequently?

• What is the potential for the project to be interesting and/or fun?

While, collectively, the identified literature provides a detailed listing of considerations, there was little common overlap between publications. In some instances, the summarized list of criteria contains several considerations that are contradictory. At least one resource [7] did recognize the potential contradiction and emphasized the delicate balance between a well-defined scope, including required deliverables, and allowing students some latitude to choose research methods and potential plans of action. In Blumenfeld et al.'s text "Motivating Project Based Learning," they state that students often do not have sufficient knowledge and insight to fully develop a scope and advance a list of requirements for the project. That is, they typically need assistance with identifying the deliverables and possible resources available for the project. Further, Blumenfeld, et al. describe that students must have the level of competence that is on-par with the complexity of the assigned project, or they will try to simplify the problem and potentially provide less effort, striving to meet only the minimum requirements. In-turn, project characteristics influence the level of interest held by students in the project and whether or not they will enjoy the experience or simply suffer through a list of requirements. Gehringer [8], states that wisely chosen projects play a significant part in students' development because such projects typically engage students at a higher level of Bloom's Taxonomy [12]. Unmistakably, to ensure that our students and faculty benefit from performance of an independent study project, consideration of the applicable criteria is paramount.

Clearly, students are not the only participants in a given independent study project. Faculty members serve in various roles associated with independent study projects, and these often requires large amounts of time to make the projects successful. Thus, the faculty's initial level of interest is an important consideration. While students stand to benefit from an interested and motivated faculty advisor, the literature did not provide a consistent message relative to the potential for tangible benefits to the individual faculty member. Gehringer [8] mentions that independent study projects can help faculty meet tenure and promotion requirements, while an article by Sanford-Bernhardt and Roth [11] described how most projects at their academic institution did not result in products that assisted with faculty development. This condition is likely the result of the disparity between the level of knowledge and skill of most undergraduate students and the forward-thinking research required of faculty for promotion and tenure at many academic institutions.

Decision modeling is a process that is not unique to academic programs. Evaluating proposals and approving potential projects are critical actions for corporations, government agencies, and academic institutions alike. The criteria considered for approving independent study projects are similar to the considerations companies utilize when developing research and development portfolios. While there is limited literature related to decision models for selecting independent study projects in academic settings, there is a sizable volume of works published about models used throughout industry to choose research and development (R&D) projects [13-16]. Brenner identified several factors that can impact R&D decisions, such as political and personal issues. Factors of this type can influence project approval, but are not easy to enumerate in a decision model. Further, Coldrick et al., noted that decision models providing, "a single project score can obscure many important details about the project." The model scores should not be the lone deciding factor. Instead, the model should be a tool used to help decision makers compare projects, with the various attributes considered as part of the informed decision.

The use of decision making models is not limited to civilian endeavors. Military planners often use formal decision making models to analyze and compare numerous courses of action for a mission. Commanders provide guidance for developing courses of action and typically emphasize criteria they believe to be most important. Staff officers then incorporate other selection criteria into the model, weighting each appropriately, and then evaluate (score) each course of action. Scored comparisons assist in recommending a particular course of action. Officers are trained to develop and routinely utilize these models with additional guidance found in field manuals (for example FM 101-5, [17]).

Iteration and optimization have long been the hallmark of a successful engineering process. It is in the nature of engineering to not only find a solution, but to find the best solution that satisfies the required parameters. Yet, optimization is not a characteristic solely unique to engineering. It should come as no surprise that in the last 40 years, a voluminous amount of literature has been generated dedicated to the subject of optimization through the application of decision modeling. Multi-Criteria Decision Making (MCDM) is a fast growing and well studied form of decision making modeling. The wide variety of MCDM applications range from selecting the right spot for maple sugar production to increasing Wall Street profit margins [18].

There are a large number of MCDM models to choose from, and an understanding of the origin of such models and their unique characteristics is critical to selecting the right MCDM for a certain application [19]. An extensive working knowledge of the subject matter is not required to apply a simple Decision Matrix (a form of MCDM), and there is an immense amount of literature available to aid in this process [18-24].

In summary, the literature review has revealed that MCDMs are routinely utilized in a variety of applications, but there is no evidence of their prior application in the process of selecting independent study projects at academic institutions. Instead, more general project evaluation considerations are reported in literature. The potential influence independent study projects have on students and faculty is clearly recognized. While there is a large variety of MCDMs to choose from, the literature provided specific guidance on utilization of a model applicable to the related criteria and goals.

3. Decision Model Development

Navigating the decision model selection process can be confusing. Accordingly, we begin this section of the document detailing the process utilized in selecting an appropriate decision making model. Then a description is provided of the development of that model in relation to the authors' independent study criteria. Each criteria utilized in the development of our MCDM model is also identified and discussed herein.

As noted previously, the MCDM field of study is extremely broad. Thus, in preparation for selecting the proper MCDM model, the authors found it helpful to create a flow chart to ensure selection of the appropriate type of model (see Figure 1).

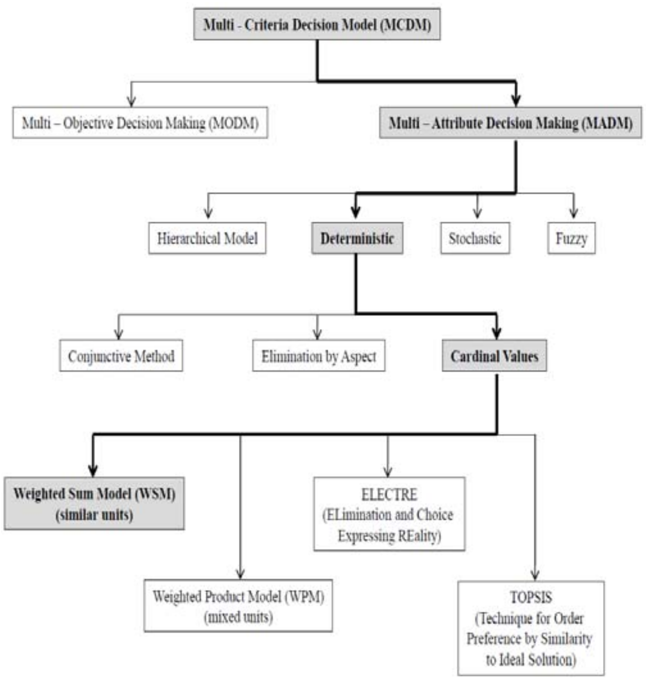

Figure 1 – Multi-Criteria Decision Flow Chart

The desired end state of this study was to provide a general order of merit for potential independent study projects. In addition, having the knowledge of a finite number of data combinations, as well as the ability to assign a value to those combinations, the decision model literature suggests that the appropriate model for application to this study was either a Weighted Sum Model (WSM) or a Weighted Product Model (WPM). Both of these approaches are subsets of Cardinal Values and Deterministic Models. However, specific to this study, a dilemma is created when considering the combination of both mixed units and a desire to generate a hierarchal rating. The most common approach to addressing this dilemma is to reassign criteria with a scaled value in lieu of actual units, which leads to selection of the WSM.

The authors utilized stakeholders identified in the D-C&ME's 10-year Strategic Plan to select the criteria that would serve to analyze each course of action [25]. The list of stakeholders is reviewed and agreed upon by the senior leadership of the D-C&ME faculty on an annual basis during a strategic planning workshop. While the list does not change often, it does serve to tie the independent study decision model to the Department's goals. The initially developed criteria provided a more focused analysis of prospective projects than the summary of considerations found in the literature and provided previously. In lieu of a strategic plan, others wishing to develop a MCDM are encouraged to evaluate their own common stakeholders associated with their department's independent study program.

Upon first analysis, it seemed natural to have a two-part decision matrix. The first set of criteria was envisioned as hierarchy based and served as a simple GO/NO-GO decision. Accordingly, any proposed independent study project that failed to meet the first set of criteria would be automatically negated. However, this logic proved unfounded; there were past academic years that always had exceptions to these criteria, wherein an independent study that would have been dismissed (NO-GO) in other years ended up being a fantastic project. Further, some of the initial criteria were noted to have little or no influence on the hierarchal rating due to commonality in the scaled criteria value. This observation resulted in modifications to the list of criteria to reflect more than simply the D-C&ME stakeholders.

Ultimately, it was determined that there were some aspects of the initial criteria list that were either redundant, did not stand out as truly independent, or were not feasible to rank and scale. Consequently, the modified criteria list was further paired down by merging some items, deleting others, and finally updating the remaining items. This final list of criteria is reflected along the left side of the model as presented in Figure 2.

By providing a "scale" for each of the criteria (for example 1-10), the model's user can then negate the predicament of mixed units and still use the WSM to generate an order of merit. Definition was provided by the authors for each scale value (e.g. with respect to "Faculty" what does a "1" verse a "10" mean?). A weighting value was assigned to each of the criterion. That is, each criterion was considered and weighted in relation to each other.

After assigning weights, a consistency check (a common mathematical tool to ensure non-biased weighting) ensured that the weighting was mathematically consistent. The consistency check provided a structured approach to review the weighting values through an Analytic Hierarchy

Process (AHP). The authors used the AHP steps outlined by Ragsdale [26] and calculated a consistency ratio of 0.064 (≤0.10 is considered satisfactory).

As noted previously, the selection of model criteria is an iterative process. The following paragraphs provide a brief description of each criterion and the methods for assigning values as a part of our model. It is recognized that model criteria are specific to the user. Undoubtedly, the D-C&ME criterion is unique to our mission. Details regarding our model's criteria are not likely directly transferable to other models; however, they are provided as an illustration of model development. The order of the individual criteria presented in this document and listed on the model (see Figure 2) does not influence the model output.

3.1 United States Military Academy

The defining metric for this criterion was the likelihood that USMA stood to directly benefit from the project. While such a benefit is significantly important, in this case, the benefit is expected to be more than just strategic communications. More specifically, this could include physical products or a new/improved process. A scale value of 1 is assigned to projects that have no foreseen benefit; while a value of 10 is assigned to projects leading to a physical artifact or process that improves conditions at USMA. This criterion carries a weighting factor of 0.7. Examples of projects earning a higher score would be the design and construction of a footbridge and improved weight-room facilities. This criterion would be synonymous with benefit to the University or College when applied in the context of another academic institution.

3.2 D-CME

The second criterion, similar to the first, is if the Department (D-C&ME) stood to directly benefit from the project. Again, the benefit is defined as more than just strategic communications. While in principle this criterion may appear very similar to the previous criterion, the end user is considered sufficiently different to justify separate criteria. Values are assigned to projects in an identical manner as the prior criterion. A value of 1 is assigned to projects that have no foreseeable benefit and a value of 10 is assigned to projects leading to a physical artifact or process that helps the D-C&ME.

Criteria	Weight 0.1-1.0	Definition (1-10)	Scale	
West Point	0.7	Does the Academy stand to benefit from the project?	1	No physical object or process gained ("artifact")
			10	Product used by USMA
Depart-ment	0.7	Does the Department stand to benefit from the project?	1	No physical object or process gained ("artifact")
			10	Product used by D-C&ME
US Army	0.8	Will the project lead to an improved engineering process that could be used by soldiers or an improved material/item that helps the US Army?	1	No physical object or process gained ("artifact")
			10	Product used by Army (i.e.: blast resistant concrete, expedient pothole repair techniques)
Prof Societies	0.5	Is the project sponsored or administered by a professional society that is important to work with?	1	No ties to any professional societies
			10	Strong tie to professional society
Project Sponsors	0.5	Is the project sponsored by an agency that worked with the department before, or could potentially sponsor more projects in the future?	1	No outside agency
			10	Project brought to the Academy by "client/customer" and is a "real world project"
Strat Comms	0.9	What type of message will the project send the engineering profession, other academic institutions, and the US Army?	1	No recognition of project outside of West Point
			10	Directly attributed to external perception/rankin gs
Costs	0.4	How much will the project cost the department?	1	funding requiring a contract
			5	funding within discretionary accounts
			10	Neutral Cost
Cadet	1.0	Potential for Cadet learning, enthusiasm, engineering thought process, and self-directed learning?	1	Low potential
			10	High potential
Faculty	0.6	Faculty availability, enthusiasm, and potential for growth?	1	Low
			10	High

Figure 2 – D-C&ME Independent Study Project Decision Model

This criterion carries a weighting factor of 0.7. Examples of projects considered beneficial would be those involving competitions (e.g., Steel Bridge, Concrete Canoe, Timber Bridge) because they potentially result in physical models which instructors could use as teaching aids during future lessons.

3.3 Unites States Army
The benefit to the US Army criterion is similar to the first two criteria, but it is applied to the Army as a whole. Values are assigned based on whether or not the project benefits the US Army. The values are assigned the same way; 1 means no benefit, and a value of 10 is assigned to projects that lead to potential physical objects or processes that could improve Army operations. This criterion carries a weighting factor of 0.8. Examples of projects earning high values for this criterion include improved designs for blast resistant concrete and expedient pothole repair techniques. Clearly, this criterion is unique to USMA and has no direct corollary for other academic institutions.

3.4 Professional Societies
Working with professional societies increases opportunities for strategic communications and allows for interaction between our program and other high quality engineering programs around the world. A project with no ties to a professional society is assigned a value of 1 while projects tied to professional societies earned a 10. This criterion carries a weighting factor of 0.5. The competition projects, such as the Concrete Canoe, Steel Bridge, and Timber Bridge, are examples of projects that earned high values for this criterion because of their direct relationship with high profile professional societies, such as the American Society of Civil Engineers.

3.5 Project Sponsors
While this criterion is related to costs, it is not synonymous with cost. It incorporates more than just the short term budgetary requirements. Cost of a potential independent study project is considered under a subsequent criterion. Rather, the project sponsor criterion is focused on development of long-term relationships. Project sponsors are desired as they often assist with strategic communications in addition to the potential for sponsoring additional projects in the future. A project not tied to any outside agency receives a value of 1 for this criterion. Higher values, up to 10, are assigned for projects associated with outside agencies that have the potential for additional projects in the future. Some project sponsors that have worked with D-C&ME in the past include the National Parks Service and the West Point Directorate of Public Works. This criterion carries a weighting factor of 0.5.

3.6 Strategic Communication
Strategic communication is critically important to any academic program, at least in part from the fact that they play a direct role in several national ranking systems. For purposes of this model and study, strategic communication is defined as positive graphics (including photographs) and supporting text that casts the D-C&ME and/or USMA in a favorable light from the standpoint of the various stakeholders identified in the D-C&ME Strategic Plan. D-C&ME views our independent study projects as a form of representation and "branding" of the department and USMA. Smaller and low impact projects are valued low within the model. High valued projects include technically advanced research, widely applicable engineering solutions, or high-visibility projects. This criterion carries a weighting factor of 0.9.

3.7 Costs
Project costs are another factor considered when evaluating independent study projects. The costs considered include hardware and materials, testing, travel, publishing, and the use of external resources. A scale value of 1 is assigned to projects requiring a contract for the Department to get funding and a scale value of 5 for projects the Department can fund within discretionary accounts. Fully funded projects, not requiring any money from the Department's budget, are assigned a scale value of 10. This criterion carries a weighting factor of 0.4. While it is considered the least important factor in our model (lowest weighting), it is still perceived to be a necessary criterion to evaluate the overall potential for success and would likely be a criterion associated with any academic institution.

3.8 Cadets
One of the most important criteria in our model (as suggested from the weighting) is the anticipated level of cadet (student) interest and cognitive development related to the project. Specifically, would the project involve challenging and unique

problems that cadets would enjoy? As mentioned in our review of the applicable literature, students must have the competence to complete the project satisfactorily, or they will try to simplify the problem and potentially provide less effort, striving to meet only the minimum requirements. They can be motivated by the type of project, the scope of the project, or by the freedom they have to influence the project goals and methods to meet the requirements. This is also the point where the model evaluates if the project is in-line with course objectives, which are developed in relation to ABET accreditation standards. This criterion is fairly subjective and it can be difficult to evaluate. Low values are assigned to projects that have a low potential for cadet development, enthusiasm, and self-directed learning; high values are given to projects with greater potential in those areas. The literature clearly indicates that benefit to the student should be a primary consideration. Thus, this criterion carries a weighting factor of 1.0.

3.9 Faculty

The final criterion in the model is faculty interest and development. Specifically, are faculty members excited about the project, and will those involved experience personal and professional growth through their involvement with the independent study? Faculty development is defined as occurring directly through gaining knowledge and experience as an advisor to the project, or indirectly for the non-advising faculty through a report or presentation. Independent study projects are typically more advanced than standard course projects and could provide an opportunity for faculty members and their peers to participate in new engineering research or learn new processes. It is possible that the project results could assist faculty advisors with promotion or gaining tenure as well. As with cadet interest and development, this criterion is subjective. Projects with little potential to capture faculty interest or help with their development are assigned a value of 1. Higher values are given to projects that are exciting and held potential for professional publication or presentation. This criterion carries a weighting factor of 0.6.

4. Model Evaluation & Application

In an effort to evaluate our MCDM model's strength as a predictor of appropriate independent study projects to authorize, the authors initially applied the model to several previously completed independent study projects. Specifically, the model was used to evaluate 11 independent study projects that were authorized and completed during the 2008-2009 academic year. All independent study projects within the D-C&ME are executed under the requirements of a contract prepared collectively at the start of the academic year by the cadets, faculty member(s) acting as the project advisor(s), and the course director responsible for oversight of all independent study projects. The authors used only those contracts to perform a "pre-performance" evaluation. In other words, the evaluation was done in a manner that provided the authors with information limited to the amount typically available prior to project performance. None of the authors were involved with 2008-2009 independent study projects, and thus, they had limited prior knowledge of each project's level of success that could have influenced the pre-performance evaluation.

Two members of the D-CME senior faculty, familiar with the 2008-2009 independent study projects, performed the post-performance analysis. The post-performance analysis was performed based on knowledge of the completed projects. Numerical values generated by the MCDM model for the pre-performance and post-performance 2008-2009 projects are reported in Table 1 (Table 1 is provided in double column format at the end of this manuscript). It should be noted that the maximum possible numerical value generated by the MCDM model is 61, while the minimum value is 6.1. The maximum value of 61 represents the highest possible score a project could achieve. Likewise, the minimum value represents the lowest possible score a project could achieve and would not likely be an approved project. These maximum and minimum values are merely an artifact of the numerical weights assigned to each criterion.

In addition to listing the pre-performance and post-performance model values, Table 1 also provides a brief description of each of the 2008-2009 academic year projects, reports the percentage difference between pre- and post- evaluation values, and lists the pre- and post- numerical rankings for the eleven evaluated projects.

When the pre-performance and post-performance MCDM model results are compared for individual projects, several interesting observations can be made. First, with the exception of only one project, all of the projects generated higher post-performance values than the pre-performance values. This might suggest that the model is dependent upon the amount of information available for consideration. The pre-performance values generated limited information, which is realistic of the assessment that is typically completed when considering proposed projects. While nearly half of the pre- and post-performance values differed by less than 10%, several of the projects have significant differences in the pre- and post- values. Looking at the pre-performance and post-performance rankings, in general, projects predicted to be successful were also ranked as having been successful upon completion.

Ultimately, using the ex post facto approach of evaluating the 2008-2009 projects, the model was deemed to generate reasonably accurate predictions of project success. No adjustments to the model were made between its initial evaluation and subsequent application. Had the model been less successful in predicting success of accepted projects, the individual criterion and associated weighting would have been revisited.

The model has since been utilized to perform both pre- and post-performance evaluations on 23 unique projects during four separate academic terms. Table 2 lists all of the projects to which the MCDM model has been applied, provides a brief description of each project, and identifies the pre-evaluation and post-evaluation (when applicable) values (Table 2 is provided in double column format at the end of this manuscript). Within Table 2, the abbreviation "NA" indicates that the project was not performed, but not for reasons associated with the pre-performance score. Whereas, the abbreviation "NG" indicates that a project was not pursued as a result of the low pre-performance score. Annual competitions, such as the Steel Bridge, Concrete Canoe, and Timber Bridge, typically generate very consistent values from one academic term to another. Accordingly, those values are only shown in Table 1 and are not carried forward into Table 2.

5. Conclusions

The model developed and evaluated during this study represents a measured approach to evaluating potential civil engineering independent study projects. The authors utilized proven decision making models and selected an appropriate model based on specific conditions. Extensive consideration was given to the applied list of criteria, their respective weighting, and their scale values. The weighting was evaluated using Analytical Hierarchy Process to ensure that the applied values are unbiased, and the model was assessed using a post-performance analysis.

The model has shown particular merit in evaluating proposed independent study projects. Continued growth of the pre-performance and post-performance dataset will provide a useful comparison during the future application of the model.

Obviously, no singular model can capture all potential risks or benefits associated with performing a particular project. Inevitably, unforeseeable conditions can occur that disrupt a projects path towards success. It is anticipated that the true value of the model will be in its future evaluation of proposed independent study projects in relation to a dataset of prior highly successful and less successful projects. Thus, as the data set grows, so will the reliability of the model.

It should be noted that a proposed project could score relatively low on the scale, but would still receive authorization under special circumstances. In such a case, the model would be used to help evaluate the known risks of proceeding with the project. An example of a special case could include a project that generally scores low, but is enthusiastically proposed by a group of cadets and supporting faculty with particularly high potential for personal and professional growth.

It is anticipated that the Department of Civil & Mechanical Engineering at the United States Military Academy is not alone in their desire and need to make carefully measured decisions and curriculum changes during this time of fiscal limitations. Accordingly, the authors anticipate that the process detailed in this document and perhaps an adapted model to meet specific needs will be of interest to other program administrators facing similar, multiple-criteria decisions.

As noted previously, the model detailed herein was specific to our concern (independent study program) and our criteria. Other academic institutions facing multi-criteria decisions must consider their scenario and stakeholders in development of a model. Creation of such a model is a time consuming task that requires extensive knowledge of the stakeholders involved. While the time and energy necessary to create a MCDM model is not trivial, ultimately such models are more accurate than experience-based or gut-based go/no go decisions on projects. In addition, such models can result in significant savings of the valuable resources (time and money) invested in performing independent study projects that should not have been initiated.

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Table 1 – Multi-Criteria Decision Make Model Evaluation Data

Project (2008-2009)	**Description**	**Pre- Perform. Rank**	**Post-Perfom. Rank**	**Pre-Perform. Evaluation**	**Post-Perform. Evaluation**	**Eval. % Diff.**
Steel Bridge Competition	National competition sponsored by the American Institute of Steel Construction and the American Society of Civil Engineers.	2	5	36.2	39.9	9.2
Timber Bridge Comp.	National competition sponsored by the Forest Product Society and the American Society of Civil Engineers.	5	3	30.5	41.5	26.4
Concrete Canoe Comp.	National competition sponsored by the American Society of Civil Engineers.	3	4	35.5	41.2	13.7
Ag. Building Design	Complete design and sighting of turkey processing facility for a one-time project sponsor.	11	11	18.6	19.0	1.8
Island Irrigation	Design and construction of a large scale garden irrigation system for a local private trust organization.	10	6	27.8	38.3	27.4
High Perform. Concrete	Design and evaluation of multiple high-strength concrete products as part of an externally funded research program.	1	1	40.8	53.0	23.0
Protective Design	Design of a future course focusing on security engineering and protective design.	9	2	27.9	49.7	43.8
Sustainable Housing	Design and economic evaluation of a sustainable log home for use by the academic institution.	8	10	28.7	30.1	4.5
Transportation Course	Design of a future course focusing on an introduction to transportation engineering.	6	9	30.3	32.4	6.5
Cross-Fit Facility	Design, analyze, and fabrication of equipment, as well as design and oversight of reconfiguration of workout room for the academic institution.	4	8	35.0	34.1	-2.6
Loading Dock Retrofit	Design and preparation of a cost estimate for construction of a loading dock retrofit for the Department.	7	7	29.9	36.6	18.2

Table 2 – Application of the Multi-Criteria Decision Making Model

Project (2008-2009)	**Description**	**Pre-Perform. Evaluation**	**Post-Perform. Evaluation**	**Eval. % Diff.**
Alternative Energy	Research on the feasibility of application of alternative energy sources for a local application.	35.4	NA	NA
Wind Challenge	Design and construction of a small-scale wind turbine without a particular project sponsor.	27.8	34.6	19.7
Parking Lot Design	Design and reconstruction of a walkway for a facility at the academic institution.	28.2	NA	NA
Aerial Tram	Development of a creative transportation solution for a one-time client.	25.5	18.9	-34.9
Statue of Liberty	Design and oversight of protype construction for a rescue system for the National Parks Service.	40.9	44.3	7.7

Project (2010-2011)	**Description**	**Pre-Perform. Evaluation**	**Post-Perform. Evaluation**	**Eval. % Diff.**
Lusk Reservoir	Investigation, design and emplacement of an aquatic wildlife deterrent system	40.6	NA	NA
9-11 Memorial	Design, sighting, and construction of memorial on the grounds of USMA	34.1	NA	NA
Grant's Cottage	Investigation, design, and recreation of a historical gazebo on the ground of Grant's Cottage	28.9	NG	NG
Energy Conversion	Investigation and evaluation of alternative energy sources for forward operating bases in Afghanistan	47.1	44	-7
IED Culverts	Investigation and evaluation of alternatives for culver emplaced IED risk mitigation	47.1	44	-7
Aquifer Testing	Modeling of contamination movement in a fracture bedrock aquifer	40.2	40.6	0.9
Blast Panel	Advancement of research in the area of ultra high performance concrete	49.1	38.5	-27.2
Stairway Project	Design and emplacement of concrete pedestrian stairway on the grounds of USMA	35.2	37.3	5.8
Road Assessment	Assessment of road improvement needs for a private community	19.7	32.6	39.4