

Analyzing Multidisciplinary Team Effectiveness in an Engineering Environment: A Case Study of the West Point Steel Bridge Design Team

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Abstract

The West Point Steel Bridge Design Team is a group of five undergraduate seniors working to design and build a steel bridge for the annual ASCE Steel Bridge Competition. The purpose of our group's research is to discover how multidisciplinary teams perform in academically competitive environments. This project provides a unique opportunity in the field of multidisciplinary collaborative work because the team's success can be objectively measured against this year's competitors and the team's performance in previous years. The traditional structure of the West Point team consisted of three-to-five civil engineering majors. This year's team includes a law and legal studies major and five civil engineers, two of which recently switched from systems engineering.

Past designs have relied heavily on the work of previous years, which has led to stagnant performance at competitions. Our hypothesis is that by entering different perspectives into the group at an early stage, a revolutionary approach will ensue and overall performance will increase. The team did not completely disregard the designs and methods of previous teams, but the reliance on their decision-making process was more heavily scrutinized with the current multidisciplinary team. Our research is not solely limited to competitive performance. We also analyzed the decision-making process of this year's team in comparison to previous years. While data on decision-making is not readily available, both the faculty advisor and two current team members who served on the team last year were able to provide personal insight into how the teams compare. Ultimately, this research seeks to provide groups in similar academically competitive environments an indication of whether a multidisciplinary composition will provide benefit to their team's performance.

1. Structure

Five members of the West Point Steel Bridge Team are enrolled in a fall and spring semester course designed to provide them with an opportunity to apply and synthesize their knowledge of structural engineering, construction management and engineering economics in an open-ended, realistic, semester-long, capstone design experience. The remaining member, a junior, is only enrolled in the spring semester to gain familiarity with the competition and to share that knowledge with next year's team. For the current team, the students developed functional requirements for their project and then performed the structural designs for their bridge. Execution of the design required extensive use of computer-based analysis and design tools. The products of this effort included a comprehensive design report to include drawings, a model of the bridge, and a briefing to the client. The integrated design experience was augmented by formal classroom instruction in civil engineering systems design and advanced topics in civil engineering component design. This 3.0 credit hour course meets a total of forty lessons at fifty-five minutes apiece and constitutes the integrative experience for students. During each class meeting, the team members are seated at a rectangular meeting table in the team's advisor's office. During the initial lessons, the team and advisor created a syllabus by backwards planning from the competition in April 2018. Overall, the team viewed the first semester as the design phase and the second semester as the refinement and execution phase. During the design phase the team conducted a lab safety overview, literature review (including previous years' feedback), review of the competition rules, two distinct bridge designs with full analyses of both, and a final design winner.

2. Designs

After reviewing previous years' reports, the team noticed that teams fully designed a single bridge and underwent an optimization process after the initial design. During previous teams' optimization processes, mainly the number of members and their sizes were refined. This year's team decided that this approach was limited in performance outcome because it constrained the team to a single structural concept from the start. The team decided that creating two designs with entirely different structures from the start would ultimately produce a better result. One design team would start with the simple structure similar to previous bridges while the other team built a new design inspired by a successful competitor's bridge from the previous year.

The updated rules were also an important factor in creating two designs. In last year's competition, the overall size of a member was nearly double what members are allowed to be this year. This change lends itself to creating a more complex bridge. While previous years' teams relied heavily on past designs, this year's rules changes were so extraordinary that full reliance on previous designs would not be nearly as beneficial as in the past.

When confronted with the issue of stagnant performance over multiple competitions from previous years, the team decided to rethink the steps of how the design was decided upon. According to the design model used by the team (Fig. 1), the team concluded both that the model could be improved and that the team could improve the way in which it used the model. The design model lends itself to an extensive conceptual design phase rather than creating sophisticated, complete models and comparing them. The team sided with the second approach, reasoning that given the technical nature of the project, choosing among conceptual models would at best be a guess. The team also reasoned that creating two full bridge designs would statistically increase their odds of success at the competition in the spring. In essence, another bridge would serve as a second entry into the competition, so to speak.

The team identified the "company requirements" element of the design model as a shortcoming from previous years. The company requirements entail the specifications the project recipient demands. For the steel bridge design team, the company requirements center largely around the rules published in the handbook. Last year, had the team adhered to the complete list of rules of the competition, the team likely would have advanced to the national competition. This year's team concluded that devoting a team member solely to understanding and applying the competition rules, and acting as a reference to the team would best mitigate this issue. The rules, though technical in nature, would best be explained and applied through the lens of someone outside of a science-oriented discipline. In a similar case study, two professors at the

Colorado School of Mines expressed the importance of matching position requirements with the people who best meet those requirements (Turner and Reynolds). The study included cases of both success and failure in the school's multidisciplinary capstone course, and ultimately noted that its primary initiative moving forward would be to "improve team formation process[es] to get the right expertise (faculty and student) on the team" (p. 12). This conclusion further fueled the team's interest in acquiring an "outside" voice with more expertise in the realm of rules interpretation. At the United States Military Academy, all students, regardless of their major, are required to take an engineering sequence, with one of the options being civil engineering. The curriculum provided an advantage to the team because they would be able to select someone with a baseline of knowledge in civil engineering but a larger understanding of how to read and interpret rules. The team found a law and legal studies major with experience in both statics and mechanics of materials to fit the job description. The success of this initiative cannot be concluded at the time of publication; however, the team believes that the decision to dedicate a team member solely to the knowledge and interpretation of the rules will prove to be beneficial at the competition given the importance of rule adherence.

Once the team decided to create two designs and analyze both fully, it had to decide whether it would work on each design consecutively or concurrently. Under the consecutive approach, the team would work collectively on the first design and upon completion, would start designing the second bridge. Alternatively, under the concurrent approach, the team would split into sub-teams and each sub-team would design a bridge. The team decided that the concurrent approach would lend itself to a better outcome based on previous years' feedback on a lack of consistent and equitable effort among the team members. Much of the design process is computer-oriented and only allows one user to access the file at a time. By reducing the number of people in a group working on the design, the team concluded that each member would be able to contribute more.

The teams were split into two sub-teams each consisting of two members (Fig. 2). The first sub-team designed the simple bridge model (Fig. 3) and the other sub-team designed the complex bridge model (Fig. 4). The fifth team member, due to his expertise as a law and legal studies major, served as the rules liaison for both groups during the design phase. Both sub-teams included a former systems engineer which would allow the sub-teams to think critically about the refining and optimization process throughout the design phase.

3. Decision Analysis

The team used the Decision Analysis model (Fig. 5), taught by the Department of Systems Engineering at West Point, to evaluate the two designs and produce a comparison (Richardson). One of the former systems engineering majors developed the model to account for the criteria judged at the competition. Since this was the first time a team has created two independent, fully functioning bridges during the design phase, it is also the first time a quantitative decision analysis has been used to compare and choose a winner between multiple design concepts.

The advantage of using a quantitative model is simple—it allows a user to appropriately weight variables which quantifies the items being compared. The numerical results are then analyzed to choose a winner. The categories used in the quantitative model and their corresponding weights were display (0.07), weight (0.29), deflection (0.44), number of members (0.05), and number of connections (0.15). The variables were derived from the categories of the competition. For example, since construction time (one of the criteria judged in the competition) cannot be easily measured prior to production, the number of parts and members used provides a reasonable estimation of the construction time. This allowed the members of the team to assign a numerical value to each aspect of the two designs to make the best decision and eliminate personal biases. The display category is a measure of the team's performance in the presentation and appearance of their bridge. Ultimately, this category was not assigned values for the two designs because it would be mere speculation to assess which design would be better presented by the team.

In applying the model to the two designs, the team concluded that the complex bridge design outperformed the

simple bridge design with regards to the performance criteria judged at the competition by a score of 296 to 255.

4. Moving Forward

Moving into the refinement and execution phase of the project, the team aims to further refine its model and practice construction of the bridge leading to the competition. The team plans to replicate the competition layout for construction according to the rules handbook to ensure practice is paralleled to the competition. Lastly, data resulting from the competition will be the ultimate factor in deciding whether multidisciplinary teams and their processes make a difference in team performance.

Acknowledgement

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References

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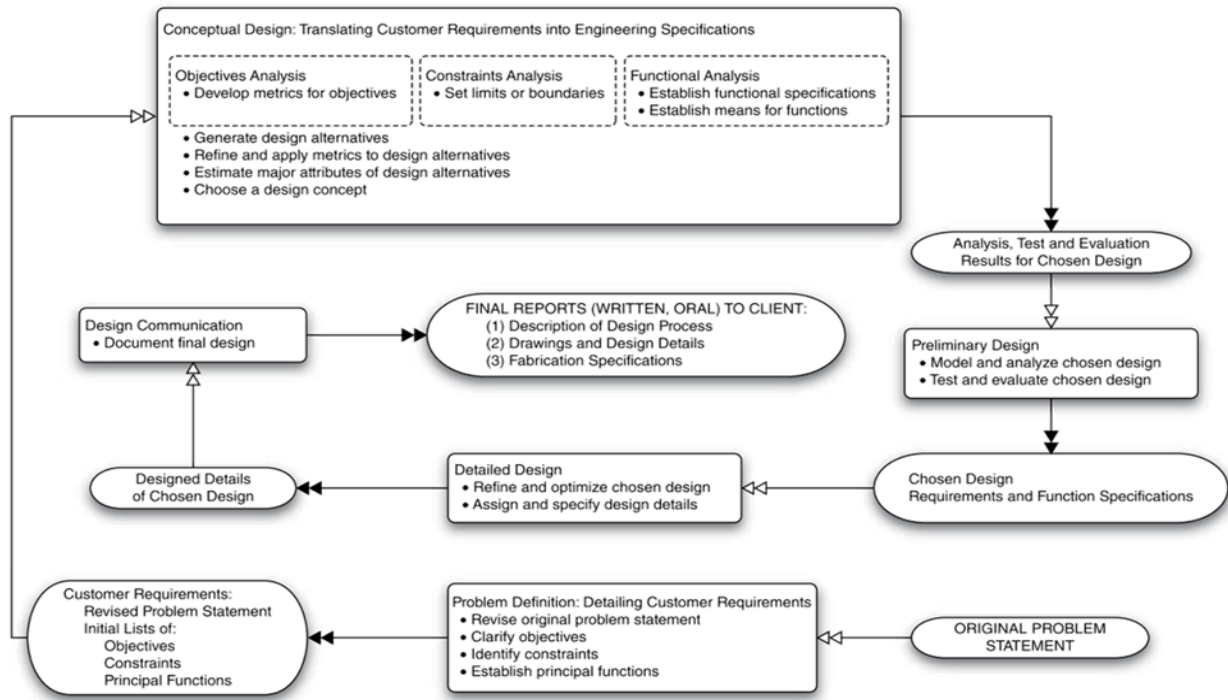


Figure 1: Design Model

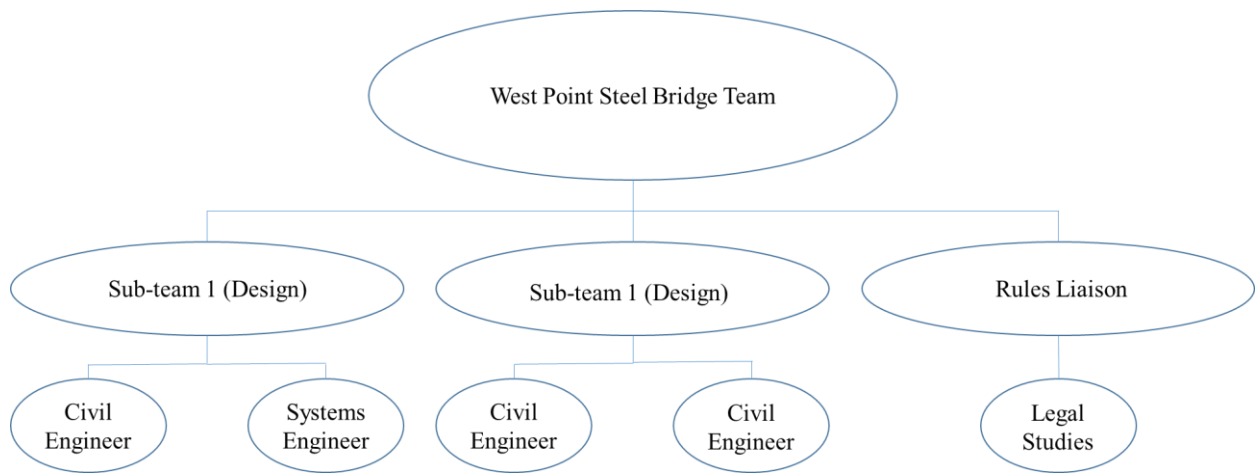


Figure 2: Team Structure

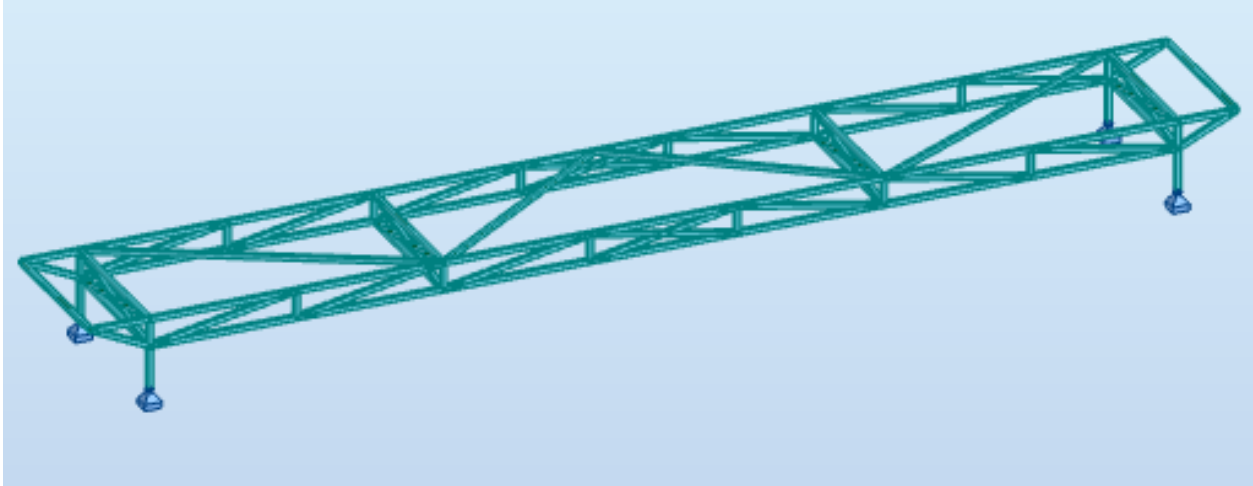


Figure 3: Simple Bridge Design

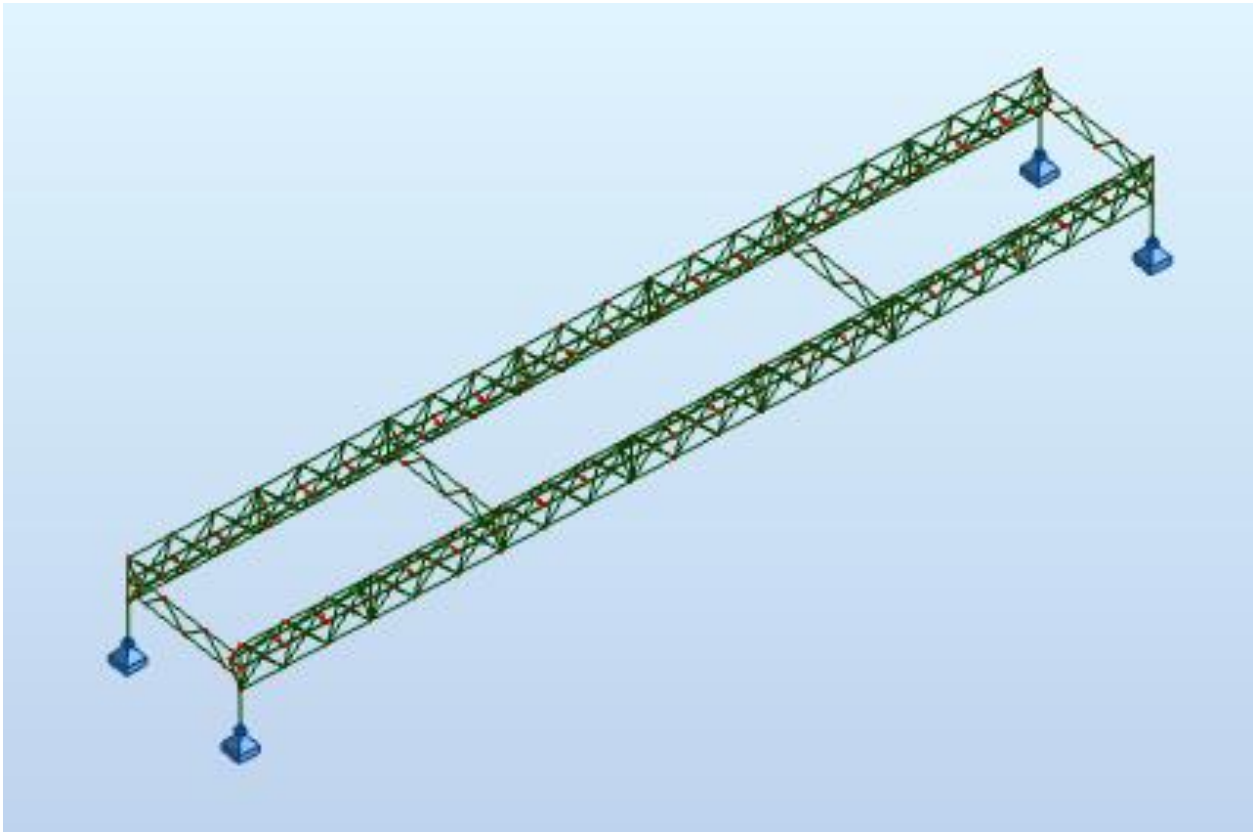


Figure 4: Complex Bridge Design

Category	Weight	Actual Values		Nominal Values	
		Simple	Complex	Simple	Complex
Display	0.07	0	0	0	0
Weight (lbs)	0.29	300	214	20	85
Deflection (in)	0.44	1.898	1.007	66	84
# Members	0.05	36	43	84	72
# Connections	0.15	56	84	85	55
			Total	255	296

Figure 5: Decision Analysis Model