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Improving Pedestrian Traffic Flow in Michie Stadium through Value Modeling and Simulation

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Author Note: Cadets Capasso, MacAfee, Marshall, McCusker, and Miller are seniors at the United States Military Academy and are participating in a yearlong capstone project in the Department of Systems Engineering. The team's advisor, Julia Lensing, is a Major in the U.S. Army and is currently an Assistant Professor in the Department of Systems Engineering. The team would like to thank Major Tiane Garner and Mr. Shane Bell from the Office of the Director of Intercollegiate Athletics (ODIA) for their dedication to and support of the capstone team.

Abstract: The Army West Point Patron Feedback Survey from the 2017 and 2018 football seasons indicate dissatisfaction with organization and flow of pedestrian traffic into entry points at Michie Stadium. This study uses value modeling and simulation to explore alternatives that would improve safety, ease of entry, fan satisfaction, and overall pedestrian flow into the stadium on game day. ProModel™ is used to model entry procedures and flow rates into the stadium and inform quantifiable metrics to evaluate alternatives. The result is a weighted scoring model identifying the alternative that maximizes patron and client satisfaction and safety, minimizes wait time at entry points, and maximizes utilization of stadium employees.

Keywords: College Football Stadium Operations and Safety, Value Modeling, Simulation, ProModel™

1. Introduction

Michie Stadium, home to the Army West Point Black Knights Football Team, was built in 1924 with an original seating capacity of 16,000. Since then, few updates have been made to the original structure of the stadium but stands have been added for additional seating capacity. For the 2018 Home Football Season, the stadium could hold approximately 38,000 fans (Blaik Field). End of season survey data indicates that Army West Point Football fans experience difficulty entering, exiting, and navigating Michie Stadium on gameday. Observational data shows various entry points, walkways, concourses, and high traffic areas are congested while others remain nearly empty. Though a renovation of the east side of the stadium is scheduled in the coming years, the Office of the Director of Intercollegiate Athletics (ODIA) identified the potential for low-cost, high-impact solutions involving traffic flow of fans that could positively impact the gameday experience in the near term.

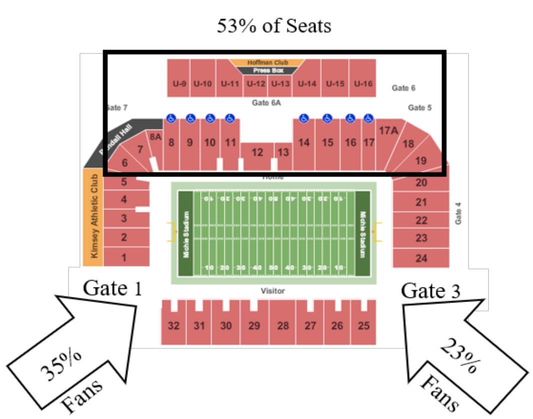

Figure 1. Michie Stadium Diagram

1.1 Problem Definition

ODIA's primary goals on gameday include ensuring the safety of patrons, creating a positive gameday experience, and ensuring assets are used effectively. Observation at home football games during the 2018 season combined with post-game survey data revealed inefficiencies in pedestrian entry procedures at stadium gates. These shortcomings are a result of uneven throughput at all gates, inefficiency of current security equipment and measures, and improper utilization of workers at the gates. As shown in Figure 1, the majority of patrons (58%) enter in gates 1 and 3 which are on the opposite side of the majority of the seating (53%). Figure 2 depicts an uneven distribution of fans entering the stadium across all gates. This causes congestion and longer wait times at gates 1 and 3 while gates 4 and 6 are underutilized and patrons experience much shorter wait times. Current security measures include the use of hand-held metal detectors and a system for checking bags. Upon arrival to the stadium, patrons enter a queue for stadium entry. The queue includes bag check, metal detector screen, and ticket scan. Tasked cadets conduct hand-held metal detection at a rate of approximately 15 seconds per patron which is significantly slower than other metal detection alternatives (Mr. Greg Overstreet, personal communication, February 23, 2019). Additionally, cadets are not trained on proper usage of hand-held metal detectors and therefore the results can be unreliable. Finally, at underutilized gates, cadets and contract employees are often standing idle while patrons are processed through each stage of the queue. The focus of this research is to explore solutions that improve entry procedures to align with ODIA goals on gameday.

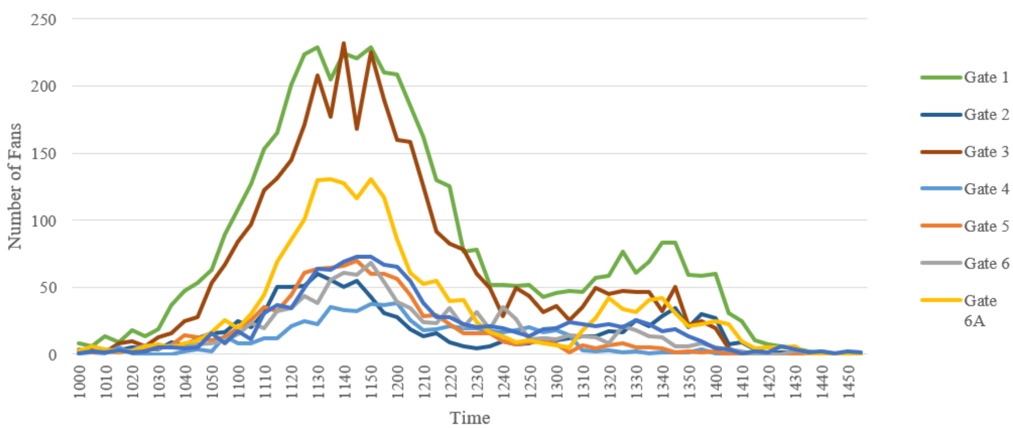

Figure 2. Fan Entry by Gate

1.2 Related Work

Previous research has shown that football is about much more than the game itself; from arrival to departure, every detail contributes to a memorable gameday experience (Duderstadt, 2003). At Mercedes-Benz Stadium in Atlanta, Georgia, host to the 2019 Super Bowl, Mr. Scott Jenkins, General Manager, places significant emphasis on reducing wait time throughout the stadium. There is an inverse relationship between the time a fan waits and their likelihood of returning to the stadium for future events. Reducing the wait time at any possible juncture plays a critical role in enhancing the gameday experience. Additionally, Mercedes-Benz Stadium utilizes walk-through metal detectors and can process 71,000 fans with an average wait time of less than 5 minutes (Mr. Scott Jenkins, personal communication, February 23, 2019). Walk-through metal detectors are also safer because they remove any chance of human error from hand-held wands when processing fans (Mr. Greg Overstreet, personal communication, February 23, 2019).

Research shows that a mixed-methods approach, using both quantitative and qualitative data, is the best way to identify both tangible and intangible problems (National Science Foundation, 2002). At Michie Stadium, it is important to capture what fans value through qualitative measures, while also collecting quantitative data that will support possible improvements to Michie Stadium and the gameday experience. Qualitative measures include surveys, interviews, and interactions with the research team. Quantitative measures include the number of fans that enter each gate and how long it takes fans to get through the gate. Both types of measures are crucial to understanding and solving the issues surrounding Michie Stadium entry.

2. Methodology

2.1 Systems Decision Process

The Systems Decision Process (SDP) is a four-phase decision making process that is used to thoroughly define a problem and formulate the best possible solution (Parnell, Driscoll, & Henderson, 2011). The four phases are Problem Definition, Solution Design, Decision Making, and Solution Implementation. This methodology places great emphasis on the client's values and priorities when evaluating solutions as identified in the Problem Definition Phase. The Solution Design phase focuses on developing feasible alternatives for evaluation. In the Decision Making Phase, value modeling and sensitivity analysis are used to make recommendations based on alternatives with high value and low cost. Simulation can be used in the Decision Making phase to test feasible alternatives and assess the value that each provides to the client. At the end of this process, the client can make informed decisions based on overall value and associated costs.

2.2 Functional Analysis and Value Modeling

The top-level required function is to admit patrons to Michie Stadium while simultaneously providing a positive gameday experience and utilizing resources effectively. The objective of each function and the measures for how each are evaluated are shown below in Figure 3. ODIA determined the weights (swing weights) associated with each of these measures based on their relative importance and range of output. Finally, the relative importance (global weight) was determined by dividing each swing weight by the sum of all swing weights.

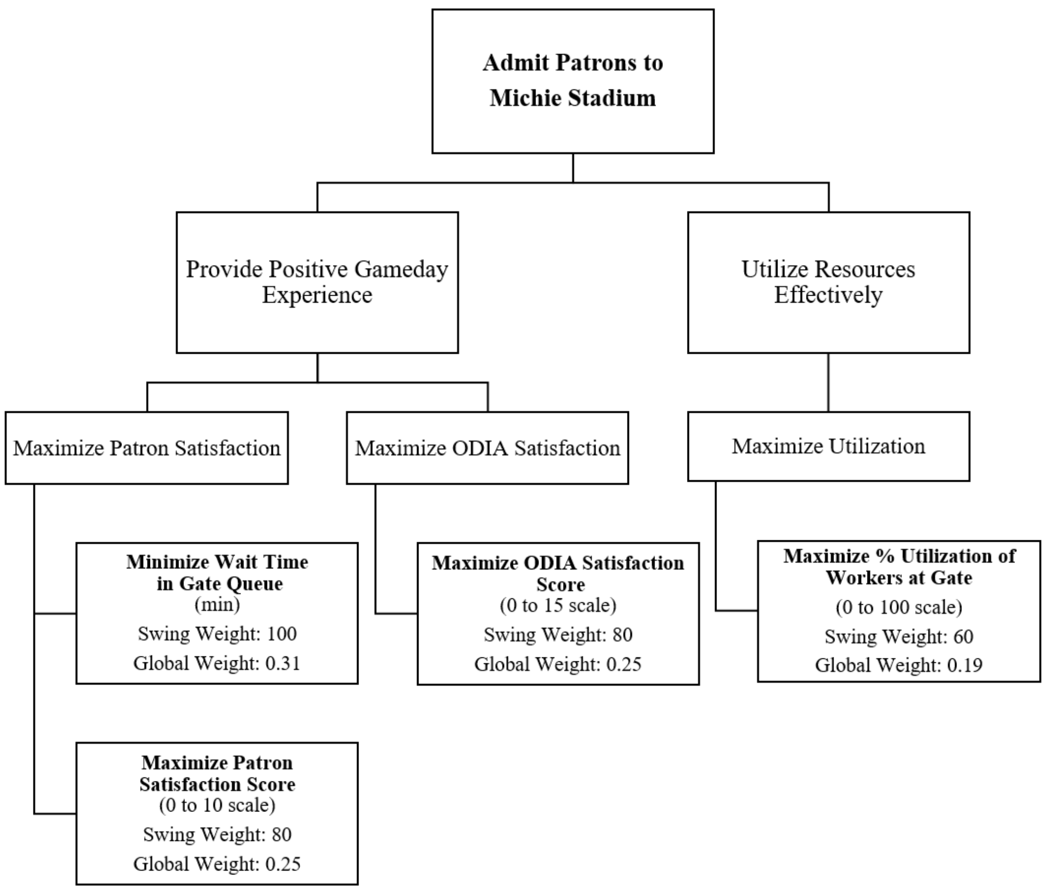

Figure 3. Functional Hierarchy

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2.3 Alternatives

Recommendations to improve Michie Stadium entry procedures were generated based on ODIA feedback, gameday observations, stadium structural limitations, and successful stadium best practices. Alternatives are listed under “Candidate Solutions” in Table 1 below. The first alternative is the baseline model, which represents how Michie Stadium currently operates. There are 32 workers across 7 gates, hand-held wand metal detectors are in use, and fans arrive at rates shown in Figure 2. Additional alternatives include implementing walk-through metal detectors in place of hand-held wands, varying the number of workers at each gate to maximize worker utilization, and hiring traffic directors that would encourage fans to enter gates based on the location of their seat. It is assumed that adding traffic directors would redistribute the number of people that choose to go through each gate. Each alternative was measured in a ProModel™ simulation which reflects gameday observations.

The inputs of the model are fan arrival rates and the number of fans that enter the gates. Fan arrivals are based on the average number of tickets scanned every 5 minutes for each home game during the 2017 season. In the model, once a fan enters the system they are placed in a queue to have their bag checked, go through a metal detector, and have their ticket scanned. The model assumes that fans will not leave a line once they enter it, nor will they switch lines after they enter one. The outputs of the model are average wait time and % utilization. Average wait time represents the time a fan waits in a queue in addition to stadium entry process time. % utilization is the average percent of time that all contract staff are not idle. Observed wait time and fan reports in surveys confirm simulation validity and ODIA verified the model by ensuring the number of metal detectors and workers in the model did not exceed the space and budget available.

Qualitative data was assessed using a survey of 350 gameday attendees and used to measure fan satisfaction based on the alternative changes from Table 1 on a scale of 0 to 15 relative to the baseline. The client provided the Staff Satisfaction Score based on their assessment of each alternative in a similar manner. Both Fan and Staff Satisfaction Scores reflect each respondent’s perception of ease of entry and safety at stadium entry points.

Table 1. Raw Data of Candidate Solutions

Candidate Solutions	**Utilization (%)**	**Fan Satisfaction Score (0 – 15)**	**Staff Satisfaction Score (0 - 15)**	**Average Wait Time (min)**	**Total Weighted Value Score (1-100)**	**Total Cost/ Game ($)**
Baseline	34.29	8.10	6.00	14.04	**40.10**	**$6,400**
Maximizing Utilization	36.17	10.65	8.00	14.25	**59.84**	**4,000**
Adding Metal Detectors	34.60	10.49	7.50	5.91	**51.58**	**11,900**
Adding Traffic Directors	27.38	9.39	7.50	13.23	**49.47**	**7,800**
Add Metal Detectors and Traffic Directors	29.44	9.94	7.50	5.94	**71.82**	**16,300**
Maximize Utilization and Add Traffic Directors	32.25	10.57	7.75	5.90	**49.18**	**5,400**
Add Metal Detectors and Maximize Utilization	43.90	10.02	7.75	14.67	**64.24**	**12,500**
Maximize Utilization, Add Traffic Directors, Add Metal Detectors	39.77	10.18	7.67	5.92	**63.43**	**13,900**
Ideal Solution	100	15	10	0	**100**	**-**

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The total value for each alternative is calculated using the equation below (Parnell, Driscoll, & Henderson, 2011). *v(x)* represents the total value of an alternative solution (shown in Figure 3), *x(i)* represents the scaled score (0 to 100) based on the raw data, and *w(i)* is the normalized swing weight. Each alternative's value score is compared to the overall cost per game to determine the best alternative.

$$v(x) = \sum_{i=1}^{n} w_i v_i (x_i) \quad (1)$$

Costs were calculated based on current labor contracts ($25 per employee per hour) and price estimates provided by the client ($500 per walk-through metal detector per game and zero cost for hand-held wands already owned). The cost represents the total cost of each alternative per football game (8-hour work day). The cost per game per employee was then multiplied by the total number of workers per game to determine the total labor cost per alternative. To determine the cost of metal detectors, the price of metal detectors per game was multiplied by the maximum number of lanes possible to fit in Michie Stadium. Summing the cost for the total number of metal detectors and cost for the workers resulted in the total cost per game.

3. Results and Conclusions

Using the total value score and cost of each alternative from Table 1, the below plot (Figure 4) depicts alternatives with the highest value relative to cost. It is clear that the current baseline model of Michie Stadium provides the lowest value according to the values of the client. Solutions that offer lower value at higher costs are considered dominated solutions and are therefore removed from further consideration. Solutions circled in red represent those feasible solutions that maximize value at various price points. Maximizing the utilization of workers at each gate provides the lowest value score of feasible alternatives but is also the least costly option. Arguably, this would be the easiest solution to implement and therefore is an attractive low-cost, high-impact option. Implementing metal detectors and maximizing the utilization of workers offers more value to the client but at almost triple the cost of only maximizing utilization of workers. Lastly, the alternative with the highest value but the highest associated cost is adding traffic directors and metal detectors. This alternative reduces the fan wait time by almost 10 minutes, increases fan satisfaction by almost 2 points, and increases staff satisfaction by 1.75 points. This alternative may also provide additional benefits not captured in the value model. For example, using traffic directors to encourage fans to enter the gate closest to their seat would help alleviate congestion inside the stadium. Additionally, using walk-through metal detectors is a safer and more reliable option. These combined benefits make this the best alternative for solving the congestion and traffic flow problem at Michie Stadium's entry points.

A sensitivity analysis, varying the swing weight of all value measures ± 10% from their original weight, shows that none of the value measures are sensitive to change. This validates the model and the recommended solutions.

Figure 4. Cost versus Value Plot for Alternatives

4. Recommendations for Future Work

This research sought to examine only one of many contributing factors to the overall gameday experience. Opportunities for future research exist in furthering the use of modeling and simulation to enhance understanding of the problem. Specifically, creating an agent-based model within the stadium that simulates human behaviors and movements about the concourse could help determine where congestion in Michie Stadium happens and ways to alleviate it. This model could also include concession stand queuing thereby creating a more comprehensive picture of overall gameday operations within the gates of Michie Stadium. Future work should also include the pricing of concessions which have shown to have a major impact on fan satisfaction (Coates and Humphreys, 2007). Research in this area could help ODIA to increase fan satisfaction and maintain West Point's reputation of having one of America's greatest gameday experiences.

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