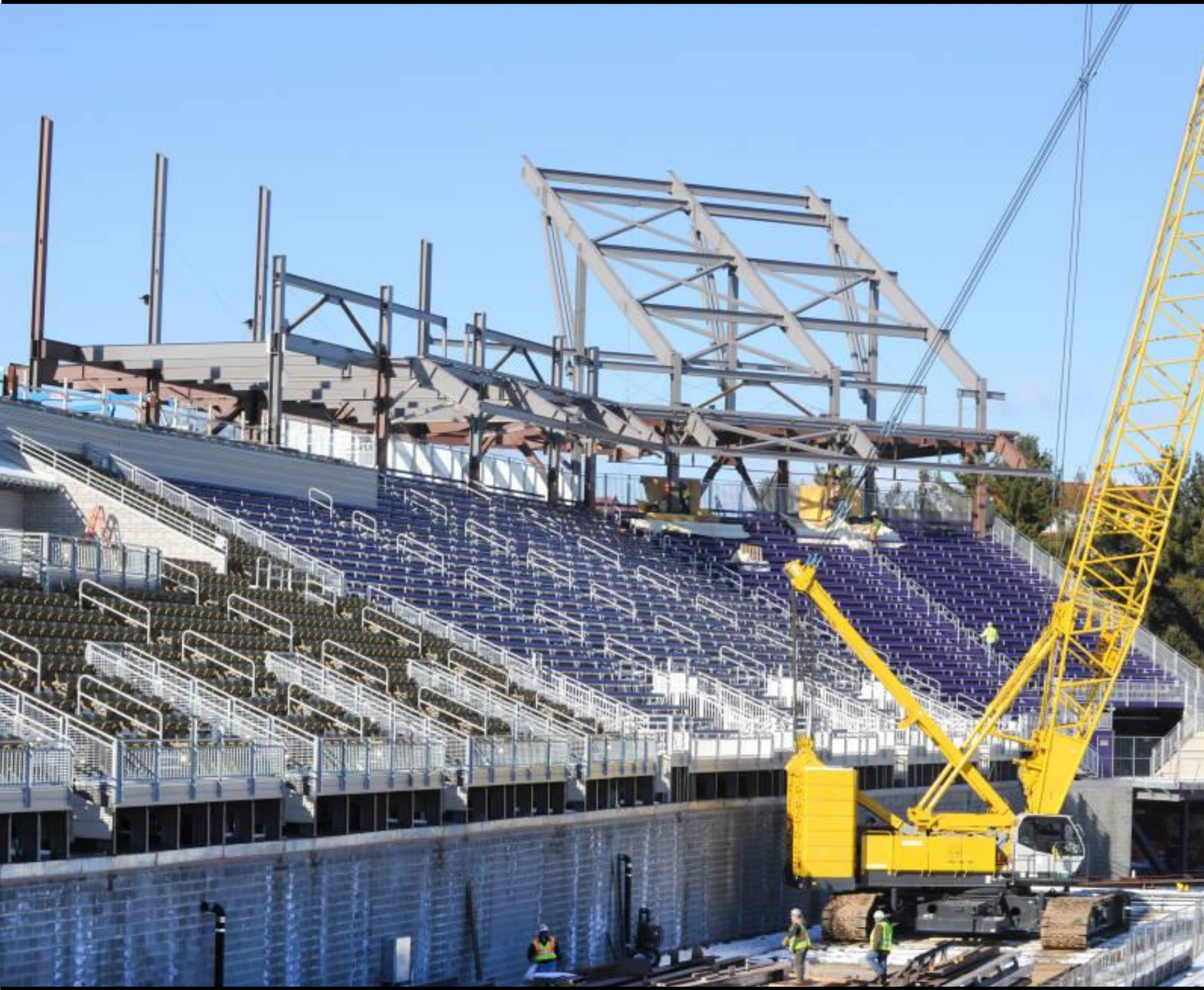
Football Stadium

Commercial Accelerated

Innovation Center for Construction Safety and Health,
Myers-Lawson School of Construction at Virginia Tech



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1. Case Study Method

The Project Case Study Method involves an in-depth examination of a single project, the case. It provides a systematic way of looking at events, collecting data, analyzing information, and reporting the results. Case Studies are one of the most effective tools you can use to promote best practices and cost-effective, experiential training. A recent search on Google.com for the term “case study” showed over 15 million hits. Of those hits, almost 750,000 hits included references to Java, which demonstrates a phenomenal uptake in the IT industry. Like its close cousin the White Paper, case studies appear to be growing in popularity every year.

1.1. NORA Goal 10

This Case Study was developed under a Cooperative Agreement with NIOSH in support of the National Occupational Research Agenda (NORA), Goal 10. Goal 10 is concerned with improving understanding of how construction industry factors relate to injury and illness outcomes; and increasing the sharing and use of industry-wide practices, policies, and partnerships that improve safety and health performance (NIOSH, 2013).

More specifically, the aim of NORA Goal 10.1 is to: Analyze how construction industry complexity and fragmentation can affect safety and health performance. Evaluate safety roles, responsibilities, interactions, and oversight among the multiple parties involved with complex construction projects. Address regular and accelerated construction project lifecycles. Identify obstacles and opportunities for improving system performance.

National Institute for Occupational Safety & Health. (2013, April 24). ”NORA Construction Sector Strategic Goals.” Retrieved from http://www.cdc.gov/niosh/programs/const/noragoals/Goal10.0/

1.2. Case Study Design

The research adopted a comparative case study approach (Yin, 1994). Data were collected from a total of 23 construction projects, 10 in Australia/New Zealand and 13 in the United States of America. For each project, features of work were purposefully identified by project participants in consultation with the research team. Features of work were selected as the unit of analysis because they presented a particular health and safety problem or challenge.

“Features of work were selected as the unit of analysis because they presented a particular health and safety problem or challenge.”

For each feature of work, comprehensive data was collected to capture decisions that were made in relation to the design of the feature of work, the process by which it was to be constructed and the way that health and safety hazards were to be addressed. Data were collected by conducting in-depth interviews with stakeholders involved in the planning, design and construction of the selected features of work. These interviews explored the timing and sequence of key decisions about each feature of work, and the influences that were at play as these decisions 'unfolded' in the project context. During the course of the research 288 interviews were conducted (185 in Australia and 103 in the USA). The average number of interviews per feature of work was 6.7.

Projects chosen for data collection represent four different construction sectors (residential, commercial, industrial, and heavy) as well as four different delivery methods (Design-Bid-Build, Design-Build, accelerated, and collaborative). This was done to help determine the role OSH plays in each type of construction project. The projects were then placed on a matrix. Figure 1 represents the 14 projects studied within the United States with the project featured in this case study highlighted in yellow. Figure 2 shows where American and Australian projects overlap on the matrix.

Figure 1: Matrix of American projects

	Residential	**Commercial**	Industrial	Heavy
Design-Bid-Build	Roanoke House	Dining Hall	Wastewater Tank	Highway Expansion
Design-Build	Blacksburg House	Psychiatric Hospital	Server Farm	New Highway
Accelerated	Blitz Build	**Football Stadium**	Chemical Plant	Bridge Project
Collaborative	Mountain House	New Hospital	Coal Plant*	Coal Plant*

**Note: The coal plant project is considered to be both an industrial and a heavy construction project.*

Figure 2: Overlap of American and Australian Projects

	Residential	Commercial	Industrial	Heavy
Design-Bid-Build	US	AUS+US	US	US
Design-Build	AUS+US	US	AUS+US	AUS+US
Accelerated	US	AUS+US	AUS+US	AUS+US
Collaborative	US	US	US	AUS+US

From: Wakefield, R., Lingard, H., Blismas, N., Pirzadeh, P., Kleiner, B., Mills, T., McCoy, A. & Saunders, L. (2014). 'Construction Hazard Prevention: The Need to Integrate Process Knowledge into Product Design'. Paper presented at the CIB W099 International Conference: Achieving Sustainable Construction Health and Safety, 2-3 June 2014 Lund, Sweden.

1.3. Case Study Analysis

Dependent variable

Data was collected about OSH hazards and the risk control solutions implemented within the case examples. This data was elicited during the interviews and supplemented with site-based observations and examination of project documentation (e.g. plans and drawings). For each feature of work, a score was generated reflecting the quality of implemented risk control solutions. This score was based on the hierarchy of control (HOC).

The Hierarchy of Control classifies ways of dealing with OSH hazards/risks according to the level of effectiveness of the control

The hierarchy of control (HOC) is a well-established framework in OSH (see, for example, Manuele, 2006). The HOC classifies ways of dealing with OSH hazards/risks according to the level of effectiveness of the control. At the top of the HOC is the elimination of a hazard/risk altogether. This is the most effective form of control because the physical removal of the hazard/risk from the work environment means that workers are not exposed to it. The second level of control is substitution. This involves replacing something that produces a hazard with something less hazardous. At the third level in the HOC are engineering controls, which isolate people from hazards. The top three levels of control (i.e, elimination, substitution and engineering) are technological because they act on changing the physical work environment. Beneath the technological controls, level four controls are administrative in nature, such as developing safe work procedures or implementing a job rotation scheme to limit exposure. At the bottom of the hierarchy at level five is personal protective equipment (PPE) – the lowest form of control. Although, much emphasized and visible on a worksite, at best, PPE should be seen as a "last resort," see, for example Lombardi et al.'s analysis of barriers to the use of eye protection (Lombardi et al. 2009). The bottom two levels in the HOC represent behavioral controls that they seek to change the way people work (for a summary of the limitations of these controls see Hopkins, 2006).

Each level of the HOC was given a rating ranging from one (personal protective equipment) to five (elimination). The risk controls implemented for hazards/risks presented by each feature of work were assigned a score on this five point scale. In the event that no risk controls were implemented, a value of zero was assigned.

Independent variable

Social network analysis (SNA) was used to map the social relations between participants involved in making design decisions about each feature of work. SNA is an analytical tool to study the exchange of resources between participants in a social network. Using social network analysis, patterns of social relations can be represented in the form of visual models (known as sociograms) and described in terms of quantifiable indicators of network attributes. In a sociogram, participants are represented as nodes. To varying extents, these nodes are connected by links which represent the relationships between participants in the network.

SNA has been recommended as a useful method for understanding and quantifying the roles and relationships between construction project participants (Pryke, 2004; Chinowsky et al. 2008). The technique has been used to analyse knowledge flows between professional contributors to project decision-making (see, for example, Ruan et al. 2012; Zhang et al. 2013). Network characteristics have also been used to explain failures in team-based design tasks (Chinowsky et al. 2008) and identify barriers to collaboration that arise as a result of functional or geographic segregation in construction organizations (Chinowsky et al. 2010). More recently, Alsamadani et al. (2013) used SNA to investigate the relationship between safety communication patterns and OSH performance in construction work crews.

In order to gauge the construction contractor's prominence in a project social network, the contractor's degree centrality was calculated. Degree centrality refers to the extent to which one participant is connected to other participants in a network. Thus, degree centrality is the ratio of the number of relationships the actor has relative to the maximum possible number of relationships that the network participant could have. If a network participant possesses high degree centrality then they are highly involved in communication within the network relative to others. Pryke (2005) argues that degree centrality is a useful indicator of power and influence within a network.

Degree centrality can be measured by combining the number of lines of communication into and out of a node in the network (see, for example, Alsamadani et al., 2013). This presents an aggregate value representing the participant's communication activity. However, the independent variable used in this research was calculated using only the construction contractors' outgoing communication. This was a deliberate choice because the research aim was to investigate whether OSH risk control is of a higher quality when project decisions are made with due consideration of construction process knowledge. Thus, the flow of communication from the construction contractor to other network members was deemed to be of greater relevance that the volume of information they received.

From: Wakefield, R., Lingard, H., Blismas, N., Pirzadeh, P., Kleiner, B., Mills, T., McCoy, A. & Saunders, L. (2014). 'Construction Hazard Prevention: The Need to Integrate Process Knowledge into Product Design'. Paper presented at the CIB W099 International Conference: Achieving Sustainable Construction Health and Safety, 2-3 June 2014 Lund, Sweden.

1.4. Benchmarking and Best Practices

Benchmarking is a powerful management technique that can be used to improve an organization's performance by searching for a partner organization that is the best at a given process and constantly adapting or adopting the partner's practices to increase performance (Kleiner, 1994). The process to be benchmarked is usually determined by analyzing performance figures and other data. A process that has relatively low performance figures and could be improved is often chosen to be benchmarked. Demand for benchmarking comes from several sources, such as increasing enforcement activity, regulations, investor and liability concerns, customer perceptions, and competition with other organizations. The results of effective benchmarking include increased productivity, efficiency, employee morale, and a competitive advantage.

The benchmarking process can be divided into five stages: Planning, analysis, integration, action, and maturity. During the planning stage, the organization identifies the process that needs to be benchmarked. This selection is usually done to fulfill a predetermined need, such as boosting performance figures in an area that needs improvement. Measurable performance variables are also identified. Benchmarking partners are selected based on their best-in-class performance in the targeted process. The partner does not necessarily have to be in the same industry. The organization concludes the planning stage by determining the data collection method and collecting the data. It is important for the organization to be able to distinguish between ethical and unethical means of data collections, especially if it involves handling sensitive information from the partner company.

During analysis, the organization determines the current performance gap for the process that will be benchmarked. The team then predicts future performance levels.

The integration stage involves the organization communicating their benchmark findings. Communication is crucial during this phase of benchmarking, especially when seeking approval from those with more organizational authority. Operational goals and plans are established from the benchmarking findings.

The action stage is characterized by implementing practices, monitoring progress and results, comparing results to stakeholder needs, and adjusting the benchmark goals as necessary. Since benchmarking is a continuous process, the last step will certainly be repeated as industry standards and the needs of stakeholders change over time.

A benchmarking process reaches the maturity stage after the best practices are fully implemented into the targeted process. While benchmarking begins with management, the employees involved in the process are the ones who ultimately integrate the new process.

Kleiner, B. M. (1994). Environmental benchmarking for performance excellence, Federal Facilities Environmental Journal, 5(1), 53-63.

1.5. Learning Objectives

- *Understand sociotechnical systems complexities of a construction work system*
- *Understand different sectors, delivery systems, and cultures*
- *Understand project and industry supply chain and work system complexities*

2. Football Stadium Expansion

2.1. Overview

The project involved in this case study was the expansion of a university football stadium. The existing stadium was to be upgraded from the then-current seating capacity of 15,000 for both football games and university functions such as graduation. The stadium had not been upgraded in over 25 years and the university had been adding temporary seating to accommodate guests during homecoming and family weekend football games. The master plan for stadium expansion was to increase seating capacity to 35,000. Part of the expansion was to have a new press box and luxury seating. The sales of the luxury suites for future football games would partially fund the project.

Behind the east stands was an aquatic center that precluded expanding on that side without removing the aquatic center. While the university's master plan had provisions for a new aquatic center, it was not planned to be built for another ten years. Thus a decision was made to expand the west stands first.

There was a parking deck very close behind the west stands. This precluded building a single deck structure out into that area. A double deck structure was chosen to accommodate the parking structure behind it and also because it would offer spectators a better view of the field.

Relocating the football team for one season was not an option for the university, so it was crucial to be able to schedule around the football seasons. The contractor who ultimately won the bid proposed an accelerated construction schedule that would take place in two phases with a football season in between. For the first phase, the existing concrete stands on the west side were demolished and new steel stands were constructed in time for the next football season.

2.2. Project Profile

2.2.1 Case Background

The football stadium is located on the campus of a large public university in northern Virginia. The university has a strong athletic program with the last few seasons of football bringing over 20,000 fans to the stadium, which is well over the stadium's capacity of 15,000. Other special events such as homecoming, family weekend games, and graduation are held at the stadium and extra temporary seating is typically required. The university determined to expand the stadium as part of the overall campus master plan.

The original stadium was constructed in 1975 with seating capacity for 5,200 fans (JMU, n.d.). The new stadium served as home for the football, track and field, lacrosse, and field hockey programs, as well has having indoor racquetball courts, classrooms, space for the ROTC program and offices for varsity athletic teams and media relations. The stadium received its first expansion in 1981 when a second set of stands were built, increasing the overall capacity of the stadium to 12,500. The stadium received a new scoreboard with video replay capability in 2004.

The $62 million stadium expansion project began in December 2009 with the removal of the old concrete bleachers on the west side of the stadium and construction of new double-deck steel stands with a new press box, hospitality suites, club-level seating, and additional stands enclosing the north end of the field. The new stands would allow the stadium to accommodate 24,877 fans. This project was funded through ticket sales (including pre-orders) and a state bond package that voters passed in 2002. Construction on the west stands was completed in August 2011. The opening game for that season had a sellout crowd of 25,102 fans in attendance (ESPN, 2011).

ESPN. (2011, September 10). Central Connecticut State versus James Madison. Retrieved from http://scores.espn.go.com/ncf/boxscore?gameId=312530256 on 1 August 2014.

JMU. (n.d.). The Hillside Gang. Retrieved from http://www.jmu.edu/centennialcelebration/hillside.shtml on 1 August 2014.

2.2.2 Case Narrative

Upper Deck Structural Steel Erection

The master plan for the stadium included a new press box and luxury suites whose sale could be used to partially finance the construction project. The amount of space between the field and garage was the primary factor in how the structures above the lower deck were designed and supported. Option #1: With enough space the structures could be supported from the ground, but the small amount of space did not allow for this type of design. Option #2 proposed supports from the top of the garage but due to cost concerns, structural capacity of the garage, and time constraints, was unviable. Option #3 was the final option and the option selected, in which a cantilever design extending from the existing structure supports the upper deck and the suite and press box above it. A portion of the adjacent garage was closed during construction due to its proximity to overhead materials.

The old stadium was an aesthetically pleasing concrete structure. The university advocated for retaining this type of design, but the weight of a concrete structure upper deck would have necessitated long cantilevers and high costs. The approved design specified aluminum bleachers supported by a steel structure along with cantilevers to support the upper deck, press box, and luxury suites.

The original plan of action was to complete the construction in 3 phases. The CM was added to the team and was able to shorten the timeframe with an accelerated schedule and reduce the project to 2 phases, with one football season in between. Phase #1 was demolition of existing stands and completing the new lower deck. Phase #2 was construction of the upper deck, press box, and luxury suites.

Crane Placement & Safe Hoisting Issues

The main safety challenge influencing the proximity of the crane to the work was accessing the upper deck structure by the crane. A crane atop the garage was considered, but the crane's weight exceeded the structural capacity of the garage. A creek behind the garage also was too close to the garage to allow a crane to reach over the garage. It was decided that steel hoisting and erection was to be done by reaching the boom and load across the lower deck from inside the stadium. A track between the field and lower deck was converted to a temporary crane pad using timber cribbing. Erection started in the back corner of the site and worked its way outward towards the site exit. Using this sequencing, obstructions to the crane were minimal and it was able to place all structural members within allowable reaches.

The steel was all set using single shifts that were longer than the normal 8 hour shift. This eliminated any hand-offs between shifts, and steel was also not set at night or under extreme weather conditions to ensure safety. The CM said that the job logistics were planned in detail due to the small time window relative to the work effort, and a priority given allowing adequate shift time to perform work safely.

Administrative safety controls were used exclusively when hoisting. At all times during crane operation, the erection crews had spotters both on the ground and in the air (in the work areas) that were in direct communication with each other via walkie-talkie. Visual hand signals were also used when visibly possible. When structural steel was being set, all areas directly below the hoisting path were cordoned off as a safety measure, as was access around the crane perimeter. All workers were prohibited entry into these areas unless authorized. Caution tape, barricades, and safety fences with safety monitors were used to keep these areas off limits.

Fall Hazards

Access points for workers to tie off were designed into the steel so that workers could attach to them while working on the structure. Rat lines were installed after the steel was placed, and used by the erection crew while setting the structural steel. These were not used as the main fall protection systems once the steel & decking was set. The steel subcontractor installed steel post and cable guardrail systems at all exposed perimeter conditions which were maintained within OSHA-compliance throughout the course of the job until the fall hazard no longer existed. Lifts were used to install sections of the facade where required.

Façade Panel Placement

There was not a lot of room for a large lift, but smaller lifts were used on the outside where possible. Prior to the elevator being used for material transport up to Pressbox level, they had a motorized material hoist in place that ran up to the Upper Concourse level. The only reason they could not extend the material hoist up to the Pressbox was due to height limitations on that type system, and due to the design of the Pressbox itself (overhanging the existing Parking Garage). No other types of material hoist systems were possible in the environment for this application. The majority of Pressbox interior materials were scheduled such that the elevator could be used to transport them up, but for the time period prior to that all materials had to be walked up the stairs between the Upper Concourse level and Pressbox level (5 stories). Lifts were also used to install the smaller pieces of the facade where required. These were fairly small, light-weight materials that were primarily aesthetic and not structural.

Phase #1 required demolition of the existing stands, excavation, and building the steel structure for the lower deck and concrete in the off season. Phase #2 was the building of the upper deck, suites, and press box after that season and before the next. Phase #2 required a compressed schedule over the time it would normally take to build a structure of this size, and the construction manager developed a detailed schedule that incorporated multiple shifts.

Foundation Design & Construction

One factor that impacted foundation design and worker safety during construction was the decision to not move any of the existing utility lines in proximity of the work. This involved a conduit bank of high voltage electric lines and fiber-optic cable. Poorly documented as-builts were available for foundation design. The owner's decision to not relocate these utilities was based on cost of installing new lines and to avoid service interruptions.

During the previous garage construction underground rock in the area was steep and erectic and required 4-5 ft drilled piers used for the garage. This construction required deeper than expected piers and exceeded cost estimates. This previous knowledge was used by the project design team propose and use micropiles 8-9 inches in diameter, minimizing the depth and cost.

Earthwork Shoring & Retention System

The soil retention system used during construction was a major design issue among the construction manager and excavation sub. The structural engineer specified that the retention system must protect the adjacent garage's existing foundation to ensure structural integrity of the garage foundation. The retention system was design-build. The selected system was a temporary retention system using driven steel plates that could be removed after the foundation system was completed. The CM indicated that leaving the retention system in the ground could impact future expansion, and it was also up against a high voltage electric conduit bank that it would have to support if it was left in the ground.

Shift Work

Multiple shifts for the micropile system installation between seasons involved minor excavation and soil removal. A one hour 'overlap' in shifts allowing the foreman and field crews to transition into the work was the only shift transition process used. The second shift was a night shift with no special safety procedures other than lighting differing from what was required during daytime work. The lighting levels met OSHA-required foot candle levels around the entire work area.

Hand Work vs. Machine Excavation

The issue of existing subsurface utilities obstructing the foundation's designed location impacted excavation means and methods. To avoid damage to existing utility lines required careful excavation, resulting in significant hand digging operations. Also, the structural engineer was out of state, so location of lines was coordinated with a surveyor file to use for foundation relocation, utility line conflicts, and crossovers. Timing was critical due to the compressed schedule.

2.2.3 Stakeholders

Internal supply for this project came from a variety of sources. The CM was part of the Design-Build team along with the lead architect. As part of the design process, it was the CM's job to ensure constructability and work on cost and schedule estimation of design. The Lead Architect for this project coordinated the design process, translated the needs of the client into that design, and communicated with the client as the design progressed and took revisions back to the team. The Sports Stadium Design Architect was brought onto the project because of their expertise in designing sporting venues. On the project, the Stadium Design Architect was responsible for site lines and the overall look of the stadium, which ultimately drove the slope of the upper deck and the cantilever design.

The Structural Engineer was responsible, along with the Civil & Environmental Engineer, for designing the foundation and structure of the stadium and the upper deck. The Structural Engineer also performed an analysis on the feasibility of working or building off of the adjacent parking garage and installing a foundation against that garage. In addition to that, the Structural Engineer resolved issues and changed design when required during construction after the existing foundation plan had issues with utilities.

Several trade contractors were brought onto the project. The Site Prep Subcontractor performed the excavation work and the Foundation Subcontractor installed the foundation system and recommended changing to a shallower foundation. The Steel Supplier and Erector delivered and set the steel using cranes as well as working with the CM to identify lift requirements and process. The Bleacher Supplier worked with the design team to develop the structural requirements of the system. After both decks were built, the Bleacher Supplier installed the bleachers. The Utility Locator worked with the Site Prep and Foundation Subs to locate existing utilities.

The University's Capital Projects Group was the client for this project, and was responsible for approving the construction project and determining the overall budget. Other forms of internal demand came from the client's tenant: the Athletic Department. The Athletic Department determined the need for the stadium expansion and managed the facility after it was completed. They also drove the decision to keep the stadium open for a season rather than relocating the entire team. Athletic Department Donors and Fans/Ticket Buyers were the client's customers and financiers of the project. Donation and ticket orders were used to determine the size the stadium expansion needed to be. The stadium was designed with the fan experience as the utmost priority.

Students and faculty were local residents who used the parking garage and were pedestrians near the construction site. The Local Utility provided as-builts for the existing utilities so that the foundation could be designed around them. In addition, the Utility also worked with the CM to upgrade utilities to the facility as required.

2.2.4 Project Objective

The objective of this project was to expand a football stadium to increase seating capacity. This work had to be done in an environment where pedestrian and car traffic was prevalent and in an accelerated manner to avoid interfering with the football schedule.

2.2.5 Sector x Delivery System

This project is an example of accelerated commercial construction.

2.2.6 Features of Work

Features of work for this project include demolition of the old concrete stands, installation of the foundation system, multiple shifts, structural steel erection, façade construction, and interior construction.

3. Problem

3.1. Context

The decision to expand the stadium was influenced by high attendance for football games and usage of the facility for events such as graduation and parent's weekend. The stadium had seating capacity for 12,500 people, and temporary seating had to be used if attendance surpassed the facility's capacity. The university decided to expand the west stands first since the aquatic center behind the east stands would need to be demolished before expansion of the stands. There was a parking structure located behind the west stands, which influenced the decision to make the stands as two stacked decks.

Another issue the project team faced was working with the football schedule. The amount of time the construction would take meant displacing the football team for one season, which was not an option for the athletics department.

3.2. Objectives

The contractor who won the bid addressed the scheduling issue with the football team by splitting the construction into two phases. The first phase would start immediately after the end of a football season with the demolition of the old concrete stands and the construction of the lower deck before the start of the next season. During that football season, the lower deck would be available for fan seating. After the end of that season, the second phase of construction would begin. The second phase included the construction of the upper deck, press box, and luxury suite seating. The second phase would be completed before the start of the next football season.

The presence of the parking structure behind the west stands led to the decision to use a cantilever structure for the new stands. Having two separate decks also had the benefit of offering fans a better view of the field. A micropile foundation for the stands was used in order to maintain the structural integrity of the garage's foundation. The presence of underground utilities was addressed by pot-holing to determine the exact positions of the utilities.

4. Results

4.1. Safety-Critical Decision Making

A construction project consists of multiple components that all have different decision-making processes. For each project, different decisions from the earliest planning stages through construction all have an impact on occupational safety and health (OSH) based on how the hazards are controlled.

To address demands for increased seating capacity for football games, the university had to decide to either expand the old stadium or build a new one. The decision to expand was influenced by the facility's current seating capacity, ticket revenues, and football recruitment. The expansion project was managed by the university administration and athletic departments. To meet targeted seating capacity, the expansion plan included upgrading both the east and west stands. The west stands were to be expanded first because of cost and an existing aquatic center located directly behind the east stands.

Decisions, Decisions: Quick View

Thom's table here

The design for the new west stands was influenced predominately by the available space. A parking deck located behind the west stands prohibited building a single deck structure. Demolition of the aging concrete stands and construction of new steel lower and upper stadium decks was the chosen configuration for the conceptual drawings. Using these drawings, structural engineers came up with load calculations to determine the support system needed for both decks. With the limited space between the rear of the stadium and the parking deck, cantilevers were chosen to support the decks. Building on top of the garage was considered, but load calculations for the garage showed that the structure could not support the extra load. The university preferred to use concrete for the new stands, but the extra costs and structural loads made this option unfeasible, so steel was used instead. After creation of the design development drawings, the university worked to determine a construction schedule that would work with the football schedule. The construction was originally divided into three phases, but the CM who won the bid proposed a plan to construct the new stand in two phases without interfering with the football schedule.

In order to erect the steel structure for the new stands, the project team had to decide where to place the crane. The site around the stands restricted crane placement to either across the creek, behind the garage, or on the track inside the stadium. Building a temporary crane pad on the track was chosen because of cost and to allow the parking deck to remain open during the erection of the structure. The scope of the project also included installing the deck's foundation near subterranean utilities. The university owned the utilities and did not want to have the service interruptions that occur when relocating utilities. The decision was made to perform structural work around the existing utilities. The particular type of foundation used was micropile. When the nearby parking deck was constructed years prior, the soil was found to be rocky and longer piers were required. This knowledge influenced the decision to use micropiles for the stadium. A temporary retention system of driven steel plates was used when excavating near the utilities. The small size of the site eliminated the possibility of benching the excavation and placing a permanent retention system would limit future expansion and require supporting the underground electrical conduit. A temporary system was the most cost-effective compromise.

Construction of the steel structure spanned two phases with a football season in between. For fall protection, instead of relying on each sub to provide their own fall protection, the steel sub set a steel post and guardrail system. This only required minimal re-work of the structure and was safer overall. The steel was set in single, ten hour shifts to eliminate handoffs, increase safety, and benefit the schedule. This was a method that the CM had experience using. Lack of space near the structure did not permit material lifts to hoist up façade panels and furnishings. Before completion of the elevator, panels were lifted part of the way using smaller lifts and carried the rest of the way by hand up the stairs.

Construction of the foundation was able to proceed during the football season with minimal disruption. Bank and lay-back was used for excavating since there was not enough room for a clam bucket. This was also due to costs and meeting OSHA regulations. There were no multiple shifts for the main excavation however the construction schedule for the micropiles was a hybrid of 1 and 2 shifts, with an hour overlap in between. A surveyor and structural engineer were on-call and JSA's and site safety plans were developed. Existing utilities were marked by the utility marker. To prevent dig-ins, there was a lot of hand digging. Information about the utilities was updated and sent to the structural engineer, who was out of state, to see if the design would need to be altered around the utilities.

4.2. Hierarchy of Controls

Elimination is the most effective method of hazard control. An example of elimination in this project was benching the sides of the excavation area adjacent to the underground utilities to prevent instances where the sides of the excavated area could collapse on a worker.

If elimination is not a possibility to solve a safety problem, the next desirable alternative is substitution, which could mean substituting in a safer material or a safer process. Using a manlift instead of scaffolding to install the exterior panels reduced the risk of falls for workers.

Engineering control is the third most effective form of hazard control. If the hazard cannot feasibly be eliminated or substituted, an engineering control reduces worker exposure to the hazard. During the lifting and placing of the steel beams, tag lines were used with the crane in order to control the payload while it was being hoisted up. A temporary guardrail system helped reduce the risk of falls to lower levels for those working at height fastening the deck to the structure. Bracing the adjacent garage's foundation helped protect workers installing the deck's foundation from being struck, caught in, or crushed in a collapsing structure, equipment, or material.

Administrative controls such as worker training, lighting for nighttime work, and communication were implemented by the constructer.

The least effective form of hazard protection is Personal Protective Equipment (PPE), which was a common response for many tasks throughout the project where the above mentioned controls would not have been possible or economically feasible. Aside from standard-issue jobsite PPE such as hardhats, gloves, and boots, the two most common forms of PPE used in the project was a fall arrest system for workers assembling the steel structure and exterior panels and dust masks for demolition crews removing the old concrete stands.

4.3. Social Network Analysis

4.4. Project Performance

The stadium expansion project was budgeted at $62 million (JMU Sports, n.d.). The funds for this project came from student fees, ticket sales, private donations, and auxiliary funds (O'Connor, 2011) Construction for the first phase of the project began one week after the conclusion of the 2009 football season. The demolition of the old concrete west stands and construction of the lower level of the two-tiered structure was completed for the 2010 football season. During this football season, fans were able to use many of the new amenities included with the new lower-tier, such as a gift shop, upgraded restrooms, and concession stands. Having the lower tier open for the 2010 season did not adversely affect the stadium's overall seating capacity for that season.

Phase two of construction started soon after the final game of the 2010 season on November 13th. The upper tier of the new west stands was built along with a new pressbox, 1,000 club level seats, and 16 suites. Permanent stands on the north endzone were also built during this time. The inaugural game for the new stadium was held on September 10, 2011.

JMU Sports. (n.d.). JMU Facilities – Football. Accessed 18 July 2014. Retrieved from http://jmusports.com/roster.aspx?rp_id=5863&path

O'Connor, Jack. (2011, October 18). Expanded Bridgeforth Stadium a hit for JMU. *Richmond Times-Dispatch*. Retrieved from http://www.timesdispatch.com/archive/expanded-bridgeforth-stadium-a-hit-for-jmu/article_e1a68262-dfa2-55ab-959d-361a9bf9d862.html

5. Case Evaluation

5.1. Results

The construction had minimal impact on the football program. The two separate phases allowed for the football team to play on their home field for the 2010 season instead of relocating to another field. The lower tier of the new stands was also completed by the beginning of the 2010 season, resulting in minimal losses to the stadium's capacity.

The new stadium's inaugural game on September 10, 2011 was attended by over 25,100 fans. The average attendance for the first four football games of the 2011 season was 24,978 (O'Connor, 2011).

Public reception of the stadium has been favorable. Upon visiting the new stadium, the athletic director of another university was asked for his thoughts on the new facility (Molinaro, 2012). The athletic director replied, "Can I have one of these?"

Molinaro, Bob. (2012, November 18). ODU AD on JMU's revamped stadium: 'Can I have one of these?' *The Virginian-Pilot.* Retrieved from: http://hamptonroads.com/2012/11/odu-ad-jmus-revamped-stadium-can-i-have-one-these

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5.2. Lessons Learned

Describe the positive aspects of project implementation, the problems encountered and how (if) were they addressed. Describe how other parties could use the solution. Describe best practices that can be adopted or adapted.

(15 to 25 lines)

6. References

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