Roanoke House

Residential Design-Bid-Build

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Myers-Lawson School of Construction at Virginia Tech

CHANGE PICTURE

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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 analyze 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. Roanoke House

2.1. Overview

The project involved in this case study was the construction of a house in Roanoke, Virginia.

2.2. Project Profile

2.2.1 Case Background

The homeowner contracted to the builder to construct a three story, four bedroom house in Roanoke, Virginia. The house is a typical wood frame structure built on a foundation with a basement.

2.2.2 Case Narrative

Site Excavation

When excavating the deep and wide area for the foundation and basement of the house, there was a cave-in hazard for workers. This was eliminated by the constructor's decision to have the sides of the excavation benched.

Substructure

The substructure for the house consisted of a foundation and cast-in-place concrete walls. By overexcavating, the constructor allowed more room for workers to maneuver around the foundation walls and eliminated the risk of cave-ins.

Floor Construction

Engineered floor trusses were used for the flooring system in the house. Workers on the floor had a risk of falling to a lower level. The constructor responded to this by mandating safety training as an administrative control.

Exterior Wall Framing

The exterior frame was built flat on the interior deck. This eliminated workers being caught or crushed by falling materials. Workers cutting the 2x4's for the frame wore appropriate PPE. The frame was moved and lifted into place manually. No fall protection was used. Worker safety training was an administrative control for workers installing the frame walls.

Roof Construction

The roof trusses were mostly pre-fabricated on the ground and lifted into place by a small crane. Having the roof structure assembled this way instead of being built in place (stick building) eliminated most of the worker fall hazards since less lifts were required and not as much work was needed to be done from roof height.

2.2.3 Stakeholders

Internal supply for this project came from several sources. The designer developed the house design and produced the drawings for the project. The constructor was responsible for using the designer's plans to manage construction of the house, working with the designer and owner to address any constructability issues, and making necessary re-design choices such as changing the roof plans to allow for pre-fabricated trusses. Several trade contractors were also brought in for this project. The excavation sub performed excavation on the site based on the design. This sub also had prior experience working with the CM, so they were familiar with the constructor's processes. The pre-cast concrete sub constructed the pre-cast concrete basement based on the plans. The framing employees built the frame of the house while the roofing sub installed the roof system. Both of these trade contractors had their own safety procedures.

Internal demand came solely from the homeowner. The owner gave input to the builder on design features of the house based on the plans chosen.

External public stakeholders included the local code inspector who went through the finished house to ensure that it met all applicable building codes and the local public utility who tied-in the utilities to the finished house and that the house was properly configured for the tie-in. The local neighborhood association was an external private stakeholder that had rules which impacted the design of the house, such as the percentage of brick used on the outside of the house.

2.2.4 Project Objective

The objective of this project was to build a new house in Roanoke, Virginia

2.2.5 Sector x Delivery System

This project is an example of Design-Bid-Build (DBB) residential construction.

2.2.6 Features of Work

Those features are the site excavation, substructure, floor construction, exterior wall framing, and roof construction.

3. Problem

3.1. Context

The owner contracted the builder and architect early on to design and construct a three story, four bedroom house. The builder was responsible for hiring subs. The scope of this project included excavating for the foundation and substructure, installation of floor decks, and framing the exterior walls and roof.

3.2. Objectives

With any standard residential project, hazards are present from the first excavation up to the final punchlist. The builder is often responsible for supervising the site and ensuring that the work is being done safely. With the excavation for the house foundation, the builder had to make sure that there would be no risk of the sides collapsing or falls from ground level. The builder also had to ensure that workers installing the floors and wooden wall frames were adequately protected from falls and collapsing structures. This was also important during the installation of the roof trusses.

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.

During the planning stage, details about the foundation were determined by the constructor. Cast-in-place concrete was used for the basement walls instead of CMU because it was quicker to install, cheaper, and complied with neighborhood codes.

During the design and procurement stage, more decisions were made regarding the house's structure and construction methods. For the initial excavation, the constructor decided to have the sides benched instead of temporarily shored. This was due to cost, schedule, and space provided to workers in the pit. The size of the site also allowed for overexcavation to give workers more room to work safely. The excavation was backfilled after the first floor deck and exterior walls were completed. Floor trusses were used instead of traditional joists to ensure higher build quality and allow for easier integration of the mechanical systems. Pre-fabricated trusses were used for the roof structure to save money and time on installation. Using pre-fabricated trusses also meant that workers spent less time on the roof during installation.

Decisions, Decisions: Quick View

Thom's table here

During the construction phase, exterior wall construction was done by building on the finished floor deck and then moving the finished wall to the outside. The gable end and interior trusses were lifted into place with a small crane. When installing the roof trusses, workers did not use fall-arrest systems. Instead, workers used ladders and scaffolds from the inside of the house. Until all the trusses were secure in place, the individual trusses would not be able to support the lateral loads if a worker fell and was tied off to that truss. Trusses were secured with blocking that was installed on the ground and secured and connected while at height attached to the crane. Once all the trusses were secured and laterally stable, disposable tie-off brackets that complied with OSHA were used as worker fall-arrest systems. A telescoping forklift was used to lift materials onto the roof where they were installed manually by workers. No fall protection was used for this part of the construction.

4.2. Hierarchy of Controls

Elimination is considered to be the most effective form of hazard control. There are several instances in this project where elimination was used. Over-excavating and benching the sides of the excavation area to give workers more room to move and work also prevented any instances of cave-ins where workers could be struck, caught, or crushed by collapsing structures, equipment, or materials. Assembly of the exterior frame was done flat on the finished interior deck. This also

eliminated the risk of being struck, caught, or crushed in a collapsing structure. Using pre-fabricated roof trusses eliminated several hazards associated with constructing the trusses at roof height. Installation using a small crane eliminated the risk of workers overexerting themselves lifting the trusses into place manually.

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. When installing the gable ends and interior trusses, blocking was installed on the ground and the trusses were connected and secured at height using a crane.

Engineering control is the third most effective form of hazard control. A telescoping forklift was used as an engineering control to lift materials onto the roof. Lifting the materials by hand poses a risk of overexertion.

Administrative controls such as communication and training were used extensively during the assembly of the exterior frame and the hoisting of roof materials.

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. PPE such as gloves, sturdy shoes, and safety glasses were absolutely required for all workers.

4.3. Social Network Analysis

Social network analysis was not done for this project due to the small size of the project and low complexity of the social networks.

4.4. Project Performance

Due to the small size of the residential project, there is no performance information readily available.

5. Case Evaluation

5.1. Results

After construction was completed, it is not known if the house received any awards or special certifications. The small size of the project also meant that there was no media coverage. It is also unknown if any injuries or deaths were reported during the project.

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

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

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/

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