Mountain House

Residential Collaborative

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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. Blacksburg House

2.1. Overview

The project involved in this case study was the construction of a 2,500ft^2 house just outside of Blacksburg, Virginia.

2.2. Project Profile

2.2.1 Case Background

The homeowners approached the builder about building a 2,500ft^2 house on the side of a mountain just outside of Blacksburg. The builder brought on the architect, with whom they have worked with since 2007. The architect was contracted separately from the builder by the owner. The three stakeholders met on the two lots purchased by the client to discuss placement of the house.

The design phase lasted around six to eight months, which is typical for residential projects. During this stage, the client worked directly with the architect, who forwarded information onto the builder to address any constructability concerns with the design. A structural engineer helped with the house's foundation and framing. At one point, the architect brought on an interior architect to work with the client on interior finishes.

Construction lasted for over a year with the architect making occasional site visits as needed. The builders were responsible for hiring subs and the 10-15 trade contractors. At the time of this report, the house is mostly complete with subs focusing on finishing the landscaping.

2.2.2 Case Narrative

~~**Site Excavation**~~

~~A basement was decided to be included in the site excavation. As both the designer and operation manager (OM) noted, the local market used to have one in typical residential houses. It is because of the area topography which lent itself to a basement since most lots have a slope. Also, the client also dictated this decision based on their needs.~~

~~The DB team chose benching and sloping methods for site excavation. This type of method is simpler and costs less than other control methods that would require temporary shoring and bracing. The builder had worked with the same excavator for years (they tried to do this with all of their trade subcontractors because they felt it allows the subs to better understand their requirements), and typically gave them the depth and area of the excavation that was needed. The designer said that he had a pre-construction meeting on site with the excavator to discuss a grading plan, but the OM said that they like to rely on the subcontractor's expertise. The OM said that they are basically paying for the time the "machine is on", but they gave the excavator latitude on the height of the bench, layback, and sloping because they trusted and preferred them to do what was required to safely perform the work.~~

The builder's policy is to over-excavate four feet past the wall lines to allow a sufficient setback for subs to work safely and efficiently in the area. This cost a little more on excavation, but allowed sufficient room for the forms to be safely maneuvered and eliminated cave-in hazard at the work face.

Basement

The designer said that they used cast-in-place concrete considering the lower cost as compared to block masonry and less complicated construction due to building codes. An additional consideration on system selection (concrete/CMU) was the scaffolding requirement for CMU considered as more hazardous and costly than concrete construction.

Framing

The exterior frame was constructed following the completion of the first floor basement structure. OSHA regulations require builders to determine what methods will be used for fall protection. The builders believed a netting system was not cost effective for a residential project and that installing tie-off points in the work area would present tripping hazards when maneuvering with nail guns and other equipment. The builder decided to paint an orange stripe 6 feet from the edge of the structure to serve as a warning system to workers.

The basement wall could be backfilled higher initially (halfway up wall, i.e. 4 foot up, 8 foot wall instead of less than a foot), which allowed workers to be at less of a height. If ladders were required on the outside, as the OM said, they could ensure to meet all Occupational Safety and Health Administration (OSHA) guidelines. The OM set up weekly safety meetings with his superintendents where they concentrated on relevant issues for the superintendents to watch for on the sites. He also said that they tried to use the same trade subcontractors, and that they all signed a master trade agreement in which they agreed to follow all OSHA and state guidelines. While they did not dictate means and methods, they did work with their subs on safety procedures in order to ensure meeting OSHA requirements to the best of their ability. As the OM said, the OSHA 1926 guidelines for residential projects were difficult to interpret, but they tried to concentrate on the "Top 10" list.

OSHA "Top Ten" Frequently Cited Standards (2013)

The OSHA "Top Ten" are ten of the most frequently cited building standards that occur following a formal inspection by federal OSHA. The list is published to alert constructors of these commonly cited standards so that the constructor can take steps to control the hazards before inspections occur (OSHA, 2013). This list is for fiscal 2013 (September 30, 2012 to October 1, 2013) and is current as of October 25, 2013.

1. 1926.501 – Fall Protection
2. 1910.1200 – Hazard Communication
3. 1926.451 – Scaffolding
4. 1910.134 – Respiratory Protection
5. 1910.305 – Electrical, Wiring Methods
6. 1910.178 – Powered Industrial Trucks
7. 1926.1053 – Ladders
8. 1910.147 – Lockout/Tagout
9. 1910.303 – Electrical, General Requirements
10. 1910.212 – Machine Guarding

Flooring

The flooring system used was a truss system. The designer explained that they chose this system over others because they thought it was a higher quality method and the long spans that could be installed (typically 24-25 feet) and make installation more efficient. This also allowed the mechanical systems to be installed within the truss, which was more effective than other methods. The OM said that the framer working at heights while installing the flooring system was a point of emphasis because of its risk. These workers were not tied-off, but the earlier backfill allowed them to work at less of a height than they would otherwise. Another point of emphasis was to have the framer work inside the orange boundary and move the frame to the outside to be installed. As the OM said traditionally the wall would be built at the edge and lifted into place, which presented a number of hazards, and working with their framer on this change was somewhat difficult because it took them more time.

Roofing

The designer indicated they had experiences of using both pre-made trusses and stick built roofs in the past. The main decision factor in this process was the complexity of the roof, and whether frames could be fabricated off-site economically. If it was cost-effective, the roof trusses were fabricated off-site and lifted into place which was much quicker. At times it was a hybrid of this process and a stick-built roof depending on the design. If it was too complicated and the owner was willing to absorb the cost, the last resort for the construction of the roof was to stick-build it.

Roof fall protection was disposable tie-off bracelets at the ridges of the roof. The tie-off bracket could be knocked off and roofed over. The OM also stated that proper use of harnesses and having the correct amount of slack was a concern for him because they could give workers a false sense of security that was not warranted if they did not understand how to properly use the fall restraint system.

Both the designer and OM confirmed that working on the roof before installing sheeting was a major hazard. Tie-off is difficult until the sheeting is installed or the trusses are laterally stabilized and a fall would result in the roof trusses falling "like a house of cards". Workers did not tie off while installing the trusses, and after installing the trusses they tried to work from the inside as much as possible using scaffolding and ladders to minimize fall hazards from the roof while being untied.

Lifting

Lifting materials was another important safety issue that the OM discussed. He said that mechanical lifts were usually not cost effective on a residential project, but they had worked with their subs on materials when possible. He said that one example was the roofing underlayment substitution of a lighter, yet more expensive material that came in 4 foot rolls instead of 3 foot rolls. This material reduced the number of rolls that had to be carried up a ladder and reduced the weight of each roll from 45 lbs to 15-20 lbs. Not only was this safer but it allowed the underlayment to be installed more quickly, he said, however that lifting materials up ladders was a danger that they were conscious of.

OSHA. (2013, October 25). Top Ten Most Frequently Cited Hazards. Retrieved from https://www.osha.gov/Top_Ten_Standards.html

2.2.3 Stakeholders

Internal supply for this project came from several sources. The builder, who was contracted by the owner, sought out the architect to design the house. Using the architect's plans, the builder was to build the house and hire subs as required. An interior architect was also brought on to discuss interior finishes with the owner. A structural engineer consulted the architect on the house's design and the structure that would be necessary to support it. During construction, there were 10-15 trade contractors and material suppliers who received orders from the builder. The builder was also in charge of supervising the project. The architect made occasional site visits but did not dictate means and methods.

Internal demand came solely from the homeowner. The owner contracted the builder and architect, gave input into the design of the house, and will be the end user once it is completed.

2.2.4 Project Objective

The objective of this project was to build a house near Blacksburg, Virginia

2.2.5 Sector x Delivery System

This project is an example of collaborative residential construction.

2.2.6 Features of Work

3. Problem

3.1. Context

The owner contracted the builder and architect to design and construct a 2,500ft^2 house on two adjacent lots he had purchased. The lots are located on the side of a mountain near Blacksburg, VA. The owner was very particular about interior finishes and small details, so there was extensive communication back and forth between the architect and owner during the planning stage.

3.2. Objectives

Describe the project's aim with details of its specific objectives and the strategies used to achieve them.

Sample: The challenge was to establish an ecommerce site that would offer a web-based business opportunity to entrepreneurs wishing to capitalize on the growing popularity of ecommerce. The solution would need to allow the fastest possible time to release, reliability, and flexibility. Java technologies were selected over several alternatives because of these requirements.

(6 to 10 lines)

4. Results

4.1. Safety-Critical Decision Making

Decisions, Decisions: Quick View

Thom's table here

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, the foundation type and material was determined by the constructor. Local topography and owner preferences led to the decision to use a basement instead of a slab on grade. Cast-in-place concrete was used for the basement 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 and sloped back instead of temporarily shored. This was due to cost, schedule, and space provided to workers in the pit. The excavation area was also set to be 4 feet past the wall faces in order to increase safety and available room for workers. The size of the site also permitted overexcavation. After the foundation walls were completed, the excavation was backfilled 3-4 feet. Since workers were not working at as much of a height, no fall protection was needed. This also was done to increase worker productivity. 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 to save money and time on installation.

During the construction phase, the constructor decided to have a painted warning barrier six feet from the edge serve as leading edge fall protection. This was cheaper and quicker than installing a netting system or tie-off points and still complied with OSHA guidelines. Exterior wall construction was done by building inside the six foot safety barrier and then moving the finished wall to the outside. This decision was made due to worker productivity, safety, and cost. Cost also influenced the decision to lift materials manually as opposed to using a mechanical lift. The constructor said that using a mechanical lift would be cost prohibitive for a residential project. 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. Once all the trusses were secured and laterally stable, disposable tie-off brackets that complied with OSHA were used as worker fall-arrest systems.

4.2. Hierarchy of Controls

~~An example of elimination in this project was using pre-fabricated roof trusses instead of stick-building. This saved time, money, and the amount of instances the workers would need to be at height installing the trusses. Overexcavating, early backfilling, and benching the sides also gave workers more room to move and eliminated several hazards associated with working in a deep confined area. Building the exterior frame flat also eliminated the need to assemble it at height.~~

~~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. In the pre-construction phase, the constructor was able to find lighter roofing material that came in larger rolls. Substituting a lighter material meant that workers did not have to lift as much weight up onto the roof. Having larger rolls also meant that workers were able to make fewer trips.~~

~~Engineering control is the third most effective form of hazard control. There are several examples of engineering controls being used in this project. The constructor decided to backfill 3-4 feet of the excavation early so the workers were not working at full height. Another example was the orange painted barrier installed six feet from the leading edge of the excavation area. This was to prevent workers from stumbling into the pit while working on the exterior frame. Breakaway fall arrest anchor points on the roof were also engineering controls used by the constructor.~~

~~Administrative controls such as training and communication were used extensively by the workers during the assembly of the pre-cast concrete basement, construction 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, safety glasses, and respirators (if applicable) were required for all workers.~~

4.3. Social Network Analysis

4.4. Project Performance

If available, describe project scope, schedule, cost, safety performance.

(6 to 10 lines)

5. Case Evaluation

5.1. Results

Since construction for this house is still ongoing, it is not known if the house will receive 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 have been 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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