

Server Farm

Industrial Design-Build

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This work was supported by Cooperative Agreement #OH009761 from the National Institute for Occupational Safety and Health (NIOSH), Centers for Disease Control and Prevention (CDC). Its contents are solely the responsibility of the writers and do not necessarily represent the official views of the CDC.

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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 than 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. Server Farm

2.1. Overview

The project featured in this case study was the renovation and partial demolition of an existing manufacturing plant for use as a server farm. Renovation of an existing building in favor of new construction is typical for server farms and in the scope of this project was the most cost efficient option that fit the company's timetable of 10-12 months. The specific manufacturing plant was chosen due to its high interior wall height, which is favored for storing server equipment, and its remote site location. For this project, the owner sought to earn LEED certification. This choice was consistent with the company's views on environment and sustainability, and would serve as a great marketing tool.

2.2. Project Profile

2.2.1 Case Background

This project was the renovation of an existing manufacturing facility to be used as a data warehouse. The renovation required the demolition of on part of the facility, as well as the removal of existing material from the rest of the facility. The facility was designed to hold three large rooms of servers, and the associated electrical infrastructure required for these servers and their battery backups. This infrastructure included a gas fire suppression system in the server rooms, as using water around the electrical equipment was a last resort. Constructing this system required the placement of dozens of tanks to hold the gas on the lower level, and the piping required to distribute the gas (separate from the water-base system). The renovation was performed to meet LEED Silver requirements, and the demolition was a major component of this certification.

2.2.2 Case Narrative

Demolition

An existing one-story portion of the plant was demolished due to low ceiling clearance necessary for the server farm and as a byproduct the demolition provided LEED credits. During the demolition process, it was required that workers wear gloves, safety glasses, and dust masks to reduce the risk of inhaling dust and airborne particles. To obtain LEED credits, all materials had to be evaluated for air quality and monitored for VOC's.

Waste Separation (LEED)

The owner desired to meet a goal of recycling 75% of construction waste. Planning had to be implemented for the separation and storage of construction waste. A cost-based decision was made to have one subcontractor for waste disposal and another subcontractor for recycling. To accomplish this process waste and recyclables would need to be separated and sorted on-site before being sent to their final destinations.

This was a straight forward process as 98% (280 tons) of the materials were considered recyclable. Separating on-site also allowed the project to meet LEED credit requirements for tracking of waste and recyclables sent to their respective locations. The co-mingled recyclables, such as cardboard, glass, and metal were safely sorted off-site by the more experienced recycling sub.

The location of the on-site recyclable bins was placed away from the demolition bins. The particular site was chosen to provide room for containers and give the subcontractor access to pick up the materials. This meant that the equipment removing the materials had a farther distance to travel, but this was outweighed by the pros of the end location. The CM did not dictate any specific methods for sorting the materials other than holding the demolition sub responsible for ensuring that the waste and recyclables were placed in their correct locations. The CM also did not state a given interval for waste pickup, other than stating that the containers should not be overflowing. A pickup schedule was determined by the subcontractors.

Fire Protection

A notable feature of this project was the incorporation of a gas-based fire suppression system. The original plans did not include such a system, as it is an expensive option. The owner wanted a clean agent gas suppression system installed in all the server rooms. Typically, these systems are safer during an initial outbreak because of the electrical equipment in the server room that would be interacting with a wet sprinkler system. The gas system included 30 large and heavy tanks that were filled with the inert gas and located in the basement.

Lift & Place Gas Fire Suppression Equipment

The large and heavy gas tanks for the fire suppression system were unloaded and installed by workers using forklifts. Once the tanks were placed upright, a uni-strut steel frame was installed around each tank to prevent movement and valves were connected to the tanks. A railed platform was installed on top of each frame as an engineering control to prevent falls to lower levels. Administrative controls via training helped prevent injuries to workers while they were installing the tanks and manually lifting the actuator valves and frames into their places on top of each tank.

2.2.3 Stakeholders

External public stakeholders in this project consisted of the local town and the fire code inspector. The town originally recruited the client to that area. The fire code inspector dictated codes that drove the design of the facility's fire suppression system as well as conducting a final inspection of the facility to ensure that it met all applicable fire codes.

Internal supply for this project came from a variety of sources. The principal contractor was part of the design-build team that was awarded the contract by the client. The principal contractor led the construction process along with a team of mechanical and electrical engineers who worked with subcontractors to design the fire suppression system. The architect of record was also part of the design team that the contract was awarded to. The architect developed a LEED accreditation plan and designed the demolition and building layout plans.

Several different subcontractors were also involved in the project and are considered internal suppliers as well. The demolition subcontractor took the architect's demolition plans and carried out the demolition work. The waste disposal and recycling subcontractors collected the waste and recyclables from the site and transported them to an off-site location to be sorted or disposed of.

The gas fire suppression system designer and installers sized the system based on the size of the facility and designed and built the system according to the needs of the DB team.

Internal demand came solely from the client. The client was involved in both phases of the project and was responsible for the decision to build a new data center for business purposes, choosing the site, developing the budget, setting the schedule for completion, and managing the building after it was finished.

2.2.4 Project Objective

The objective of this project was to renovate an existing manufacturing plant into a server farm complete with demolition of an unusable portion of the building, installation of an advanced gas fire suppression system, and compliance with LEED requirements for the sorting and disposal of construction waste.

2.2.5 Sector x Delivery System

This project is an example of an industrial constructing process using Design-Build as a delivery method.

2.2.6 Features of Work

Features of work within this project include demolition, waste separation, fire protection, and lifting & placing of equipment.

3. Problem

3.1. Context

The owner wanted a new location for the company to use as a data storage warehouse with a time table of 10-12 months. Given the limited schedule, it was more realistic for the company to renovate an existing structure than build a new one. An old warehouse was ideal as a server room since there is adequate ceiling clearance for equipment. A server farm also needs an up-to-date fire suppression system in the event of an electrical fire.

3.2. Objectives

Once the warehouse was selected, the owner determined that part of the building which was already unsuitable for housing servers could be demolished to earn LEED credits. Credits would be earned for how the demolition waste was handled and sorted as well as the air quality and VOC's of the materials. A specialized sub handled sorting of the recyclable materials in order to reduce exposure to potentially hazardous materials.

The owner also decided to use a gas fire suppression system for the server rooms since water could severely damage the electronic equipment. The gas system requires large storage tanks and extensive piping to the server rooms.

4. Results

4.1. Safety-Critical Decision Making

The owner wanted the server room to have a gas-based fire suppression system. These systems are typically more expensive to install and maintain, but they are quicker to extinguish fires and will not damage sensitive electronic equipment in the process. A traditional water sprinkler system was also installed alongside the gas system.

The gas for the fire suppression system is stored in 30 tanks in the basement of the building from where it is piped up into the server room. The tanks are secured into place with a steel frame. A platform and guardrails were installed on top of the tanks for workers who were installing actuator valves on top of the tanks. This greatly reduced fall risks for those workers installing the valves.

The high ceiling of the server room made manual lifting of the pipes impossible. Engineering calculations of the gas system advised the pipes be upsized to account for friction loss.

Decisions,
Decisions:
Quick View

Thom's table here

4.2. Hierarchy of Controls

Elimination is seen as the most effective method of hazard control. An example of elimination in this project was having recyclable materials from the demolished portion of the building sorted off-site by the recycling sub. This eliminated worker risk of contact with objects and equipment as well as overexertion in holding, carrying, or welding. Using an inert gas system that did not require dangerous electrical currents also eliminated the risk of electrocution for the workers installing the system.

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. There were no notable examples of substitution in this project.

Engineering control is the third most effective form of hazard control. If the hazard cannot feasibly be eliminated or substituted, and engineering control reduces worker exposure to the hazard. Guard rails and a platform were installed on top of the gas tanks for workers installing actuator valves. This greatly reduced the fall risk for workers working on top of the tanks. Using a mechanical lift to install overhead pipes is also an example of an engineering control.

Administrative controls such as worker training and pick plans were used extensively throughout the project.

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.

4.3. Social Network Analysis

4.4. Project Performance

The server farm project was budgeted at \$40 million and given a timeframe of 12 months for planning and design and 7 months for construction. There is no evidence to indicate that the project deviated far from the schedule. The finished facility earned LEED Silver certification. There was no media coverage for this project. It is unknown if any injuries or deaths occurred during the project.

5. Case Evaluation

5.1. Results

After the facility was finished, the company was able to increase server space and create jobs. The environmentally-conscious decisions made by the owner to achieve LEED certification can also be used as a precedent for other companies undertaking a similar project. Additional performance information or statistics of the facility are not available.

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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