# Chemical Plant Upgrade

## Industrial Accelerated

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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. Chemical Plant Economizer Upgrade

## 2.1. Overview

The project involved in this case study was the installation of a hot oil economizer onto a unit in a chemical plant to improve the plant's operational efficiency.

## 2.2. Project Profile

### *2.2.1 Case Background*

The project featured in this case study was the addition of a hot oil economizer to an existing chemical plant. An economizer (figure 1) preheats combustion air and can also warm up oil to be used in other processes. An economizer was installed twenty years earlier for one of the plant's two hot oil units. The plant decided to install a second economizer on the other hot oil unit in order to reduce dependency on the primary unit. The project budget was $1.2 million to purchase, install, and tie in the new economizer to the existing plant structure.

*Figure 1: Typical Hot Oil Economizer*

The plant has a "turnaround" period that takes place once every three to five years. During this 20 day period, workers at the plant perform preventative maintenance, inspections, and cleaning. While the plant is offline, there is also a three day power outage to the utility equipment. The plant also has several shutdowns a year to perform maintenance. The project engineer had to choose to coordinate the economizer installation with the turnaround, as the time window during a shutdown would be too brief. This put the project on a tight schedule from start to finish.

### *2.2.2 Case Narrative*

**Steel Frame Assembly**

The new economizer was to be mounted on the stack in an identical manner to the existing unit. The new unit was to be installed 70 feet up the 100 foot stack and supported by a steel structure. The design team contracted out the fabrication of the steel structure. The structure was fabricated off-site prior to the turnaround, which is a method that the owner's project engineer was familiar with. Fabricating off-site saved valuable time and removed risks associated with working in proximity to the main plant site as well as fabricating the structure at installation height.

**Lift & Place Equipment**

The pre-fabricated steel frame was transported to the plant site on a truck. The structure was to be located near the back of the plant site and there was already an existing road/aisle from the plant back to the location. The construction coordinator, project engineer, and contractor walked the path to check for any potential hazards to the trucks or crane operating crews. An electrical line was found along the path that could pose a hazard to the crane. The line was found to be unused and was safely removed.

Once a clear and safe work area was established for the trucks and crane, the capacities of the truck and crane were used to determine how much of the steel frame could be fabricated off-site. It was determined that the structure could be completely fabricated off-site and assembled at the plant. This was much safer for workers since less lifts were required and workers did not have to climb up onto the structure to assemble it. The structure's design only required four bolted connections to the economizer. This minimized the amount of time that the economizer was at height and not secured into place.

Man-lifts were used for workers securing the economizer to the frame. Scaffolds were too cumbersome, required more time for assembly and disassembly, and only four connections needed to be made due to the design of the frame. The ductwork to the stack was welded instead of being bolted in place. While the owner preferred to have bolted connections for safety reasons, welds were necessary to prevent oil from escaping.

### *2.2.3 Stakeholders*

Internal supply for this project came from several sources. The Engineering Firm for Permitting was responsible for handling permitting for the project with the Parish and the Corp of Engineers. The Economizer Designer and Installer designed and built the steel structure to hold the economizer to the stack. The Foundation Designer designed the foundation for the economizer structure based on load calculations and subcontracted the construction of the structure's foundation to the Foundation Installer. The Economizer Supplier manufactured the economizer for this project.

The four sources of internal demand all came from within one company. The company's Capital Engineering division was the owner and designer for this facility. As the owner and designer, the Capital Engineering division developed the need for the project, managed the project throughout the entire process, coordinated the design, and performed the design for tie-in to the plant infrastructure. The Turnaround Coordinator was responsible for coordinating all activities during the 2 week turnaround. The Turnaround Coordinator gave approval for all work conducted during the plant turnaround and made the decision to tie-in the stack until after turnaround. The Operations Division was responsible for the day to day operations at the plant. Operations gave approval for all work occurring in the plant and were the ultimate decision maker for upgrading the equipment. The company's Construction Coordinator was the PM for this project and ensured that all work had proper approval and all contractors followed safety requirements.

External stakeholders for this project consisted of the local Parish and the Corp of Engineers. Both parties gave approval for all new equipment at that location.

### *2.2.4 Project Objective*

The objective of this project was to increase the efficiency of a chemical plant by adding an economizer to one of the units. The economizer had to be supported by a custom-built steel frame and tied into the rest of the facility. The plant had limited downtime and any extra time would cost the plant money, so adhering to a tight schedule was crucial for the contractors.

### *2.2.5 Sector x Delivery System*

The economizer retrofit is an example of an accelerated industrial project.

### *2.2.6 Features of Work*

Two features of work featured in this project are the assembly of the steel frame and the lifting and placing of the economizer and frame into position on the stack.

# 3. Problem

## 3.1. Context

The owner of the chemical plant decided to install an economizer on one of the plant's units to increase operating efficiency. The plant would have to be shut down in order to tie-in the new economizer. One of the biggest problems that the project team faced was carrying out the installation as quickly as possible to minimize the plant's downtime. The plant loses a considerable amount of money each time it is shut down. This meant that the team had to plan the project schedule well in advance.

## 3.2. Objectives

The economizer installation was coordinated to take place during the plant's turnaround period, which is a period once every 3 to 5 years where the plant goes offline for 20 days so that workers can perform inspections, preventative maintenance, and cleaning. Since the plant is already shut off during this time, any impact the construction would have on the plant's daily operations was minimal. Much of the construction was pre-fabricated in advance in order to save time during the turnaround.

# 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.

The decision to install an economizer on the second unit was made after the procurement of the plant's capital project budget. Data from the existing unit and the facility's operations demonstrated that an economizer would have long-term cost-saving benefits for the plant. Following the approval of the project, the project team needed to decide whether to coordinate the installation with a turnaround or shutdown period. The scope of the project required too much time to take place during a shutdown, so the project team decided to coordinate the project with the next turnaround period. The project engineer was familiar with coordinating other projects during turnarounds. The owner would have preferred to have bolts used for tie-in of the ductwork however the connections had to be welded instead in order to prevent oil leaks.

The design was further developed by determining crane requirements and specifics about the economizer's steel support structure. While the economizer height was 70ft, a 100ft crane was used since the top part of the 100ft stack would have to be temporarily removed to install the economizer and tie it in. Off-site fabrication of the steel structure was chosen because of the accelerated schedule and to isolate construction from the rest of the plant's operations. Before the project team could determine specifics about the pre-fabrication, they had to decide on the delivery method from the fabrication site to the plant. The economizer's planned location was accessible by a small roadway, so a truck would be used to deliver the frame. An overhead electrical line was identified along the roadway that needed to be addressed before crane placement. Since the line was not in use, it was removed.

Based on the capacity of the delivery trucks, the project team determined that the frame could be pre-fabricated and delivered in one piece. The economizer was connected to the frame with four bolts. Compared to welding, bolting in the economizer minimized the time workers needed to spend at heights installing the economizer. Man-lifts were used during the tie-in of the economizer since scaffolding required too much time for assembly and disassembly. It was also not economical to use scaffolding for the few connections required to secure the economizer unit.

## 4.2. Hierarchy of Controls

Elimination is the most effective method of hazard control. The project management team decided to have the steel economizer frame assembled off-site and on the ground. Using a pre-fabricated structure eliminated hazards associated with constructing such a structure at heights. It also required only one lift to attach the structure to the stack. Another example of elimination was the owner's decision to remove the inactive electrical line so it would not pose a hazard to the crane crew.

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 used in this project.

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. The assembled steel frame was delivered to the site on a flatbed truck. The area where the truck would back in to was roped off and controlled by flagmen, which was an engineering control from the owner. Mechanical lifts and engineered scaffolds for installing the economizer were engineering controls implemented by the constructor to reduce worker fall risks.

Administrative controls are the next most effective hazard control if engineering controls are not feasible. Worker safety training as an administrative control was common for this 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. The most common form of worker PPE aside from gloves, hardhats, and safety glasses were fall arrest systems where workers installing the economizer and steel frame tied off to the man-lift.

## 4.3. Social Network Analysis

## 4.4. Project Performance

The project was scheduled to take place during one of the plant's 20 day turnaround periods. The budget to purchase, install, and tie in the economizer was $1.2 million. The project did not receive any special awards, ratings, or media coverage. It is not known if any injuries or deaths occurred on this project.

# 5. Case Evaluation

## 5.1. Results & Benefits

To ensure the security of the chemical plant, information about the plant beyond the scope of the project is limited. Installing the second economizer allows for the chemical plant to save money and run more efficiently.

## 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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