New Highway

Heavy Design-Build

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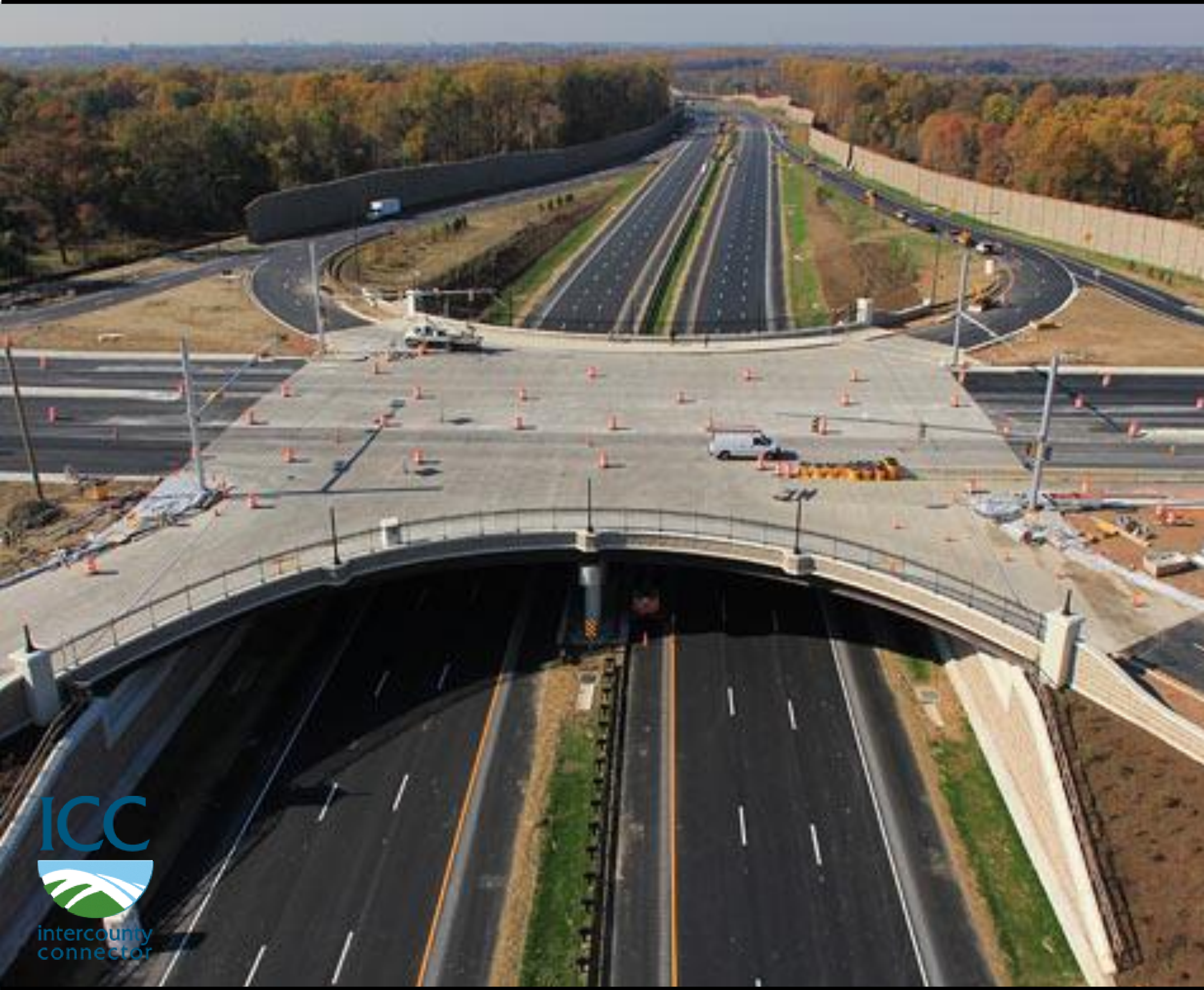

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1. Case Study Method

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, 2013), 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 (CDC.gov, 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. New Highway

2.1. Overview

The project involved in this case study was the construction of a 6.9 mile stretch of the Intercounty Connector. The Intercounty Connector, or ICC, is an 18.8 mile tollway that connects two major highways in Maryland. The particular stretch of the ICC featured in this case study is known as Contract B. Contract B crosses environmentally sensitive wetlands and forests, which necessitated extra planning and implementing design features to minimize the impact on the local ecosystems.

2.2. Project Profile

2.2.1 Case Background

The concept for a new tollway was developed approximately sixty years ago. While the tollway made it to the design phase and land was acquired for the right of way, it was never constructed (Samuel, 2003). It remained on the master plan until the 1990's when the design was re-evaluated to address environmental concerns about the proposed highway.

Proponents for the highway claimed that it would improve regional traffic flow and alleviate congestion on local roads. It would also increase national security by allowing an evacuation route should Washington need to be evacuated. Opponents to the project claim that the new highway would disrupt local traffic patterns, disturb communities, and have detrimental effects on the surrounding environment (EDF, 2005). The ICC finally became a reality when the state governor fulfilled his campaign promise by conducting a formal groundbreaking in October 2006 (Samuel, 2003) with construction officially beginning on November 13, 2007.

The ICC was divided into five separate design-build phases, named Contracts A, B, C, D, and E (Gay, 2006). Contract B covered 6.9 miles of the highway's total length and featured two Single Point Urban Interchanges (Wagman, n.d.). The contract for Contract B was awarded on July 22, 2008 to the design-build team for $559.7 million, which was 22% higher than anticipated (Shaver, 2008). The contract award was protested by another design-build team that was not awarded the bid, despite having a lower bid price by $670,000. There was concern that this would delay the start of construction for Contract B, but this protest was rejected by the state procurement officer.

Environmental sensitivity was an emphasis for this project since Contract B traverses some of the area's most sensitive environments. Contract B has several innovative features designed to sustain the area's plant and wildlife. A special environmental crew was present during the construction to ensure that disruption to the ecosystem was kept at a minimum (Wagman, n.d.). During construction, 8 foot high fences were erected along the jobsite to keep out deer. These fences have smaller openings towards the bottom to keep out smaller animals. Box turtles in the path of the highway alignment were located by a team of trained retriever dogs and safely relocated. Over 200 box turtles were relocated over the course of the project. Over 1000 trees were also removed with roots intact to be placed along a future stream stabilization project. Culverts were designed to allow fish to swim through and fish in the work zone were safely relocated using electroshock methods.

Environmental Defense Fund. (2005, March 16). Proposed Highway Would Hurt Air, Congestion. Retrieved from http://web.archive.org/web/20070813232355/http://www.environmentaldefense.org/article.cfm?ContentID=4220 (archived)

Gay, R. P. (2006, May 8). ICC procurement process update letter. Maryland State Highway Administration. Retrieved from http://apps.roads.maryland.gov/businesswithsha/contBidProp/ohd/constructContracts/pdf/5_06_ContractC_Packaging.pdf

ICC Project. (n.d.). ICC Background. Retrieved from http://www.iccproject.com/icc-background.php on 1 August 2014.

Samuel, P. (2003, October 20). Intercounty Connector to toll. *TollRoadsNews.* Retrieved from http://tollroadsnews.com/news/intercounty-connector-to-toll on 1 August 2014.

Shaver, K. (2008, September 4). Connector segment will cost 22% more. *The Washington Post*. Retrieved from http://www.washingtonpost.com/wp-dyn/content/article/2008/09/03/AR2008090303564.html on 29 July 2014.

Wagman. (n.d.). Intercounty Connector, Contract B. Retrieved from http://www.wagman.com/gafc/projects/iccb.asp on 1 August 2014.

2.2.2 Case Narrative

Haul Road

A haul road was used to transport materials and equipment along the project corridor. The haul road to the site was limited in size to a single lane design due to the smaller construction footprint. Maintenance of the haul road over time was necessary in order to keep it open and accessible at all times during construction. During this phase, there was risk for workers to be struck, caught in, or compressed by equipment or objects. This was solved by the constructor implementing communication between workers and drivers as an administrative control. Using stone and grading allowed for the road surface to remain safe and prevent instances of slips, trips, or falls.

Temporary Bridges

Since the project corridor traversed wetlands and creeks, temporary bridges needed to be built to allow movement of equipment and materials. To ensure the safety of workers on the bridge, the CM needed to take measures to prevent falls or being struck by equipment or vehicles. Instead of delegating fall protection to the subs, the CM had temporary walls put up along the bridges to meet OSHA requirements for fall protection. The design width of the bridges eliminated the risk of workers being struck by equipment or vehicles, although signage, temporary barricades, and communication between workers and drivers were still utilized to ensure worker safety.

Maintenance of Traffic

The MOT plan for this project consisted of a hybrid of temporary roads and lane shifts. This was due to cost, traffic flow design studies, and the local topography. With the schedule and number of subs involved in the project, the MOT was left up to each sub to execute, as opposed to the GC. Public vehicles entering and exiting the streets leading to the jobsite became a hazard for both the motorists and workers, who could be struck by one of these vehicles. This was solved with administrative controls such as communication as well as barricades as a form of engineering control. Signage and jersey barriers were also used when dealing with construction vehicles entering and exiting the job site from the surface streets.

2.2.3 Stakeholders

Internal supply for this project came from a variety of sources. The CM and two other subcontractors were part of the DB joint venture. There also was a Lead Designer, Environmental Engineer, and a Landscape Engineer. One firm provided highway, traffic, bridge, and geotechnical engineering services. Another firm was the lead roadway, traffic, and drainage design engineer. This firm also provided the structural design for two bridge crossings, environmental compliance reviews, stream mitigation designs, and coordination of utilities. A third firm provided engineering, cultural, and environmental services.

The sole source of internal demand for this project came from the state's Department of Transportation, who was the client. The client approved the project and provided the funding.

External stakeholders in this project included the local, state, and federal governments, local residents, environmental interest groups, and environmental regulation authorities. The state government was responsible for providing a majority of the funding for the project. Local residents were affected by the construction and road closures. Environmental interest groups gave input into the location and design of the highway.

2.2.4 Project Objective

The objective of this project was to complete a 6.9 mile stretch of a future tollway using construction practices and design features that minimize disruption to the area's sensitive environment.

2.2.5 Sector x Delivery System

This project is an example of heavy construction delivered by a Design-Build (DB) team.

2.2.6 Features of Work

Three features of work in this project were the usage and upkeep of the haul roads, the usage of temporary bridges, and maintenance of traffic at points where construction vehicles entered and exited the site.

3. Problem

3.1. Context

A new tollway was being constructed to link two larger highways and alleviate congestion problems by diverting traffic from smaller streets. The new highway was divided up into five separate contracts. The contract featured in this study, Contract B, traverses through sensitive environments as well as quiet residential areas. Environmentally-friendly design and construction practices were important to the client and the rest of the project team and taken into consideration from the earliest stages of design. Additionally, with the amount of vehicle traffic and equipment movement along the construction corridor, worker safety was important especially for those near or on the haul roads and temporary bridges.

3.2. Objectives

In order to minimize disruption to the local ecosystems, the highway itself was designed with sustainability in mind. Sound barriers were set up along the corridor to lower noise levels near residential areas. Wildlife fences and escape ramps were also erected to keep deer and other small animals from wandering into the highway area. Local species, such as box turtles, were found and safely relocated from the highway corridor before construction began. For segments of the highway that crossed wetlands, culverts were installed. Trees that needed to be removed were handled in a way where they could be relocated to other areas for future projects (Wagman, n.d.).

Since the haul road was only one lane, it was an important safety decision to use flagmen, signage, and reliable communication to let workers and drivers know of any approaching vehicles or other obstacles. Temporary barriers and additional signage was used in areas where construction vehicles would enter and exit the site on public roads where local traffic was present.

Wagman. (n.d.). Intercounty Connector, Contract B. Retrieved from http://www.wagman.com/gafc/projects/iccb.asp on 1 August 2014.

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.

There were two components associated with the haul road: transit issues and maintenance. For workers and equipment using the road, stone and grading was used on the road as an engineering control to prevent falls, trips, and slips. Communication as an administrative control was used to prevent workers being struck, caught in, or compressed by objects or equipment. Communication was also used extensively during haul road maintenance in order to keep the road open and accessible.

Decisions, Decisions: Quick View

Thom's table here

Temporary bridges were used in this project to allow workers and equipment to traverse the site's wetland location. The bridges were designed wider than normal to allow workers more room to safely cross alongside vehicles. Communication and signage were used as administrative controls to alert workers to traffic on the bridge. Temporary barricades served as fall protection for workers on the bridge.

Maintenance of traffic was important for the public side roads where construction vehicles access the site. In order to keep the multiple site access points safe, signage and barricades were used to reduce the risk of workers being struck by object or equipment. These controls were also used to keep the flow and safety of construction vehicles entering and exiting the site.

4.2. Hierarchy of Controls

An example of elimination in this project was the constructor's decision to design the temporary bridges wider than needed. This extra width eliminated the risk of workers on the bridge being struck by or compressed by objects or equipment.

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. Examples of engineering controls used within this project include stone grading on the haul road to prevent falls, trips and slips; barricades on the temporary bridges to prevent falls to lower levels, and jersey barriers for construction vehicles entering the site to prevent being struck by objects or equipment.

Administrative controls such as communication and signage were used extensively throughout the project for the haul roads, temporary bridges, and construction vehicles entering and exiting the jobsite.

The least effective form of hazard protection is Personal Protective Equipment (PPE), which was a common response for many tasks throughout the project where the above mentioned controls would not have been possible or economically feasible. Aside from mandated PPE such as gloves, sturdy shoes, and safety glasses, there were no other instances where alternative forms of PPE were used.

4.3. Social Network Analysis

4.4. Project Performance

Construction on Contract B began with a limited Notice to Proceed (NTP) in July 2008 followed by a full NTP in January 2009. This portion of the highway was ready for service on November 22, 2011 (Wagman, n.d.). The budget for Contract B was $559 million, which was 22% higher than earlier estimates (Shaver, 2008). Most of the funding for this project came from bonds and the state's general fund, with the remainder coming from the state's transportation trust fund and federal funding. (*The Connector*, 2007)

Shaver, K. (2008, September 4). Connector segment will cost 22% more. *The Washington Post*. Retrieved from http://www.washingtonpost.com/wp-dyn/content/article/2008/09/03/AR2008090303564.html on 29 July 2014.

Wagman. (n.d.). Intercounty Connector, Contract B. Retrieved from http://www.wagman.com/gafc/projects/iccb.asp on 1 August 2014.

The Connector. (Summer 2007). "Wall Street gives ICC a AAA Vote of Confidence". Retrieved from http://www.iccproject.com/PDFs/ICC_NL_Summer07.pdf on 29 July 2014.

5. Case Evaluation

5.1. Results

The completed section of the new highway won several awards for its eco-friendly design and engineering (Wagman, n.d.). The awards received are listed below:

2013 Award of Excellence, Partnering Silver Award – Maryland Quality Initiative (MDQI)
2012 National Design-Build Award - Design-Build Institute of America (DBIA)
2012 Exemplary Ecosystem Initiatives Award - Federal Highway Administration (FHWA)
2012 Alliance Award - Northern Virginia Transportation Alliance
2012 Globe Award for Environmental Excellence - American Road & Transportation Builders Association (ARTBA)
2012 Best Transportation Project - Engineering News Record (ENR)

Wagman. (n.d.). Intercounty Connector, Contract B. Retrieved from http://www.wagman.com/gafc/projects/iccb.asp on 1 August 2014.

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

Environmental Defense Fund. (2005, March 16). Proposed Highway Would Hurt Air, Congestion. Retrieved from http://web.archive.org/web/20070813232355/http://www.environmentaldefense.org/article.cfm?ContentID=4220 (archived)

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