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International benchmarking for performance improvement in construction safety and health

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International benchmarking for performance improvement in construction safety and health

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Abstract

Purpose – The purpose of this paper is to advance knowledge on the advantages of integrating safety earlier in the construction project lifecycle.
Design/methodology/approach – A case study approach is used to collect data from construction sites in the USA, which performs poorly in construction safety and health, and Australia (AU), which performs well in construction safety and health. Qualitative data are collected to determine how and when safety is considered in the project lifecycle in both countries, and then the results are benchmarked to determine the benefits of addressing safety earlier in the process.
Findings – Data show that addressing a potential hazard earlier in the project lifecycle has performance benefits in terms of the level of hazard control.
Research limitations/implications – The processes that are identified as possibly explaining the performance difference are just based on qualitative data from interviews. Targeted research addressing the relationship between these processes and safety outcomes is an opportunity for further research.
Practical implications – The case study data are used to identify specific processes that are used in AU that might be adopted in the USA to improve performance by integrating safety earlier into the decision-making process.

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Social implications – This paper highlights the advantages of integrating safety as a decision factor early in the process. Worker safety is not just an issue in the construction industry, and thus the findings are applicable to all industries in which worker safety is an issue.

Originality/value – This paper advances the safety in design literature by quantitatively supporting the link between when a hazard is addressed and performance. It also links the results to specific processes across countries, which advances the literature because most research in this area to data is within a single country.

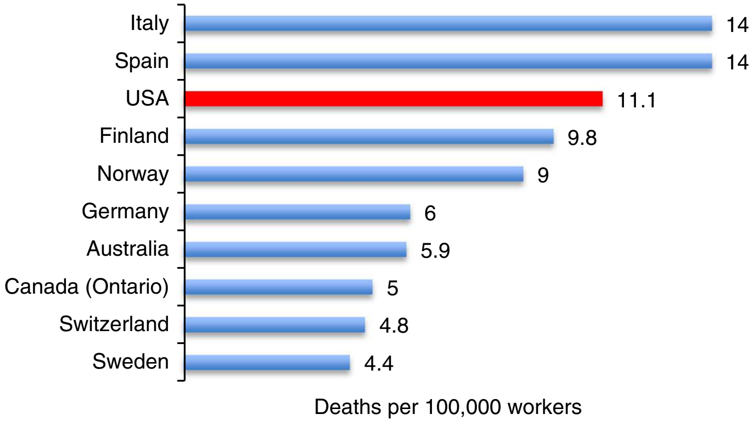
Keywords Project management, Supply chain management, Process management, Benchmarking, Occupational safety and health, Prevention through design, Design for safety

Paper type Research paper

1. Introduction

Benchmarking is the identification of a best performer in a class of processes, then adapting or adopting best practices to improve one's own performance (Kleiner, 1994b). In industry, benchmarking is a technique used to measure a firm's process performance against "best-in-class" in order to determine how to achieve higher performance levels, and the information is used to establish company goals and strategies as well as improve business processes (Shetty, 1993). This type of competitive benchmarking is performed by identifying best practices that demonstrate how performance goals can be reached (Pickering and Chambers, 1991) through the improvement of processes. Although often misapplied, the focus is on process and practices, irrespective of industrial context. That is, a manufacturing firm looking to improve its training programs could find best practices in other industries such as retail or the military as the key focus should be on the process and adaptation to the target sector (Kleiner, 1994b).

The demand for benchmarking at a firm can come from a variety of factors such as regulatory issues, liability concerns, investor concerns, competitive pressures, and public perception (Tosi *et al.*, 1973). This leads the benchmarking organization to find a "best-in-class" partner organization for a given process and assess why they are the best (Kleiner, 1994b). In the USA, occupational safety and health (OSH) in the construction industry is a potential area to benchmark best practices, because as Figure 1 shows the USA lags behind numerous countries in OSH performance (as measured by fatalities per 100,000 workers). Additionally, the lost time rate (a common metric to measure OSH performance) for 2010 was 3.9 recordable injuries per 100 workers in the USA (US Bureau



Source: Ayers *et al*. (2007)

Figure 1. Rates of deaths from construction industries from selected countries, 2005

of Labor Statistics, 2011a). This rate was in comparison to Australia (AU) in which there were 2.22 serious claims per 100 workers (Safe Work Australia, 2011). Calculated using the same method, these results represent a difference of 43 percent.

Benchmarking OSH at the national level for the USA is a potential tool for assessing contextual factors of performance. Establishing such a context is appropriate for the US construction industry because it could represent an opportunity to improve performance.

In the area of safety and health in the construction industry, literature supports the use of benchmarking as a tool to identify practices for improving performance. The tool has been useful in previous studies for identifying specific processes and practices that affect OSH performance, but these studies were at the firm or project level and did not look at industry-level factors that affected performance. This literature not only uses benchmarking to quantitatively identify factors affecting performance, but also is supported by qualitative data that explains the results. Examples of this literature include:

- Jaselskis *et al.* (1996) reviewed project-level safety data and compared 48 company and 69 project-specific safety programs to identify best practices. The analysis identified multiple company and project-specific factors that were statistically significant in improving safety performance.
- de la Garza *et al.* (1998) used workers' compensation data to compare how size affected OSH performance, if rates differed for firms that used performance measurement principles to track accidents vs those who did not, and if rates differed between union vs non-union workers for 44 contractors in the USA. The result of the study is a list of nine best practices in this area that should be adopted in order to improve OSH performance.
- Lin and Mills using benchmarking with a sample of 44 companies to also determine how size affected OSH for maintenance construction workers in Victoria, AU. The results showed that size did matter in terms of OSH performance, and the authors discuss how future research should investigate specific processes and practices that lead to the performance gap.
- Fang and Huang (2004) using the method to identify management practices that affect OSH performance in China on 82 construction projects. The result was a safety assessment method that was applied on six construction projects, and which was effective in detecting poor safety management practices.
- Ramirez *et al.* (2004) using benchmarking of 13 companies in Chile to identify safety management system processes that potentially lead to increased OSH. The study identifies four areas that lead to better performance, and discusses how other companies can evaluate their own performance by using the qualitative benchmarking process in the paper.
- El-Mashaleh *et al.* (2010) using data envelope analysis to benchmark safety data between 44 contractors in Jordan. This process was useful in identifying high performing projects, and the authors discuss how the next step is the identification and analysis of specific processes within a project that lead to the performance differences.

This literature can be used as a foundation for using project-level data as a sample to compare process and practices at the international level. In this context, groups of projects can be compared similarly to identify differences in how OSH is approached between the USA and a benchmark partner that might explain the performance gap. In order to benchmark these factors, this work conducts a comparative analysis of OSH best practices, controlled across project lifecycle and within a sample of similar projects in both the USA and AU. A benchmarking process adapted from Camp (1989) by Kleiner (1994b) is used to guide this manuscript, and will be adapted where necessary for benchmarking at the national (rather than organizational) level. We also use qualitative examples from the sample to support the quantitative results as a mixed method toward explaining higher incidence rates in the USA. The aim of the research process is to identify potential differences in preventative design practices between the USA and AU that could explain gaps in OSH performance.

2. The benchmarking process

As mentioned previously, traditional benchmarking often focusses on comparison at the firm level with a focus on processes. These methods can be adapted to understand safety at the national level as well. Figure 2 illustrates a generic benchmarking process that was adapted from Camp (1989) and presented by Kleiner (1994b). This adaptation was for environmental restoration, which is largely comprised of construction

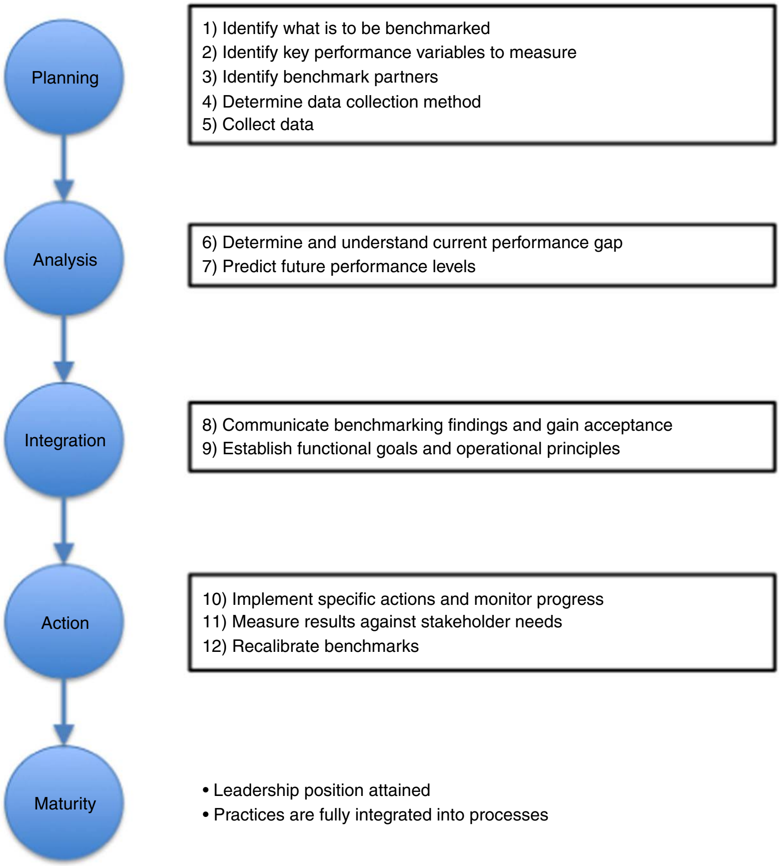


Figure 2.
Benchmarking process

(i.e. heavy earth moving) processes. The specific steps in Figure 2 align with a benchmarking process developed specifically for the construction industry (Garnett and Pickrell, 2000).

The focus in this paper will be on the "planning" and "analysis" steps shown in Figure 2 (the first and second circles from the top down). The emphasis will be on these early stages in order to explore how the benchmark partner addresses safety and potential practices that could be adopted or adapted within the USA. Later stages of benchmarking, often dealing with implementation, will be addressed in the conclusions section.

2.1 Need identification

As discussed previously, others have previously benchmarked OSH in the construction industry, as the USA lags behind other industrialized countries, such as AU, in terms of OSH performance. Benchmarking facilitates the identification of potential sources of this performance gap, and OSH quantitative factors such as lost time rate and fatalities can be used to quantify the extent of the performance gap. This level of analysis highlights the gap, allowing goal setting, but is not conducive to identifying factors that affect processes or practices, as it is difficult to identify potential roots causes or processes leading to these differences. Therefore, the researchers must perform a deeper level of analysis, using methods appropriate for capturing relevant data, which can identify differences in practices between the benchmark partners.

The research team, funded by a US National Institute of Occupational Safety and Health (NIOSH) grant, included faculty and industry experts from both Virginia Tech (Virginia, USA) and RMIT University (Melbourne, AU). Team members collectively possessed subject matter expertise in both the construction industry and OSH in both countries. The team conducted field visits together in both countries, and one Australian researcher worked at both universities in their respective university construction programs.

The expert team decided to explore practices in AU that could potentially be adopted to improve performance in the USA and were related to the integration of safety in the planning and design stages of a construction project. This area was chosen because research indicates, for a sample of construction accidents, that a significant proportion of causation can be traced back to stages prior to the implementation of construction processes (Hide *et al.*, 2003; Suraji *et al.*, 2001; Behm, 2005). Work in construction business literature has also verified that appropriate decisions and actions in the early stages of process development can have significant benefits downstream, and the focus on design is also consistent with the prevention through design movement in the USA (e.g. NIOSH www.niosh.gov).

2.2 Data collection methods

The main goal of benchmarking is the identification of best practices or processes. The construction industry has many different sectors and delivery types, and thus care must be taken to study safety decision making in design in a representative sample of the industry for external validity purposes. Individual construction projects have previously served as the unit of comparison for benchmarking research in the construction industry topics such as rework and communication using technology (Love *et al.*, 1999; Weippert *et al.*, 2002), and if similar in project delivery type and sector could allow for the comparison of design practices as they relate to OSH. Therefore sample projects for comparison needed to be diverse and representative of the construction industry at the same time. As a result, researchers categorized and collected projects by industry sector and project delivery mechanism (see Figure 3).

The team decided on a case study approach to compare across projects. Yin promoted the case study methodology as the best approach for investigating how or why phenomena occurred and relationships among these phenomena. Accordingly, the research team used case studies to discover key factors within the context of safety decisions along the delivery of the construction project. The research team began by identifying appropriate projects across nations, using purposeful sampling, which would align well with factors that aid and/or impede the adoption of safety decisions early in the delivery of a project. Once projects were determined, the team used criterion-based sampling (LeCompte and Preissle, 1993) processes to solicit proprietary knowledge on site for safety decisions and influences along the delivery process of the projects. The team then interviewed *participant-observers*, those key project stakeholders from firms who have knowledge from concept to implementation of similar projects, across the two nations and market segments for data (Yin, 2009). These data could not be obtained from other methods or subjects (Maxwell, 1996), because of the large amount of projects (including multiple stages of decisions) presented in this study sample. The US data set is presented in Table I, and the AU is shown in Table II.

2.3 Data collection

A construction project involves many features of work such as site preparation, excavation, structural assembly, etc. Collecting data on design relative to all of these features would make the volume of data, including the required time, extensive. Thus, 2-3 "features of work" that contained safety hazards for each project were identified as criteria within which data were collected. The identification process began through conversations with project personnel, where features of work were identified and then data were collected in an interview format, across key project stakeholders such as constructors, designers, and owners. Decisions for a given feature of work were collected and documented upstream to where initial hazard control decisions originated or were impacted. Each case was then broken down into a set of hazards that were

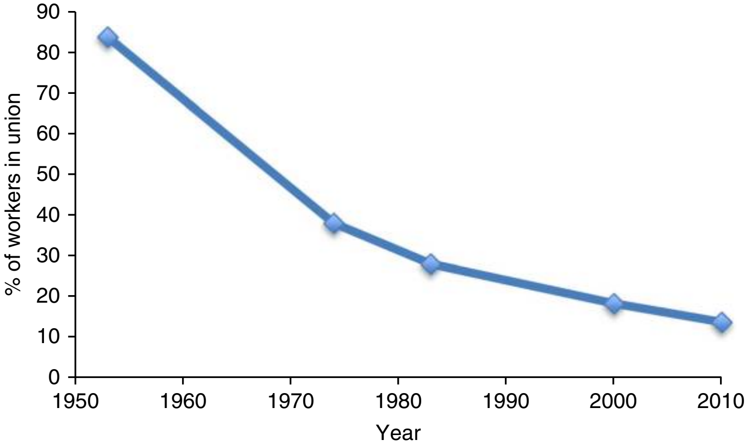


Figure 3.
US construction industry unionization rate

Project	Case (feature of work)	Descriptions
Football stadium	Foundation system	Excavation and installation of micro-pile foundation system adjacent to existing parking garage and around existing utilities
	Steel superstructure	Demolition of existing stands and steel erection of new seating structures and press box
Psychiatric hospital	Exterior pre-cast concrete panels	Lift and place of pre-cast concrete panels on exterior and attachment to structural steel
	Roof structure and barricades	Installation of roof membrane and construction of permanent roof barricades around HVAC
House construction	Exterior structures (basement, exterior walls, roof)	Pre-fabrication and construction of exterior and interior walls and roof structure
Waste water tank	Pre-stressed concrete steel tank	Excavation and shoring of tank location and construction of pre-stressed concrete tank
	Sewer trunk line across creek	Installation of sewer trunk line across creek from barge using divers
Design-build house	Exterior structures (basement, exterior walls, roof)	Site excavation, installation of pre-formed concrete basement, and construction of exterior walls and roof structure
Server farm	Demolition of existing structure	Demolition of existing one-story structure and separation of waste and recyclables for LEEDS
	Gas fire suppression system	Installation of tanks, actuator valves, and distribution pipe for gas fire suppression system
College cafeteria	Foundation system	Excavation of site and construction and backfill of front retaining wall
	Steel superstructure	Delivery of steel beams and lift and place of steel structure around two adjacent buildings
Chemical plant upgrade	Steel structure for new equipment	Pre-fabrication of steel structure for new equipment and tie-in to existing plant infrastructure
Road reconstruction	Maintenance of traffic	Maintenance of traffic plan during reconstruction of 6-lane highway and re-pavement of adjacent side streets
	Utility replacement	Excavation and condemnation of existing utilities and installation of new utilities
Bridge reconstruction	Maintenance of traffic	Maintenance of traffic during removal of existing asphalt and installation of new asphalt on one lane of 4-lane bridge
New interstate	Maintenance of traffic	Maintenance of traffic on haul roads, temporary bridges, and public roads
Hospital	Steel superstructure	Lift and place of steel beams for structure
	Internal systems	Pre-fabrication of internal walls and installation of electrical and mechanical systems in building
Design-bid-build house	Exterior structures (basement, exterior walls, roof)	Site excavation, installation of pre-formed concrete basement, and construction of exterior walls and roof structure
Coal plant upgrade	Utility installation	Excavation for and installation of new utilities for recycling water for new air scrubbers
	Steel structure for duct system	Assembly and lift and place of steel supports and installation and connection of ducts for new air scrubbers

Table I.
Descriptions of US cases

ultimately controlled during the construction process. Each hazard could then serve as an observation, and categorized as to how it was controlled, when it was controlled, etc.

The multiple, comparative case study methodology using interviews was useful for collecting a large quantity of data around safety decisions evolving from the beginning to

Project	Case/feature of work	Description
Centrifuge replacement for sewerage treatment facility	Installation of centrifuge	Removing 2 old centrifuges and installing one larger centrifuge to replace them
	Pipe works	Upgrading and installation of new pipes to connect the new centrifuge to the existing infrastructure
	Installation of a steel platform	Erection and installation of a steel platform over a void to provide access around the centrifuge for maintenance
Theatre demolition	Demolition	Demolition of a standalone lecture theatre to open up the area in preparation for future work
Public space landscaping	Landscaping	Landscaping an open square area using colored artificial turf to create a geometric overlay
42-story residential Complex	Construction/installation of WRAP façade	Construction/installation of a self-supporting, architectural façade element with steel and RC members connected to the exterior of the building
	Construction of internal stair egress	Construction of a "U" shape stair egress around the central building core with alternative landings between each floor to comply with fire regulations
Manufacturing facility	Roof and wall cladding	Installation of roof panels/sheets and skylights on roof structure, wall panels and openings
	Erecting/installation of roof structure	Construction and installation of main spine trusses and trussed rafters for roof structure
	Erection/installation of steel columns	Erection/installation of four rows steel columns
	Construction of foundation system	Excavation and construction of pad foundations
Food processing plant reconstruction	Steel columns	Strengthening of the existing steel structure
	Sewerage disposal system	Installation of a new system for treatment/disposal of waste water with higher capacity and efficiency
	Fire wall	Construction of a fire wall as well as fire tunnels inside the production facility to comply with fire regulations
Cemetery mausoleum	Construction of basement mausoleum	Construction of basement mausoleum including excavation, temporary works, retaining walls, roof slab, finishing and mechanical works
Suburban train station	Construction of RC columns	Construction of RC columns supporting a pedestrian access bridge
	Construction of ramp access	Construction of a ramp accessing the platform
	Construction of platform and supporting columns	Construction of a concrete platform with steel frame and its supporting columns and foundation
Water pumping station upgrade	Construction of wet well	Construction and installation of an RC tank and pipework
	Construction of valve chamber	Construction of valve chamber including concrete walls and a base slab

(*continued*)

Table II.
Descriptions of Australian cases

Table II.

Project	Case/feature of work	Description
Flood recovery works	Construction of a retaining wall on site 1	Data collection, clearing works, building access road on site 1 and construction of a gabion wall and its foundation
	Construction of a retaining wall on site 6	Data collection, clearing works, building access road on site 6 and construction of a gabion wall and its foundation
	Rectification of a pedestrian bridge	Installation of temporary works and elevation of a bridge deck over a creek

the end of a project's delivery process. These data had to be converted however to a form that can convey key decision points in the process while still being concise enough to allow comparison between projects. As a result, the team used process mapping for benchmarking specific processes in the construction industry at the project level such as the timing of the procurement process (Winch and Carr, 2001). This method was useful for temporal comparisons of features in the project lifecycle, but could be built upon to address other factors, such as a lack of choosing alternative options and the key decision influences of specific actions that were taken for in-depth analysis of the decision-making process.

Upon creating process maps for project features of work, the project team in each country reduced the maps to a set of hazards that could be categorized according to the feature, the hazard control category according to the hierarchy of control (HOC), time (when it was controlled), the decision maker of the control (project stakeholder), and the type of hazard. Figure 4 and Table I, illustrate the data reduction for pre-cast concrete panels of a psychiatric hospital in the US data set. The team used IDEF-0 for mapping features, as it is a standard method "designed to model the decisions, actions, and activities of an organization or system" (Knowledge Based Systems Inc., 2010). Another strength of the mapping method is that construction features should not be modeled as a sequence of activities, therefore dependent on the process, but rather a series of individual inputs and outputs. This distinction is important, as complex product systems, such as a construction project, often have timing in events that is non-sequential while modular to the system (Table III).

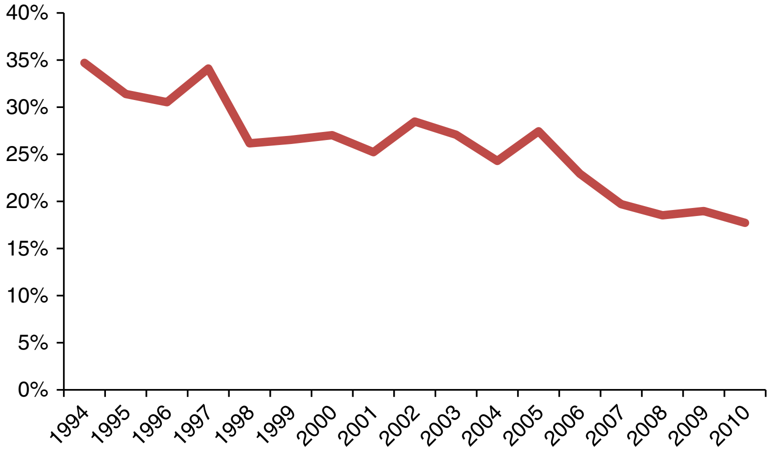


Figure 4.
AU construction industry unionization rate

Feature of work	Activity description	Work task description	Safety challenge category	Response	HOC category	Response timing
Pre-cast concrete panels	Blind wall panels lifted by crane into position at small court	Use bullhorn, spotter, roped off area when lifting x crane	Struck by object or equipment	Rules and procedures	Admin	Construction
Pre-cast concrete panels	Blind wall panels lifted by crane into position at small court	Use bullhorn, spotter, roped off area when lifting x crane	Caught in or compressed by equipment or objects	Rules and procedures	Admin	Construction
Pre-cast concrete panels	Visible wall panels lifted by crane into position at large court	Sequence work to leave access for crane	Struck by object or equipment	EC via job redesign	Control	Pre-construction
Pre-cast concrete panels	Visible wall panels lifted by crane into position at large court	Sequence work to leave access for crane	Caught in or compressed by equipment or objects	EC via job redesign	Eng. control	Pre-construction
Pre-cast concrete panels	Pre-cast panel structural attachment	Workers attach from second floor deck	Falls to lower level	Elimination (from ladder)	Elimination	Construction
Pre-cast concrete panels	Pre-cast panel structural attachment	Workers attach from second floor deck	Falls to lower level	PPE tying off to structure	PPE	Construction

Table III.
Categorizing hazard data for feature of work in Figure 4

With data sets representing the US and AU projects, one potential limitation is rater reliability. In our analysis, different sets of experts were rating the hazard controls in each country. In order to align the ratings as closely as possible, the international team developed a document of HOC ratings for common responses to different types of hazards. This document served as a basis for reducing as much variability between the ratings of the two countries as possible. A follow-up inter-rater reliability exercise was performed after each country had finalized their data sets in order to test the reliability of the ratings between the two groups. A list of safety challenges from one case and a description of the response to those challenges was sent from the US group to the AU group (and vice versa). Each group then rated each response blindly as to the HOC score, and then these ratings were compared to the original ratings from the expert review. The US rater gave the same rating as the AU group for 12 of 14 hazards (85.7 percent) from the AU data set, and the AU rater gave the same rating as the US group for nine of the ten hazards (90 percent) reviewed from the US data set. This level of agreement suggests that their is sufficient evidence to support the reliability of the ratings between the two groups, and allows sufficient confidence for analyzing differences in the control of hazards between the two data sets.

3. Analysis

3.1 Differences in control methods

The team initially analyzed the hypothesis that higher level controls on the HOC (technological vs behavioral) were more prevalent in AU than the USA. This analysis can be done at the feature of work case level, because each case represents a sample and the individual safety controls are the trials within each sample. The analysis also supports additional hypotheses based on the original benchmarking reasoning that AU is more advanced in implementing higher level controls than the USA. Such analysis was performed using an Analysis of Variance (ANOVA) procedure to indicate evidence of a difference in the average HOC results, by case and between countries. One of the key assumptions of this procedure is normality and the team therefore also performed a Shapiro-Wilk goodness-of-fit test. Results do not indicate enough evidence to reject the null hypothesis that the data sets are not normal (although the AU data had a value of 0.07 close to the cut-off for a 95 percent confidence level). Figure 5 presents the results of the ANOVA analysis.

The average HOC score for each case in the AU data set was 3.69 vs 2.54 for the US cases. The *p*-value from the ANOVA analysis was less than 0.0001, indicating a statistically significant difference between the two groups. The AU mean is 49 percent greater than the US mean, and interestingly there is a 47 percent difference in lost time rates between the two countries (11.1-5.9) according to recent data presented earlier. While we cannot make the assumption that controlling at a higher level is the sole cause for this discrepancy in performance, it is interesting that the differences are so close.

3.2 Differences in control implementation timing

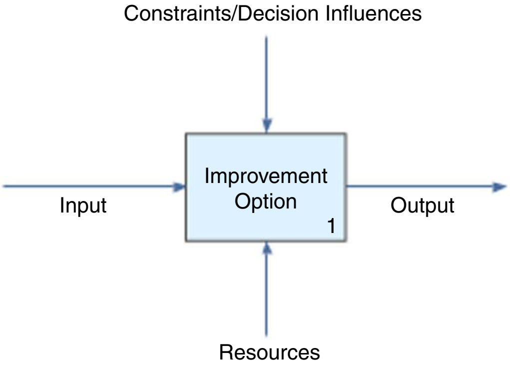
The overall percentage of hazards that were controlled in the pre-construction stages of a project (planning, conceptual design, design development, etc.) was calculated for each case. This result gives an indication of when safety is considered in the construction lifecycle. As discussed earlier, lower level controls such as PPE and administrative controls are many times the only methods feasible once the construction stage is reached. The team again performed a Shapiro-Wilk normal goodness-of-fit test on both groups, and evidence exists to reject the null hypothesis that the AU data for pre-construction response percentage is normal (goodness-of-fit *p*-value = 0.0288).

The team also performed a nonparametric version of an ANOVA (Wilcoxon Test) to explore for evidence of differences, and the results are presented in Figure 6. Results support a difference in the percentage of hazards that were addressed during pre-construction between the two countries, with the AU cases having a median of 62.5 percent of hazards controlled in pre-construction vs 27 percent in the USA. The *p*-value of 0.0028 supports the hypothesis that safety is considered earlier in the construction lifecycle in AU than in the USA.

The benchmarking data show that potential safety hazards are addressed earlier and more effectively in AU vs the USA. The team uncovered evidence of several recurring themes from the case studies that supports the findings of the previous

		Project Delivery Mechanism (Supply Chain Type)			
		Traditional (D-B-B)	Design and Construct	Accelerated	Collaborative
Industry Sector	Residential				
	Commercial				
	Industrial				
	Heavy Engineering				

Figure 5.
Data collection matrix



Notes: Constraints – 1 = efficiency (resource utilization or schedule), 2 = effectiveness (meeting project and organizational objectives or scope), 3 = productivity (output/input), 4 = quality (broadly defined), 5 = OSH and worker well-being, 6 = innovation, 7 = funding (budget and cost), 8 = regulatory (legal, external), 9 = policy (organizational and project level), 10 = other stakeholders (direct or personnel absent); Resources – 1 = personnel/manpower, 2 = machine/equipment/tools, 3 = materials, 4 = information/data, 5 = time, 6 = management, 7 = money, 8 = space (physical)

Figure 6.
IDEF-0 graphical overview

hypothesis test, and which are supported by literature in the design for safety area (Gambatese *et al.*, 2008; Behm, 2005). These themes are discussed in the following sections of this paper.

4. Discussion

Quantitative analyses support more frequency in use of technological controls implemented earlier in the project lifecycle in AU vs the USA. While this itself is not enough to prove causality for the performance gap, previous literature does support that higher level controls do lead to a safer work environment. Further, interviews also suggested differences in OSH cultures, such as legal/regulatory and labor factors between the two countries that qualitatively support a prevention through design approach and might provide an important root cause of the gap. A brief discussion follows to elaborate on differences discovered in quantitative analysis of OSH practices across countries. The qualitative discussion is meant to provide a deeper understanding and context of specific practices that are occurring in AU that support safety as a consideration earlier in the process.

4.1 Legal factors

A major difference between the USA and AU is regulations that pertain to liability for accidents. In AU, there is legislation that governs the liability of design professionals on construction projects (Rinks, 2007). In the USA, there is no such legislation that requires a design professional to consider occupational construction safety as part of the design process (Behm, 2005). In fact, anecdotal evidence suggests the opposite since designers' standard contracts (from American Institute of Architects, AIA) protect against liability for safety. As a result, designers in the USA tend to avoid OSH issues, putting the onus on the contractor (Dewlaney and Hallowell, 2012). That is, most Occupational Safety and Health Administration (OSHA) regulations in parts 1926 and 1910 place the responsibility of OSH on the constructor (Labor, 1979). While OSHA has acknowledged the importance of design on OSH (Korman, 1999), prevention through design is a major strategic initiative for NIOSH because it is believed that attention to safety upstream in design can reap benefits downstream to the health and well being of workers and occupants. Proposed legislation requiring designers to consider on site construction safety as part of the design process was challenged and was never passed, and the success of legislation that has passed is debatable due to questions over OSHA's ability to regulate design professionals in the first place (Behm, 2005). As recently as 2007, additions to AIA contractual documents were added to "entrust public safety (of the final product) to the designer" without mention of construction worker safety. Currently, Leadership in Energy and Environmental Design certification that is gaining momentum in the USA also is void of OSH foci.

Liability in the USA is primarily guided by insurance documents that specify responsibility for claims. A common phrase in the US construction industry is "means and methods," and most standard contract documents place the responsibility and supervision for this on the constructor regardless if issues were created upstream in design or if opportunities for prevention through design existed. This is counter to the well-known HOCs for safety which dictates that risk should ideally be designed out of the system as compared to administrative controls and protective personal equipment which are more relevant to means and methods of the construction phase (Holmes *et al.*, 2000). Design professionals are careful to not implicate themselves via review or approval of the construction means and methods, staying in the realm of design intent, in order to remove liability. Constructability reviews typically do not address safety as well. Designers are also careful not to "stop, direct or supervise construction work" unless contractually obligated to do so (Barker, 2010). The design/build trend challenges these traditional roles to some extent.

The introduction of new project delivery methods in the USA such as Design-Build has complicated traditional contracts and insurance documents. Generally the standard Insurance Services Office type of Commercial General Liability insurance is on the construction project, and is used to govern who is liable for means and methods and the extent that professional services such as designers are liable (Ahlers, 2010). The liability of the construction manager varies greatly depending on the type of contract used, as many times it is responsible for supervision of general safety on the site, including oversight, implementation and administration of subcontractor safety for an owner, even though it performs no direct construction work. Generally, the only universal truth in the USA as to the liability of the construction manager is that it depends upon what is stated in the contract (Block and Curran, 2010). Increasingly, liability is moving toward subcontractors and away from design intent as a mechanism to control OSH in the USA. Subcontractors are generally one of the last stakeholders brought into a project, which further pushes safety decision making until later stages in the project lifecycle.

Furthermore, courts in the USA have ruled that designers are not liable for approval of shop drawings based on standard contract documents unless the contractor notes a specific deviation. By way of example, in D.C. McClain vs Anderson County, the Supreme Court of Virginia ruled that the designer was not responsible for means and methods even though the shop drawings showed a method of post-tensioning the concrete in a bridge that was found to be dangerous. It was found that approval of the shop drawings was only to check if they met the intent of the design, and that the contractor was still wholly responsible for the means and methods of construction unless a deviation was noted (Hughes, 2006).

In AU, recent legislation has attempted to homogenize the various OSH laws around the country. The harmonized laws do not simply standardize the various OSH laws, but introduce changes designed to reflect and promote best practices. Moving away from the type of employment relationship, which determined a duty of care, the new legislation places responsibilities on those who expose others to OSH risks that arise from their undertakings or activities. While arguably difficult to implement for stakeholders such as architects and engineers, this implies their duty of care is based on the "practical" relationship of the work being undertaken, rather than legal titles or contractual arrangements. All states and territories will be aligned, thus requiring designers to consider the health and safety of persons involved in the construction, use, maintenance and demolition of a structure.

The current legal framework for managing OSH is contained in the legislation of each state and territory in AU. The approach taken by the various jurisdictions' is similar and places general duties on employers and designers, whereby measures which prevent workplace accidents, injuries and illnesses are to be planned for and implemented, "so far as is reasonably practicable." Practical application means that evidence is required to show that the level of risk to health and safety is proportional to the degree of effort exerted in controlling the risk. Risk assessment during the construction lifecycle by performing safety reviews of the design is therefore an essential part of ensuring compliance with the legislation.

While the legal framework adopted across AU appears to be similar, a review of the technical detail and its application highlights the disparity between states and territories. This is particularly apparent in the regulation of designers, where some jurisdictions have specific statutory obligations for OSH, while other states and territories have none. Further, specific requirements for construction designers differ between the jurisdictions that place responsibility on designers. For example, Western AU requires designers to consider the OSH of persons who will construct the building/structure, while others (e.g. Victoria) establish responsibilities for the OSH of persons who use the building/structure being designed as a workplace, implying that only the OSH of end users needs to be addressed.

The lack of national consistency in OSH legislation has led to "unnecessary complexity and often, inconsistencies" in AU. Recently, steps have been taken to establish a uniform, national OSH legislation. The harmonization of OSH legislation aims to produce a model principal OSH Act, supported by standard regulations and codes of practice that can be readily adopted in all jurisdictions. While each state and territory has agreed in principal to the concept, not all states have passed legislation to adopt the new harmonized OSH Act, however it is expected that those jurisdictions yet to commit will follow those states that implemented the changes in January of 2012.

Another change impacting designers in AU is the need for consultation and communication. Under the new harmonization legislation there is a requirement to consult, cooperate and coordinate activities with others who have a duty over the same matter such as constructors. Designers will need to consider other parties and consult on design issues by ensuring steps have been taken to not only identify and mitigate risks, but to communicate the risks to relevant stakeholders, if they are to fulfill their legislative duty of care requirements. Again, this is very different than processes and practices in the USA.

4.2 Labor force factors

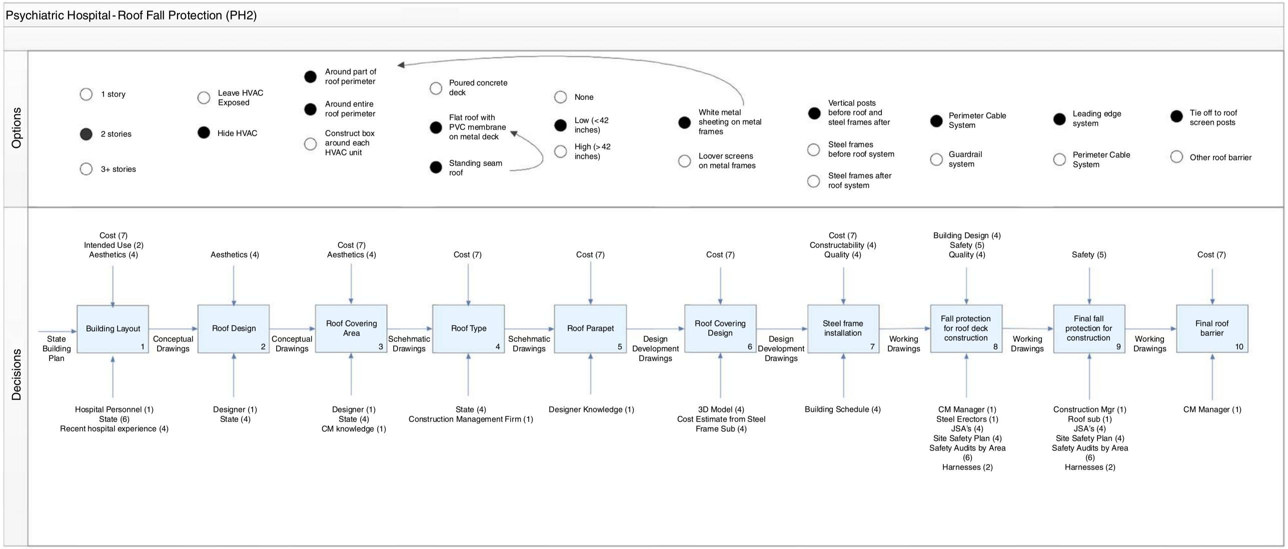
Another difference between AU and the USA is the prevalence of unionization in certain parts of the industry. It is often perceived that density in AU is much higher in the USA and perhaps this is a major explanatory cause for OSH differences. The unionization rate/density (percent of possible workers that are members in a trade union) has been shown to be a good indicator of the power of labor unions in a country (Ebbinghaus and Visser, 1999). Further research would be required to determine the effect of unionization on safety between the countries, but we can use the unionization density as a proxy to measure the influence of workers in the safety planning process via safety committees.

In the USA, the percentage of construction workers in a trade union is 14 percent (US Bureau of Labor Statistics, 2011b). Membership has also declined steadily since it reached its peak in the 1950's (see Figure 7). In their cross-national study on the decline of labor unions in the USA, Sano and Williamson (2008) discussed numerous political and economic reasons that have contributed to the decline such as the business cycle, globalization, inflation, strike activity, domestic institutions, "corporatism," and social and demographic shifts. Sano and Williamson (2008) discussed how much of the union strategy in the USA in fighting the decline has been focussed on globalization, while countries with a higher union density have focussed on having more of a national voice between unions and benefits-based recruiting. Previous work has shown that union workers reported higher levels of positive safety processes such as safety training when being hired, regular safety meetings, and risk and hazard perception recognition skills (Gillen *et al.*, 2002).

In AU 18 percent of the workforce in the construction industry is a member of a trade union (Australian Bureau of Statistics, 2010a). As shown in Table IV, AU has seen a decrease in trade union membership similar to the U.S. The difference in union density is 4 percent between the countries, but this difference is not large enough at first glance to suggest a drastic difference in influence by trade unions in AU vs the USA.

However, closer inspection of specific groups within the construction industry as shown in Table I reveals a possible source of unionization that could be a source of some differences in OSH practices. The union density of trade workers is very similar, but laborers have a much higher density in AU than in the USA. Even linearly adjusting for the 23 percent decline in union density in the Australian construction industry since the study gives a union density of 29 percent for Australian laborers (a linear adjustment was made in absence of other evidence and to be conservative in the current estimate of AU union density). This density is still 165 percent higher than the 11 percent of laborers that are members of a union in the USA for the same time period. A bottom-up characteristic, such as this, might be indicative of safety awareness, as unions are known for educating workers in safety. Further, such a characteristic could indicate broad support of safety goals on projects, with centralized dissemination of safety information toward these goals. Again, we present this difference not to justify the difference in safety performance, but as another indicator of potential process differences explained below that might explain part of the performance gap (Table V).

Further, this level of trade union representation, and the differences in resulting power at a basic level, is a possible explanatory factor for legislative differences, such as safety committees, that are required on projects in highly unionized Australian regions. Safety committees are required, as they promote collaboration in a cross-functional team setting. Safety committees meet early in, and throughout, the delivery



Sources: Friedman (2010), US Bureau of Labor Statistics (2011b)

Figure 7.
Decision map for roof structure of mental hospital

Table IV. Social networking questionnaire

Stage	Role	How often did you communicate with this person regarding information that impacted or could have impacted safety or risk of incidents/near incidents?	Did you send information to this person that impacted or could have impacted safety or the risk of incidents/near incidents?	Did you receive information from this person that impacted or could have impacted safety or the risk of incidents/near incidents?	How strong was the influence of this person on decisions that impacted or could have impacted safety or the risk of incidents/near incidents?
		Daily Weekly Monthly or greater	Yes/no	Yes/no	Little to no influence Moderate influence Strong influence

Sources: Australian Bureau of Statistics (2005, 2010a, b)

Table V. Membership by construction occupation

Country	Construction trades workers	Construction laborers
USA	20.9% (2010)	10.8% (2010)
Australia	20.3% (2009)	37.0% (2006)

Source: Worksafe Victoria (2006)

process and include management and workers, typically with 50 percent of the members affiliated or representing union organizations on site. These committees are required of employers in Victoria, for example, if the required Health and Safety Representative for the union requests their establishment. Their stated goal is to create a healthy environment between management and employees, and unions being able to request these committees could explain why they were more prevalent in the data set in AU vs the USA. Regardless of their source, this type of practice is another example of safety being part of the decision-making process earlier in AU, and is a potential mechanism to better integrate this type of behavior in the USA.

5. Conclusion

Data show that the USA lags behind countries such as AU, Canada, and Germany in terms of OSH performance, commonly gauged in fatalities per 100,000 workers. The researchers applied a benchmarking process that has been used in manufacturing and logistics sectors since inception in the 1980s (Kleiner, 1994b) and adapted by Kleiner (1994a) for federal facilities' environmental restoration safety concerns at the country and organizational levels to identify possible explanations for the performance gap and paths forward. The work identified a significant performance gap between the USA and AU and explored contextual factors. Then, using a multiple, comparative case study method, the researchers analyzed process-level differences. Results suggest that in AU safety decisions were generally made further upstream than in the USA. Technological controls were implemented more frequently and earlier in the project lifecycle in AU vs the USA. These types of interventions are regarded in the literature as more effective, and are a potential source of the gap in OSH performance between the two countries. Implementation of these types of practices is a complex undertaking at the national level, but is a potential avenue for closing the gap in both fatal and non-fatal construction injuries in the USA.

Data indicate that the decision process in the USA was more compliance based, in which safety is considered as construction means and methods are developed. Data indicate that the Australian construction worker safety was more integrated into the decision process earlier, as safety committees and safety in design meetings were both witnessed on the AU project set. As discussed, responsibility for OSH is a major difference between the two countries. As an innovative process, design for safety in OSH could benefit from a top down "broker," as in the Australian industry. In the USA, lack of this champion seems to push such OSH risks down the chain, relegating liability to various pieces of the fragmented industry without a uniform solution. Benchmarking against the Australian system provided best practice in terms of examples in uniform legislation and union-based labor practices that lead to a more safety-conscience workforce, and aligns with culture change literature that states policy changes are a mechanism for quickly changing culture (Cummings and Worley, 2009). While advocating new legislation or an increase in union membership is outside the scope of this paper, the behavior that a more engaged workforce can have on construction safety is an avenue to addressing potential hazards earlier in the project lifecycle. Specific practices such as safety committees with worker representation and safety in design meetings at different project milestones are however practical tools that can be used in the USA to better integrate safety earlier in the decision-making process.

Future papers will address specific research-to-practice recommendations for US adoption or adaptation, role differences in how safety and health risk is perceived, how integration of stakeholders affects OSH, and quantitative validation of the time-safety curve (Figure 8).

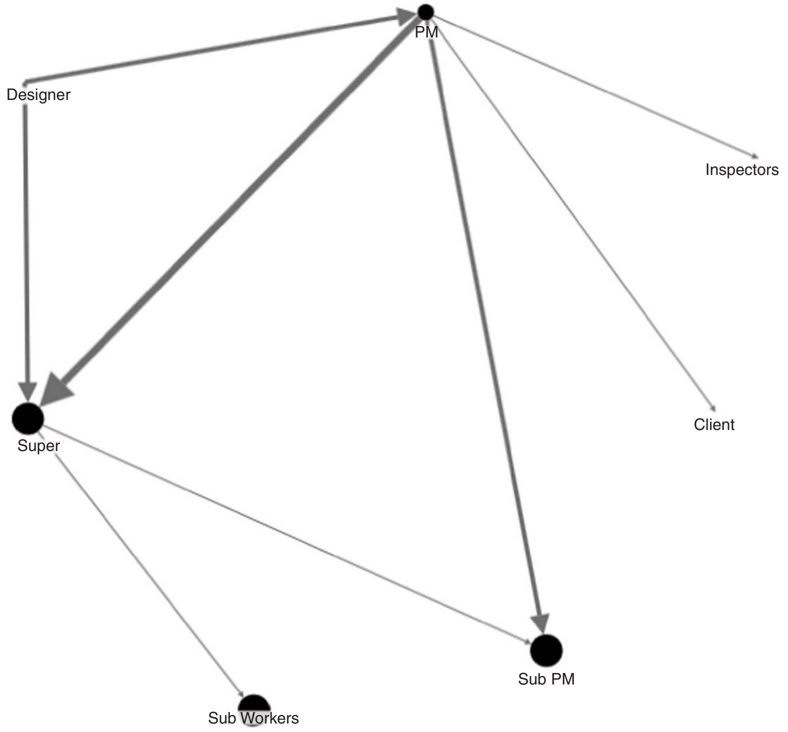


Figure 8.
Social network diagram for residential project of construction stage

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