# Perception Differences between Contractors and Owners Regarding Drivers of Construction Safety

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**Abstract** Perceptions about the impact of practices on construction project safety can vary based on the role of the organization on the project. The difference between contractors and owners on what is perceived as important could have an impact on the safety performance of the project. The authors have developed an Operational Excellence Model (OEM) to assess the degree safety related practices are employed on a project. The OEM contains 12 main safety drivers chosen by construction safety experts. In order to evaluate the perception difference, a questionnaire was developed and the data was analyzed using an Analytical Hierarchy Process (AHP). The primary contribution to the body of knowledge is evaluating the perceptions of contractors and owners about the influence that specific practices have on construction safety. The results show that three safety drivers are significantly different between contractors and owners, which are learning organization, training and competence, and owner's role, which could lead to poor safety outcomes in those areas.

**Keywords** Construction Safety, Operational Excellence, Operational Excellence Model (OEM), Analytical Hierarchy Process (AHP), Safety Perception

## 1. Introduction

The construction industry is one of the most hazardous industries in the United States (Edwards and Nicholas, 2002). Although the trend of construction accidents has recently decreased (Huang and Hinze, 2006), there is still room for improvement. Construction accidents account for 30-40% of all fatalities worldwide (Sunindijo and Zou, 2011) and 20% of all fatalities in the United States (Center of Fatal Occupational Injuries, 2003). The United States is third in industrialized countries in terms of an occupational fatality rate (Georgine et al., 1997). In terms of cost, construction accident costs vary between 7.9% to 15.0% of the total project cost in non-residential projects (Everett and Jr, 1996). In medical case injuries, the indirect cost of injuries could rise to 20.3 times of the direct cost of injuries (Hinze and Applegate, 1991). Both researchers and practitioners seek improvements in safety, but unsafe conditions continue to plague the industry.

Traditionally, construction safety is the sole duty of the prime or general contractor (Tymvios and Gambatese, 2015). This claim is further supported by the Occupational Safety and Health Administration (OSHA), which states that employers are responsible for safe work place of their employees (Hinze and Wiegand, 1992). The other problem that has created a gap between safety responsibilities of parties involved in construction is conventional contracting method such as design-bid-build (Tymvios and Gambatese, 2015). Owners traditionally are not involved in the construction process. However, owners are becoming more active and participating in safety management issues through each phase of the project (Huang and Hinze, 2006), which according to Jazayeri and Dadi (2017), recently, safety management systems have adopted owner's role as part of their core elements. According to Huang and Hinze (2006), owners can have a positive influence on safety performance of the project. Subsequently, investigating their perceptions regarding construction safety and comparing that with contractors is a valuable exercise.

Safety perception has different definitions. For example, Griffin and Neal (2000) defines safety perception as "how workers view safety related policies, procedures, and practices and other workplace attributes concerned with safety". Reese and Eidson (2006) correlates safety perception to "accident rates, quality of the safety climate, worker's working attitude, management and equipment, organizational culture and management support". In the past, owners and designers tried not to involve and interfere in construction safety to avoid liability. Recently, all parties have realized that to achieve a zero accident goal they should all dedicate resources (Huang and Hinze, 2006). Having uncertainty about safety roles in construction codes and regulations (Toole, 2002) could lead to different perceptions in parties about construction safety. Workers react to hazards the way they perceive hazards (Kahneman, 1982), thus, their

perceptions effect their decision making process which could lead to injuries (Rundmo, 1995). However, management perceptions and worker perceptions about safety and risk is not always the same (Gilkey et al., 2011) (Pungvongsanuraks and Chinda, 2010), but recognizing the safety perception in upper management is crucial due to their decision making power. Safety perception among workers research have been conducted in the past, but there is lack of research about safety perceptions among parties involved in construction. The primary objective of this research is to discuss safety perceptions between owners and contractors regarding safety procedures and practices based on the Operational Excellence Model (OEM) developed by the authors (Liu et al., 2015).

## 2. Operational Excellence

The Operational Excellence (OE) concept has been used in a variety of industries to improve execution and performance of the work across the organization. The concept has not been defined well for the construction industry. One of the main reasons is the uniqueness of the industry due to its dynamic and temporary work environment.

This concept leads organizations to desired outcomes such as performance, safety, quality. The first research on Operational Excellence (Operational Effectiveness) was by Porter (Porter and Advantage, 1985). Bigelow (2002) believes that operational excellence needs three pillars; establishing requirements, communicating requirements, and assessing requirements. According to (Liu et al., 2017), creation of a culture focused on safety and operational excellence gives the basis for progression and sustainable improvement in safety performance. According to Gleich (2008), OE is "the dynamic capability to realize effective and efficient core process in the value creation chain utilizing technological, cultural, and organizational factors in an integrative way and based on the respective strategy". Another OE definition from Sutton (2012) states that it focuses on maximizing the value that being delivered to the customer through leadership power, power of people, and the use of best practices.

Operational excellence can be defined and interpreted in each industry. Basu (2004) defines operational excellence as "a broader program of improving and sustaining business performance in which quality management is embedded". According to Jaeger et al. (2014), "Most Operational Excellence literature is dominated by pursuit if activities to strip away waste and nonvalue-added activities to attain efficient and frictionless process". Based on all these

definitions mentioned in this section, the goal of operational excellence is to engage all the members of the organization to do the right thing, the right way, every time, and even no one is watching. Subsequently, a model of OE for construction project safety helps project participants gauge their holistic level of commitment to safe outcomes.
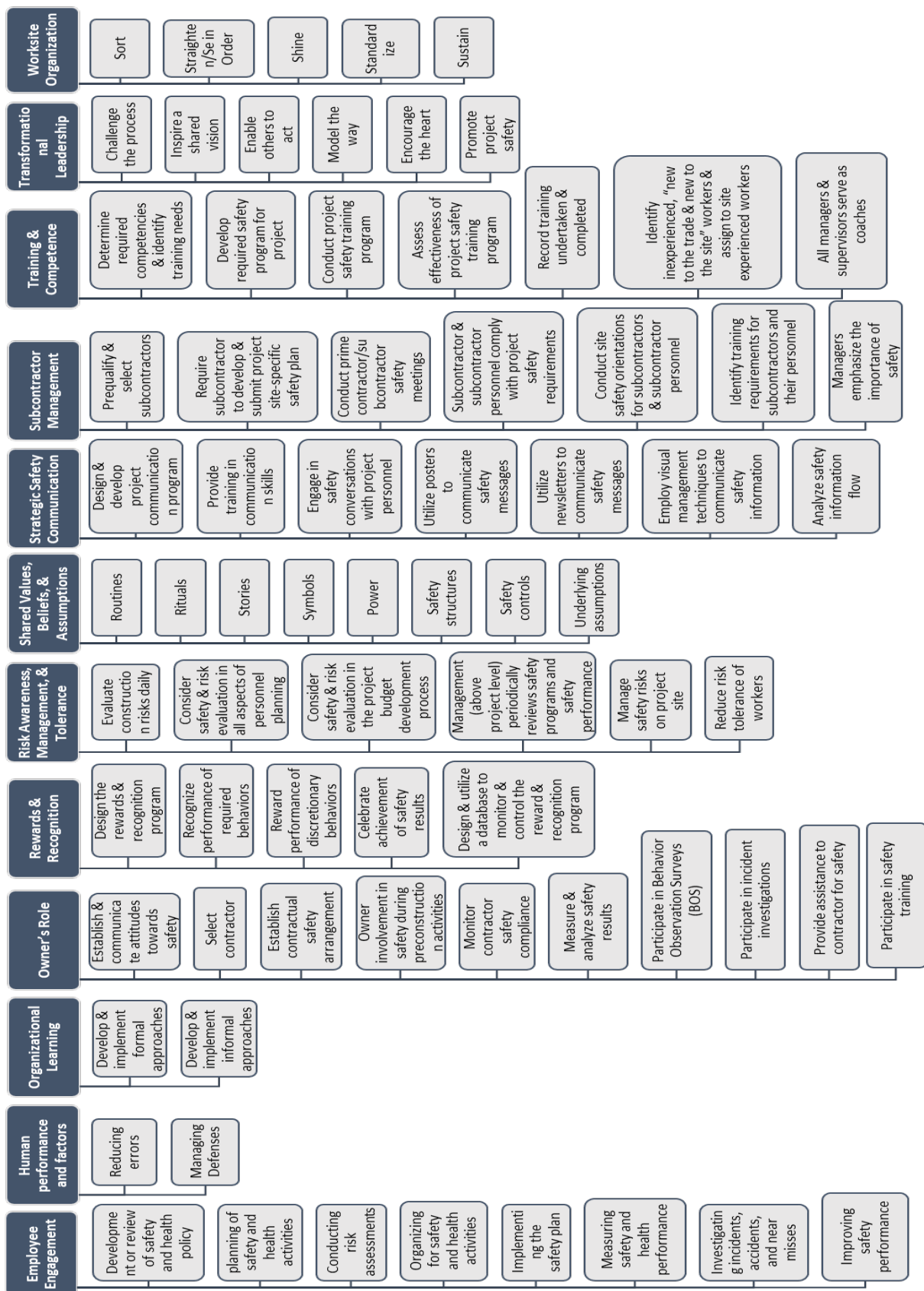
## 3. Operational Excellence Model

The Operational Excellence Model (OEM) is based on the Six Sigma Critical to Quality (CTQ) tree concept (Van Aartsengel and Kurtoglu, 2013), since it is used to break broad objectives into smaller, quantifiable elements. To achieve the Operational Excellence Model (OEM), the research team conducted a two-step validation method. After having eight face-to-face internal review session and webinars with an industry research team, a preliminary model was produced. Outside subject professionals, Construction Industry Institute (CII) member companies, and Construction Users Roundtable (CURT) member companies provided additional input through a survey. The extensive survey of the importance of the contents of the model helped validate the conceptual model. Details about this process can be found in Liu et al. (2015).

The model has four different levels. The first level is comprised of Safety Drivers (SD) that are used for evaluating the performance of safety program. The next level is Critical to Safety (CTS), which are specific elements to define their corresponding SDs. The third level is Critical to Expectation (CTX), which are behaviors and processes that should be applied and implemented to achieve its CTS. The basic level of the model is Specifications/Measurements (S/M), which help quantify the level of achievement in the corresponding CTXs. The last version of the Operational Excellence Model (OEM) includes 12 SDs, 75 CTSs, 256 CTXs, and 293 S/Ms. Figure 1 below shows the list of SDs and their corresponding CTSs (CTXs and S/Ms are not included for space limitations, but can be seen in full detail in Maloney et al. (2016)).

## 4. Research Method

The research team considered several methods to establish the weight and importance of the contents of the model. The authors decided to use an Analytic Hierarchy Process (AHP) approach as the data collection is straightforward, the analysis is simple, it is an ASTM standard, and its widespread use in publications (Steuer and Na, 2003). A statistical analysis on the results of the AHP follows.

**Table 1.**　OEM Structure

**Worksite Organization**
- Sort
- Straighten/Se in Order
- Shine
- Standardize
- Sustain

**Transformational Leadership**
- Challenge the process
- Inspire a shared vision
- Enable others to act
- Model the way
- Encourage the heart
- Promote project safety

**Training & Competence**
- Determine required competencies & identify training needs
- Develop required safety program for project
- Conduct project safety training program
- Assess effectiveness of project safety training program
- Record training undertaken & completed
- Identify inexperienced, "new to the trade & new to the site" workers & assign to site experienced workers
- All managers & supervisors serve as coaches

**Subcontractor Management**
- Prequalify & select subcontractors
- Require subcontractor to develop & submit project site-specific safety plan
- Conduct prime contractor/subcontractor safety meetings
- Subcontractor & subcontractor personnel comply with project safety requirements
- Conduct site safety orientations for subcontractors & subcontractor personnel
- Identify training requirements for subcontractors and their personnel
- Managers emphasize the importance of safety

**Strategic Safety Communication**
- Design & develop project communication program
- Provide training in communication skills
- Engage in safety conversations with project personnel
- Utilize posters to communicate safety messages
- Utilize newsletters to communicate safety messages
- Employ visual management techniques to communicate safety information
- Analyze safety information flow

**Shared Values, Beliefs, & Assumptions**
- Routines
- Rituals
- Stories
- Symbols
- Power
- Safety structures
- Safety controls
- Underlying assumptions

**Risk Awareness, Management, & Tolerance**
- Evaluate construction risks daily
- Consider safety & risk evaluation in all aspects of personnel planning
- Consider safety & risk evaluation in the project budget development process
- Management (above project level) periodically reviews safety programs and safety performance
- Manage safety risks on project site
- Reduce risk tolerance of workers

**Rewards & Recognition**
- Design the rewards & recognition program
- Recognize performance of required behaviors
- Reward performance of discretionary behaviors
- Celebrate achievement of safety results
- Design & utilize a database to monitor & control the reward & recognition program

**Owner's Role**
- Establish & communicate attitudes towards safety
- Select contractor
- Establish contractual safety arrangement
- Owner involvement in safety during preconstruction activities
- Monitor contractor safety compliance
- Measure & analyze safety results
- Participate in Behavior Observation Surveys (BOS)
- Participate in incident investigations
- Provide assistance to contractor for safety
- Participate in safety training

**Organizational Learning**
- Develop & implement formal approaches
- Develop & implement informal approaches

**Human performance and factors**
- Reducing errors
- Managing Defenses

**Employee Engagement**
- Development or review of safety and health policy
- planning of safety and health activities
- Conducting risk assessments
- Organizing for safety and health activities
- Implementing the safety plan
- Measuring safety and health performance
- Investigating incidents, accidents, and near misses
- Improving safety performance

Note: Safety Drivers are shown as headers, and the sub components are CTSs.

**AHP Approach**

The critical problem in decision making is how to find priorities for elements based on their importance (Saaty, 1977). To make judgments easier for participants in this research AHP was utilized. AHP has been used widely according to Vaidya and Kumar (2006). Its applications have been conducted on selection, evaluation, benefit-cost analysis, allocations, planning and development, priority and ranking, decision making, forecasting, and medicine related fields. The aim of this research is to identify the different perceptions between contractors and owners about construction safety. There are many publications that have utilized a similar "priority and ranking" category approach. As an example, Alidi (1996) used AHP method to measure the initial viability of industrial projects. Arbel and Vargas (1993) used AHP in preference simulation and performance programming. Hafeez et al. (2002) have used AHP to determine key capabilities of a firm. Jain and Nag (1996) developed a model which was the integration of qualitative and quantitative variables via AHP. Integration of AHP with other approaches is the other feature which makes this method attractive for researchers and decision makers. Weber (1993) used AHP to automate a machine shop, so they modified the AHP to be compatible within a manufacturing environment and integrated into decision support software for microcomputers.

AHP should be developed and applied step by step. According to Zahedi (1986), using AHP in decision making problems includes four steps:

- Step 1- Breaking down the elements to develop an AHP matrix
- Step 2- Collect the input pair wise comparison data to be computed
- Step 3- Use the "eigenvalue" method to calculate relative weights of elements
- Step 4- Aggregate relative weights to have a set of weighted elements

According to Carlsson and Walden (1995), AHP has its own strengths and weaknesses like many other approaches. Some strengths are:

- AHP collects the elements under the umbrella of one single model.
- The use of pairwise comparison allows AHP users to find the relative importance of criteria and then see the relative contribution of elements to the criteria.
- Inconsistency measure allows AHP users to make sure that they are aware of the importance of any inconsistent judgments.

Weaknesses of AHP include:

- AHP users have to rely on their experiences to make a decision on pair wise comparisons. Respondents in this survey included safety experts from large, multinational organizations. Thus, this weakness should be minimized.
- A starting reference point is essential in AHP because it

could have impact on user's decisions. In this study, the intent and method of the procedure and detailed descriptions of the CTS were presented to the respondents. The thorough orientation language should allow the respondents sufficient information to formulate appropriate responses.

# 5. Analysis and Findings

*Survey Structure*

The objective of the study is to distinguish the perception of owners and contractors regarding construction safety. This was achieved by collecting data via an electronic survey. The survey was hosted by an online survey platform called Qualtrics. The survey consisted of 66 pair-wise questions followed by some demographic questions. The pairwise comparisons asked respondents to evaluate each safety driver against the other safety drivers. For an example, one of the survey questions is "How much more valuable is Employee Engagement than the Owner's Role?" Response options range from equal to strongly important based on a 1 to 5 scale. If a respondent assigns 1 to the example question, it means the Employee Engagement safety driver is as important as the Owner's Role. If a respondent assigns 5 to this question, it means that the Employee Engagement safety driver is extremely more important than the Owner's Role. Data out of each response goes to an AHP matrix template in Excel to perform data analysis. All 66 questions were shown to respondents in a random order to eliminate any bias or random responses. A consistency ratio calculation confirms this claim. This calculation is outlined in a later section of this paper. The target group for this survey were safety related positions such as safety managers and safety supervisors in owner and contractor firms.

*Demographic info*

The survey was deployed to Construction Industry Institute (CII) member organizations, Construction Roundtable Organization (CURT) member organizations, and to other employees from the research team companies. Demographic questions such as job title, industry sector, and other project details were asked. Figures 1 and 2 show the number of responses divided into their classification (Owner v. Contractor) and their sectors respectively.

*Steps through AHP process on model calculation*

To develop an AHP matrix, the calculation procedure below has been conducted in accordance with ASTM E1765.

1. Assign each cell in the 12 by 12 matrix with its corresponding question in the survey and transfer the values in the survey to the one of the 144 cells in the matrix. There are n(n-1) required judgments in each AHP matrix (n is the number of elements in the matrix which in this case is 12). Each cell in the matrix has to be more than zero and all the cells on the diagonal of the matrix are 1.
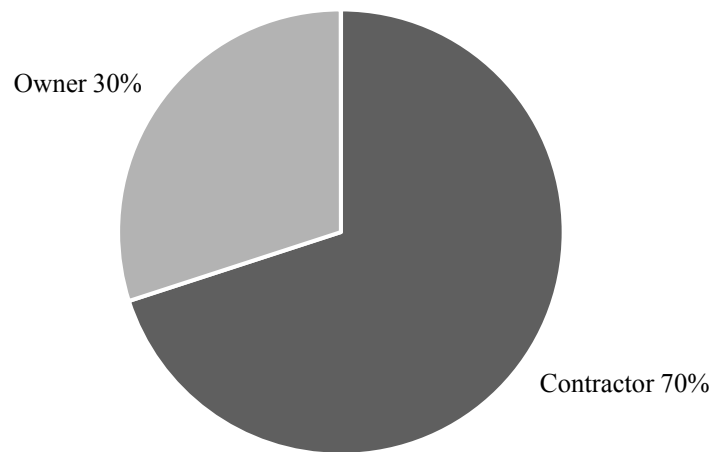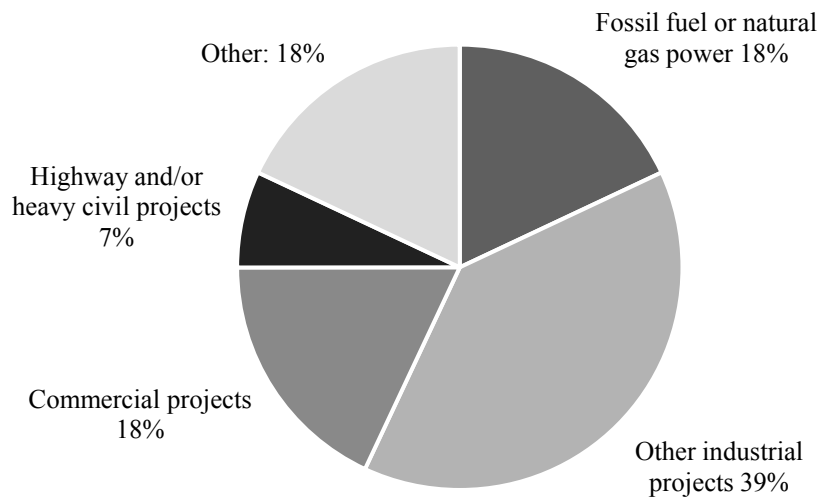
**Figure 1.** Firm Type



**Figure 2.** Firm Sector

**Table 2.** Pair-wise matrix

| - | SD1 | SD2 | SD3 | SD4 | SD5 | SD6 | SD7 | SD8 | SD9 | SD10 | SD11 | SD12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **SD1** | 1.00 | 0.33 | 0.33 | 0.31 | 0.33 | 0.42 | 0.44 | 0.38 | 0.41 | 0.45 | 0.49 | 0.40 |
| **SD2** | 3.05 | 1.00 | 0.62 | 0.47 | 0.49 | 0.83 | 0.75 | 0.60 | 0.88 | 0.79 | 0.68 | 0.63 |
| **SD3** | 3.05 | 1.60 | 1.00 | 0.48 | 0.42 | 0.54 | 0.51 | 0.46 | 0.54 | 0.66 | 0.56 | 0.51 |
| **SD4** | 3.21 | 2.11 | 2.08 | 1.00 | 0.73 | 0.92 | 0.94 | 0.62 | 0.78 | 0.86 | 0.97 | 0.62 |
| **SD5** | 3.06 | 2.03 | 2.37 | 1.37 | 1.00 | 0.85 | 0.90 | 0.55 | 0.59 | 0.89 | 0.54 | 0.57 |
| **SD6** | 2.38 | 1.21 | 1.84 | 1.09 | 1.11 | 1.00 | 077 | 0.52 | 0.60 | 0.66 | 0.53 | 0.48 |
| **SD7** | 2.29 | 1.32 | 1.95 | 1.06 | 1.11 | 1.31 | 1.00 | 0.50 | 0.55 | 0.70 | 0.75 | 0.54 |
| **SD8** | 2.60 | 1.67 | 2.17 | 1.62 | 1.82 | 1.92 | 2.00 | 1.00 | 0.55 | 0.83 | 0.60 | 0.52 |
| **SD9** | 2.45 | 1.14 | 1.86 | 1.29 | 1.69 | 1.68 | 1.83 | 1.80 | 1.00 | 0.78 | 0.68 | 0.53 |
| **SD10** | 2.21 | 1.26 | 1.52 | 1.17 | 1.12 | 1.52 | 1.43 | 1.21 | 1.28 | 1.00 | 0.73 | 0.48 |
| **SD11** | 2.05 | 1.48 | 1.79 | 1.03 | 1.86 | 1.89 | 1.33 | 1.66 | 1.47 | 1.37 | 1.00 | 0.66 |
| **SD12** | 2.52 | 1.59 | 1.95 | 1.62 | 1.75 | 2.09 | 1.86 | 1.91 | 1.89 | 2.07 | 1.51 | 1.00 |

2. Create a synthesized matrix by dividing each cell of the AHP matrix by its column sum.
3. Calculate priority vectors (weights) by calculating the mean of each row resulting in the weight for that row. In this case, there are 12 weights for our 12 Safety Drivers (See Table 2).
4. Verify the validity of the judgments with a consistency ratio. The consistency ratio shows if the judgments are consistent or not. T. Saaty (1980) suggests that the

consistency ratio should not exceed 0.1. This example results in a Consistency Ratio (CR) of 0.027, well below the 0.1 threshold. A CR above 0.1 could be due to randomized responses (Finan and Hurley, 1997).

There are 20 aggregated responses with their aggregated priority vectors (weights) for both owners and contractors. These can be seen in Tables 4 and 5.

The results of Step 2 (Developing the synthesized matrix) with priority vectors are shown in Table 3.

**Table 3.** Synthesized matrix

| - | SD1 | SD2 | SD3 | SD4 | SD5 | SD6 | SD7 | SD8 | SD9 | SD10 | SD11 | SD12 | Priority Vector |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SD1 | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | 0.03 | 0.03 | 0.03 | 0.04 | 0.04 | 0.05 | 0.06 | **0.03** |
| SD2 | 0.10 | 0.06 | 0.03 | 0.04 | 0.04 | 0.06 | 0.05 | 0.05 | 0.08 | 0.07 | 0.07 | 0.09 | **0.06** |
| SD3 | 0.10 | 0.10 | 0.05 | 0.04 | 0.03 | 0.04 | 0.04 | 0.04 | 0.05 | 0.06 | 0.06 | 0.07 | **0.06** |
| SD4 | 0.11 | 0.13 | 0.11 | 0.08 | 0.05 | 0.06 | 0.07 | 0.06 | 0.07 | 0.08 | 0.11 | 0.09 | **0.08** |
| SD5 | 0.10 | 0.12 | 0.12 | 0.11 | 0.07 | 0.06 | 0.07 | 0.05 | 0.06 | 0.08 | 0.06 | 0.08 | **0.08** |
| SD6 | 0.08 | 0.07 | 0.09 | 0.09 | 0.09 | 0.07 | 0.06 | 0.05 | 0.06 | 0.06 | 0.06 | 0.07 | **0.07** |
| SD7 | 0.08 | 0.08 | 0.10 | 0.08 | 0.08 | 0.09 | 0.07 | 0.04 | 0.05 | 0.06 | 0.08 | 0.08 | **0.08** |
| SD8 | 0.09 | 0.10 | 0.11 | 0.13 | 0.14 | 0.13 | 0.15 | 0.09 | 0.05 | 0.07 | 0.07 | 0.08 | **0.10** |
| SD9 | 0.08 | 0.07 | 0.10 | 0.10 | 0.13 | 0.11 | 0.13 | 0.16 | 0.09 | 0.07 | 0.08 | 0.08 | **0.10** |
| SD10 | 0.07 | 0.08 | 0.08 | 0.09 | 0.08 | 0.10 | 0.10 | 0.11 | 0.12 | 0.09 | 0.08 | 0.07 | **0.09** |
| SD11 | 0.07 | 0.09 | 0.09 | 0.08 | 0.14 | 0.13 | 0.10 | 0.15 | 0.14 | 0.12 | 0.11 | 0.10 | **0.11** |
| SD12 | 0.08 | 0.09 | 0.10 | 0.13 | 0.13 | 0.14 | 0.13 | 0.17 | 0.18 | 0.19 | 0.17 | 0.14 | **0.14** |

**Table 4.** Contractors pair-wise comparison mean

| - | SD1 | SD2 | SD3 | SD4 | SD5 | SD6 | SD7 | SD8 | SD9 | SD10 | SD11 | SD12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SD1 | 1.00 | 0.36 | 0.56 | 0.58 | 0.65 | 0.51 | 0.83 | 0.73 | 0.44 | 1.09 | 0.68 | 0.93 |
| SD2 | 3.29 | 1.00 | 1.08 | 0.81 | 0.97 | 1.43 | 1.63 | 1.37 | 1.29 | 1.55 | 1.08 | 1.69 |
| SD3 | 3.00 | 1.80 | 1.00 | 0.61 | 0.69 | 0.97 | 0.82 | 0.90 | 0.98 | 1.21 | 1.16 | 0.96 |
| SD4 | 3.23 | 2.16 | 2.14 | 1.00 | 1.45 | 1.74 | 1.92 | 1.43 | 1.36 | 1.57 | 1.76 | 1.57 |
| SD5 | 3.09 | 1.97 | 2.17 | 1.10 | 1.00 | 1.62 | 1.49 | 1.01 | 1.01 | 1.71 | 1.26 | 1.21 |
| SD6 | 2.75 | 1.37 | 1.84 | 0.99 | 1.19 | 1.00 | 1.35 | 1.29 | 1.00 | 1.38 | 0.94 | 0.73 |
| SD7 | 2.27 | 1.44 | 2.00 | 0.88 | 1.17 | 1.49 | 1.00 | 0.97 | 0.82 | 1.34 | 1.48 | 0.95 |
| SD8 | 2.70 | 1.66 | 2.23 | 1.52 | 1.87 | 1.75 | 2.26 | 1.00 | 0.86 | 1.59 | 1.21 | 0.68 |
| SD9 | 2.57 | 1.15 | 1.84 | 1.11 | 1.63 | 1.56 | 1.92 | 1.64 | 1.00 | 1.31 | 1.17 | 1.05 |
| SD10 | 2.21 | 1.33 | 1.57 | 0.95 | 1.04 | 1.46 | 1.42 | 1.17 | 1.15 | 1.00 | 1.13 | 1.15 |
| SD11 | 2.14 | 1.41 | 1.72 | 1.01 | 2.04 | 1.75 | 1.38 | 1.51 | 1.43 | 1.47 | 1.00 | 1.72 |
| SD12 | 2.68 | 1.67 | 2.09 | 1.68 | 1.78 | 2.29 | 1.98 | 1.93 | 2.01 | 2.11 | 1.39 | 1.00 |

**Table 5.** Owners pair-wise comparison mean

| - | SD1 | SD2 | SD3 | SD4 | SD5 | SD6 | SD7 | SD8 | SD9 | SD10 | SD11 | SD12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SD1 | 1.00 | 0.45 | 0.45 | 0.30 | 0.36 | 0.77 | 0.57 | 0.51 | 0.70 | 0.48 | 0.62 | 0.92 |
| SD2 | 2.80 | 1.00 | 2.45 | 0.70 | 0.69 | 1.80 | 1.27 | 0.97 | 1.20 | 1.27 | 1.25 | 1.45 |
| SD3 | 3.00 | 1.17 | 1.00 | 0.84 | 0.35 | 0.67 | 0.57 | 0.67 | 0.80 | 0.75 | 0.62 | 1.35 |
| SD4 | 3.60 | 2.20 | 2.10 | 1.00 | 0.75 | 1.30 | 1.00 | 1.00 | 1.17 | 1.32 | 1.40 | 1.47 |
| SD5 | 3.20 | 2.40 | 3.20 | 1.80 | 1.00 | 1.30 | 1.50 | 1.07 | 1.00 | 1.55 | 1.50 | 1.45 |
| SD6 | 1.60 | 0.75 | 1.80 | 1.07 | 1.00 | 1.00 | 0.60 | 0.67 | 0.67 | 0.95 | 0.77 | 1.65 |
| SD7 | 2.00 | 1.27 | 2.00 | 1.30 | 0.97 | 0.60 | 1.00 | 0.97 | 0.67 | 1.13 | 0.87 | 1.05 |
| SD8 | 2.60 | 1.50 | 1.80 | 1.30 | 1.30 | 1.80 | 1.50 | 1.00 | 1.13 | 1.20 | 0.97 | 1.55 |
| SD9 | 2.30 | 0.90 | 1.70 | 1.47 | 1.67 | 1.80 | 1.80 | 2.05 | 1.00 | 1.47 | 1.20 | 1.45 |
| SD10 | 2.60 | 1.27 | 1.80 | 1.77 | 1.53 | 1.70 | 1.67 | 0.90 | 1.25 | 1.00 | 1.10 | 1.15 |
| SD11 | 2.20 | 1.47 | 2.20 | 0.87 | 0.97 | 1.90 | 1.40 | 1.50 | 1.27 | 1.10 | 1.00 | 1.35 |
| SD12 | 2.27 | 1.37 | 1.57 | 1.25 | 1.45 | 1.35 | 1.50 | 1.64 | 1.37 | 1.67 | 1.65 | 1.00 |

To distinguish the preliminary differences between owners and contractors individually and aggregately, both owners' weight and contractors' weight have been calculated separately. These can be seen in Tables 4 and 5 for contractors and owners respectively.

Each respondent has a 12 by 12 pair-wise comparison matrix, the mean of each cell for each group has been calculated and gathered in new tables which are shown in Table 4 and 5. AHP calculation for each group (Owner, Contractor) has been conducted and the weights for contractor and owner group have been demonstrated separately. Based on the difference of mean, pair-wise comparisons between Owners and Contractor shown in Table 6 as their rank order of importance, there could be a potential difference between the weights assigned for Safety Drivers in each group.

**Table 6.** Rank Order Weights for all the Safety Drivers

| Safety Driver (SD) | Rank Order Importance (Contractor) | Rank Order Importance (Owner) |
|---|---|---|
| Recognition and Rewards | 12 | 12 |
| Employee Engagement | 7 | 8 |
| Subcontractor Management | 11 | 11 |
| Training and Competence | 1 | 7 |
| Risk Awareness, Management & Tolerance | 6 | 4 |
| Learning Organization | 9 | 10 |
| Human Performance and Factors | 10 | 9 |
| Transformational Leadership | 2 | 5 |
| Shared Values, Beliefs, and Assumptions | 4 | 2 |
| Strategic Safety Communication | 8 | 6 |
| Worksite Organization | 3 | 3 |
| Owner's Role | 5 | 1 |

**Table 7.** Mean differences for all the Safety Drivers

| Safety Driver (SD) | Mean (Contractor) | Mean (Owner) | P-value |
|---|---|---|---|
| Recognition and Rewards | 0.0393 | 0.0370 | 0.322 |
| Employee Engagement | 0.0815 | 0.0820 | 0.491 |
| Subcontractor Management | 0.0648 | 0.0591 | 0.314 |
| Training and Competence | 0.1196 | 0.0825 | 0.047* |
| Risk Awareness, Management & Tolerance | 0.0879 | 0.0978 | 0.300 |
| Learning Organization | 0.0761 | 0.0637 | 0.049* |
| Human Performance and Factors | 0.0752 | 0.0745 | 0.475 |
| Transformational Leadership | 0.0942 | 0.0977 | 0.416 |
| Shared Values, Beliefs, and Assumptions | 0.0891 | 0.1023 | 0.191 |
| Strategic Safety Communication | 0.0783 | 0.0936 | 0.182 |
| Worksite Organization | 0.0923 | 0.1011 | 0.289 |
| Owner's Role | 0.0882 | 0.1523 | 0.024* |

* - significant at 95% confidence

To measure the difference between these two groups, a statistical analysis should be conducted. The authors utilized a student's T-test to evaluate the significance of difference of means between two groups. This test is also appropriate for comparing two independent groups with unequal variances and sample sizes. T-test has been conducted in SPSS statistical software. Table 7 shows the mean for contractors and owners for each single driver and the P-value associated with them.

Nine of the safety drivers did not have a statistically significant difference in their means between Owners and Contractors. This indicates that they agree on the importance of those individual safety drivers. Conversely, three have p-values less than 0.05, signaling a difference in the perception of Owners and Contractors on the impact that they have on safety performance. A discussion on those three significantly different drivers follows.

### Discussion on Learning Organization

Table 8 provides detailed results from the t-test on the Learning Organization driver. The p-value is considered significantly different between owners and contractors.

**Table 8.** Learning Organization Safety Driver T-test Result

| | Contractor | Owner |
|---|---|---|
| Mean | 0.076 | 0.064 |
| Variance | 0.00047 | 0.00010 |
| Observations | 14 | 6 |
| df | 18 | |
| t Stat | 1.74 | |
| P(T<=t) one-tail | **0.049** | |
| t Critical one-tail | 1.73 | |

To discuss the probable reasons for the significant difference between owners and contractors, a brief description of this driver follows as it was shown to respondents.

"Organizational learning is an organization-wide continuous process that enhances its collective ability to accept, make sense of, and respond to internal and external change. Organizational learning is more than the sum of the information held by employees. It requires systematic integration and collective interpretation of new knowledge that leads to collective action and involves risk taking as experimentation. To be effective, organizational learning requires both formal and informal approaches. Formal approaches include suggestion schemes, lessons learned systems, and investigation reports. Informal approaches include safety huddles, conversation between workers, and conversation with management".

Contractors rated this driver significantly higher than Owners did. This difference could be due to Owner's lack of understanding how organizational learning can tie into safety behaviors. As the driver description reads, the goal of organizational learning is to continuously improve. For an Owner, they are likely familiar with organizational learning and have their own policies in place for it, but it focuses on

their business processes and not necessarily on safety. Thus, they may not feel as if it impacts safety significantly. In addition, the formal and informal approaches that define organizational learning in this context tend to skew towards efforts made by the contractor such as safety huddles and investigation reports. Although Owner involvement in these practices can demonstrate their commitment to safety, they often do not participate in them.

Fiol and Lyles (1985) suggest there is not specific agreement among disciplines about what Organizational Learning is and how to do it. Another reason could be the rapid change that happens in construction contractor section such as new delivery methods, keeping up with new technologies, software, and materials that make contractor firms to keep up with changes by learning them and implement them in their day to day work (Dodgson, 1993).

### Discussion on Training and Competence

Table 9 provides detailed results from the t-test on the Training and Competence driver. The p-value is considered significantly different between owners and contractors.

**Table 9.**   Training and Competence Safety Driver T-test Result

|  | *Contractor* | *Owner* |
| --- | --- | --- |
| Mean | 0.12 | 0.083 |
| Variance | 0.0018 | 0.0017 |
| Observations | 14 | 6 |
| Df | 18 |  |
| t Stat | 1.84 |  |
| P(T<=t) one-tail | **0.048** |  |
| t Critical one-tail | 1.81 |  |

A brief description of this driver introduced to respondents is shown below.

> "Construction work is performed by a highly diverse workforce. Many workers have received extensive training and gained extensive experience. Many others have not. This is particularly true for training and competence for safety-related skills. Many contractors assume that the new hire has the necessary safety competencies. This is a very poor practice because the lack of necessary competencies may lead to injury and even death. It is imperative that contractors know what competencies are required and be able to assess whether the new hire possesses those competencies".

Similar to Organizational Learning, Contractors more heavily weighed the Training and Competence driver than the Owners. Table 6 rank orders the list of the drivers in their perceived level of importance. Contractors felt like training and competence is the most impactful driver towards safety, whereas Owners ranked it seventh. The authors believe that one of the reasons for these results could be the difference between the two groups. Contractor firms traditionally are more involved in training of construction workers than Owners are. However, involving both owner and contractor in training shows better safety performance (Huang and

Hinze, 2006). According to Detsimas et al. (2016), construction employees tend to use informal training rather than formal training, which could lead to safety hazards. Therefore, employees in contractor firms are likely more concerned about training and competence than Owners did. Lee and Halpin (2003) named "lack of safety training" as one of the most critical factors resulting in construction accidents. Toole (2002) has noted that lack of recognizing and avoiding job hazards stemming from lack of training is one of the root causes of construction accidents. Thus, it is imperative that owners and contractors place a strong emphasis on appropriate safety training and competency assessment for any employee expected to perform on a project.

### Discussion on Owner's role

Table 10 provides detailed results from the t-test on the Owner's Role driver. The p-value is considered significantly different between owners and contractors.

**Table 10.**   Owner's Role Safety Driver T-test Result

|  | *Contractor* | *Owner* |
| --- | --- | --- |
| Mean | 0.088 | 0.15 |
| Variance | 0.0028 | 0.0035 |
| Observations | 14 | 6 |
| df | 18 |  |
| t Stat | -2.28 |  |
| P(T<=t) one-tail | **0.024** |  |
| t Critical one-tail | 1.83 |  |

For the sake of clarification, a brief description of the Owner's role safety driver introduced to respondents is shown below.

> "Owner organizations play a critical role in safety on construction projects. An engaged owner that sets expectations for all parties, establishes a safety culture, and monitors and demands achievement of safety objectives is the model. The tone of the project is set by the owner, and this opportunity should be used to reinforce the importance of safety".

An interesting finding for this driver is that Owners weighed their involvement as more impactful than the Contractors did. Table 6 shows that the Owners believe this is the most important driver in the model, while Contractors rated it the fifth most importance driver. Given the survey participation from Owners in the industrial sector (>50%, see Figure 2) of the construction industry, these are likely some of the Owners that value involvement more than most typical Owners.

Another potential difference between these two groups could be the confusion and uncertainty of roles in the construction industry. The portion of contracts that designate safety roles and responsibilities are often in the general conditions by the American Institute of Architects (AIA) and Engineer Joint Contract Documents Committee (EJCDC). Both of these organization's documents note that safety responsibilities are with the general contractor (Toole, 2002).

According to Hinze (1997), Owners can have an impact on construction safety by selecting contractors, being involved in design stage, and participating in safety meetings during construction.

# 6. Conclusions

The primary objective of this research is to investigate perceptions between owners and contractors regarding safety procedures and practices based on an Operational Excellence Model (OEM). The authors presented the concept of Operational Excellence for construction project safety and outlined a weighting process of the model through an Analytic Hierarchy Process (AHP). The participants in the AHP weighting procedure were safety experts in both contracting and owner organizations, thus providing their respective opinions on how impactful certain practices are on improving construction safety. A statistical analysis on their weights provided feedback on the perception differences between owners and contractors.

Based on the statistical procedure, three drivers were found to have significant differences (p <0.05) in their perceptions of the impact that they have on safety between owners and contractors, while nine did not have statistically significant differences. The nine drivers that were not found to be different were Rewards and Recognition, Employee Engagement, Subcontractor Management, Risk Awareness, Human Performance, Transformational Leadership, Shared Values, Communication, and Worksite Organization. The three significantly different drivers were Organizational Learning, Training and Competence, and the Owner's Role.

Although there were no differences found between owners and contractors, they both place little value in the role that rewards and recognition programs have on safety outcomes compared to the other drivers. Based on the data, it seems that owners and contractors do not believe that rewards and recognition serve as a motivator towards desired safety behaviors. A survey of site workers is needed to understand motivating factors for safe behaviors to see if there is congruence with this finding.

Owners and contractors agree that an organized jobsite and having shared values, beliefs, and assumptions have a stronger impact on safety than the other drivers. The former is a strong behavior based safety element, while the latter is a measurement of a project's safety culture. While it may seem trivial, having a clean, organized, and ergonomic project can help avoid the frequent subconscious incident. For instance, one working at height should consciously be aware of the need for fall protection. However, a project with multiple extension cords loosely draped across a frequently travelled corridor causes a subconscious tripping hazard. In addition, it is important that labor and management share similar strong values, beliefs, and assumptions about safety. When this occurs, a resilient safety culture drives predictable, desirable, and safe behaviors on the jobsite. Safety is no longer part of the job; it is the job.

Contractors believed organizational learning was more important to influencing safety than owners did. Organizational learning is critical process towards continual improvement of an organization. An organization should seek to collect information such as lessons learned and establish a feedback mechanism that allows successes to be repeated and failures to be avoided. While owners are likely not involved in a contractor's organizational learning program, they should encourage, incentivize, and participate where possible to help the contractor improve in all business outcomes. Ultimately, with continuous improvement, both owners and contractors will see projects delivered faster, less expensive, higher quality, and safer, which benefits all parties.

Contractors also ranked training and competence higher in regards to its impact on safety than owners did. Similar to organizational learning, the responsibility of training and ensuring competence of construction workers falls on the contractor. However, if workers are not prepared to do their jobs, project performance can suffer including safety. While owners may not have the expertise to conduct training and competency programs, they can assess them in selecting and evaluating a contractor.

Finally, owners believe that they can have an impact on safety, more so than contractors believe the owners can. From the owner's responses, this is an encouraging finding as the owner has the most influence on the project given their position as financier. A future research effort to study the impact of owner practices and procedures from the contractor's perspective could help in understanding why the contractor's responses were lower. Hopefully, the contractors see owner participation in safety related issues as an opportunity to improve safety and shared commitment to safety.

In summary, the process of weight and determining the perceptions that owners and contractors have on safety related policies, practices, and procedures yielded some interesting findings. The results of which should help each party understand what the other sees as most impactful on safety. With this information, practitioners can be aware of these differences and seek to understand and agree on what practices should be in place to improve construction project safety performance.

# ACKNOWLEDGEMENTS

# REFERENCES

[1] Alidi, A. S. (1996). Use of the analytic hierarchy process to measure the initial viability of industrial projects. *International journal of project management,* 14(4), 205-208.

[2] Arbel, A., and Vargas, L. G. (1993). Preference simulation and preference programming: robustness issues in priority derivation. *European Journal of operational research,* 69(2), 200-209.

[3] Basu, R. (2004). *Implementing quality: a practical guide to tools and techniques: enabling the power of operational excellence:* Cengage Learning EMEA.

[4] Bigelow, M. (2002). How to achieve operational excellence. *Quality Progress,* 35(10), 70.

[5] Carlsson, C., and Walden, P. (1995). AHP in political group decisions: A study in the art of possibilities. *Interfaces,* 25(4), 14-29.

[6] *Center of fatal Occupational Injuries.* (2003). Retrieved from http://stats.bls.gov/iif/oshcfoi1.htm.

[7] Detsimas, N., Coffey, V., Sadiqi, Z., and Li, M. (2016). Workplace training and generic and technical skill development in the Australian construction industry. *Journal of Management Development,* 35(4), 486-504.

[8] Dodgson, M. (1993). Organizational learning: a review of some literatures. *Organization studies,* 14(3), 375-394.

[9] Edwards, D., and Nicholas, J. (2002). The state of health and safety in the UK construction industry with a focus on plant operators. *Structural Survey,* 20(2), 78-87.

[10] Everett, J. G., and Jr, P. B. F. (1996). Costs of accidents and injuries to the construction industry. *Journal of Construction Engineering and Management,* 122(2), 158-164.

[11] Finan, J. S., and Hurley, W. J. (1997). The analytic hierarchy process: does adjusting a pairwise comparison matrix to improve the consistency ratio help? *Computers and operations research,* 24(8), 749-755.

[12] Fiol, C. M., and Lyles, M. A. (1985). Organizational learning. *Academy of management review,* 10(4), 803-813.

[13] Georgine, R., McCormick, R., Dunlop, J., Englund, A., and Frankowski, R. (1997). The Construction Chart Book: The US Construction Industry and its Workers. *The Center to Protect Workers' Rights,* Washington, DC.

[14] Gilkey, D. P., del Puerto, C. L., Keefe, T., Bigelow, P., Herron, R., Rosecrance, J., and Chen, P. (2011). Comparative analysis of safety culture perceptions among homesafe managers and workers in residential construction. *Journal of Construction Engineering and Management,* 138(9), 1044-1052.

[15] Gleich, R. (2008). *Operational excellence: innovative Ansätze und best practices in der produzierenden Industrie:* Haufe-Lexware.

[16] Griffin, M. A., and Neal, A. (2000). Perceptions of safety at work: a framework for linking safety climate to safety performance, knowledge, and motivation. *Journal of Occupational Health Psychology,* 5(3), 347.

[17] Hafeez, K., Zhang, Y., and Malak, N. (2002). Determining key capabilities of a firm using analytic hierarchy process. *International journal of production economics,* 76(1), 39-51.

[18] Hinze, J. (1997). *Construction safety:* Prentice Hall.

[19] Hinze, J., and Appelgate, L. L. (1991). Costs of construction injuries. *Journal of Construction Engineering and Management,* 117(3), 537-550.

[20] Hinze, J., and Wiegand, F. (1992). Role of designers in construction worker safety. *Journal of Construction Engineering and Management,* 118(4), 677-684.

[21] Huang, X., and Hinze, J. (2006). Owner's role in construction safety. *Journal of Construction Engineering and Management.*

[22] Jaeger, A., Matyas, K., and Sihn, W. (2014). Development of an assessment framework for operations excellence (OsE), based on the paradigm change in operational excellence (OE). *Procedia CIRP,* 17, 487-492.

[23] Jain, B. A., and Nag, B. N. (1996). A decision-support model for investment decisions in new ventures. *European Journal of operational research,* 90(3), 473-486.

[24] Kahneman, D., Slovic, P., and Tversky, A. (1982). *Judgement under uncertainty: Heuristics and biases, .* New York: Cambridge University Press.

[25] Lee, S., and Halpin, D. W. (2003). Predictive tool for estimating accident risk. *Journal of Construction Engineering and Management,* 129(4), 431-436.

[26] Liu, H., Jazayeri, E., and Dadi, G. B. (2017). Establishing the Influence of Owner Practices on Construction Safety in an Operational Excellence Model. *Journal of Construction Engineering and Management,* American Society of Civil Engineers. DOI: 10.1061/(ASCE)CO.1943-7862.0001292.

[27] Liu, H., Jazayeri, E., Dadi, G. B., Maloney, W. F., and Cravey, K. J. (2015). Development of an operational excellence model to improve safety for construction organizations." Proceedings from the *International Construction Specialty Conference 2015¸* Canadian Society of Civil Engineering, Vancouver, CA.

[28] Maloney, W.F., Dadi, G.B., Cravey, K., Janusz, C., Liu, H., and Jazayeri, E. (2016). "Improving Site Safety Performance through Operational Excellence." Construction Industry Institute. Research Team 317, Research Report 317-1. The University of Texas at Austin.

[29] Porter, M. E., and Advantage, C. (1985). Creating and sustaining superior performance. *Competitive advantage,* 167.

[30] Pungvongsanuraks, P., and Chinda, T. (2010). Investigation of safety perceptions of management and workers in Thai construction industry. *Suranaree Journal of Science and Technology,* 17(2), 177-191.

[31] Reese, C. D., and Eidson, J. V. (2006). *Handbook of OSHA construction safety and health:* CRC Press.

[32] Rundmo, T. (1995). Perceived risk, safety status, and job stress among injured and noninjured employees on offshore petroleum installations. *Journal of Safety Research,* 26(2), 87-97.

[33] Saaty, T. (1980). The Analytic Hierarchy Process, McGraw-Hill, New York, 1980. *There is no corresponding record for this reference.*

[34] Saaty, T. L. (1977). A scaling method for priorities in hierarchical structures. *Journal of mathematical psychology,* 15(3), 234-281.

[35] Steuer, R. E., and Na, P. (2003). Multiple criteria decision making combined with finance: A categorized bibliographic study. *European Journal of operational research,* 150(3), 496-515.

[36] Sunindijo, R. Y., and Zou, P. X. (2011). Political skill for developing construction safety climate. *Journal of Construction Engineering and Management,* 138(5), 605-612.

[37] Sutton, D. (2012). *Back to basics: A practitioner's guide to operations excellence:* Operations Excellence Services Cincinnati.

[38] Toole, T. M. (2002). Construction site safety roles. *Journal of Construction Engineering and Management,* 128(3), 203-210.

[39] Tymvios, N., and Gambatese, J. A. (2015). Perceptions about Design for Construction Worker Safety: Viewpoints from Contractors, Designers, and University Facility Owners. *Journal of Construction Engineering and Management,* 142(2), 04015078.

[40] Vaidya, O. S., and Kumar, S. (2006). Analytic hierarchy process: An overview of applications. *European Journal of operational research,* 169(1), 1-29.

[41] Van Aartsengel, A., and Kurtoglu, S. (2013). *Handbook on Continuous Improvement Transformation: The Lean Six Sigma Framework and Systematic Methodology for Implementation:* Springer Science and Business Media.

[42] Weber, S. F. (1993). A modified analytic hierarchy process for automated manufacturing decisions. *Interfaces,* 23(4), 75-84.

[43] Zahedi, F. (1986). The analytic hierarchy process-a survey of the method and its applications. *Interfaces,* 16(4), 96-108.

[44] Elyas Jazayeri, Gabriel B. Dadi, Construction Safety Management Systems and Methods of Safety Performance Measurement: A Review, Journal of Safety Engineering, Vol. 6 No. 2, 2017, pp. 15-28. doi: 10.5923/j.safety.20170602.01.