

Safety Constructability of Different Project Delivery Methods on Construction Projects

Ali A. Karakhan¹, Mohammed Azeez², Mahmoud Shakouri³, and John Gambatese⁴

¹ Associate Professor, Department of Reconstruction and Projects, University of Baghdad, Baghdad, Iraq 10071, E-mail: karakhan@uobaghdad.edu.iq (corresponding author).

² Lecturer, Department of Reconstruction and Projects, University of Technology, Baghdad, Iraq 10070, E-mail: mohammed.n.azeez@uotechnology.edu.iq

³ Associate Professor, Department of Construction Management, Colorado State University, Fort Collins, Colorado 80523, E-mail: Mahmoud.Shakouri@colostate.edu

⁴ Professor, School of Civil and Construction Engineering, Oregon State University, Corvallis, OR 97331, E-mail: john.gambatese@oregonstate.edu

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Abstract: Design professionals play a pivotal role in shaping the built environment, not only through the development of drawings and technical specifications but also by serving as a proxy between project owners and constructors in certain project delivery methods. Every design must fulfill the owner's objectives and project specific criteria that include quality, cost, time, and, crucially, construction safety, all of which can vary across projects. The study objective was to investigate the extent to which designers prioritize worker safety during the design phase across three categories of project delivery methods: non-collaborative, collaborative, and mixed. To achieve the study objective, an online survey was utilized to collect data from 62 designers working in the Architecture, Engineering, and Construction (AEC) industry. Following survey data collection, statistical analysis was used to examine the extent to which designers focus on worker safety relative to other design criteria for each delivery method. The survey findings reveal that, within the studied sample, designers' attention to construction worker safety remained relatively consistent regardless of the delivery method employed. Thus, no statistically significant relationship was found between the delivery method and the degree of safety emphasis among designers. However, collaborative delivery methods that foster greater transparency and interdisciplinary engagement are expected to positively influence project safety performance. Industry stakeholders interested in improving safety performance are encouraged to adopt collaborative delivery approaches and implement structured interventions, such as formal safety constructability reviews, to actively integrate safety into the early stages of project design.

Keywords: Design; safety; delivery methods; contracts.

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1. Introduction

As an occupation, construction is extremely hazardous. Each year, hundreds of work-related fatalities, injuries, and illnesses are recorded across different work classifications in the construction industry (Rasheed, 2015; Rasheed, 2016). According to the Center for Construction Research and Training, there were approximately 79,660 nonfatal injuries in the U.S. construction industry in 2019, resulting in thousands of days away from work (CPWR, 2020). Between 2011 and 2022, construction experienced an average of 978 fatal injuries annually, with 1,092 fatalities recorded in 2022 alone, a 7.6% increase from 2021 (CPWR, 2024). The U.S. Bureau of Labor Statistics (BLS) reports that construction had the highest number of fatal work injuries across all industries in 2019, with 1,061 deaths, representing 20% of all private-industry fatalities, even though it employs a much smaller share of the workforce (Jones, 2020). The most recent injury statistics published by the Bureau of Labor Statistics continue to show that the US construction industry has the highest number of fatalities across all sectors, with 1,075 deaths reported in 2023 (BLS, 2021).

To improve working conditions and reduce occupational injuries, key stakeholders in the construction industry need to collaboratively address worker safety throughout the project lifecycle (Karakhan and Gambatese, 2017; Nnaji et al., 2020). Typically, three major parties are involved in the development of construction projects: owners, designers, and constructors (Hinze and Wiegand, 1992; Al-Bayati et al., 2021). Designers, in particular, play a unique role not only by developing the facility's drawings and technical specifications, but also by serving as a proxy between the owner and the constructor in

some delivery methods (Shadhar and Mahmood, 2018). Moreover, every design produced must fulfill the project owner's goals and particular design needs with respect to different criteria that include quality, cost, time, and, crucially, end user safety, all of which may vary from one project to another.

Although construction worker safety is not typically the responsibility of designers in the U.S., either contractually or regulatory, the designs produced by architects and engineers can substantially influence safety outcomes and performance during the construction phase. Designers can engage with constructors during early stages of the design process to produce designs with high levels of constructability that can be efficiently built in a safe manner (Hinze and Wiegand, 1992; Gambatese, 2000). Such designs can incorporate elements that facilitate pre-fabrication in a shop before construction begins or allow erection and assembly at ground level instead of at height (Gambatese and Hinze, 1999), both of which can enhance worker safety and reduce exposure to jobsite hazards. Moreover, designers can specify the use of specific materials (e.g., low-emitting paints and coatings) that are non-toxic and safe to handle and install during construction (Akadiri et al., 2012).

Constructability is a generic term that refers to the collaboration among different project stakeholders (e.g., designer and builder) to promote a more efficient construction process and deliver higher quality outcomes. "Safety constructability" refers to when constructability reviews explicitly address the safety of construction workers (Gambatese, 2000). The present study focuses on the role of the design team in enhancing construction worker safety.

2. Point of Departure

Given the influence of the facility design on project performance outcomes, previous studies have speculated that designers could be more proactive with respect to construction safety in some project delivery methods. Their research suggested that different delivery methods could be associated with different safety outcomes (Gambatese et al., 2005; Wanberg et al., 2013). From a legal liability perspective, it has been argued that different project delivery methods shift safety liability and responsibility to different parties, making it easier or more challenging for some stakeholders to engage in efforts to protect construction workers (Korkmaz et al., 2010; Buniya et al., 2023). For example, under the traditional Design-Bid-Build (DBB) contracting arrangement, general and trade contractors bear safety liability and responsibility according to existing rules and regulations stipulated by Occupational Safety and Health Administration (OSHA) standards, leaving designers with no or a minimal role regarding construction safety (Toole, 2002). In contrast, under Design-Build (DB) arrangements, designers are expected to play a more active role regarding construction safety, given that both the designer and the constructor typically represent the same entity and share matching interests when it comes to protecting construction workers on site (Toole, 2005).

Project delivery methods are generally grouped into two types: collaborative and non-collaborative (Kulkarni, 2012). Non-collaborative methods include those delivery systems, such as DBB projects, where the level of collaboration among the principal parties (e.g., designers and constructors) during early phases of the project lifecycle is minimal. In such cases, a constructor is typically not on board until the design is fully developed (Hinze, 2010). Having the constructor join the project team after fully developing the design hinders opportunities for collaboration between the designer and the constructor and inhibits the designer from receiving input about the constructability of the design. On the other hand, collaborative methods are those delivery systems, e.g., Construction Manager/General Contractor (CM/GC), Construction Manager At Risk (CMAR), Integrated Project Delivery (IPD), and Public-Private Partnerships (PPP), where the principal parties collaboratively work together to identify and resolve any potential constructability and schedule issues before construction begins (Bonner, 2018; Kulkarni, 2012). Working collaboratively as a single team reduces the likelihood of constructability and schedule issues arising, bringing several benefits to all project parties, including fewer legal disputes, change orders, and schedule delays. It should be recognized, however, that there are cases, depending on the nature and type of the project, where design and construction entities work with multiple project delivery systems. That is, designers and constructors may sometimes conduct business using a combination of collaborative (e.g., DB) and non-collaborative (e.g., DBB) project delivery methods; if so, this is referred to as a mixed approach.

It is expected that certain project delivery methods would increase designer involvement in and attention toward construction worker safety. The goal of the present study is to examine the impact of different project delivery methods on the designer's role in addressing construction safety early in the project lifecycle.

3. Method

To achieve the research goal, the research question "How do designers prioritize worker safety during the design phase in different project delivery methods?" was investigated. Three types of project delivery methods (collaborative, non-collaborative, and mixed) were recognized in the present study, as previously described. It was expected that investigating different types of delivery methods would account for the nature of the contractual relationship between design and construction entities in the AEC industry. Information regarding the level of involvement and attention toward construction safety during the design of a project was obtained from designers working with different project delivery systems in the U.S. The study was reviewed and approved by the Institutional Review Board (IRB) at Oregon State University for research involving human subjects.

3.1. Data Collection

An online survey was used to collect data from licensed architects and engineers in the U.S. Potential participants were identified from online member directories of professional organizations, namely the American Institute of Architects (AIA), American Institute of Building Design (AIBD), and American Society of Interior Designers (ASID). Once the participants were identified, an email seeking participation in the study and containing a link to the survey was sent to the prospective participants. Two sets of questions were of primary interest in this research study. The first set of survey questions asked the participants to indicate all of the contracting arrangements (DBB, DB, IPD, PPP, etc.) they are involved in. After collecting

the survey responses, each participant was placed in a category according to the type of project delivery methods (collaborative, non-collaborative, and mixed) in which the participant is involved.

The second set of questions pertained to the level of involvement in and attention given to construction safety by the participants during different stages of the design process, specifically as to whether the participants typically consider or address the safety of workers who will construct the facility in the design process. For example, a question asked whether the participant specifies permanent anchorage points in the design and shows the anchorage points in the design drawings to provide tie-off points for fall-arrest systems during the construction and maintenance phases of a facility. To further clarify what is meant by “level of involvement in and attention to construction safety,” consider that there are two building designs prepared by the same designer: a building with a parapet that is 20 inches tall versus a building with a parapet that is 42 inches tall along the entire perimeter of the roof. These two designs indicate different levels of designer involvement in and attention to worker safety. In the first case (i.e., a 20-inch parameter), workers would be exposed to significant fall hazards assuming that there are multiple activities/tasks that need to be performed on the building’s roof near the edges; therefore, the constructor would be required to implement additional safety measures/controls (e.g., installing a temporary guardrail on the roof edges that is at least 42 inches tall according to OSHA requirements) to protect workers from falling over the edges. Even with such protection, negative outcomes could be encountered, including worker exposure to safety risks when installing the guardrail. In the second case, designing the building with a 42-inch parapet along the entire perimeter of the roof demonstrates the designer’s high level of involvement in or attention to construction safety. In this case, the 42-inch parapet serves as a permanent guardrail to protect workers from falling over the roof edges, complying with OSHA requirements for fall protection. The second design could bring several benefits, including improved safety performance, accelerated project schedule, and limited additional expenditures. This clarification was clearly explained to the participants, and it was made clear that such involvement in and attention to safety would not include supervising construction activities or involvement in specifying means and methods of performing construction activities.

Other questions in the survey questionnaire aimed at collecting demographic information about the participant, and additional contextual information regarding the participant’s responses to the two aforementioned sets of questions was also requested. The most relevant questions asked are presented in Table 1.

Table 1. Professional experience of respondents (n = 62)

Experience Profile	Frequency	Percentage
Design experience:		
Less than 5 years	–	–
From 5–10 years	5	8%
From 11–20 years	11	18%
Greater than 20 years	46	74%
Construction site experience:		
Less than 5 years	9	15%
From 5–10 years	7	11%
From 11–20 years	10	16%
Greater than 20 years	36	58%
Number of projects involved in:		
One project	–	–
From 2–10 projects	–	–
From 11–20 projects	5	8%
Greater than 20 projects	57	92%

3.2. Respondent Demographics

Over 1000 architects and engineers in the U.S. were contacted and asked to participate in the study. One hundred and seventeen (117) responses were received. Fifty-one (51) participants started the survey but did not finish the questions of interest, and their responses were therefore eliminated from the analysis. Four responses were deleted because the participants were not licensed. This screening process resulted in 62 complete responses for analysis, which is an adequate number of responses for empirical and statistical analyses. A complete response in this regard means that the respondent is licensed, provided adequate demographic information, and answered all questions included in the questionnaire. The respondents are scattered across different geographical locations that extend across 30 states and the District of Columbia. The greatest number of participants are located in Oregon and Pennsylvania (five respondents each). The respondents are employed by different types of AEC firms: 51 respondents (82%) in architectural firms, three respondents (5%) in construction firms, two respondents (3%) in DB firms, two respondents (3%) in engineering firms, and four respondents (7%) in other types of firms.

With respect to the respondents’ professional experience, they have many years in both design and construction, as shown in Table 1. All of the respondents have been involved in at least 10 projects throughout their careers, with approximately 92% of the respondents involved in more than 20 projects.

4. Results

As previously mentioned, two sets of questions are of primary interest to the present study. The first set of questions asked the participants to indicate the contracting arrangements they are typically involved in on their projects, and the second set of questions collected information on how the participants prioritize construction safety during the design of a project. For the second set of questions, the participants were asked to rate their involvement in and attention to worker safety during the design of the project using a 5-point Likert scale where “1” is “Never,” “2” is “Rarely,” “3” is “Sometimes,” “4” is “Often,” and “5” is “Always.” Then, for the analysis, the researchers linked their rating to the type of project delivery methods (PDMs) the participants are typically involved in, namely collaborative, non-collaborative, and mixed. Sixty-two (62) complete responses were received and analyzed as part of the present study. Table 4 provides descriptive statistics of the collected survey responses.

Table 2. Descriptive statistics of the collected response ratings regarding designer involvement in safety (n = 62)

Measure	Non-collaborative PDM	Collaborative PDM	Mixed PDM
Mean rating	2.85	2.55	2.95
Median rating	3	3	3
Mode rating	3	3	3 and 4 (bimodal)
Rating standard deviation	0.85	0.86	1.11
Minimum rating value	1	1	1
Maximum rating value	4	4	5
Rating range	3	3	4
Count (number of responses)	20	20	22

Fig. 1 and Fig. 2 provide a graphical representation of the distribution of responses and level of attention to construction safety during the design process, classified according to the delivery method stated. Based on the survey results, designer involvement in and attention to construction employees’ safety during the design process appear to be greater in mixed project delivery methods, as shown in Table 2. However, both figures show analogous trends across the three project delivery methods. To statistically examine whether designer involvement in and attention to construction safety during the design process is dependent on the type of project delivery method used, statistical hypothesis testing was performed as described in the next section.

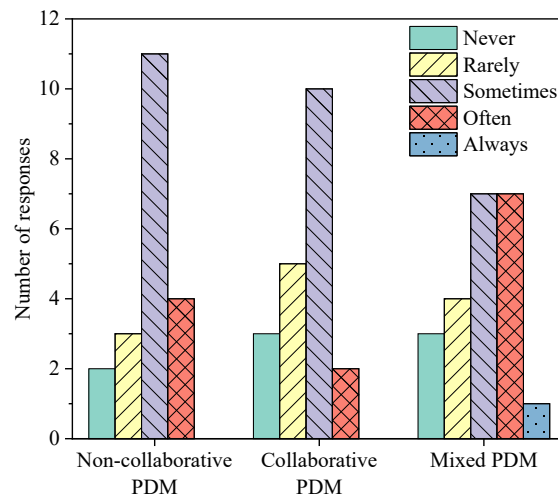


Fig. 1. Histogram showing distribution of responses regarding designer involvement in safety (n = 62)

5. Results of Statistical Analysis

Statistical hypothesis testing was performed to determine whether designer involvement in, and attention to, construction worker safety during the design phase of a project differ among the three recognized project delivery methods (non-collaborative, collaborative, and mixed). To compare between three groups or more, the one-way analysis of variance (ANOVA) test is typically used. However, given that the data obtained from the survey in this study is ordinal and collected using a Likert scale, a non-parametric version of the one-way ANOVA, referred to as Kruskal Wallis rank sum test, is more appropriate for data analysis (Clason and Dormody, 1994; Harpe, 2015). Under the Kruskal Wallis rank sum test, the null hypothesis is that the medians of all groups analyzed are of the same value, and the alternative hypothesis is that the median of at least a single group is not equal to the median of the remaining two groups.

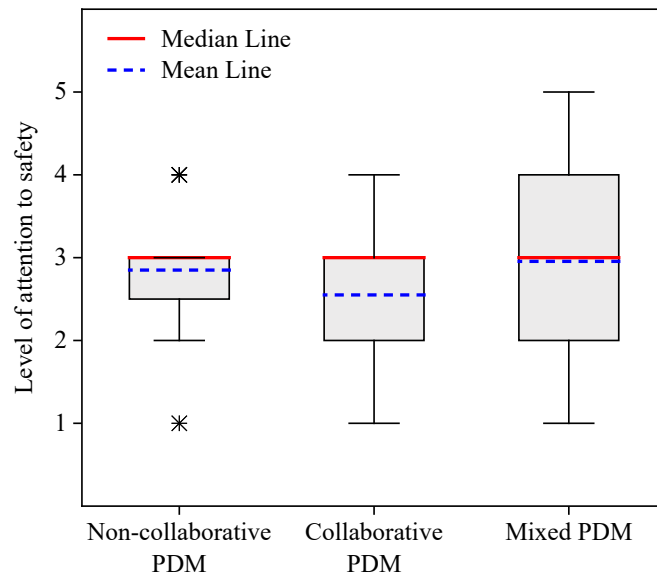


Fig. 2. Boxplot showing level of attention to worker safety during design in different delivery methods (n = 62)

In order for statistical tests to provide reliable results, the data collected and analyzed should meet certain test assumptions. For the one-way ANOVA test, three primary assumptions should be typically examined: normality, independence, and homogeneity of variance (Ramsey and Schafer, 2013). However, the Kruskal Wallis rank sum test used for data analysis in the present study is a non-parametric approach for testing differences between groups and, therefore, does not require that the data collected and analyzed follow a normal distribution (Harpe, 2015). As a result, only two assumptions (independence and homogeneity of variance) should be examined to verify the reliability of the statistical analysis performed. With respect to the independence assumption, the data points collected should exhibit no relationship of any kind in order for the statistical analysis to be valid (Ramsey and Schafer, 2013). Because the survey respondents represented different companies and geographical locations, there is no reason to suggest dependence within or between groups. Finally, to ensure that the variance is homogeneous across the three recognized groups, the Bartlett test of homogeneity of variances is utilized. The result from the Bartlett test revealed no statistical evidence ($K\text{-squared} = 1.74$, degrees of freedom = 2, $p\text{-value} = 0.42$) of any significant inhomogeneity of variance across the three recognized groups. Based on the aforementioned discussion, the sample data collected and analyzed strictly meet the Kruskal Wallis rank sum test assumptions and, therefore, the results of the statistical analysis performed are believed to be reliable.

After performing the hypothesis testing, the result revealed no statistically significant evidence ($p\text{-value} = 0.34$) against the null hypothesis that the medians of all groups are equal. The insignificant statistical evidence means that designer involvement in and attention to construction employees' safety during the design phase of a project is somewhat similar regardless of the project delivery method used. It should be noted, however, that finding no statistically significant does not mean that an impact does not exist, and such an insignificant result does not imply a cause-and-effect relationship; it simply means that no statistically significant evidence was found on the relationship between the type of project delivery method used and the level of involvement in and attention to construction safety during the design phase. The result of the Kruskal Wallis rank sum test is presented in Table 3.

Table 3. Kruskal Wallis rank sum test results of difference in designer involvement in safety (n = 62)

Kruskal Wallis $K\text{-squared}$	Degrees of freedom	$p\text{-value}$
2.16	2	0.34

Note: $p\text{-value}$ of 0.05 or less indicates significant evidence against the null hypothesis.

6. Discussion of Findings

The findings of the present study indicate that designer involvement in and attention to construction worker safety are relatively the same regardless of the delivery method used. Based on the findings, it can be concluded that collaborative delivery methods (e.g., DB, IPD, and PPP) do not necessarily exhibit different levels of designer involvement in addressing worker safety during the design phase of a project. To reiterate, designer involvement in worker safety was interpreted as addressing worker safety in the design process and producing designs that are easier to build safely. It should be mentioned that studies available in the literature have reported conflicting findings. While Huang and Hinze (2006) found statistically moderate evidence that DB projects had lower recordable injury rates (RIRs) compared with projects performed under other forms of contracting arrangements, the study of Thomas et al. (2002) reported no statistically significant difference between safety performance on DB and DBB projects. In Thomas et al.'s (2002) study, DB projects had lower RIRs but higher lost time injury rates (LTIRs). Another point to consider is that DB projects can take multiple forms. Shoemaker (2016) stated that joint-ventures, partnerships, and teaming agreements can sometimes be considered or classified as

design-build arrangements. In such cases, say in a joint-venture agreement, minimal involvement of the designer in addressing employees' safety during the design process is not unexpected.

However, in the present study, when asked whether a different level of attention is given to worker safety depending on the project delivery method used, an overwhelming majority of the study participants indicated that they typically keep their involvement in construction worker safety efforts as minimal as possible, regardless of the delivery method used. The study participants indicated that the reasons why designers are not involved in construction safety include, among others, fear of liability and lack of safety training/education in addition to the fact that addressing worker safety in the design process is not a standard practice in the AEC industry in the U.S. Previous studies recommended incorporating specific legal language in the contract to protect designers from potential lawsuits filed by injured workers or their families when designers participate in safety efforts on the jobsite (Toole and Erger, 2019). Such incorporation could minimize designer liability for construction injuries and help overcome the barriers hindering the designers from greater involvement in construction safety efforts (Toole and Erger, 2019). Nevertheless, individuals and organizations should exercise extreme caution before including any legal language in the contract to indemnify designers from legal liability and should carefully discuss this decision with a licensed attorney who regularly practices construction law.

Similarly, professional engineering associations and engineering higher education institutions are encouraged to provide specific project safety training and education to architects and engineers as part of their professional activities and educational curricula. These types of training and education programs are expected to improve the ability of the designers to address the safety of construction employees when designing a facility. Addressing the safety of construction employees in the design process could minimize worker exposure to workplace hazards, leading to reduced numbers of work-related injuries and fatalities in the construction industry.

The findings of the present study indicate that project delivery methods do not have a statistically significant impact on the designer's level of involvement in construction safety efforts early in the project lifecycle. That being said, the possibility that collaborative project delivery methods could eventually lead to preferred safety outcomes cannot be eliminated. Such preferred outcomes may not necessarily result from higher levels of designer involvement in construction safety efforts but could be attributed to other influencing factors, such as increased collaboration between project team members, early involvement of the owner in project planning, improved constructability, and reduced rework.

7. Limitations

The study has multiple limitations that should be acknowledged. First, the study findings cannot be generalized across the different professional domains of the AEC industry due to the fact that more than 50% of the responses came from architectural firms. Second, the proportion of designers who participated in the study does not necessarily reflect current trends in the market and industry. For example, engineering, procurement, and construction (EPC) firms, such as oil and gas companies, were not represented in the study sample. Third, the data collected is perception-based, meaning that it was based on the perception of the study participants and not based on facts or empirical data. Notwithstanding these limitations, the study provides useful information on the level of safety involvement in and attention to construction safety during the design phase of a project.

8. Conclusion

The present study examined the impact of different project delivery methods on designer involvement in addressing construction worker safety during the design phase of the project lifecycle. Perception data on the level of designer involvement in addressing worker safety during the design phase under different project delivery methods were collected from architects and engineers working in the AEC industry across the U.S. using a survey questionnaire. After collecting participant perceptions about their involvement in construction safety efforts during the design phase, statistical analysis using the Kruskal Wallis rank sum test was carried out. Findings from the statistical and empirical analyses of responses to the research question: "How designers prioritize worker safety during the design phase in different project delivery methods?" reveal two important conclusions. First, designer involvement in and attention to construction worker safety is limited, regardless of the delivery method used (non-collaborative, collaborative, or mixed), according to this study's findings. That is, only a limited number of designers in the study sample indicated that they explicitly address or consider worker safety during the design of a project. Second, the analysis showed no statistically significant impact of the delivery method type on designer involvement in project safety efforts during the design phase.

To overcome the barriers hindering designers from greater involvement in construction safety, the researchers provide two key recommendations. First, it is suggested that project owners consult with a licensed construction attorney about the possibility of incorporating specific legal language in the contract in order to distance designers from liability for construction accidents when they participate in the safety effort (e.g., participating in safety design reviews) before construction begins. Second, professional associations in the AEC industry and engineering educational institutions are encouraged to provide specific construction safety training and education to architects and engineers to increase their knowledge of and ability to design for construction safety. These recommendations aim to reduce liability concerns and knowledge gaps, supporting increased designer involvement in construction safety efforts.

The study findings have important implications for future research and practice as well. One of the implications is that stakeholders interested in improved levels of construction safety should not only seek collaborative project delivery methods such as DBB and IPD but also implement certain strategies to ensure that worker safety is addressed early in the project lifecycle, especially during the design phase. Such strategies could include formal constructability review sessions that bring the design and construction teams together to discuss potential workplace safety hazards initiated in part by the design of the facility. In this case, this effort is referred to as "safety constructability," as opposed to the generic term "constructability."

Equally important, it should be understood that, based on the study findings, the majority of designers lacked the understanding of what constitutes a safety hazard to construction workers, and they did not receive construction safety education and training during their higher education studies, post-graduation, or over the span of their careers. Accordingly, stakeholders interested in addressing construction safety in the design phase should provide the necessary training and professional development opportunities that allow their design teams to acquire knowledge and skills about how to address construction worker safety in the design process. The findings of the present study contribute to knowledge by providing anecdotal evidence that even collaborative project delivery methods cannot always improve designers' involvement in construction safety during the project life cycle if other strategies, such as safety training for designers and formal safety constructability review sessions, are not carried out.

Although the present study reveals no direct impact of project delivery systems on designers' involvement in construction safety efforts, there is still a possibility that certain collaborative delivery systems, such as IPD and PPP, would be associated with enhanced safety performance outcomes due to the increased level of collaboration and transparency between different project players. This possibility is especially true when designers believe in their critical role to improve worker safety and when they are voluntarily willing to collaborate with constructors and other stakeholders to ensure their designs can be safely constructed in an efficient manner. To investigate this possibility, future research should collect safety data from construction projects built using emerging collaborative project delivery methods (IPD and PPP) and then perform statistical analysis to compare safety performance on those emerging collaborative delivery methods with respect to conventional non-collaborative delivery methods (e.g., DBB). In addition, it is recommended that future studies investigate whether design professionals who have received safety training and education in their work or college education are more involved in construction safety efforts during the design phases of their projects.

Author Contributions

Ali A. Karakhan contributed to conceptualization, survey design, methodological design, data collection, data analysis, draft preparation and writing, and project administration. Mohammed Azeez contributed to conceptualization, reviewing, and manuscript editing. Mahmoud Shakouri contributed to data analysis, visualization, reviewing, writing, and proofreading. John Gambatese contributed to survey design, reviewing, writing, and proofreading. All authors have read and agreed with the manuscript before its submission and publication.

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Institutional Review Board Statement

The study received approval from the Institutional Review Board (IRB) at Oregon State University on April 28, 2016 (approval ID 7454).

Declaration of Artificial Intelligence (AI) Tools

The authors used ChatGPT for formatting, organizational assistance and rewriting of some sentences. No AI tools were used to generate scientific content, analysis, conclusions, or references. All content was reviewed and validated by the authors.

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Ali Amer Karakhan, Ph.D., is an Associate Professor at the University of Baghdad in Iraq. Dr. Karakhan holds a Ph.D. in Civil Engineering from Oregon State University, an M.S. in Civil Engineering from the University of Baghdad, and a B.S. in Building and Construction Engineering from the University of Technology. Dr. Karakhan is a member of the American Society of Civil Engineers Construction Institute Construction Safety Committee. His research interests include construction site safety, workforce development in construction, sustainable design and construction, and technology adoption in construction.



Mohammed Azeez is an Assistant Professor at the University of Technology in Iraq. Dr. Azeez holds a Ph.D. in Civil Engineering from Oregon State University, an M.S. in Civil Engineering from the University of Baghdad, and a B.S. in Building and Construction Engineering from the University of Technology. Dr. Azeez has more than 8 years of professional experience in the Iraqi construction industry. He is a member of the American Society of Civil Engineers (ASCE). His research interests include construction safety, risk-taking, hazard recognition, and risk and reward in construction.



Mahmoud Shakouri, Ph.D., is an Associate Professor in the Department of Construction Management at Colorado State University. He earned his Ph.D. in Civil Engineering with a focus on Infrastructure Materials from Oregon State University in 2017. Dr. Shakouri serves on two committees in the American Concrete Institute: (i) ACI 222- Protection of Metals against Corrosion, and (ii) ACI 365-Service Life Prediction. His research interests include construction safety, infrastructure materials, concrete durability, service life modeling, chloride-induced corrosion, and biobased cementitious materials.



John Gambatese is a Professor in the School of Civil and Construction Engineering at Oregon State University. Dr. Gambatese's educational background includes a Bachelor of Science and a Master of Science in Civil Engineering from the University of California, Berkeley, and a Ph.D. in Civil Engineering from the University of Washington. Dr. Gambatese is a Fellow in the American Society of Civil Engineers (ASCE), a member of the American Society of Safety Professionals (ASSP), and a member of the National Academy of Construction (NAC). His research interests include construction safety, work zone safety, prevention through design, and construction innovation.