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 CPWR is the research and training arm of NABTU. Production of this document was supported by cooperative agreement OH 009762 from the National Institute for Occupational Safety and Health (NIOSH). The contents are solely the responsibility of the authors and do not necessarily represent the official views of NIOSH.

Using Delphi Panels to assess construction safety research to practice: a narrative review

INTRODUCTION:

Despite ongoing efforts to improve site safety, the construction field still accounts for a disproportionate injury rate and remains one of the most dangerous industries for workers. The Delphi Method is a systematic procedure that is employed to achieve a reliable consensus among a selected panel of experts. This project's purpose was to review relevant papers and research on Delphi Panels and their potential use in assessing whether construction safety and health research findings are being used by target audiences of workers and contractors to reduce injuries and illnesses (research to practice). A secondary objective of this review was to

Delphi panels as the primary or secondary research method. These papers were published between 1990 and 2012 in the ten selected journals: (1) Construction Management and Economics (CME), (2) Journal of Construction Engineering and Management (JConstr.EM), (3) Engineering, Construction and Architectural Management (ECAM), (4) Journal of Management in Engineering (JME), (5) International Journal of Project Management (IJPM), (6) Automation in Construction (AC), (7) Building Research and Information (BRI), (8) Building and Environment (BE), (9) Journal of Civil Engineering and Management (JCiv. EM), and (10) Journal of Facilities Management (JFM). The articles included ones from researchers such as Gambetese, who have done extensive research on safety and health in construction. Additional papers published since the review were identified using the same method as Amenyaw et al. by searching the same journals used in their review. The Amenyaw review along with the updated literature search represent all current, relevant articles presenting Delphi panel use in construction research.

Abstracts for all articles included in tC/P <MCID 2 >>7.9 (s)-5.5 (an)2i(h)-0.7. (h)2.2 (db6.6 Tc 0.014-0.001 Tc 0r[(A)ri)d( )Tj/P

Delphi method have concluded that the appropriate number of panelists for the typical Delphi study ranges from 8 to 15.

How are surveys/interviews distributed and collected?

This can be completed through questionnaires sent to respondents. The amount of time between each round (i.e. one week/month) should take into consideration the number of items in the questionnaires.

How many rounds are needed?

Iteration is a critical quality of the Delphi method, because through each round the group can be brought to a consensus (Linstone & Turoff, 1975). Through the use of both iteration and anonymity,

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How is consensus among panelists statistically assessed?

The Delphi method was originally developed by the Rand Corporation study in order to obtain the most reliable consensus opinion from a group of experts (Calhoun, 2010). With consensus building being a critical and integral part of the Delphi method, the method of achieving consensus varies depending on multiple factors including construction and research methodology. It is therefore not possible to recommend an ideal level of consensus in the varied construction areas of study. However, consistent with Ameyaw el al.'s review, three techniques were identified in measuring consensus: Deviation, Kendall's coefficient of concordance (W), and Chi-square ($\chi 2$). Additionally, Che et al. (2015) used a technique called the intraclass correlation coefficient (ICC), which combines interrater agreement (IRA) and interrater reliability (IRR), while Rad et al. (2017) adopted an integrated method based on Chiclana et al. (2018).

Deviation was the most common tool for measuring consensus, consistent with Ameyaw et al.'s findings. Also consistent with the review is there is no common agreement on the minc(')2.1s2g(6m43 (an)2(th)5.3 (e)(a

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Ameyaw, E. E., & Chan, A. P. (2015). Evaluating key risk factors for PPP water projects in Ghana: a Delphi study. Journal Of Facilities Management, 13(2), 133-155. doi: 10.1108/JFM-10-2013-0051

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Che Ibrahim, C.I., Costello, S. B., & Wilkinson, S. (2015). Establishment of Quantitative Measures for Team Integration Assessment in Alliance Projects. Journal Of Management In Engineering, 31(5), 1-11. doi: 10.1061/(ASCE)ME.1943-

Kraft, E., & Molenaar, K.R. (2015). Quality Assurance Organization Selection Factors for Highway Design and Construction Projects. Journal Of Management In Engineering, 31(5), 1-9. doi: 10.1061/(ASCE)ME.1943-5479.0000289

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Seyis, S., Ergen, E., & Pizzi, E. (2015). Identification of Waste Types and Their Root Causes in Green-Building Project Delivery Process. Journal of Construction Engineering and Management, 142(2). https://doi.org/10.1061/(ASCE)CO.1943-7862.0001038

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Sourani, A. & Sohail, M. (2015). The Delphi Method: Review and Use in Construction Management Research. International Journal of Construction Education and Research, 11(1), 54-76. doi: 10.1080/15578771.2014.917132

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Summary of initial article search for articles describing Delphi panels in construction research

The following databases: Academic Search Complete, ArticleFirst, Business Search Complete, Proquest, and ScienceDirect. Using the terms: Delphi, Delphi panel, Delphi method, Delphi technique, construction, construction safety, surveillance

Citation	Abstract	Methodology
Sourani, A. & Sohail, M. (2015). The Delphi Method: Review and Use in Construction Management Research. International Journal of Construction Education and Research, 11(1), 54-76. doi: 10.1080/15578771.2014.917132	The Delphi Method is a systematic procedure that is normally employed to achieve a reliable consensus among a selected panel of experts. It can be utilized for different purposes, such as the study or definition of areas of considerable uncertainty and/or a lack of agreed knowledge. Although the method has been used in different fields, few studies have used Delphi in construction r011 (rhtio)-6.6 14 245.52.006 Tw 0 -1.200.001 Tw 0.511 0 T.6 14 24fer13.1 (e	

	research. The discussion covers the features and characteristics of Delphi technique, its strengths and flaws, activities to be performed for its implementation, and also its implementation in this research. In addition, previous research conducted by scholars that utilised the same technique will also be reviewed and examined. Therefore, this paper aims to provide an insight into how the Delphi technique may provide some guidance to other researchers when considering methods for their research.	
Hallowell, M.R. (2008). A formal model for construction safety and health risk management. Ph.D. diss., Oregon State University	Despite recent efforts to improve site safety, construction still accounts for a disproportionate injury and illness rate. According to the 2007 injury and illness data released by the National Safety Council, the construction industry has a fatality and disabling injury rate that is approximately three times higher than the all-industry average. The transient, unique, and complex nature of construction projects makes safety management exceptionally difficult. Most construction safety efforts are applied in an informal fashion under the premise that simply allocating more resources to safety management will improve site safety. Currently, there is no mechanism by which construction site safety professionals may formally select safety program elements for a particular process. This dissertation describes a research effort that introduces, populates, and validates a formal method to evaluate construction safety risk and strategically match safety program elements to construction processes. The decision scheme introduced, based on the application of Newton's third law, assumes that every construction activity is associated with specific safety risks and that each safety program element is capable of mitigating a portion of such	Field observations, industry survey, and Delphi method to quantify safety risks associated with the construction of concrete formwork. 8-15 members, 3 rounds

	health and safety (H&S) experts in two separate case studies in the construction industry in South Africa. The first case study used three rounds of iteration whilst the second case study used four rounds of iteration. The authors argue that the Delphi method is a comprehensive method of attaining consensus on challenging issues of H&S in the construction industry. Furthermore the method requires proper communication to achieve the required results.	
Li, Y. & Wang, C. "Based on the Delphi method of deep excavation safety risk analysis,"2010 International Conference on Artificial Intelligence and Education (ICAIE), Hangzhou, 2010, pp. 347-349. doi: 10.1109/ICAIE.2010.5641503	To prepare th (t)-578B(m)-3.0.1 (u30.1 (TjEMC ET/P /H	

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techniques in the 88 Delphi papers are reviewed. The mix use of the Delphi method with three advanced modelling methods, such as Fuzzy sets, Analytical Hierarchy Process, and Analytical Network Process is also examined. These review results provide practical references for researchers having interests in applying Delphi method in CEM research.

Calhoun, M.E. (2010). Quantifying the effectiveness of pair-wise interactions among safety program elements through a cross-impact analysis. Ph.D. diss., University of Colorado at Boulder

The current construction safety and health management strategy is informal and safety program elements are selected without consistency across the industry. This is especially true for small construction companies who typically operate with a limited safety and health management budget. To guide these small construction firms, this study develops a tool to maximize the effectiveness of their current safety program. This study uses the Delphi method to gain consensus among thirteen experts in the field of construction safety and health. The experts quantify the interrelationships of the following highly-effective safety program elements: emergency response planning; first aid facilities; frequent safety inspections; job hazard analysis; project based safety incentives; record keeping and accident analysis; safety and health committees; safety and health orientation; site-specific safety manager; site-specific safety plan; subcontractor select g (c)-4.9 (t)03 Theec8l9 (t)036.7 (m)-6.4 (e)-6 (ltwr(p)2.2 (e.8 (b)-0.7 (c)-4.9)-3.37 (o)-1T.83006 Tw 9

related skills and competencies. Any academic programs seeking to implement BIM related topics into existing courses should do so in a careful manner. This research revealed in five-years BIM will continue to enter the mainstream. Building Information Modeling theory suggests that AEC industry will completely change because of BIM. However, this is not the entirely the case. This research discovered that soft skills are more important because of BIM diffusion.

This research will be of particular interest to industry and academic programs seeking to increase BIM usage, or begin development of curriculum that

Citation	Abstract	Methodology
Esmaeili, B. (2012). Identifying and quantifying construction safety risks at the attribute level(Order No. 3527285). Available from ProQuest Dissertations & Theses A&I. (1095099789).	The number of injuries and fatalities is disproportionally high when compared with other	

quantified by conducting reliable content analysis on 1771 accident reports from the National databases. The last paper uses the attribute-based risk management concept and proposes several safety predictive models to determine the outcome of possible injuries in early phases of a project. This research yield robust data and mathematical forecasting models that can be to objectively, accurately, and reliably predict hazardous conditions based on the identifiable attributes that characterize the workplace. It is expected that the findings of this research will transform the current risk analysis techniques and the created database have the potential to be applied to information models and emerging construction technologies.

	from the USACE construction productivity database interface: the Resident Management System (RMS). Subsequently the pilot projects were compared to a control dataset consisting of similar facilities across the USACE using traditional approaches through benchmarks aligned with metrics similar to the KPIs used in the surveys. Both BIM-based projects demonstrated statistically significant (favorable and unfavorable) performance differences when compared to the control dataset. Finally, an evaluation tool was developed and validated for implementing a construction productivity measurement system to supplement existing procedures suitable for evaluating construction productivity differences on BIM-based projects.	
Behm, M. (2004). Establishing the link between construction fatalities and disabling injuries and the design for construction safety concept(Order No. 3138452).	Construction remains the most hazardous industry in the United States in terms of the aggregate number of fatalities. Twenty percent of all occupational related fatalities occur in construction; approximately three construction workers die per calendar day. Moreover, this trend has been prevalent for too long. One method to reduce this trend is to involve architects and design engineers in considering construction safety during the design process. The concept of designing for construction safety is a viable intervention to improve worker safety. However, in the United States many barriers (legal, contractual, regulatory) exist that prevent this intervention from becoming part of a standard practice within the construction industry. Four-hundred and fifty construction accidents from two databases were analyzed and a link to the design for construction safety concept was determined. An objective investigation model was developed to make these determinations. A significant link between the concept of designing for construction safety and construction fatalities and disabling injuries was established. Specific construction project parameters	Establishing the link between the design for construction safety concept and construct fatalities and disabling injuries and then determining the extent/magnitude of that link. Done through: 1. Locating list of construction fatalities and disabling injuries where sufficient

Cwalina, A. M. (2013). Organizational	linked to the concept of designing for construction safety include the minimization of risk due to falls through and from roofs, skylights and structural steel construction; and the minimization of risk due of contact with electric and other utilities. It is recommended that the concept of designing for construction safety be considered by regulatory agencies, insurance companies, and the United States' construction industry as one intervention of a comprehensive safety agenda to reduce the disproportionate number of fatalities and disabling injuries.	the various project parameters

	organizational culture, to determine those organizational practices that lead to a positive safety culture. Delphi is a mixed methodology that begins with an exploratory approach followed by the more traditional quantitative method. The exploratory front-end was deemed appropriate given that prior traditional survey instruments most likely introduced researcher bias through a myopic view of safety culture. Delphi also differs by utilizing purposeful sampling versus random sampling which provides a high level of expertise to inform the research. After four rounds of inquiry with a panel of experts, a consensus was reached on 18 organizational practices that lead to a positive safety culture. This research adds to the understanding of safety culture, provides useful information for both practitioners and academic researchers, and offers launch points for extensions of the research.	

Luai, M., El-Sabek, L.M. & McCabe, B.Y. (2017). Framework for Managing Integration Challenges of Last Planner System in IMPs. Journal of Construction Engineering and Management, 144(5). https://doi.org/10.1061/(ASCE)CO.1943-7862.0001468

International megaprojects (IMPs) have a poor record of budget and schedule overruns. Lean Construction methods and the associated Last Planner System (LPS) have been successfully implemented 15ig0.8 (a)-3.2 (t)-6 (i)-3.2 (o)-9.6 (n)-0.8 (a)-3.2 (l)-3.3 ( )10.

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for Selection of Corr.5nectio7(.5n(n)5.2 ( )]TJ-0.012 Tc 0.034 Tw0)-1.17 TDm[PM C1 63.6 je-.5nect71.9 (M)4586i0.6 f:M.5n(S21.9 (t)31 u61)3.1 d

Chan, A. C., Wong, F. W., Hon, C. H., Ali Javed, A., & Lyu, S. (2017). Construction safety and health problems of ethnic minority workers in Hong Kong. Engineering Construction & Architectural Management (09699988), 24(6), 901-919. doi:10.1108/ECAM-09-2015-0143	Purpose With increasing employment of ethnic minority (EM) workers from different nationalities to mitigate the growing demand for a construction workforce, the safety and health problems of these workers have become a significant concern. The purpose of this paper is to identify and rank according to severity the safety and health-related problems confronted by EM construction workers. Design/methodology/approach Grounded theory approach was employed to construct the main categories and subcategories of the construction safety and health problems of EM workers. A two-round Delphi survey of 18 experts, who are highly experienced in managing EM workers, was conducted to rank the relative severity of the identified safety and health problems. Findings A total of 14 subcategories and 4 categories of construction safety and health problems of EM workers were identified. Among the 14 subcategories, the most urgent and serious ones were insufficient safety materials and training in their native language, insufficient safety staff from EM origin, and safety communication barriers. In addition, safety and health problems at the corporate and governmental levels are also worth paying attention. Originality/value This study contributes to the update on the existing body of knowledge on safety and health problems encountered by EM construction workers and revelation of their peculiar situation in Hong Kong. Findings of the study will be of value to various stakeholders in formulating safety and health measures for EM construction workers.

Cheng, M., & Lu, Y. (2015). Developing a risk assessment method for complex pipe jacking construction projects. Automation In Construction, 5848-59. doi:10.1016/j.autcon.2015.07.0

Gharaibeh, H.M. (2013). Managing the Cost of Power Transmission Projects: Lessons Learned. Journal of Construction Engineering and Management, 139(8). https://doi.org/10.1061/(ASCE)CO.1943-7862.0000665	A major driver to project success is the ability to manage the project cost effectively. Despite the agreement among scholars and practitioners on the importance of managing the project cost, exce

Kraft, E., & Molenaar, K. R. (2015). Quality Assurance Organization Selection Factors for Highway Design and Construction Projects. Journal Of Management In Engineering, 31(5), 1-9. doi:10.1061/(ASCE)ME.1943-5479.0000289	A project quality assurance organization (QAO) assigns project quality responsibilities and relationships, both for design and construction. In the highway sector, all project quality roles and responsibilities have historically been assigned to the state highway agency (SHA), an accepted and well-understood industry practice. However, increasing use of alternative project delivery methods and reductions in SHA staffing are having an impact on traditional QAO practices. SHAs are increasingly selecting alternative QAOs, but they are making these selections in an ad hoc manner because of limited staff knowledge and experience, and a lack of guidance from the research community. Highway design and construction quality research focuses almost exclusively on inspections, observations, corporate quality, warranties, and materials testing, resulting in a gap in the research about shifts in project quality roles and responsibilities. This research extends the civil engineering quality management body of knowledge by identifying factors that influence the selection of QAOs and rating the appropriateness of the QAOs for each selection factor. Because of the complexity of the topic, scope of the decision process, and the limited project data available, structured interviews and the Delphi method were chosen to explore the selection factors. The research discovered 10 factors: project size, project complexity, project delivery method, project schedule sensitivity, availability of agency project staff, agency project staff experience, agency culture, industry ability to manage their own quality, trust between agency and industry, and amount of quality risk to shift away from the agency. The research provides the highway industry with new understanding of the effects that each selection factor has on the fundamental QAOs. This fundamental knowledge will allow SHAs to make more informed QAO selections.
Mayo, G., & Issa, R. A. (2016). Nongeometric Building Information Needs Assessment for Facilities Management. Journal Of Management In Engineering, 32(3), 1-12. doi:10.1061/(ASCE)ME.1943-5479.0000414	Building information modeling (BIM) tools hold promise for owners in terms of collecting the information needed for facility operations. The introduction of BIM technology has increased the need for project teams to deliver information earlier in the project timeline. BIM has been a catalyst for process change in the architecture, engineering, and construction (AEC) industry in terms of earlier decision making and in identifying the need for more precise and accurate information throughout the design and construction process. Because of the use of collaborative project delivery methods, and the owner's participation on the project team, the same catalyst is now forcing owners to decide and specify in more detail their informational needs and deliverables. To date, owners are dependent on broad recommendations regarding what information they should collect as well as what methods may be used to collect it. To assist owners with specific recommendations, this study examined a microlevel view of the information required for owners to help them specify their closeout deliverables. The methodology included a Delphi panel of facility management personnel employed by universities in 18 states who were surveyed to establish a consensus resulting in a basic list of building information needs. The Delphi panel questions addressed the issue from the perspective of providing value as determined by the perceived need for product information in operations and maintenance (O&M), as well as the frequency of use of the product information categories. The final research result(s)-1.4 (u1)n9 -1.217 Td[(p)2.-6.6 (003 Tr9 (q)2.3 (u)13.1)-8.5 (f)2.4 (u)afmtas-0.7 (l)-3.3 (i)-3.2 (s)y

Tymvios, N. &Gambatese J.A. (2016). Direction for Generating Interest for Design for Construction Worker Safety—A Delphi Study. Journal of Construction Engineering and Management, 142(8). https://doi.org/10.1061/(ASCE)CO.1943-7862.0001134	C9

Wong, J. K., & Kuan, K. (2014). Implementing ‘BEAM Plus’ for BIM-based sustainability analysis. Automation In Construction, 44163-175. doi:10.1016/j.autcon.2014.04.003

Escalating energy costs and the need to improve energy efficiency have increased public awa