# Qualitative Research: Application of the Delphi Method to CEM Research

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**Abstract:** Construction engineering and management (CEM) researchers often rely on alternative research techniques when traditional methods fail. For example, surveys, interviews, and group-brainstorming techniques may not be appropriate for research that involves confounding factors and requires access to sensitive data. In such an environment, the Delphi technique allows researchers to obtain highly reliable data from certified experts through the use of strategically designed surveys. At present, the Delphi method has not seen widespread use in CEM research. This is likely due to variation among studies that implement Delphi in CEM research and ambiguity in literature that provides guidance for the specific parameters associated with the method. Using the guidance in this paper, the reader may: (1) understand the merits, appropriate application, and appropriate procedure of the traditional Delphi process; (2) identify and qualify potential expert panelists according to objective guidelines; (3) select the appropriate parameters of the study such as the number of panelists, number of rounds, type of feedback, and measure of consensus; (4) identify potential biases that may negatively impact the quality of the results; and (5) appropriately structure the surveys and conduct the process in such a way that bias is minimized or eliminated.

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## Introduction

The dynamic and transient nature of construction projects makes construction engineering and management (CEM) research particularly challenging. For example, experimental research on safety, risk management, innovation, and technology forecasting is often unrealistic due to the sensitivity and complexity of the topics. To study such subjects, researchers typically rely on survey and group-brainstorming techniques to collect subjective data. The inherent structure of these studies may involve substantial bias that researchers must recognize and minimize. Therefore, a structured research method that offers researchers the opportunity to control bias and ensure qualification of the respondents is desirable. The Delphi technique, originally developed by the Rand Corporation to study the impact of technology on warfare, allows researchers to maintain significant control over bias in a well-structured academically rigorous process using the judgment of qualified experts.

The Delphi method is a systematic and interactive research technique for obtaining the judgment of a panel of independent experts on a specific topic. Individuals are selected according to predefined guidelines and are asked to participate in two or more rounds of structured surveys. After each round, the facilitator provides an anonymous summary of the experts' input from the previous survey as a part of the subsequent survey. In each subsequent round, participants are encouraged to review the anonymous opinion of the other panelists and consider revising their previous response. The goal during this process is to decrease the variability of the responses and achieve group consensus about the correct value. Finally, the process is concluded after a predefined criterion (e.g., number of rounds or the achievement of consensus) is met and a statistical aggregation of the responses in the final round determines the results.

This research method differs from traditional simple survey methods in that the respondents are certified as experts according to predefined guidelines before the survey process begins, and consensus is achieved through the use of controlled and anonymous feedback provided by the facilitator during multiple rounds. This research technique also allows the expert panelists to anonymously interact and allows the facilitator to exhibit strong control over the interactions among panelists.

In contemporary research, the Delphi method is particularly useful when objective data are unattainable, there is a lack of empirical evidence, experimental research is unrealistic or unethical, or when the heterogeneity of the participants must be preserved to assure validity of the results. Despite its application to CEM research, this well-defined and highly successful research technique has not seen widespread use. Several factors may contribute to the limited use of the Delphi method. For example, some critics claim that many Delphi studies result in low-quality findings limited by the facilitator's survey instruments, poor choice of experts, lack of effort to reduce bias, unreliable analyses, and limited feedback during the study (Gupta and Clarke 1996). Furthermore, the significant variation in the Delphi process

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**Table 1.** Characteristics of Delphi Studies in CEM Research

| Study | Panelists qualifications | Number of rounds | Number of panelist | Feedback | Measure of consensus |
|---|---|---|---|---|---|
| Arditi and Gunaydin (1999) | Specific prequalified | 3 | 14 | Mean | Standard deviation |
| del Caño and de la Cruz (2002) | Specific, not prequalified | 1 | 20 | None indicated | None indicated |
| de la Cruz et al. (2006) | Specific not prequalified | 1 | 20 | None indicated | None indicated |
| Gunhan and Arditi (2005a) | Specific, prequalified | 2 | 12 | Mean | Standard deviation |
| Gunhan and Arditi (2005b) | Specific, prequalified | 2 | 12 | Mean | Standard deviation |
| Hyun et al. (2008) | Specific, prequalified | 3[a] | 7 | None indicated | None indicated |
| Robinson (1991) | Not specific | 3 | 26 | Mean | Standard deviation |

[a]Involved three rounds of independent and unique surveys with no apparent feedback between rounds.

implemented in CEM studies makes the method confusing and unclear.

The objective of this paper is to provide CEM researchers with a standard methodology for implementing the Delphi method in rigorous studies intended for publication in journals such as the ASCE *Journal of Construction Engineering and Management*. Using a combination of available literature and the experiences of the writers, a detailed procedure for implementing the method is introduced. Initially, the paper describes the traditional procedures required to conduct the research methodology as described in literature. In an effort to create a standard and adaptable methodology with application to many types of CEM research, guidelines and minimum requirements for effective implementation of all phases of the Delphi process are presented. The writers pay special attention to techniques that may be implemented to minimize judgment-based bias due to the highly subjective nature of the research method.

The standard Delphi method presented in this paper has strong potential for widespread application in CEM research. Characteristics of the industry such as dynamic work environments, transient nature, exposure to the elements, coordination of multiple trades and engineering disciplines, multidisciplinary engineering, and the workplace hazards often make traditional objective research infeasible. For example, an experimental research study that tested the viability of a safety intervention on active construction sites would be unethical as it may increase the risk of injury. For such a study, Delphi could serve an alternative methodology for validating the effectiveness of the intervention without exposing workers to increased safety risk. Delphi is also preferred to subjective research methodologies such as traditional surveys or focus groups because of the exceptionally high quality of the participants, ability to minimize judgment-based bias, and ease of implementation in an increasingly global industry.

## Literature Review

Since a significant portion of this paper is devoted to the careful collection, analysis, and summation of a large body of literature, this section will be devoted to identifying and discussing construction-related Delphi studies published in peer-reviewed journals and alternative opinion-based research methods.

### *Delphi in Construction Engineering and Management Research*

In total, the writers identified seven studies published in peer-reviewed journals that used Delphi as the primary or secondary research method to study construction-related topics (Arditi and Gunaydin 1999; del Caño and de la Cruz 2002; de la Cruz et al. 2006; Gunhan and Arditi 2005a,b; Hyun et al. 2008; Robinson 1991). The method was used in a variety of capacities and involved varying degrees of rigor. Three of the seven papers studied construction risk, two studied impact factors, one identified differences in perceptions of construction process quality, and one used the method to define pairwise comparisons for input into the analytic hierarchy process (AHP). All studies used the qualitative Delphi method to obtain quantitative results. Specifically, researchers used the Delphi process to quantify risk, impact factors, or perception of process quality. While the application of the Delphi method appeared to be consistent among construction-related publications, there was significant variation on the specific characteristics of the research processes. Table 1 summarizes the various characteristics of the publications reviewed. This table was created using the information provided in the publications.

To clarify the table, studies that used objective criteria to qualify expert panelists are denoted in the table as "specific, prequalified." Those that simply report the qualifications once the process is complete are denoted "specific, not prequalified," and studies that did not indicate any specific requirements are listed as "not specific."

There is significant variation in the Delphi studies reviewed. For example, the requirements for expert qualification, the appropriate methods for data collection, analysis and transmission of controlled and anonymous feedback, the sufficient number of rounds of surveys to complete the process, and appropriate measures of consensus are inconsistent among publications. Four of the seven publications indicate that the mean was used as feedback and standard deviation was used to describe consensus while three did not indicate that any feedback existed between rounds and no measure of consensus was discussed. Similarly, the number of rounds ranged from one to three and in one study, Hyun et al. (2008), surveys with a completely different focus were administered in each of the three rounds. In a creative adaptation of the Delphi method, Arditi and Gunaydin (1999) used two distinct panels in an effort to compare the perception of process quality between entry-level and long-term practitioners. In this study, one of the expert panels consisted of entry-level professionals with little experience as these individuals are experts in entry-level perception. While there was variation in the application of the Delphi method, five of the seven studies incorporate all of the basic elements. However, significant errors in the other two Delphi studies were identified.

In a careful review of the publications by del Caño and de la Cruz (del Caño and de la Cruz 2002; de la Cruz et al. 2006), the writers appear to have confused the Delphi method with interviews with highly qualified respondents. In these two publications, there is no discussion of specifics that characterize the

Delphi method such as multiple rounds, feedback, and achievement of consensus. Due to the misconception of some researchers regarding the appropriate procedures required, the variability among construction-related applications, and the lack of specific guidance in literature, a clear description of the Delphi method that provides researchers with specific guidance for the appropriate use of the Delphi method to achieve high-quality results is clearly warranted.

There is a great deal of literature outside of ASCE journals that discusses the Delphi method. Unfortunately, most publications simply review the steps required to complete a research study, or survey researchers who have used the method to determine the range of applications. There is little focus on the specific details of the research methodology that ultimately defines the level of rigor, the scope of inference, and the reliability and defendability of the results. Because of the nature of the Delphi method, it is possible to apply the technique to many fields of study and incorporate a diverse group of participants. However, the variability of minimum requirements for expert panelists, type of feedback, number of rounds, structure of surveys, and measures of consensus often leads to significant methodological diversity. This allows a study to be poorly constructed leading to biased results.

### *Alternatives to the Delphi Method*

A key decision in any research project is the careful selection of an appropriate research methodology. Delphi has been found to be the preferred research method when the problem does not lend itself to precise analytical techniques, questions to be answered by intuitive judgment supersede questions to be answered by concrete measurement, and disagreement exists among experts to the extent that a refereed communication process is desired (Pill 1971; Linstone and Turoff 1975).

The Delphi method is not appropriate for all studies. Researchers are always encouraged to explore all reasonable and objective options for the collection of such data before considering a qualitative method such as Delphi. For example, objective and empirical data that can be measured or collected in a controlled scientific method are always preferred to subjective opinions. The Delphi method is also inappropriate when the general recommended structure cannot be followed, the method is applied for a purpose other than achieving the consensus of a group of experts, the ideals of the process are violated, objective data are available, experts are unavailable or unwilling to participate, and when the facilitator does not have the appropriate experience, education, or time to lead the study or interpret results (Veltri 1985). When the Delphi process is inappropriate there are three alternative methods of obtaining expert opinion that may be considered: staticized groups, interacting groups, and the nominal group technique. Each of these methods is described next.

#### Staticized Groups

The staticized groups research method is identical to the Delphi method with the exclusion of feedback or iteration. That is, the method represents the aggregate responses of certified experts from initial questioning. Therefore, there is no interaction between panel members. Some writers such as Erffmeyer and Lane (1984) prefer this methodology because panel members are less likely to conform about an incorrect value.

#### Interacting Groups

This method, otherwise known as "focus groups," involves collecting experts in one physical location, via teleconference, or other modern method of virtual meetings where experts can communicate with one another in real time. In this method, the panel members are not anonymous. The main pitfalls of interacting groups are bias effects due to potential dominance of one group member over another and the financial and logistical difficulties associated with gathering experts in one physical location.

#### Nominal Group Technique

The nominal group technique (NGT) is also referred to as "estimate-talk-estimate" or "brainstorming NGT." The NGT procedure uses the same process as Delphi except that feedback is delivered through face-to-face meetings and discussions between rounds. This method has been proven effective in expediting the data collection procedure but often results in significantly more biased results and conformity (Erffmeyer and Lane 1984). Similar to interacting groups, this method is difficult to conduct because it requires the collection of experts in one geographic location.

The three alternative techniques to Delphi may be appropriate when standards cannot be met for Delphi, the experts are already located in one physical location, or when time is severely limited. However, Rowe and Wright (1999) found that literature supports Delphi as the preferred method in a review of peer-reviewed studies that implement expert-based studies.

## Structure of the Delphi Method

To orient readers who are unfamiliar with the Delphi process and to provide a context for the remainder of the paper, the typical events associated with a complete, traditional Delphi study must be discussed and graphically illustrated. It is vitally important that the basic steps are understood and incorporated and that any deviation from the standard process is recognized, discussed, and justified in any resulting publication. Most Delphi studies published in ASCE journals do not recognize or justify deviations in the methodology, making the publications unnecessarily vague.

The typical order of events of the Delphi process is summarized in Fig. 1. This flowchart represents the order of events and illustrates the role of multiple rounds. This general structure is suggested for all Delphi studies applied to CEM research.

During design of a recent Delphi study, the writers found that guidance for the basic steps of the Delphi procedure illustrated by Fig. 1 was abundant (Hallowell 2008). However, the specific design of the Delphi process was limited, outdated, and difficult to obtain. In particular, there was no literature that addressed controls that may be implemented to reduce the effects of biased responses.

The following section of the paper is devoted to the creation of specific guidelines for the rigorous implementation of the Delphi method. For reference, the writers highlight specifics associated with a recent study conducted by Hallowell (2008) that attempted to quantify safety and health risks. The study successfully used the Delphi method to obtain probability and severity values, on 1–10 scales, from expert panelists. The specific Delphi process used for this study is discussed in detail and is summarized in Fig 1. The writers believe that the methods described lead to highly reliable results and are applicable to many types of CEM research.

### *Expertise Requirements*

In the Delphi process, the most important facet of a panel member is their level of expertise. Nevertheless, the characteristics re-

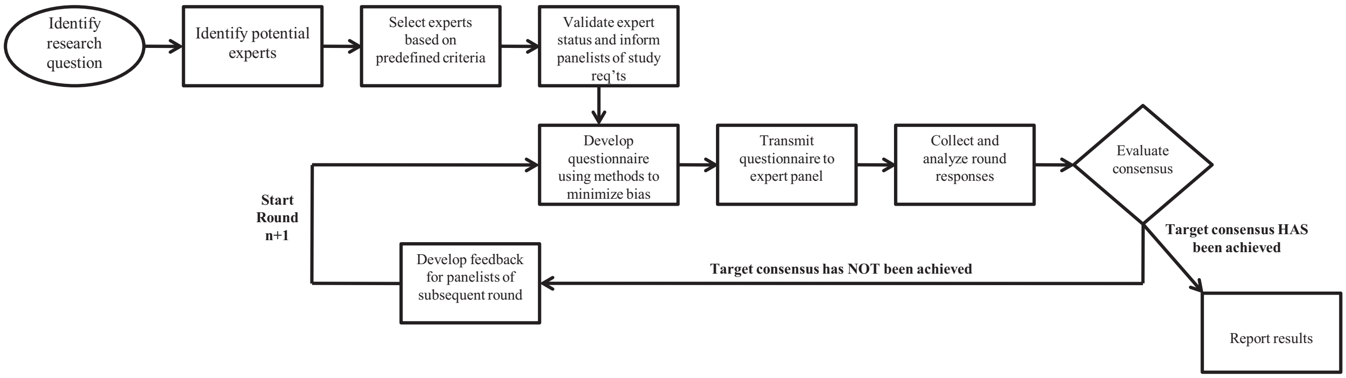


**Fig. 1.** Suggested Delphi procedure

quired to define an individual as an "expert" are equivocal. As in nearly all studies, a major objective is to obtain an unbiased representative sample. Therefore, the method of selecting expert panel members should be strategic and unbiased as well. Two studies were identified that provide explicit guidance for qualifying individuals as experts. Unfortunately, the requirements discussed in these publications are dissimilar and vague (Rogers and Lopez 2002; Veltri 1985).

Rogers and Lopez (2002) required that all expert panel members meet at least two of the following requirements (within the field of study under examination): authorship, conference presenter, member or chair of committee, employed in practice with 5 years of experience, and employed as a faculty member at an institute of higher learning. One will note that the authorship and conference presenter requirements are especially vague and open to interpretation. In a similar study, Veltri (1985) incorporated more flexible guidelines requiring that panel member meet one of the following: demonstration of knowledge which members of recognized professions and society at large judge as being of expert quality, exhibition of expertise by willingly submitting for critical examination, various publications related to the discipline involved, participation in professionally related forums, conferences, and workshops with colleagues interested in advancing the related profession. While these guidelines are flexible and are likely to qualify many available participants, the quality of the results may be compromised. Because of the lack of complete guidance, the writers created two sets of specific expertise requirements for use in a recent study based on literature and characteristics of well-known and widely recognized experts (Hallowell 2008).

When a diverse group of highly qualified and well-rounded experts is desired for rigorous CEM research, the writers suggest that panelists meet at least four specific requirements listed in Table 2. Requiring that panelists meet at least four requirements

**Table 2.** Guidelines for the Rigorous Implementation of the Delphi Research Method

| Characteristic | Minimum requirement |
|---|---|
| Identifying potential experts | Membership in a nationally recognized committee in the focus area of the research (e.g., ASCE Site Safety Committee) |
| | Primary writer of publications in ASCE journals |
| | Known participation in similar expert-based studies |
| Qualifying panelists as experts | Experts must satisfy at least four of the following criteria in the topics related to the research:<br>• Primary or secondary writer of at least three peer-reviewed journal articles<br>• Invited to present at a conference<br>• Member or chair of a nationally recognized committee<br>• At least 5 years of professional experience in the construction industry<br>• Faculty member at an accredited institution of higher learning<br>• Writer or editor of a book or book chapter on the topic of construction safety and health, or risk management<br>• Advanced degree in the field of civil engineering, CEM, or other related fields (minimum of a BS)<br>• Professional registration such as Professional Engineer (PE), Licensed Architect (AIA), Certified Safety Professional (CSP), Associated Risk Manager (ARM) |
| Number of panelists | 8–12 |
| Number of rounds | 3 |
| Feedback for each round | |
| Round 1 | Data from preliminary research or archived data (if available) |
| Round 2 | Median response from Round 1 |
| Round 3 | Median response from Round 2 and reasons for outlying responses |
| Measuring consensus | Absolute deviation (with consensus indicated by a value $<1/10$ of the range of possible values for quantitative studies) |

**Table 3.** Flexible Point System for the Qualification of Expert Panelists

| Achievement or experience | Points (each) |
|---|---|
| Professional registration | 3 |
| Year of professional experience | 1 |
| Conference presentation | 0.5 |
| Member of a committee | 1 |
| Chair of a committee | 3 |
| Peer-reviewed journal article | 2 |
| Faculty member at an accredited university | 3 |
| Writer/editor of a book | 4 |
| Writer of a book chapter | 2 |
| Advanced degrees: | |
| BS | 4 |
| MS | 2 |
| Ph.D. | 4 |

in the field under examination encourages a healthy balance of academic and professional experience and ensures that panelists have distinguished themselves as experts on the topic.

The requirements listed in Table 2 are likely to lead to a well-qualified and diverse panel with a wide range of experience. In some studies, however, researchers may wish to have a more narrow focus requiring the qualification of specific types of individuals. For example, a study may not require academic experience if such experience is irrelevant or unlikely to add value. In such a study, having panelists with academic accolades and publishing experience may be inappropriate. In this case, a relative point system that allows one to select specific expert qualities may be more appropriate. The writers offer a relative point system in Table 3 for qualifying experts that may be more flexible for some studies. This point system is based on the relative time commitment required to successfully complete each of the achievements or experiences and is based on the best judgment of the writers and practices of professional licensing agencies. One should note that this point system may need to be adapted to meet the specific goals of a research project. In order to meet a minimum level of qualification using the point system shown in Table 3, it is suggested that panelists score at least one point in four different achievement or experience categories and a minimum of 11 total points in order to qualify for participation.

### Number of Panel Members

The impact of the number of panelists on the accuracy and effectiveness of the method has been studied by Brockhoff (1975) and Boje and Murnighan (1982). Neither study found a significant correlation between the number of panel members and effectiveness. A summary in Rowe and Wright (1999) indicates that the size of a Delphi panel has ranged in peer-reviewed studies from a low of three members to a high of 80. Since most studies incorporate between eight and 16 panelists, a minimum of eight is suggested. The specific number of panelists should be dictated by the characteristics of the study such as the number of available experts, the desired geographic representation, and the capability of the facilitator. The selected number of panel members should also take into consideration that some panelists may decide to drop out of the study due to other commitments or disinterest. A sufficient number of panelists should be selected at the start of the process to ensure a qualified panel at the end of the study assuming some will not complete each round. In a recent study the writers created two independent panels of 12 and 15 members each (Hallowell 2008). This number was easily managed by a full-time facilitator.

### Number of Rounds

The purpose of multiple rounds is twofold. The main objective is to reach consensus by reducing variance in responses. The second purpose is to improve precision. Both of these objectives are achieved through the use of controlled feedback and iteration. It is assumed, and supported by literature, that convergence to a collective opinion and precision (i.e., "closeness" to actual state) are improved as a result of each round. However, literature provides very little guidance for the acceptable number of iterations.

A summary of peer-reviewed Delphi studies indicates that the number of rounds ranged from two to six (Dalkey et al. 1970; Gupta and Clarke 1996; Linstone and Turoff 1975; Pill 1971). Over one-half of these studies found acceptable convergence after three or fewer iterations. In fact, Dalkey et al. (1970) suggests that the Delphi results are most accurate after round two and become less accurate as a result of additional rounds. However, the use of at least three rounds allows the facilitator to obtain reasons for outlying responses as a part of the second round and to report these reasons as feedback in round three. By reviewing the reasons for outlying responses in the third and final round, panelists are more likely to consider all options and reach consensus about the correct value rather than conforming to an incorrect opinion. Studies that include only two rounds are incapable of adequately identifying outlying viewpoints, obtaining justification, and sharing this information with other panelists.

### Feedback Process

As indicated earlier, the feedback process is the mechanism for informing panel members of the opinions of their anonymous counterparts. Without iterating and providing this controlled feedback, the process could not be called, "Delphi." The most common feedback provided in subsequent rounds is simple statistical summaries such as median, mean, or quartile ranges. Some studies provide additional information such as the arguments from the panel members whose opinions are outside the interquartile range. Including anonymous justification for outlying observations ensures that all opinions are considered.

Best (1974) found that Delphi groups that were given reasons as part of the feedback in addition to median and range of estimates were significantly more accurate than Delphi groups that were provided with only the latter. Despite conflicting evidence in social psychology regarding the influence of various feedback methods on accuracy, conformity, change in opinion, and consensus, Delphi studies that included reasons and simple statistical summaries lead to more accurate results (Rowe and Wright 1999). One should note that none of the seven construction-related publications appear to have used reporting reasons as a form of feedback.

### Measuring Consensus

One of the more difficult aspects of the Delphi process is the appropriate method of measuring consensus. While it is common to use variance as a measure of consensus, guidance that describes the level of variance that represents consensus is not available in literature. The writers believe that such guidance is not provided because the data collected for nearly every study is unique. Therefore, it would be inappropriate to indicate a certain level of variance that represents adequate consensus for all studies.

In the Delphi study completed by Hallowell (2008) the respondents' consensus was considered to have been achieved when the absolute deviation was within one unit on a 1–10 scale (i.e., +/−5% deviation about the median). The absolute deviation was used as a measure of consensus in lieu of the standard deviation because it measures variability in response about the median rather than the mean. For this study, the median values represented the results of this study because the median is less likely to be influenced by biased results.

A summary of the suggested guidelines for the Delphi process is provided in Table 2. These guidelines are suggested by the writers to ensure a high level of rigor in any CEM study. However, one may be required to augment or modify the specific requirements and parameters in Table 3 to meet the specific needs of a particular study. One should also note that the guidelines offered in Table 2 are for the standard application of the Delphi method to any type of study. These guidelines do not include specific controls to minimize judgment-based bias during the process, an important aspect of any rigorous study. This topic is discussed as it relates to risk quantification in the subsequent section of this paper.

In addition to following the suggested guidelines, researchers should take care when developing the Delphi survey to ensure that the length is reasonable to ensure an adequate response rate. Also, pilot tests of the surveys are suggested to ensure that the level of detail is appropriate for the study, the role of the expert panelists is well defined, and survey instructions are easy to follow.

## Methods to Minimize Bias

Rigorous and defendable research studies must hold the minimization of bias paramount. Bias in judgment is important to consider because cognitive shortcuts that distort the true nature of opinion or observation may lead to inaccuracies in judgment (Heath and Tindale 1994). Unlike objective methods where bias is mainly introduced by the researcher, the success of the Delphi process depends on the unbiased judgment of experts. Despite the fact that bias can be detrimental to Delphi studies, no literature reviewed specifically addresses bias during the Delphi process with only one exception. Anonymity, one of the elements that characterize the Delphi process, is incorporated to minimize one form of judgment-based bias: dominance. Other forms of bias such as primacy, recency, and the Von Restorff effect may also adversely affect the study if not recognized and controlled.

This section of the paper is devoted to the identification and discussion of eight judgment-based biases that may adversely affect a Delphi study that aims to quantify risks in the construction industry. The writers chose to highlight risk studies because major forms of bias have been identified and controlled in a recent Delphi study completed by Hallowell (2008) and three of the eight construction-related Delphi studies identified in literature specifically address risk quantification. Furthermore, identification of all types of cognitive bias that may affect all types of CEM studies is outside the scope of this paper because literature in the field of social psychology has identified hundreds of cognitive biases. It is the opinion of the writers that implementing the controls suggested for the eight biases discussed in this paper is sufficient for the purpose of most CEM research. This should, however, be evaluated by researchers on a case-by-case basis to ensure the quality of the study.

### *Judgment-Based Bias in Risk Studies*

Judgment is a skill that is used in decision making when disputable factual information is absent and is the primary mechanism for data collection in any Delphi study. One or more of the following three classes of judgment are used to reason and eventually make choices:

- *Diagnostic:* diagnostic judgment involves using intuition, visualization, organization and structuring of evidence, and the understanding of relationships to reach a conclusion.
- *Inductive:* inductive reasoning requires the synthesis of evidence and information from a variety of sources. Inducing requires use of an individual's awareness of signs and evidence to draw conclusions. The ability to draw correct conclusions using inductive reasoning is directly related to an individual's experience, observations, and ability to recognize evidence.
- *Interpretive:* interpretive reasoning involves the recognition of patterns, spatial relationships, correlations and causal relationships. Individuals who can effectively reason through interpretation must be able to critically review, evaluate and develop and context for a particular scenario.

In a Delphi study it is assumed that identified experts are uniquely capable of providing proficient judgment using one or more of the three reasoning methods identified earlier due to their extraordinary experience or intelligence. One should note, however, that various sources of bias may exist despite the panelists' status as certified experts. Any panelist is likely to be susceptible to one or more of the eight major forms of judgment-based bias during the Delphi process to some degree. Although there are hundreds of types of biases, the writers selected eight major forms of bias because of their potential ability to negatively impact the quality of the results of a Delphi study. These factors are not necessarily controlled when following traditional guidelines for Delphi implementation. Special attention is paid to biases that may affect risk perceptions.

#### Collective Unconscious

Simply, the theory of collective unconscious, otherwise known as the "bandwagon effect," states that decision makers tend to join a popular trend. In other words, individuals are likely to unconsciously feel pressure to conform to the common or standard beliefs within a particular group. According to Durkheim (1982), individual beliefs are limitless unless constrained or directed by social forces such as peer pressure or dominance. The bandwagon effect occurs when social forces compel an individual to conform. The collective unconscious must be considered in a Delphi study because bias occurs when a decision maker conforms to popular belief without examining the merits of the position.

#### Contrast Effect

The contrast effect occurs when the perception of a given subject is enhanced or diminished by the value of the immediately preceding subject. Bjarnason and Jonsson (2005) contend that an individual's evaluation of a criterion may be directly influenced by a previous exposure of substantially higher or lower value. In theory, the contrast effect can cause significant bias, especially when Delphi panel members are to rate risks or identify relative differences among multiple factors. In such a case, a significant contrast bias may exist when panelists are asked to rate back-to-back factors of substantially different values. Since most Delphi studies in construction research involve rating risks or factors of some kind, the Delphi questionnaire must be structured to minimize contrast effects.

**Neglect of Probability**

There are many cases where individuals underestimate the role of probability in the subjective quantification of risk. This bias involves the disregard of likelihood when making a decision under uncertainty. For example, Rottenstreich and Hsee (2001) found that while the average individual was willing to pay $7 to avoid a 1% chance of a painful electric shock, the same individuals were only willing to pay $10 to avoid a 99% chance of the same shock. In this case, the subjects have devalued the concept of probability in this scenario. Any study that involves risk quantification or ratings of likelihood may be susceptible to the neglect of probability bias. Controls are especially important because researchers suggest that the neglect of probability is relatively common (Martin 2006).

**Von Restorff Effect**

The Von Restorff Effect was first introduced to the field of psychology when subjects were found to recognize and remember relatively extreme events more often and more accurately than less extreme events (Restorff 1933). Simply, individuals are more likely to remember events associated with severe outcomes thereby distorting the perception of probability.

This phenomenon is likely to bias risk perceptions because more extreme events are likely to be recalled. It is especially important to consider this bias when soliciting risk perceptions because individuals are more likely to overestimate probability values when an especially high magnitude is involved (Krimsky and Golding 1992). This effectively creates an artificially inflated risk score for potential events associated with a higher level of severity.

**Myside Bias**

According to Perkins (1989), myside bias occurs when an individual generates arguments only on one side of an issue. Perkins provided a demonstration of this bias by asking the study participants to list the thoughts that occur to them when considering controversial subjects. The majority of the participants recorded thoughts that pertained to only one side of the controversy. According to (Baron 2003), participants can be, "easily prompted for additional arguments on the other side, although prompting for further arguments on their favored side is less effective. So the failure to think of arguments on the other side is typically not the result of not knowing them."

The persistence of irrational belief is generally a result of one's personal opinion and has little basis in pure fact. This phenomenon also exists when uncompromising individuals do not seek objective viewpoints. Myside bias is especially important to consider in Delphi studies because the chief objective is to reach consensus among the experts. Therefore, controls that ensure the consideration of multiple viewpoints are essential.

**Recency Effect**

The recency effect occurs when subjects are more likely to artificially inflate risk ratings because similar incidents have recently occurred in their personal lives. That is to say, recent events are given inappropriate levels of salience in relation to others. The effect of recency is relatively common. While recency is relatively difficult to control for, one method of controlling for this bias is the removal of panelists who have recently experienced events related to the study.

**Primacy Effect**

The primacy effect is a relatively subtle form of cognitive bias. This effect results from the unconscious assignment of importance to initial questions, observations, or other stimuli. The theory states that individuals are inherently more concerned with initial stimuli. That is, relatively speaking, the first stimulus will be considered more important than the final observation. In terms of risk quantification, an individual is more likely to assign importance to a risk scenario at the beginning of a Delphi survey than at the end of the survey.

**Dominance**

Dominance occurs when one, usually very vocal or intimidating group member, exhibits great control over the ratings of the other members. This common source of bias is typically controlled through anonymity and equal weighting of responses. These means for limiting the bias ensure that each panel member submits their true opinion without the influence of a dominant member.

The eight biases discussed represent the salient biases for most construction-related studies. Depending on the nature of the research, the facilitator may need to review social psychology literature to identify other potential biases. Once biases are identified, it is essential that the facilitator take all reasonable steps available to control and minimize their potential effects. The following section defines some methods for designing a Delphi study to minimize and avoid the eight biases discussed earlier.

## Minimizing the Effects of Biases

In the field of statistics, a prominent method of bias reduction is the use of randomization. Randomization is a control by which a researcher ensures that every subset of the greater population has an equal chance of being selected. Randomization may be achieved through the use of workbooks with random number tables, using the last four digits in telephone directories, or by using a pseudorandom number generator such as MS Excel. For construction risk studies, randomization can be used to reduce bias associated with the contrast, Von Restroff, and primacy effects. The remaining five biases may be controlled by the strategic design of the survey and feedback mechanisms. Table 4 provides the reader with a summary of controls that may be implemented. A short description of each of the six controls listed in Table 4 is provided next. These controls were successfully implemented on a recent study (Hallowell 2008).

1. *Randomize questions in the survey:* the order of questions in the Delphi surveys may be randomized for each Delphi panel member. In addition, a new randomized order for each panelist should be created for each round. Random numbers may be generated and assigned to each question using a random number generator and the relative ranking (e.g., highest to lowest) may be used to determine the order of the questions.
2. *Include reasons in controlled feedback:* as indicated, Delphi groups that were given feedback that included reasons for specific panelist responses in addition to median and range of estimates were significantly more accurate than Delphi groups that were provided with only the latter. Expert panel-

**Table 4.** Controls for Bias in the Delphi Process

| Bias | Control/countermeasure |
|---|---|
| Collective unconscious | Include reasons in the controlled feedback to the Delphi panel for each round |
| Contrast effect | Randomize the order of questions for each panel member and for each round, and report final results as a median |
| Neglect of probability | Require that the probability ratings and severity ratings for each risk are recorded independently |
| Von Restorff effect | Include reasons in controlled feedback and conduct multiple rounds of surveys |
| Myside bias | Include reasons in the controlled feedback and report final risk ratings as a median |
| Recency effect | Remove individuals who have experienced recent events, remove outlying observations, conduct multiple rounds, and report results as a median |
| Primacy effect | Randomize the order of questions for each panel member |
| Dominance | Ensure anonymity of expert panelists |

ists should be asked to provide a very brief justification for their ratings during the second round. This justification should be summarized and reported as part of the controlled feedback in the third round.

3. *Conduct multiple rounds of surveys and maintain anonymity:* iteration is an essential component of any Delphi study. The primary role of multiple rounds is to achieve a high degree of consensus among panel members. The potential reduction in bias is rarely discussed. Iteration involves the redistribution of the Delphi survey accompanied with controlled feedback. Maintaining anonymity is essential for avoiding the influence of dominant panel members.
4. *Require independent probability and severity ratings:* surveys should be structured such that panel members will be required to consider probability and severity values separately for each risk scenario.
5. *Report medians:* results should be reported in terms of the median rather than the mean because the median response is less likely to be affected by biased responses.
6. *Remove members who experienced recent events:* in the introductory survey, Delphi members should be asked a series of questions related to their recent experience with construction risks. Respondents who indicate recent exposure should be closely monitored during the Delphi process or removed from the study completely. If the individual appears to be affected by recency bias, the results may be omitted using statistical justification.

It is important for one to understand the limits of the controls suggested. Some of the controls, such as randomization of question order theoretically eliminate contrast and primacy biases while others such as reporting medians only partially mitigate recency bias. Table 5 summarizes the impacts of the controls on the various biases. In this table, the complete removal of a judgment-based bias is denoted “*x*“ while the partial removal of a bias is denoted “x.” In two recent risk studies, the writers implemented all of the controls listed in Table 5 and were confident that bias was successfully minimized. Also, one should note that the controls developed for Table 5 may also minimize other forms of bias not previously mentioned in this paper.

## Conclusions

The challenging nature of construction management research requires the use of alternative research techniques in studies where traditional methods are not applicable or effective. Many topics of CEM research, such as safety and health, risk management, forecasting, and innovation, are complex, involve many confounding factors, or are extremely sensitive precluding the use of traditional research methodologies. Despite its potential application, the Delphi method has seen minimal use in CEM research. In fact, a review of literature indicated that only eight major studies implemented Delphi as the primary or secondary research method. Also, a significant variation in methodological approach was found to exist in this small body of literature. Additionally, these publications ranged significantly in quality. The writers believe that this variation is a result of the inconsistencies and ambiguity of literature that provides guidance for the method.

In an effort to consolidate a relatively large body of literature, the writers have created a standard but flexible method that may be applied to most types of CEM research. Using the guidance in this paper, the reader may: understand the merits, appropriate application, and appropriate procedure of the traditional Delphi process; identify and qualify potential expert panelists according to objective guidelines; select the appropriate parameters of the study such as the number of panelists, number of rounds, type of feedback, and measure of consensus; identify potential biases that may negatively impact the quality of the results; and appropriately structure the surveys and conduct the process in such a way that bias is minimized or eliminated. By following the guidelines suggested in this paper, high-quality, minimally biased results are expected.

**Table 5.** Bias Reduction Resulting from Controls Implemented during Delphi

| | Bias | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Control | Collective unconscious | Contrast | Neglect of probability | Von Restorff | Myside bias | Recency | Primacy | Dominance |
| Randomize question order | | *x* | | | | | *x* | |
| Include reasons in feedback | x | | | x | x | | | |
| Iteration and anonymity | | | | x | | | | *x* |
| Separate probability and severity ratings | | | *x* | | | | | |
| Report medians | | x | | x | x | x | x | |
| Remove members who experienced recent events | | | | | | *x* | | |

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