Heuristics in Construction Project Management

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Thesis submitted to the faculty of the Virginia Polytechnic Institute and State University
in partial fulfillment of the requirements for the degree of

Master of Science
In
Civil Engineering

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12 December 2018
Blacksburg, VA

Keywords: heuristics, decision science, rules of thumb, construction, project management

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ABSTRACT

Modern construction projects are delivered in complex, fast pace environments. Stakeholders are required to participate in dynamic project settings with resource constraints, information constraints, and time constraints. To overcome gaps in knowledge, to deliver decisions quickly, and to overcome human limits in cognitive ability, decision makers typically employ heuristics, or "rules of thumb" to arrive at relatively quick answers. Heuristics are cognitive shortcuts that an individual employs to arrive at quick decisions (Goodwin et al., 2004). These heuristics are used in a variety of ways, ranging from using the process of elimination (elimination heuristic) to applying different cognitive weights to options based on recent experience, reputation, or familiarity (Shah & Oppenheimer, 2008). This research aims to identify heuristics present in the implementation phase of construction. By summarizing the results of two studies conducted with a Mid-Atlantic Contractor, this thesis prescribes seven heuristics commonly used by construction stakeholders.

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GENERAL AUDIENCE ABSTRACT

Modern construction provides a difficult decision making environment for workers. Construction stakeholders often work in environments with limited time, with limited information, and with limited knowledge. Decision makers in these environments typically use mental rules of thumb (formerly known as heuristics). These rules of thumb help decisions makers arrive at quick answers and often increase efficiency. They can be used in a variety of ways. An individual may use the process of elimination to find a solution. Others may base their decision off a company, person, or object 's reputation. Others may only choose an option that is recognizable. Rules of thumb take many forms and are used by all people. Studying rules of thumb can benefit an industry. This has already been proven in many industries, such as insurance (Handel & Kolstad, 2015), medicine (Martin et al., 2012), and economics (Grandori, 2010). The construction industry has begun to study rules of thumb that impact early stages of the construction process, but it still lacks rules of thumb that impact the process of physical construction. This paper aims to assist the construction industry in gaining a fuller view of decision making shortcuts used by its stakeholders. By summarizing the results of two studies conducted with a Mid-Atlantic Contractor, this thesis outlines seven heuristic used by construction workers.

ACKNOWLEDGEMENT

I would like to express my immense gratitude to my advisor, Dr. Tripp Shealy. I would not have been able to complete this thesis without his constant mentorship. He is honestly one of the hardest working professors that I have ever met, and zealously dedicated to his students. His dedication to my research and my success was evident in our frequent meetings where he always found time to mentor me through the research process. Tripp has been a huge role model in my life while at Virginia Tech, and has inspired me to continually work hard and instilled in me a passion for decision science.

I would like to express my respect and thankfulness to my co-advisor, Dr. Michael Garvin. Dr. Garvin also served as a key contributor to this thesis. His expertise in writing and communication were evident through his multiple recommendations on rhetorical adjustments for this paper. Dr. Garvin has also served as a role model in my life, always reminding me in subtle ways the importance of professionalism and hard work.

I would also like to thank my committee member, Dr. Josh Iorio. Josh is an extremely dedicated professor, who demonstrates a love of teaching and an appreciation for his students. Josh's feedback on both my research methods and my writing proved crucial in the final development of this thesis.

Finally, I would like to thank my immediate family, especially my mom and siblings. My mom, Tina, has served as the biggest inspiration in my life by always encouraging me to push through difficult times. I would also like to thank my relatives, particularly my Uncle Harvey for his constant involvement in my life.

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ATTRIBUTION

In this section, I will explain the various contributions made by Dr. Tripp Shealy, my advisor, Dr. Michael Garvin, my co-advisor, and myself. I was the primary researcher for this project. Dr. Shealy served as the primary research expert overseeing all my research activities and providing feedback on my methods, data collection, and paper. Dr. Michael Garvin served as a secondary research expert, providing similar contributions as Dr. Tripp Shealy.

In the pre-data collection phase, I outlined my research activities during my thesis proposal. Dr. Shealy and Dr. Garvin provided significant feedback on my data collection methods. I met with both of them several times before my research period to refine my interview questions and qualitative data collection methods.

I collected all data for this project. I also conducted all data analysis for this project. Dr. Garvin and Dr. Shealy both met remotely with my once a week throughout my research period to provide advice and commentary on my methods and data analysis. Data analysis continued throughout the Fall 2018 semester at Virginia Tech, and both Dr. Garvin and Dr. Shealy met with me weekly to oversee and assist in my analysis efforts.

I composed all major portions of this paper. Dr. Shealy and Dr. Garvin both provided significant commentary and revisions to my writing. Dr. Shealy, particularly, took the time to provide substantial editing to my paper.

INTRODUCTION

Decision Making in Construction

The building construction market is an ever growing field with increasingly complex systems and an abundance of new technologies. Many of the industries technological advancements, such as BIM modeling (Zhou et al. , 2018), infrared technologies (Fernández-Carrasco et al., 2012), and virtual reality (Goulding et al., 2012), have attempted to assist companies in project delivery. While these tools have many benefits, the industry still appears to be less than optimal. Even with a wide range of tools that stakeholders have at their disposal, projects still often fail to meet basic requirements of cost (Rosenfeld Yehiel, 2014), quality (Arditi & Gunaydin, 1997), and schedule (Larsen et al., 2016).

While one solution cannot optimize the construction industry, many modern solutions skip over the root problem: individual decision making. If the construction industry can influence its stakeholders to make less mistakes in their decision making, then it can reduce the amount of problems produced. Less mistakes in judgements or decisions can result in fewer material delivery delays, fewer cost estimate mistakes, fewer mistakes in scheduling, and fewer mistakes in material installment. By reducing the amount of mistakes that occur on a construction site due to bad decision making, the construction industry can begin to improve its practices overall.

Descriptive Decisions in Construction

This paper attempts to provide insights into decision making specific to project implementation. The dynamic environments present during the actual construction of a project require quick, and sometimes immediate decisions. These environments typically have constrained resources of time, information, and processing ability, and often contain complex problems. These kind of decisions environments may present themselves in a variety of typical situations. For example, when a problem arises during a concrete pour, a quick decision is required due to the drying time of concrete. Further, when an individual is creating a schedule, they often have limited information about future factors that can impact a project. When a decision is required in a subcontractor meeting, resources of time and information may be limited.

These types of scenarios require descriptive decision making that employs heuristics as a mental shortcut. Problems that don't have the luxury of drawn out, systematic decision making, are often solved by an individual's rules of thumb, or heuristics. Heuristics are the brain's natural response to its own bounded rationality and limited processing power (Simon, 1956). Heuristics are a brains mental shortcuts that aid decision makers (Goodwin et al., 2004). Heuristics are often built off experience and assist decision makers by increasing decision efficiency. Heuristics take many forms, and are often used in a variety of contexts. For example, when employing the representativeness heuristics, an individual will make a judgement or decision about a whole population based on a sample size (Kahneman & Tversky, 1972; Shah & Oppenheimer, 2008). Moreover, when employing the anchoring heuristic, an individual will anchor to a salient, or known value, and make adjustments to that value cognitively (Epley & Gilovich, 2006). These mental shortcuts are performed in almost all human decision making, but few people are aware of how they use them.

Heuristics are first and foremost, mental benefits to an individual (Goodwin et al., 2004). Heuristics are partly the reason why experience in a particular industry is so valuable. Experienced individuals in a particular area of study will have typically developed beneficial heuristics in that industry. But, heuristics don't always result in positive outcomes. If over relied on and used unknowingly, especially by less experienced individuals, heuristics can have negative decision making results (Tversky & Kahneman, 1974).

Heuristics in Construction

Behavioral economists have embraced heuristics to improve their models. Although their early predictions of human behavior were flawed, researchers have since improved models to demonstrate man's typical decision making behavior. Edwards (1954) was one of the first individuals to model man's behavior with his model of "the economic man." His model was quickly improved upon by Simon (1956), by the discovery of bounded rationality. Simon demonstrated that man's decision making tendencies were limited to his own finite rationality, and that man's decisions were often irrational. Prospect theory built off this model, and accounted for the influences of gains and losses in decision making (Tversky & Kahneman, 1974). Since, prospect theory and the theory of bounded rationality have served as a basis for heuristic models. Heuristics have since provided insights into how individuals make decisions in a variety of contexts (Tversky & Kahneman, 1974). The construction industry has begun to study heuristics that influence stakeholders, but has yet to establish a holistic picture of heuristics that impact all areas of project delivery.

Few researchers have begun to demonstrate heuristics that impact a construction project's delivery. But, these researchers have only touched on heuristics present in the initial planning and design phase of a project. Farsi (2010) discovered the risk averse nature of apartments and homeowners. Beamish and Biggart coined four construction specific heuristics: 1) default building, 2) function, 3) flexibility, and 4) reputation. VanBuiten et al. (2013) recognized the affect heuristic in private public partnerships. Finally, Eriksson et al. (2016) determined that the availability, satisficing, and familiarity heuristics were all evident throughout the construction of a large rail tunnel project. While these researchers have contributed to the construction industries' understanding of decision making, literature lacks details about decision making during construction implementation.

Summary of Results

The goal of this research was to build off the existing body of knowledge by providing stakeholders a clear picture of heuristics that impact the bid and build phase of a project. The focus of this research was to answer the following research question.

What heuristics do project stakeholders use in the bid and construction phase?

This question was further broken down into two subsequent research questions that were addressed by two studies between the months of May and August 2018. Both studies were conducted at a mid-sized, Mid-Atlantic contractor ranked among ENR's top 400 contractors. This first study was guided by the following research question:

What heuristics are the most prevalent in the field during project implementation?

The results of this study were compiled from 35 interviews among employees at the company. Among the 35 interviews, five heuristics appeared as themes in the majority of transcripts. The affect, reputation, risk reduction, anchoring, and temporal preference heuristic were all used in multiple contexts.

The second study was conducted with the same contractor, but consisted of observational research. The following research question was used as a guide for this study:

How and when are heuristics employed in the field?

The results of this study were compiled from 41 observations in the field. Observations of decisions and decision environments were recorded, and heuristics were identified for applicable decisions. In this study, the familiarity, representativeness, reputation, and anchoring heuristic appeared as the majority of heuristics observed.

Journal Paper 1: Heuristics in Construction Project Management

Intended Outlet for Publication:

Journal of Management in Engineering

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Abstract

The construction of facilities and infrastructure systems are increasingly complex. Advancements in building systems, technology, and architectural design make construction projects more difficult to build and manage. Consequently, the need for optimal construction practices is evident now more than ever. Much prior research on optimization has attempted to address this growing complexity of project management and decision making by routinely developing new decision making models. These models predominately rely on normative processes that assume stakeholders are rationale actors with requisite information to make informed decisions. Construction project managers, however, do not typically use normative models when making decisions in the field since they face time and resource constraints; rather, they frequently rely on heuristics, or rules of thumb, to make project-level decisions. To develop a more descriptive explanation of the decision-making processes in the construction industry, more than 30 interviews were conducted with construction professionals in a contracting firm in the Mid-Atlantic region of the United States. The results demonstrated five heuristics that appeared in a majority of the interviews. The affect, reputation, risk reduction, anchoring, and temporal preference heuristic were all used in a variety of contexts such as scheduling, material installment, contract assignment. Overall, these heuristics proved to have both positive and negative impacts on a project's delivery.

1.0 Introduction

Owners, designers, and contractors in the construction industry continue to strive towards delivering projects that better balance cost, quality, and schedule. But, even with generations of experience, sophisticated software, and professional training, construction costs are still frequently overrun (Yehiel, 2014), project scheduling goals are seldom met (Larsen et al., 2016), and owners often express some form of regret with project deliverables (Arditi & Gunaydin, 1997; Larsen et al., 2016). It is not surprising, then, that research continues to investigate better project management practices. While more technical solutions do offer industry advances, solutions that take advantage of recent developments in behavioral decision science remain underexplored (Klotz et al., 2018; Shealy & Klotz, 2017).

In any form of decision making, individuals and groups (Sunstein, 2005) often subconsciously use mental shortcuts, or heuristics. An individual's decisions are limited to their own mind, time, given or known information, and the complexity or simplicity of a problem (Simon, 1982). Heuristics are used by individuals in almost all decisions where resources are limited. When faced with an excessive of variables that impact a decision, heuristics are employed due to the limited processing power of the human brain (Goodwin, Wright, & Phillips, 2004). When faced with the pressure of time to meet a deadline, heuristics are employed to produce a faster decision (Goodwin et al., 2004). When faced with limited information, heuristics are employed to overcome a gap in understanding (Goodwin et al., 2004). Further individuals employ heuristics when trying to reduce their cognitive load. Perfect decision outcomes that weigh all decision variables would often require the use of computers with close to unlimited processing capability, an impossible task for the human brain (Goodwin et al., 2004). Heuristics are the human brain's natural response to its own bounded rationality and they are often built off experience, aiding decision makers by creating a cognitive toolbox for arriving at quick problem solutions (Goodwin et al., 2004).

These shortcuts, or heuristics, are present in almost all types of decision making, and can be beneficial, saving time and money. For example, a mechanical engineer who performs building load calculations does not always account for every possible form of heat generation and transfer in a building. Instead, he or she only focuses on the major sources of heat load, yet arrives at a reasonable solution. By relying on the familiarity heuristic, performing the task per his familiar standard, the engineer's mental shortcuts are considered to be a time saver. While a more perfect decision might be found by including all the intricacies of heat generation and transfer, it would require additional resources and time.

However, when a decision maker becomes too reliant on heuristics, or does not fully understand why they make certain decisions, heuristics can hinder decision making. Over reliance on mental shortcuts without user awareness can result in distorted judgements and have negative impacts (van Buiten & Hartmann, 2013). For example, in the case of one Dutch contractor's experience, over use of the affect heuristic, by maintaining an overly optimistic view of project progress, often led to failed deadlines and group disappointment (van Buiten and Hartmann, 2013). By becoming more aware of the heuristics used in the construction industry, professionals can become better decision makers.

Other disciplines like medicine (Martin et al., 2012), law (Gigerenzer et al., 2006), insurance (Handel & Kolstad, 2015), economics (Grandori, 2010) and marketing (Nobibon et al., 2011) have improved their theoretical frameworks about decisions and produced real-world advances by including more focus on heuristics. Additionally, the National Academy of Engineering recognizes the opportunity to improve decision making in engineering by better understanding how heuristics are used in the field and teaching both students and professionals to be aware of when heuristics are helpful and detrimental for decision outcomes (National Research Council, 2001).

While other disciplines have benefited from applying behavioral science concepts to their industry, the construction industry is still lacking such benefits. Consequently, this research aims to improve understanding about heuristics in construction management.

2.0 Background

Decision making in project and construction management is a routine requirement of a variety of stakeholders. Thousands of decisions are made on every construction job (Solis & O'Brien, 2011). These decisions range from a variety of topics including preconstruction, construction, project billing, field supervision, and procurement. Most prior literature approach this range of decisions from a normative perspective (Kim et al., 2018; Leśniak & Plebankiewicz, 2015; Perera & Sutrisna, 2016; Wei et al., 2016). For example, recently developed decision making models assist stakeholders with concession periods of PPPs (Zhang et al., 2018), project delivery method selection (Mayra et al., 2018), and policy selection (Katarina & Nikša, 2018). These systematic decision making models can be helpful, but have many pitfalls. In early stages of project planning, when a project team has an abundance of time, normative models can assist stakeholders in answering questions on project feasibility, location, and scope. But, the reality of project implementation stages of construction provides a stark contrast in decision making environments. Project teams tasked with project implementation often operate in dynamic, fast pace environments with constrained resources, information, and time, and make dozens of project related decision daily. Normative, systematic decision tools are hardly practical in an environment where stakeholders are pressured to meet deadlines. Project stakeholders typically rely on and are aided by their own decision making shortcuts when weighing options and making a decision (Simon, 1982). For example, in studying a decision maker's process for selecting a HVAC system for Lee III Building at Clemson, Klotz and Nikou (2014) discovered that decision makers, even when provided a normative model (multi-attribute utility theory), still defaulted to employ heuristics to guide their decision (Klotz & Nikou, 2014). Further, a study by Arroyo et al. (2016) discovered the same result. Stakeholders tasked with selecting an HVAC system for a net zero energy museum defaulted to employing heuristics, rather than the Choosing by Advantages (CBA) normative model (Arroyo et al., 2016). Surprisingly, in both of these examples, both the normative and heuristic approach provided the same results, but with the heuristic approach requiring much less time.

Nearly four decades ago, economists began recognizing the importance of descriptive approaches to decision making. Utility theory viewed decision makers as perfectly rational (Edwards, 1954). The emergence of theories about bounded rationality and prospect theory highlight the flaws in utility theory. Decision makers are at times irrational from a normative point of view, overly risk averse and limited in their processing ability by time and information (Simon, 1956, 1982). Heuristics explain these limitations and led to improved theories about decision making related to money (Shang & Croson, 2009), time (Frederick et al., 2002), and preferences (March, 1978).

Just as heuristics are present in decisions in emergency rooms (Loewenstein, 2005), court rooms (Gigerenzer et al., 2006), and board rooms (Davenport, 2009), heuristics play a key role in the planning and design phase of facilities and infrastructure (Beamish & Biggart, 2012; Farsi, 2010;

van Buiten & Hartmann, 2013). Several heuristics present in the design and initial planning phase of project delivery have already been identified by research.

Heuristics can help explain when decision outcomes deviate from expected utility theory during the design process (Norman, 2010). Over reliance on heuristics, particularly the risk reduction heuristic, are partly to blame for why owners and designers have not more fully adopted energy efficient technologies (Vanegas et al., 1995) or more sustainable building features (Wilson & Dowlatabadi, 2007). Owners and designers are often risk averse (Shealy et al., 2017). Risk aversion is common in the construction industry because of the high risks associated with building failures, significant financial loss, loss of life, and therefore is not irrational.

Medhi Farsi (2010) explained the risk averse nature of home and apartment owners when given the option of improving insulation types and ventilation technologies. Given a consumer's limited knowledge and experience in construction, they often used heuristics to fill gaps in a complex problem. Despite the improved savings, Farsi (2010) proved that owners typically utilize the risk reduction heuristic, defaulting to less risky options, when making decisions on home improvement.

VanBuiten et al. (2013) discovered that the affect heuristic was apparent in the design and planning phase of a Private Public Partnership. The affect heuristic occurs when an individual cognitively minimizes the risks and exaggerates the benefits of a decision. They discovered that members of the contractor's team for a Dutch Highways project often maintained an overly favorable view of potential net benefits when infatuated with a project.

Beamish and Biggart (2012) contributed four heuristics to the construction industry's knowledge of decision making shortcuts. The default building, flexibility, function, and reputation heuristic were all identified in a study on several construction companies. Since building decisions can often be complex, the default building heuristic describes an owner's tendency to select a design that aligns with industry and societal norms, rectangular commercial office buildings often between 50,000 – 65,000 sq. ft. in size with executive windowed offices on exterior borders and an interior space with moveable walls and office cubicles (Beamish & Biggart, 2012). Function and flexibility describe an owner's tendency to choose decision options that cut costs (function) and allow for a variety of occupants (flexibility). Lastly, owner's typically relied on the reputation heuristic, cognitively weighing reputation heavily in decision making, for making decisions on contractors.

Finally, Eriksson et al. (2016) discovered that satisficing, availability, and familiarity heuristics all affected the design and development of large rail tunnel projects. They discovered that stakeholders often utilized the satisficing heuristic by selecting the first acceptable and organized solution in decision making. Further, they found that the availability and familiarity heuristic both affected decisions by stakeholders in project planning. Individuals often assigned a greater weight to options that were both familiar (familiarity) and easy to recall (availability).

3.0 Point of Departure

The construction industry can benefit from studying real-life decision making habits of stakeholders, just as other disciplines, such as economics (Thaler & Benartzi, 2004) and insurance (Baicker et al., 2012), have improved their decision making models. While some literature in construction exists that describes decision making shortcuts in early stages of a project's delivery (Beamish & Biggart, 2012; Eriksson & Kadefors, 2017; Farsi, 2010; van Buiten & Hartmann, 2013), there is a scarcity of research in project implementation.

The objective of this paper is to identify heuristics that are present in the bid and construction phase of a project. Through interviews from a contractor in the Mid-Atlantic region, the research presented in this paper aims to answer the following research question:

What heuristics are the most prevalent in the field during project implementation?

By identifying potential heuristics employed by construction staff, stakeholders can become more informed of heuristics that impact their industry. An increase in understanding in industry decision making habits will likely lead to better project management and delivery practices.

4.0 Methods

The first step in the research process was to create an initial list of heuristics from prior literature in both construction management (Beamish & Biggart, 2012; Farsi, 2010; Son & Rojas, 2011) and behavioral decision science ((Arkes & Blumer, 1985; Ball et al., 1998; Kahneman & Tversky, 1972; Shah & Oppenheimer, 2008; Tversky & Kahneman, 1974)). A systematic literature review was conducted to determine possible heuristic candidates for this study. Prior literature was reviewed from behavioral science (Kahneman & Tversky, 1972; Simon, 1956, 1982; Tversky, 1972a; Tversky & Kahneman, 1974), the Behavioral Economics Guide (Samson et al., 2018) , pre-developed summaries of heuristics (Metzger et al., 2010; Mousavi & Gigerenzer, 2014; Shah & Oppenheimer, 2008), literature on heuristics in design (Beamish & Biggart, 2012), decision making for facilities (Delgado & Shealy, 2018) and decision making in construction (Shealy & Klotz, 2017). Thirteen heuristics were selected as a starting point based on their prevalence in the literature. While the research was not limited to consideration of only these heuristics, they did serve as a guide for semi-structured interview question development for professionals in the construction industry. Table 1 provides the list of heuristics and definitions.

Table 4: List of A-Priori Heuristics

Heuristic	**Definition**
Affect	Risk and benefit judgments are inversely related (Zajonc, 1980).
Anchoring	"Anchoring" to a salient and known value, basing judgment off this value (Tversky & Kahneman, 1974).
Availability	Individuals perceive the likelihood or risk of an event based on how easily one can recall an example of that event (availability) rather than its actual probability (Tversky and Kahneman, 1973).
Default Building	Using traditional, default building characteristics (Beamish & Biggart, 2012).
Recognition	Cognitively weighing "recognizable" options heavier in choice selection. (Goldstein & Gigerenzer, 2002).
Representativeness	Judging a whole group by a sample size (Kahneman & Tversky, 1972)."
Risk Reduction	Allowing fear of risk to impact decision making (Hansen & Singleton, 1983; Mitchell & Greatorex, 1993).
Sunk-Cost	Allowing Sunk Costs to affect a decision. (Arkes & Blumer, 1985)
Myopia	Evaluating options based on immediate gain rather than long term potential gains (Shiv et al, 2005).
Elimination	Using the process of elimination to make a decision (Tversky, 1972).
Reputation	Placing a high cognitive weight on reputation in decision making (Metzger, Flanagin et al., 2010).
Function	Targeted profits become dominant factors for cost-cutting decision making (Beamish & Biggart, 2012).
Flexibility	Producing "flexible" buildings that can meet the needs of many individuals (Beamish & Biggart, 2012).
Familiarity	Individuals assume circumstances underlying past behavior still apply for a present situation (Metcalfe, Schwartz et al., 1993).

Semi-structured interview questions were developed for each job type within a project's construction phase, including individuals involved in project oversight, supervision, estimation, marketing, and field activities. Interview questions were developed through iterations of feedback on face-validity and content-validity from two experts in qualitative methods, Dr. Michael Garvin and Dr. Tripp Shealy, with nearly 30 years of combined experience in the construction industry. These experts helped eliminate question bias, leading questions, and question ambiguity by carefully reviewing each interview question and applying their knowledge and experience to revisions. Prior to data collection, the semi-structured interview questions were piloted with a sample of industry experts. Small modifications, such as, question phrasing and question content were made based on this feedback.

Semi-structured interview questions also included opportunities for emergent heuristics not previously discovered or discussed in literature (see appendix for more detail). The broad, open ended structure of interview questions allowed for a variety of responses. If participant responses indicated a decision making shortcut not listed in the "a-priori" codes, the decision making shortcut would be labeled an "emergent" code and included in future coding efforts.

A mid-sized contractor in the Mid-Atlantic Region of the United States with roughly half a billion dollars of expenditures per year and ranked among ENR's top 400 contractors volunteered to participate in the interviews. This company's size offered a range of participants, and its locality provided a reasonable travel distance for the research team. Participants were recruited to participate through email and were not incentivized. A wide pool of interviews was conducted to ensure the collection of employee opinions from project marketing to field supervision. Since employees were interviewed on a volunteer basis, maintaining an even amount of interviews across job titles proved difficult. The intent to interview individuals in each "role" of a project was generally met. Interviews were conducted until the research team had interviewed all individuals who were willing to participate in the research.

Semi-structured interviews were conducted from May through August of 2018. On average interviews lasted one hour. A summary of the pool of participants interviewed is depicted in Table 2. Thirty-two employees from the contractor were interviewed along with three employees from sub-contractors that performed work for this contractor. These employees held positions in roles including project oversight, project supervision, field supervision, task supervision, project estimation, and project marketing.

Table 2: Employee Interview Count

Job Title	Count	%	Role
Project Executive	4	11	Project Oversight
Project Manager	9	26	Project Supervision
Project Engineer	6	17	Project Supervision
Senior Superintendent	1	3	Field Supervision
Superintendent	7	20	Field Supervision
Assistant Superintendent	1	3	Field Supervision
Foreman	2	6	Task Supervision
Estimator	3	9	Project Estimation
Subcontractor-Owner	1	3	Project Estimation/Bid/Oversight
Marketing	1	3	Project Marketing
Total:	35	100	

The interviews were then transcribed and coded using a qualitative tool called Dedoose (*Dedoose*, 2018). Each "a-priori" and emergent heuristic was given a code label. Each code label was then given a context label depending on how it was used. The following quote provided by a project engineer demonstrates the coding process. In discussing subcontractor relations, a project engineer stated "that is how we keep our prices low because our subs will give us better numbers because they trust us. They want us to win the job because they want to work with us." Since she is discussing reputation in this portion of the interview, this excerpt would be provided a code label of 'reputation'. Further, the context would be labeled 'contractor – subcontractor relationship', since she is discussing how subcontractors weigh reputation when pricing services for different contractors whom they work with. Each coded excerpt was labeled as an 'element'. Element counts helped determine the frequency of heuristic use.

In total, there were 334 elements clustered into the 13 "a priori" codes and 7 emergent codes. The emergent codes were labeled with descriptors including: 1) Temporal Preference 2) Mental procrastination 3) Sub not following through 4) Path of least resistance 5) Higher authority 6)

First come first serve and 7) Working Backwards (scheduling). The descriptors provided a brief explanation of the emergent behavior not yet identified in a heuristic.

The coded elements include both concrete decision events and potential primers for future decisions. Interviewees described both heuristics that impacted specific decisions points and potential heuristics that could impact future decision making. In some cases, there was an actual decision point that was mentioned and the thought process that assisted that decision maker was described. For example, in describing how they created project schedules, several project managers broke down their methodical process for scheduling, which included many decision shortcuts, such as the affect and anchoring heuristic. In other cases, employees described situations that may could prime decision makers for use of a heuristic. An actual decision point wasn't mentioned, but attitudes and perspectives of key decision makers suggested a particular heuristic. For example, project employees described the tendencies of owners during interviews, which in some contexts suggested they employed certain heuristics, such as the affect, temporal preference, and risk reduction heuristic. In this case, actual decisions weren't being described, but the descriptions of owners' behaviors or actions correlated strongly with a particular heuristic.

5.0 Results

Four "a-priori" codes and one emergent code appeared in 50% or more of the transcripts. The a-priori heuristics and their frequency in the transcripts follows: affect heuristic - 86% (30 of 35), risk reduction heuristic - 71% (25 of 35), reputation heuristic - 66% (23 of 35), and anchoring heuristic - 60% (21 of 35). The emergent code was temporal preference, which describes how project stakeholders placed a high value on time when making decisions, often defaulting to decision options that provided quicker outcomes. It appeared in 54% (19 of 35) of the transcripts. The next closest code, the familiarity heuristic, appeared in only 38% (13 of 35) of the transcripts. Only codes that appeared in the majority of interviews are reported in this paper.

Elements within codes were tallied to rank reoccurrence of the heuristics. The number of elements for the affect heuristic was 71, reputation heuristic was 51, risk reduction heuristic was 45, anchoring heuristic was 44, and temporal preference heuristic was 31. To allow for demonstration of heuristic use, but to also ensure brevity of this paper, only the top three contexts of each code application was chosen for discussion.

Table 3: Interview Results

Heuristic	%	# Elements	# Contexts
Affect	86	71	11
Reputation	66	51	7
Risk Reduction	71	45	15
Anchoring	60	44	14
Temporal Preference	54	31	5

5.1 Affect heuristic

The affect heuristic was the most frequently mentioned heuristic appearing in 86% of the interviews with a total of 71 elements and 12 contexts. The top three contexts of the affect heuristic were found in interviews when discussing 1) construction duration, 2) building estimates and 3) owner's expectations.

Individuals in this context faced both the pressures of time and information constraints, and often demonstrated a tendency to maintain an overly confident view of their favorable outcome, emphasizing its benefits and minimizing its risks.

Of the 71 elements, 26 were coded when discussing the topic of construction duration. There was an apparent theme of unequal weighting of risks and benefits in scheduling decisions by both contractors and the subcontracting crews.

Predicting a construction project's completion date and cost can be a daunting task for a contractor. Many projects may not finish until several years after the contractual agreement. In these decision environment, countless variables could potentially impact activity durations. Problem simplification is a requirement in a context with countless unknowns that warrants heuristic use.

When asked about mistakes the contractor had made in past projects that failed to meet schedule, there was a re-appearing theme of over commitment by the contractor. In one instance, a project executive summarized the responses of many employees who admitted to their over optimism in either predicting activity durations or providing owner's with progress updates. He stated, in reference to a project that failed to meet schedule, "at the end of the day, I made a mistake in judgement. I was overly optimistic about the project forecast, even when the facts were in front of my face." Ironically, subcontractors described the contractor in a similar way. The words of one foreman depict the ideas of both subcontractors interviewed and the other contractor employees. "It all goes back to the GC [general contractor] saying that we [the subcontractors] could do it quicker than we've done it before." While late project delivery wasn't a theme at the contractor studied, in the few instances where it occurred, use of the affect heuristic appeared to influence stakeholder decision making.

Employees of the contractor had similar perspectives of subcontractors. A project executive for the contractor described the decision making process that occurs for some subcontractors who win a job due to an error in an estimate. He stated, "[If a general contractor or subcontractor makes] a mistake in their estimate and they found out after they've already given the price and they decide to take it anyway, [then they will justify it by thinking] they can get it done quicker and they'll save money because it can't rain as much as it did last year." In this example, the same underlying factor influences heuristic use. The decision maker is faced with an abundance of variables, particularly influencers of future events in a project, that often leads to problem simplification through the affect heuristic. In this context, in the infrequent instance that subcontractors mistakenly underbid a job, they often employed the affect heuristic. Even in face of their error, they maintained an overly confident view of the potential benefits of the job and discounted risks.

Second to construction duration, another apparent usage of the affect heuristic occurred in the contractor's initial building estimates, appearing in 11 elements. This particular company handled many construction projects using a construction management at risk delivery method, and therefore often performed initial, non-contractual, building estimates for owners before published drawings were available. Initial estimates were performed with either no design documents, or partial design documents - a case of very limited information. As one project manager described when discussing the company's accuracy of initial building estimates: "typically we end up being low. Hopefully your close, a lot of times you're not." The lack of knowledge about the building in early design phases was often filled by employing the affect heuristic and assuming more optimistic terms for a project in estimating, frequently resulting in initial project estimates that were lower than actual costs.

The third most frequently mentioned instance of the affect heuristic was evident in an owner's overall expectation of a construction job, appearing in 10 elements. Owner's often based their expectations of project delivery on their own past projects, or comparable project's in the area. If a similar project had been completed four years ago, they wanted the same price. If a contractor had constructed a project for them five years ago, they wanted it delivered in the same amount of time. Inflation, escalation, and current market prices dictate project costs, and often didn't align with owner expectations. Further, market demands also affect project delivery times, depending on the current constraints on subcontractors. Owner opinions, then, were likely influenced by heuristic use. Simply put, an abundance of variables that impacted their expectations were simplified by the affect heuristic.

In summary, when asked about current owner expectations on a job, employees described many owners as having unrealistic expectations of project cost and duration. One superintendent for the contractor summarized the ideas of many others. He commented, "The owner at some point has decided that they want things way too fast and they want them at an accelerated pace and they don't understand what that means to quality, what that means with time, what it means with trades, what it means period." These descriptions of the owner, suggest that they employed the affect heuristic in their decision making by emphasizing the potential benefits (low price, fast delivery), and down-playing potential risks (inflation, market changes, building complexity).

5.2 Reputation Heuristic

The reputation heuristic was the second most mentioned heuristic appearing in 66% of the interviews with a total of 51 elements and 7 different contexts. The top three contexts of the reputation heuristic included the following relationships 1) the subcontractor's reputation with the contractor, 2) the contractor's reputation with the owner, 3) the contractor's reputation with the subcontractor.

Selection of contractors and subcontractors in the construction delivery can be a difficult task. Owners are faced with entrusting a project's success with a contractor. Further, both owners and contractors, depending on the contract type, influence subcontractor selection. Lastly, a subcontractor's selection of projects to pursue, and subsequent bids for those projects requires careful decision making. The qualities and characteristics of all major stakeholders on a project influence its delivery. Owners may only have limited information, such as company size, location, and price, about the pool of contractors who compete for a job. Similarly, contractors and subcontractors face the same decision constraints when deciding on subcontractors to employ, and jobs to bid, respectively. Due to limitations in information, these stakeholders often overcome a gap in knowledge by employing the reputation heuristic.

The most common application of the reputation heuristic, appearing in 28 elements, occurred in the contractor's weighting of a subcontractor's reputation in decision making. When asked why certain subcontractors were chosen for jobs, employees of the contractor frequently mentioned reputation first. For starters, the contractor often short listed subcontractors when requesting bids for a job, intentionally attempting to narrow bids down to pools of subcontractors with higher reputations. One project engineer described this process when saying "a lot of the subs are shortlisted … we liked working with them on a previous job, we both made money, they were on time, their supervision was adequate." Further, several employees went on to discuss their process of convincing owner's to pay for more quality subcontractors. In the words of one superintendent, he stated "A lot of times we'll say [to the owner], here's the price of y contractor, here's the price of x contractor. We really recommend x contractor even though [they cost more than] a lot of [other subcontractors]." One project executive discussed how he placed a monetary value on reputation. When dealing with an owner who wants to choose a subcontractor with a poor reputation, he said "maybe we'll tell the owner that we're going to take all of the difference of cost and we're going to add it to our contingency because we feel very strongly that this subcontractor is going to be a problem." Another project engineer went on to summarize the logic behind paying more for a subcontractor that has a higher reputation. He stated "they may not be the lowest price, but at the end of the day, I'm not going to have to worry about [their performance and timeliness], your performance speaks for you along with your price."

In the same way that a subcontractor's relationship played a large role in their ability to gain work with this contractor, the contractor's relationship with the owner played a large role in their dynamic, appearing in nine different elements. An apparent weighing of reputation in an owner's selection of contractors was evident. One project engineer discussed the reality of a good owner – contractor relationship. He said, "the biggest honor is to have a negotiated price with a repeat customer. Next to that is if you're on the select bid list, but the biggest thing with repeat customers [is they] will be good." Interview data indicated that some owners place an emphasis on reputation by shortlisting, or even by negotiating a price with a repeat contractor - not necessarily looking for the lowest price, but weighing reputation substantially in their decision making.

While reputation can benefit a contractor, one project executive discussed when it hurt their ability to earn a job. He discussed the difficult conversation he had with an owner after performing poorly on a past job. He recalled the words of the owner, "I think both of us understand circumstances and know why we got to where we got. No hard feelings, but for this job we're going to take a break." In this case, the owner's negative impression of the contractor from a past job appeared to significantly influence the owner's decision to rehire this contractor.

The contractor's reputation also played a role in the eyes of the subcontractor. Subcontractors and material vendors have limited time throughout the work week to manufacture and install building components, and thus often prioritized their workload by applying the reputation heuristic. Multiple employees in six different contexts (elements) discussed how subcontractors gave priority to a contractor that treated them well. One project engineer who had worked for a subcontractor in the past discussed the preference that a particular subcontractor gave to a contractor with a high reputation. "Whatever the work was for the day. I pushed their stuff first. It went through first. It had, you know, quality control. Because of that relationship, I understood that, that [contractor] takes care of their subcontractors. You don't hear about [contractor] going into litigation. They pay on time, they're fair." Several employees also discussed how this results in monetary savings for the contractor and the owner. One project engineer commented "that is how we keep our prices low because our subcontractors will give us better numbers because they trust us. They want us to win the job because they want to work with us." Thus, reputation affected both the bids a contractor received from subcontractors and the quality and timeliness of work that they produced.

5.3 Risk Reduction Heuristic

The risk reduction heuristic was the third most mentioned heuristic appearing in 71% of the interviews with a total of 45 elements and 15 different contexts. There was strong evidence of employees applying the risk reduction heuristic, attempting to minimize and avoid risk by all means possible, to their decision making. The top three most mentioned contexts of the risk reduction heuristic occurred when 1) stakeholder's preferred to do nothing in a decision, 2) contractor's decided to bond a sub to mitigate risk, and 3) contractors used the contingency fund to cover uncertainty in scope.

Project delivery requires input from stakeholders for a variety of deliverables including interior buildout design, material selections, and color/finish selections. With the time constraints associated with project deadlines and material delivery, and the information overload that an individual may face when presented with multiple options, stakeholders sometimes decided to refrain from a decision. By refraining from deciding, stakeholders defaulted to the least risky choice: no choice.

The most common use of the risk reduction heuristic occurred in stakeholder's decision to do nothing when faced with a problem or choice, shown in five different elements. To reduce the risk of making a poor decision, some stakeholders often would delay that decision making process for an extended period of time, hoping to avoid the consequences of a bad decision. One superintendent discussed the affect this often had on a project's schedule. He said, "some of the biggest holdups that we've had in the past have been the owner and the lack of decision, the ability to make a quick and decisive decision." Another project executive, discussed a possible solution to this decision making dilemma. He said, "I'll assign one person that is the representative of the owner that has the authority, the ability, and the experience to make a proper decision. That's the root cause of all. Probably in my experience, 75 percent of the problems. People can't make a decision."

The contractors use of contingency funds to reduce risk is another demonstration of the risk reduction heuristic, apparent in 5 elements. The amount of time allotted to draft a construction contract is relatively short compared to the overall timeline of construction. Further, capturing all variables such as weather, subcontractor performance, and material prices that may impact a project is near impossible. Since decision makers cannot accurately predict the exact cost of a project in this case, contactors often leveraged a contingency fund to mitigate financial risk, employing the risk reduction heuristic. One estimator justified his use of contingency funds in a contract when saying "First and foremost, I'm not perfect. I'm going to miss something. It's just when and how much." Further, another project manager discussed how he leveraged a contingency fund when dealing with riskier products. In his words, “so, you know, let's say somebody quotes a [non-specified] product, and we use that in our bid thinking that we should be able to get that through. Sometimes we do that and then we'll put a little pot of money aside just in case to cover if it wasn't to go through.”

Last, the risk reduction heuristic was also evident in the contractor’s use of performance and payment bonds shown in 4 elements. Contractors only receive a limited amount of information about subcontractors from other states and regions. This lack of information and knowledge about outside or risky subcontractors led to the use of the risk reduction heuristic. This particular contractor did not typically bond subcontractors, unless the contractor had limited information about the company. In the words of one project executive, he stated “What we do is we bond as a company we bond every out of town contractor and every roofer.” Thus, the contractor utilized bonds as a way of risk reduction when faced with limited information about out of town subcontractors.

5.4 Anchoring Heuristic

The anchoring heuristic was the fourth most mentioned heuristic appearing in 60% of the interviews with a total of 44 elements and 14 contexts. By mentally anchoring to a salient or known value, and making cognitive adjustments to that value, decision makers typically used the anchoring heuristic in a variety of contexts. The top three contexts of objects that were anchors in decision making were 1) past projects, 2) subcontractor input and 3) contractual dates.

Scheduling and estimating a project can create a very complex problem for construction stakeholders. Both require the prediction of a future event, with multiple factors such as market prices, demand, and workforce efficiency influencing each. Moreover, both tasks need to be completed in a relatively short time period to allow for proper project planning, bidding, and consulting. The strains of time, such as bid dates and project delivery dates, combined with the countless variables associated with each of these tasks contribute to heuristic use. Particularly, stakeholders discussed their use of the anchoring heuristic when faced with tasks of estimating and scheduling.

The most common reference that contractors anchored to in their decision making was past projects, in both scheduling and estimating. Overall, employees showed evidence of anchoring to past projects in 16 elements throughout the interviews.

The contractor's staff discussed how they used the cost of past project in their preparation of construction estimates. They frequently anchored to their past project data and adjusted for either time, risk, location, or material price increases. In preliminary estimating stages when employed as a consultant, one estimator described how he provided the owner with a project price. He stated "In the early budgeting phase, owners and clients will call and say, we want to build a hotel for 120 rooms or whatever it may be ... [we then provide a cost] range based on historical data. So it's pulling from the jobs that we've all done." Another project manager described how different building types have different square footage costs, in his words when responding to how he performed early project estimates "Well is it a hospital? Is it a car dealership? Is it an office building? You know, is it a hotel? Because all those markets have different square footage costs."

When scheduling a job, there was significant evidence of the contractor anchoring to a past project's schedule. In the initial stages of scheduling, one project manager described the company's methods for providing a preliminary schedule. In discussing how initial schedules are provided for owners, he said "We can kind of pinpoint maybe three or four of our jobs that we've and done, kind of run averages and say, okay, well based on that in this timeframe, here's what you might be looking at." Likewise, when building a project specific schedule, one project manager summarized the thoughts of many other staff. In talking about how he uses scheduling software to build a schedule, he stated "you can actually copy and paste the logic [from a past project] and then you can start setting the logic between all the different areas and seeing kind of where you're at."

Another popular anchor among the staff was a project's contractual date, shown in 6 elements. The time constrained environment of scheduling combined with the complexities of predicting durations, often led project managers to anchor to the contractual date when scheduling. When building a full schedule, project managers often used the agreed upon contractual date as a basis for their schedule adjustments. Once they created a schedule in scheduling software, they often adjusted activity durations until they hit the contractual date. In the words of one project manager, he discussed this reality "If you've got a 12-month job and all my information, took it out to 14 months then we'll say okay, we got to pull this back two months. So let's go back down our whole list. Let's see what you can tweak and what we really think is going to happen."

Further, a superintendent described the opposite scenario when his initial schedule was shorter than the contractual schedule. He said, “conversely, if the job, if my finish date, doesn't match my contractual, you know if I am finishing early I will gently stretch things out. I will go back into the schedule and look at activities that I may have been too aggressive on and increase the duration.”

The last most commonly used anchor was subcontractor input, demonstrated in 5 different elements. Determining activity durations is a difficult task, one must accurately predict the time required to complete an activity given very limited information such as weather, crew size, and onsite conditions. Several employees conversed about using input from subcontractors to build a schedule. However, seldom did they actually use the timeline provided for them from the sub. Rather, they typically anchored to the activity duration provided to them, and adjusted for risk (usually adding time). In the words of one project manager, he stated “I call the subcontractor and ask him, I say, you gave us a price for this, you know, what's your, what's your anticipated duration? Then typically I add a couple of weeks to that.” This method of determining activity durations provides a much quicker solution that utilizing textbook methods that require much more time and require arduous use of the RS means manual.

5.5 Temporal Preference

The one emergent heuristic, temporal preference was the fifth most mentioned heuristic appearing in 54% of the interviews with a total of 31 elements and 5 contexts.

When coding the transcripts, one of the codes documented was stakeholders’ tendency to choose an option with the quickest results, even in spite of a cost increase. When this code emerged, the research team did a thorough literature search for a heuristic that explained this phenomenon. Since there was no pre-defined term that described this decision making shortcut, the research team coined this heuristic as “temporal preference.”

There was strong evidence in many interviews that project stakeholders placed a high cognitive value on time when making decisions, often defaulting to decision options that provided quicker outcomes. The top three contexts of temporal preference occurred when 1) stakeholders decided on material types 2) owners made project related decisions and 3) contractors made decisions related to means and methods.

Construction environments often contain many unknowns, such as submittal and permit approval dates, weather, and future job progress, that can delay a project. Since predicting future events is often difficult, stakeholders often used temporal preference when making decisions on materials and means and methods to quicken the pace of construction.

Stakeholders often placed a high value on time when selecting material types, as shown in 11 different elements, often discussing their willingness to pay higher premiums for materials that provided higher productivity or products that allowed for the overall construction process to move quicker. One superintendent summarized the thoughts of many other employees, in discussing his justification for paying a higher premium for moisture retardant drywall on interior walls, he stated “So we paid for the material to help with the schedule to help increase when we can start other trades.” A mason foreman discussed the same thought process that subcontractors have when selecting materials, in describing how he selects a brick type, he stated “There are only two suppliers that represent the 15 different manufacturers, so they'll come up and they'll bring me a couple boards … the ones I know that we'll get good production on, I'll submit them to the architect have them look at it, [and will pay more for the brick that has a higher production rate even if it is costlier].”

Employees also weighed time heavily in their decision making process, particularly when making decisions in respect to schedule, appearing in a total of 8 elements. The contractor noted helping subcontractor’s by sometimes paying overtime fees for their employees. In the words of one superintendent, he stated “Let's say you lost three weeks because you had to go rework something that's three weeks gone. So you've got to go back and say okay, I'm going to start making this up on longer hours on Saturdays or more manpower, we've got to take that, that three weeks and we gotta make that so it gets back to zero.” Likewise, a project executive described the thought process of project planning when describing his process for managing a job. “[I ask myself], how can I get the most trades involved at the earliest point in time where they can provide continuous employment for their crew until their part of the job is finished.”

Owner’s also attributed a heavy mental weight to time in their decision making processes, demonstrated in 5 elements throughout the interviews. Time conscious owners often were limited in their time allotted for contractor selection, and utilized temporal preference to decide on contractors. Mental accounting of variables that influence contractor selection requires the weighing of multiple variable including cost, reputation, delivery time, and company resources. To simplify the accounting of these variables, owners often defaulted to select contractors with a quicker delivery time. Employees described how owners would often pay a higher premium for a contractor who could deliver the project faster. One superintendent described an example of this on a small scale project. In describing this particular job, he said, “we were 14,000 over [the expected budget] and 7,000 over number two, and they took our price because we [completed the job] four weeks shorter.”

5.6 Discussion

Individuals use heuristics frequently throughout decision making processes to allow for a quick, available solution to a problem. Heuristics are a cognitive benefit to decision makers, allowing people to arrive at a solution much quicker than normative methods (Weber & Johnson, 2008). Take for example, the contractor’s utilization of past projects for project estimating. By formulating an initial estimate by just comparing the job to past projects, the staff arrived at a quick dollar figure they could provide an owner in the initial stages of a project. In this case, performing the calculation more systematically by using a square-foot or assemblies estimating technique would require more time and manpower. Further, consider how the contractor utilized the reputation heuristic to help protect both the owner, and themselves. By placing a high cognitive weight on reputation, the contractor helped avoid some of the risks associated with less reputable subcontractors: rework, quality issues, schedule delays, or bankruptcy (Proctor, 1996). But, decision makers should be cognitively aware of when they are using heuristics.

While heuristics can be a timesaver, they can also have negative effects on decision makers. If used excessively and unknowingly, heuristics can have negative consequences (Tversky & Kahneman, 1974). For example, reconsider the words of the project executive who was humble enough to admit his use of the affect heuristic: “At the end of the day, I made a mistake in judgement. I was overly optimistic about the project forecast, even when the facts were in front of my face.” He later went on to say “That mistake cost us an owner relationship that we are trying to reestablish.” In this case, the executive had failed to inform the owner of an apparent scheduling delay that pushed the project past its delivery date. He maintained an overly optimistic view of the outcome, even when the facts were presented to him, thinking that he could still deliver the project on time. The result was not only the project delivery delay, but a tarnished owner relation: a clear instance of how overreliance on a heuristic can have drastic affects.

Another example of an over utilized heuristic occurred with the anchoring heuristic. One employee did warn of anchoring too much on past projects, and not receiving enough subcontractor input. He described a project estimate that was far below the actual project cost. In his words, he stated “We just got so involved [in one particular job estimate] with these metrics, we were scaling previous jobs and trying to use coefficients and multipliers and trying to adjust for market and we got to bid day and it just busted badly … That was probably a 3 million dollar bust. So we expected it to be about 10 million I think it bid at like 13 million.” In this case, the contractor anchored too much to past project data, that they under projected the job by over 25%.

The emergent code, temporal preference was unexpected. In the context of this study, temporal preference is an individual’s tendency to choose an option with quickest results, even in spite of a cost increase. Not to be confused with temporal discounting (Green et al., 1996), temporal preference was a distinctive discovery in this construction firm. In an industry that has been thought to be focused on cutting costs (Beamish & Biggart, 2012), a different theme was found in this research: schedule oriented stakeholders that were willing to spend extra money for a quicker product. One possible explanation for this discovery could be this contractor’s typical facility profile, which included retail space, university buildings, and hospitals. Retail owners want to typically open early to allow for sooner payment schedule, universities have to work around student population and academic terms (semesters or quarters), and hospitals are often pressured to open quickly to meet health care demands. For example, one of the marketing employees described the reasoning for rigid construction schedules when working for a university. She stated “You only can open a dorm in the summer because you can't open a dorm throughout the year and you can't open the dorm in the middle of the year because where are you going to put those kids? The first half, first semester? So a classroom is different. You will have to work everything by semesters because like they're never going to tell you that you have your first three weeks of class here and then you have it there. So for schools everything is either opened in July or December.”

Moreover, the findings of this research also support normative decision making. Normative decision making models require the use of variable weighing or scoring inputs from users.

Individuals are tasked with assigning percent weights to a variety of variables depending on the stakeholder's preferences. For example, two popular decision models, AHP (analytic hierarchy process) and CBA (choosing by advantages) both require users to input scores for characteristics of each choice an individual is choosing from. By referencing this paper, stakeholders can better rank preferences of stakeholders in construction. For example, when selecting a contractor, an owner may attribute higher scores to variables such as 1) project duration 2) company reputation and 3) perceived risk.

6.0 Future Research

This paper is the first of hopefully many future studies that will continue to document heuristics in the construction industry. While the results of this research are telling, more similar research is needed to verify the results shown in this paper. Further, a quantitative analysis that considers multiple projects, their performance measures, and types of heuristics employed on each job could provide more understanding on the tangible impacts of heuristics in the construction industry. Lastly, a study on the impacts of intervention strategies that educate stakeholders on heuristics could be conducted.

7.0 Conclusions

The results of this paper provide stakeholders in the construction industry with a clearer picture of heuristics that potentially can impact the construction of a project. By summarizing the results of 35 interviews, this study proved to indicate five heuristics employed in the industry with three common applications of each.

The affect, reputation, risk reduction, anchoring, and temporal preference heuristic were all major decision making shortcuts utilized by the industry professionals in this study. These heuristics, when employed correctly, saved decision makers time. For example, by placing a large focus on time, when decision makers employed temporal preference, they stream lined their decision making to select options that produced a quicker output. However, there were also themes where these heuristics displayed negative effects. For example, project managers who anchor to a past schedule without a full understanding of scheduling, may produce flawed or less than optimal schedules.

By reviewing this paper, stakeholders in the construction industry can have a snap shot of some of the heuristics utilized by their peers. By reviewing literature on heuristics, individuals can become more self-aware of possible heuristics they employ in their daily lives. By raising awareness of these cognitive shortcuts, this paper attempts to reduce the number of negative outcomes produced by heuristics that develop due to less informed decision makers in the construction industry. By continuing to make headway in the understanding of human decisions in construction, project stakeholders can hopefully continue to improve their efforts towards optimal project management practices.

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Journal Paper 2: Decision Heuristics During the Construction Process: Observations from the Field

Intended Outlet for Publication:

Journal of Management in Engineering

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Abstract

Dynamic construction management teams are faced with thousands of decisions throughout the delivery cycle of a construction project. It is not surprising, then, that they are often required to make relatively quick judgements with limited time and resources. By employing heuristics, or decision shortcuts, decision makers increase their decision making efficiency and effectiveness. Better understanding when and how heuristics are used can improve the decision making process. Observational field research of construction project personnel was conducted to identify heuristics used by project stakeholders, and when the use of these heuristics led to positive or negative outcomes for the project team. Observations were conducted for three months. Instances of decision shortcuts observed were recorded and coded using established definitions of decision heuristics. The most frequently observed heuristic was the familiarity heuristic followed by the risk reduction, representativeness, reputation, and anchoring heuristic. These heuristics are used in multiple contexts and by varying project staff including design engineers, construction project managers, and construction subcontractors. The results presented in this paper advance understanding about decision heuristics employed in the field and can help professionals become aware of when and how these decision shortcuts are employed and better anticipate their outcomes in the future.

1.0 Introduction

In an era of modern technology, advanced scheduling software packages, and an abundance of normative decision making models, construction stakeholders have a richness of available tools for optimizing project practices. However, the construction industry as a whole still fails to meet many expectations such as project performance outcomes (Anantatmula 2015) and building sustainability goals (de Paula and Melhado 2018). Advances in normative decision making models, such as models for scaffolding planning (Kim et al, 2018), transportation project selection (Wei et al. 2016), PPP concession periods (Zhang et al. 2018), project delivery methods selection (Mayra et al. 2018), and policy selection (Katarina and Nikša 2018) attempt to address failure to meet performance outcomes. While many researchers have taken a normative approach, few have provided descriptive explanations of construction decisions in the field (Beamish and Biggart 2012).

In a dynamic environment, like a construction project, multiple decisions are made daily within a variety of contexts (Mondragon Solis and O'Brien 2011). Decisions are often made in "real time" or "limited time" with multiple moving parts and limited resources. These types of constraints typical during a construction project do not provide the luxury of detailed, drawn out, or systematic decision making, in which normative methods are most appropriate. Rather, dynamic project environments require quick judgement and decisions. Heuristics are likely employed in these types of decision environments, with limited resources, including time, information, and processing capability (Goodwin et al., 2004). In a time constrained situation, heuristics assist decision makers to arrive at a quick outcome. In an information constrained environment, heuristics help overcome a gap in knowledge. When faced with the task of cognitively weighing and accounting for multiple variables, heuristics help simplify decision making. For example, if faced with the task of creating a new schedule, a project manager may employ the anchoring heuristic by using a previously created schedule as a starting point for activity durations and logic. In using this heuristic, she would use a previously known value and make adjustments to that value to allow for a simpler decision making process (Tversky and Kahneman 1974). Heuristics are an individual's natural response to his or her bounded rationality, or limited processing capacity (Goodwin et al., 2004).

Heuristics are often built from personal experience (Gigerenzer and Gaissmaier 2010). They can increase efficiency and effectiveness, especially when utilized by senior level decision makers with a high level of experience because their heuristics have often been refined through trial and error. This is one of the many reasons why experience in an industry is a valuable asset. For example, a subcontractor deciding on a material vendor to select for a product may utilize the elimination heuristic. When using this heuristic, he would eliminate vendors based on specific criteria that has evolved overtime, for instance, using location, product specifications, and cost until he arrives at a solution (Tversky, 1972b). In this case, the user applies his own elimination criteria based on experience to arrive at a solution quickly, saving time.

However, heuristics may introduce mistakes in decision making and led to unwanted decision outcomes. If relied on too much unknowingly or in unwarranted circumstances, heuristics can lead to irrational decision outcomes (Tversky and Kahneman 1974). For example, engineers and architects may employ the anchoring heuristic in building design. By anchoring to buildings codes to meet a required minimum, engineers may produce less resilient designs, subsequently producing less than optimal products for an owner.

Despite various studies over the past several decades on heuristics and their applications in various industries, heuristics remain under-explored in their application to the construction field. In an attempt to improve project management practices in the construction industry, this paper aims to provide insight into decision making habits of construction project stakeholders.

2.0 Background

Decision making methods consist of normative and descriptive models (MacCrimmon 1968). Normative decision making models prescribe decision makers with a methodical, systematic decision making process that applies weights to all considered variables of options (Bell 1988). Using this information, normative decision models calculate a user's best option. Descriptive decision making approaches describe a more realistic reality of decision making (Klotz and Nikou 2014). Human beings often apply mental shortcuts in their personal decision making that weigh options in a variety of ways. Take for instance, the reputation heuristic. When employing this heuristic, a decision maker applies a significant mental weight on a person, product, or company's reputation when considering options (Shah and Oppenheimer 2008).

Improved methods in decision making related to construction project management have primarily focused on normative decision making models and tools (Bakht and El-Diraby 2015). While the development of normative decision making models in the construction industry can be beneficial in many decision making environments that offer a luxury of time, resources, and information, they are usually not practical in construction implementation. Dynamic construction environments are typically constrained by resources, time, and information, and require quick decisions. For example, in comparison to the time an owner's committee has to decide on the feasibility of a project, construction site stakeholders would be constrained to make decisions in the environments of daily construction requirements such as subcontractor scheduling conflicts, concrete pours, or framing issues (Zhang et al., 2008).

Behavioral science offers a more descriptive approach to understand models of decision making. Several industries have benefited from studying and understanding more descriptive approaches to decision making (Samson et al., 2018). For instance, when selecting health insurance, from a nominal decision making perspective, more choices are better. But, in reality an overabundance of health care plans cognitively overloads patients and leads to indecisiveness (Besedeš et al. 2015). Reducing the number of options increases the number of people selecting a plan.

Behavioral economics was the frontrunner of descriptive behavioral models. Edwards (1954) was one of the first to attempt to model decision making but incorrectly assumed man is all knowing and completely rationale. Simon (1956) made significant improvements to Edward's model by including a description about bounded rationality. Prospect theory followed, providing a more accurate picture of the effects of bounded rationality or man's limited cognitive ability. Prospect theory accounts for man's tendency to weigh losses heavier than gains (Kahneman and Tversky 1972). The use of prospect theory can help predict decisions in politics (Patty 2006), insurance (Handel and Kolstad 2015), medicine (Milkman et al. 2011) and military interventions (Nincic 1997). Today, it is being used to design new 401k plans (Thaler and Benartzi 2004), government forms (Sunstein and Hastie 2015), and the built environment (Shealy and Klotz 2017).

The insurance industry has leveraged behavioral science to improve their profits. Through better understanding human behavior, insurance companies have learned to frame their products in relationship to other products that appear to provide less generous coverage. The result is consumers that are more willing to pay higher premiums for that coverage even when it is not of immediate value (Handel and Kolstad 2015). Further, less informed customers are more likely to choose more generous insurance plans, and thus also pay more for their coverage (Handel and Kolstad 2015).

The medical industry has also leveraged behavioral models of decision making and adopted new heuristics. By leveraging a person's tendency to live up to his or her commitments, hospitals and patient centers have reduced no-shows. Two strategies developed by decision making science prompt hospitals to capitalize on an individual's tendency to live up to verbal or written agreements. By asking patients to verbally agree to an appointment time and by having patients write out their own appointment cards, hospitals have seen a reduction of patient no-shows (Martin et al., 2012). Further, the medical industry has discovered behavioral solutions to common shortsightedness of patients. Medical centers have succeeded in getting patients to think more about their future health. By prompting patients to write down desired outcomes of health treatments, the medical field has been able to influence individuals to take more preventative health measures (Milkman et al. 2011).

The construction industry gains to benefit by incorporating similar behavioral insights into decisions that impact construction stakeholders. Evidence that construction stakeholders would benefit from further development of descriptive models exist in several prior observational and theoretical studies. For instance, Farsi (2010) explains the unique risk averse nature of construction clients. Clients are also observed to be guided by heuristics to reduce their perceived risks. For instance, the default building heuristic leads clients to both traditional design elements in new commercial buildings and flexible design elements within the space to reduce their commitment to design choices (e.g. moveable interior walls) (Beamish and Biggart 2012). Design teams also rely on heuristics. The availability and familiarity heuristics were apparent in the design of a large rail tunnel project (Eriksson and Kadefors 2017). In another instance, VanBuiten et al. (2013) describes how the affect heuristic (Zajonc 1980), which depicts an individual's tendency to assign unequal cognitive weights to benefits and consequences of a decision, led to fixating on differences and ultimately eroding a Public Private Partnership. These examples only begin to depict human decision making in construction in the initial design and plan phase. In order for the construction industry to begin capitalizing on the benefits associated with studying behavioral science, research is needed in the project implementation phase of a project.

3.0 Point of Departure

The impact and benefits of more descriptive models of decision making has improved fields from medicine to insurance, leading to real-world outcomes in patient satisfaction and increased profit. The construction industry can also benefit from a better understanding of how decisions are made from a descriptive perspective. The intent of the research described in this paper is to look more closely at how heuristics are used during construction. Heuristics can help and hinder the decision making process. By understanding how they are used, individuals can determine where these shortcuts are beneficial or detrimental in construction project management.

The objective of this paper is to give construction stakeholders a more complete understanding of the decision making that occurs through a construction project. By documenting the heuristics employed through construction, this paper helps fill the void of descriptive decision making in construction by answering the following research question:

How and when are heuristics employed in the field?

4.0 Methods

One source does not exist that outlines all possible heuristics and decision making shortcuts, multiple sources had to be considered to develop an initial set of heuristics for this research. Prior literature was synthesized to create a list of heuristics from the following sources: behavioral science articles including, Simon (1956), Simon (1982), Kahneman and Tversky (1972), Tversky and Kahneman (1974), and Tversky (1972b); the Behavioral Economics Guide (Samson et al., 2018); and pre-developed summaries of heuristics, including Metzger, Flanagin, and Medders (2010), Mousavi and Gigerenzer (2014), and Shah and Oppenheimer (2008). Literature reviews on heuristics in design (Beamish & Biggart, 2012), decision making for facilities (Delgado & Shealy, 2018) and decision making in construction (Shealy & Klotz, 2017) provided a list of heuristics that likely could be observed during construction. Thirteen heuristics were selected as candidates for this research based on their prevalence in the above schools of literature. While the research was not limited to consideration of only these heuristics, these were the primary heuristics considered in this study. Table 4 provides the list of heuristics and definitions.

Table 4: List of Heuristics

Heuristic	**Definition**
Affect	Risk and benefit judgments are inversely related (Zajonc, 1980).
Anchoring	"Anchoring" to a salient and known value, basing judgment off this value (Tversky & Kahneman, 1974).
Availability	Individuals perceive the likelihood or risk of an event based on how easily one can recall an example of that event (availability) rather than its actual probability (Tversky and Kahneman, 1973).
Default Building	Using traditional, default building characteristics (Beamish & Biggart, 2012).
Recognition	Cognitively weighing "recognizable" options heavier in choice selection. (Goldstein & Gigerenzer, 2002).
Representativeness	Judging a whole group by a sample size (Kahneman & Tversky, 1972)."
Risk Reduction	Allowing fear of risk to impact decision making (Hansen & Singleton, 1983; Mitchell & Greatorex, 1993).
Sunk-Cost	Allowing Sunk Costs to affect a decision. (Arkes & Blumer, 1985)
Myopia	Evaluating options based on immediate gain rather than long term potential gains (Shiv et al, 2005).
Elimination	Using the process of elimination to make a decision (Tversky, 1972).
Reputation	Placing a high cognitive weight on reputation in decision making (Metzger, Flanagin et al., 2010).
Function	Targeted profits become dominant factors for cost-cutting decision making (Beamish & Biggart, 2012).
Flexibility	Producing "flexible" buildings that can meet the needs of many individuals (Beamish & Biggart, 2012).
Familiarity	Individuals assume circumstances underlying past behavior still apply for a present situation (Metcalfe, Schwartz et al., 1993).

This study was conducted between May 2018 and August 2018 at multiple job sites for a mid-sized contractor in the Mid-Atlantic Region of the United States with roughly half a billion dollars of expenditures per year and ranked among ENR’s top 400 contractors. The size of this company promised a variety of observational opportunities across different construction sites.

Among the construction sites studied were a commercial office building, a hospital, a high rise hotel, and a governmental research facility. These four construction sites were chosen because of their locality, phase of construction, and diversity of scope. All four were within a reasonable travel distance and at peak stages of construction, ensuring a wide base of subcontractor representation. Further, all four served a different sector of the construction economy with different owner categories, to allow for a diversity of data. A short observational period with the estimating department was also conducted. While studying these job sites, participant observational research methods were used to collect data.

The research methods for undisguised participant observational research outlined in *Research Methods in Psychology* (Price et al. 2017) were conducted in this study. The researcher conducting participant-observations in this research worked among multiple project teams and environments as a field assistant for the contractor. By working in the field, and also taking notes on behavioral science and decision making, the researcher was provided a rare opportunity as an involved observational researcher.

Daily observations and conversations were recorded in a notebook. Observations included both concrete decision events and situations that may have influenced or suggested heuristic use. In some observations, an actual decision point was documented and the thought process that assisted decision makers was described. In other observations, project environments or situations and environment that suggested particular heuristic use were documented. Observations were reported in the notebook including context, date and time, stakeholders involved, possible follow up questions, and potential heuristics that may have impacted the decision.

Observations were initially labeled with potential heuristics and updated through reflection of the recorded decision scenario, decision outcome, and definition of the heuristic from literature. In some instances, decision scenarios included multiple heuristics. These observations were provided labels of “primary” and “secondary” for each heuristic. For example, one of the observations included experiences during a welding inspection. This observation included both a primary heuristic, representativeness, and a secondary heuristic, reputation. In order to save time in the inspection, the welding inspector only viewed some of the most important welds, and made a judgement on the whole staircase based on a sample size (representatives). After the inspection, he also discussed that he knew the welder on this job was reputable and trusted that his welds were good (reputation).

On a weekly basis, this list of observations was reviewed with two external researchers to help confirm and validate the coding's of heuristics for observations and develop any further follow up questions to the stakeholders involved in the observation.

5.0 Results

After refining the list of observations made over three months, 29 observations emerged of heuristics in the field. Occurrences of heuristic were tallied among all 29 observations to determine which heuristic occurred the most frequently. The top five heuristics are described in this paper because they represent the majority of observations. This included 16 observations, 6 of which contained both a primary and secondary heuristic in the observation. The observations are listed in Table 5 and described in more detail below.

Table 5: Observations

Observation	**Heuristic**	**Rationale**
O1: Plumber installed rain leaders the same as he did in the past	Familiarity	Pipe install performed per familiar methods/design, which was incorrect.
O2: Electrical Engineer designed electrical design per company standard	Familiarity	Electrical line designed per familiar standards.
O3: An owner described typical building requirements	Familiarity	Owner's design wants portrayed familiar building layouts for this company.
O4: Windows were installed incorrectly	Familiarity	Windows installed per familiar methods, which was incorrect.
O5: Initial concrete demolishment proposal was per company standard	Familiarity	Subcontractor's initial demolition methods were chosen based on familiar means and methods.
O6: Employee warned of potential pitfalls of recycled products in meeting	Risk Reduction, Representativeness	Attempted to reduce future financial losses associated with faulty recycled products. Made judgement based on sample size.
O7: Electrical engineer refused to change pull box design when requested to remove it per code standard	Risk Reduction	Engineer attempted to protect company from absorbing any perceived risk.
O8: Owner representative did a rough calculation for a door order	Risk Reduction, Anchoring	Owner ordered excess doors to cover risk of falling short. Owner anchored to similar building for calculation.

O9: Project Managers don't release extra money until end of project	Risk Reduction	PMs fear having a shortage of funds at the end of a project.
O10: Contractor avoided subcontractors with no or negative reputation	Risk Reduction, Reputation	Contractor protected themselves by avoiding risky subs. Contractor placed a high weight on reputation in sub selection.
O11: Welding inspector only checked a sample of welds in inspection	Representativeness, Reputation	Inspector made judgement of all welds based on a sample. Inspector considered welder's reputation in decision process.
O12: Employee experiences with subcontractors shared	Representativeness, Reputation	Employees shared judgements of their experience with subcontractors.
O13: Engineer based condensate line design off similar building	Representativeness	Engineers design was based on similar type buildings.
O14: Owner selected reputable carpenter, despite high price	Reputation, Anchoring	Owner selected reputable carpenter in spite of cost increase. Owner originally selected carpenter based on low bid.
O15: Mason foreman anchored to past material lead time for project	Anchoring	Subcontractor told contractor an incorrect material lead time. He was referencing a lead time from a past project.
O16: EIFS subcontractor anchored to contract documents and adjusted size	Anchoring	Subcontractor anchored to contract documents and made adjustments based on actual framing.

5.1 Familiarity Heuristic

The familiarity heuristic was the most frequently observed heuristic over the three-month observational period. It emerged in multiple contexts among project staff and subcontractors. It is defined as a decision making shortcut where individuals assume circumstances underlying a past behavior still apply to a present situation (Metcalfe et al., 1993).

The first observation (O1) involved a plumbing subcontractor installing cast iron rain leaders on the interior of a building. Subcontracting crews often work within time constraints set by their company owner and the contractor. The foreman in this example made a judgement of time, and opted to not reference the particular construction and submittal documents for this job. Rather, he employed the familiarity heuristic to quicken his installation procedure. In performing his installation practices, the plumber neglected to refer to the construction documents and instead installed the cast iron rain leaders based on his typical, personal standards. The plumber installed six-inch pipe hangers for six-inch pipe. However, per submittal documents, the hangers were supposed to be 10 inches to allow for 2 inches of continuous pipe insulation.

The superintendent noticed the error in hanger size at 40% completion of the piping installation. When pressed for an explanation, the plumber responded that this is the way "he has always performed this work." The plumber further explained that his company typically performed pipe installation with 6 inch hangers and insulated around hanger sleeves instead of through them. While this may have been the practice that the plumber was familiar with, the construction and submittal documents specified continuous insulation around the pipe. The plumber neglected to check the submittal documents and instead relied on the familiarity heuristic. The use of this heuristic resulted in rework of pipe hanger installation costing the subcontractor both time and money.

A second observation (O2) of the familiarity heuristic involved an electrical engineer. Engineers typically follow rules of thumb, whether industry, personal, or company specific, in design to simplify decision making. In this observation, the electrical engineer employed the familiarity heuristic to simplify the intricacies of wire stresses in conduit. During a subcontractor's meeting prior to an exterior pull box's installation, the electrician voiced his concern about the engineer's design of a main electrical line for the commercial building. A pull box for the main electrical line was specified to be located in the buildings south east corner of the property. The electrician noted that this pull box was not required by code because there were three, not four 90-degree bends in the conduit. The pull box was added because the design engineer's rule of thumb to specify a pull box every 200 feet. When asked, the engineer could not provide supportive rationale for his design but continued to resist when the electrician asked to remove it.

To overcome his reliance on company practice required the contractor to absorb the perceived liability by paying for an additional stress test and research documents to prove the specified pull box was unnecessary. No code or standard electrical practice requires pull boxes every two hundred feet, yet the electrical engineer maintained this was the standard for design based on his use of the familiar heuristic developed through his company and personal norms.

The third observation (O3) of the familiarity heuristic revolved around the owner's description of building scope for a commercial office building. Owners are often faced with decisions related to building design and layout. Buildings layouts can present endless options of wall placement and interior design; countless variables that impact decision making. This example depicts an owner's use of the familiarity heuristic to simplify decision making. In a meeting between the contractor and owner, the owner stated, "we want offices around the outside and cubicles on the inside. We want to be able to move people around." He later described his desire for the space to be "flexible" and useable by many departments if the company decided to change office layouts. This idea for a flexible space with executive suites on the outside and cubicles in the middle is reflected in Beamish and Biggart's (2012) description of business owner norms. The layout of this building and the idea of flexible spaces was almost identical to Beamish and Biggart (2012) description of a typical commercial office buildings, "two to three stories, 50,000 – 65,000 gross square feet, rectangular form and an elongated floor plan with windowed premium offices around the outer edges [and an open interior space for office cubicles]". In other words, this project, like so many others, conform to society and industry norms of what an office building is supposed to look like and how it is supposed to function. The owners use of the familiarity heuristic, by applying underlying past experiences with building types led to this building design.

A fourth observation (O4) of the familiarity heuristic occurred during the installation of windows and insulation. Time pressures often influence the decision making of foreman and laborers on a construction site. Rather than obtaining and referencing construction documents and submittals, in this example, the subcontracting crew relied upon heuristic implementation to quicken decision making. The window subcontractor incorrectly assumed that the process to hang windows on a building with a spray foam vapor barrier was the same as a building with Tyvek house wrap (the typical moisture barrier used in commercial construction). Window details for this building required the installation of rubber flashing around the frame of the window to provide a water tight seal. The rubber flashing's adhesive began pealing from the spray foam surface several hours after installation. After incorrectly installing 12 windows and finally referencing the construction documents, the subcontractor and contractor's crew realized that they had relied on familiar installation methods rather than specified instruction. After talking with both crews, both parties realized their mistakes. The construction team was unaware of differences in installation practices associated with various vapor barriers and conducted and planned installation based on practices they were familiar with.

In contrast to the prior examples, another observation (O5) of the familiarity heuristic ultimately led to an innovative outcome, albeit through a challenging obstacle. An employee from the estimating department described a recent situation he faced with a concrete subcontractor. The concrete subcontractor had put in a bid to demolish a concrete retention pond. During the estimating process, the subcontractor initially employed the familiarity heuristic using common means and methods for demolition – using several jack hammers, front end loaders, and a dump truck. His reliance on the familiarity heuristic was due to an initial lack of information or experience with technical concrete demolition practices. However, a financial obstacle eventually challenged his reliance on common practice to perform the work. The subcontractor won the project through the bidding process for $500,000. Once the project began, the concrete subcontractor discovered that the water table was above the retention pond. This unexpected condition increased their costs to $600,000 in order to continuously pump the water out of the retention pond. Constrained by financial resources eventually forced the contractor to innovate.

Given these new constraints, the subcontractor abandoned their typical methods for concrete demolition and developed a new approach to remove the concrete pond. By cutting the slab in sections and attaching anchors to each section, the subcontractor was able to use a crane to lift out each slab into dump trucks. The result was both the saving of a relatively large amount of money ($300,000) and the creation of a new method of demolishing concrete for this subcontractor. While the company had initially relied on the familiarity heuristics to develop means and methods, new information that challenged previous performance practices forced the team to innovate, ultimately resulting in new cost savings and additional profit.

5.2 Risk Reduction Heuristic

The application of the risk reduction among project stakeholders was observed in multiple instances and with varying context across stakeholder groups.

The first observation (O6) occurred during an orientation event when a senior level employee explained his caution with new products. In this observation, the employee had limited, negative experiences with new products. His limitation of experiences with new products in the construction industry led him to employ the risk reduction heuristic to protect his company of perceived risks of installing new products. The employee addressed company members by saying, “new products are not fully tested due to a decrease in barriers in product development. In the past, products were tested extensively, because a whole manufacturing plant had to be built to manufacture it. Nowadays, with 3D printing and other manufacturing advancements products can be produced in small quantities for cheaper and are often tested less.” The employee continued to give an example of a recent replica slate product that was used on a commercial building roof. While the product initially appeared as advertised, over time, the replica slate shingles faded and turned grey. The contractor had to replace the entire roof within five years because the color had faded considerably more than the traditional slate roof material. The contractor discovered that the roofing product was recycled tires that contained large amounts of salt which produced the grey color over time. The theme of his story was be wary of new products because they present unnecessary risk.

The second observation (O7) of risk reduction revisits the observation of the electrical pull box design. While the electrical engineer initially used the familiarity heuristic in his design of a main electrical line, he employed the risk reduction heuristic when faced with the complexities of balancing both his companies and clients perceived needs. The design engineer followed his company’s rule of thumb to specify a pull box every 200 feet, regardless of the number of bends in the conduit. This example is also a demonstration of the risk reduction heuristic because even when pressed to remove the pull box, the engineer refused until being provided an agreement from the contractor to provide a wire stress test. For two months, the designer persisted to keep the pull box because this was the risk reduction option, protecting his company from any liabilities associated with overly stressed wired. This reliance on risk reduction delayed the project and devoted considerable time among project managers and salary staff.

The third observation (O8) of the risk reduction heuristic occurred during a meeting with the owner’s team during the construction of a commercial building. The exterior shell of the building had been designed, but the owner and designer had not yet finalized a design for the interior space. This limitation of information about the final interior build out prompted the owner’s committee to perform a rough calculation using the risk reduction heuristic. During a meeting with the owner, design team, and contractor, the contractor’s team was pushing to order doors, but the owner and designer had not yet decided on an interior design and thus did not have a quantity for the order. The owner's representative said to "go ahead and order 100 doors now. If we don't need them all, then OKAY. But, we would much rather have too much at the end then not enough."

In a follow up interview, the owner's representative said he had performed a rough estimation of the number of doors to be in the building by calculating the number of doors in a similar building, and adding several additional doors to cover risk of under estimating, and thus delaying project delivery. In other words, the owner representative intentionally ordered more doors than he expected to compensate for the risk of falling short. Risk reduction led to additional material expenses but the owner was willing to pay extra to reduce his future risk of project delay.

The fourth observation (O9) of risk reduction demonstrates a project manager's typical practice when maintaining a project's budget. Predicting final project budgets requires the weighting of countless variables and various assumptions. Since many variables, such as weather, subcontractor completion dates, and site conditions remain ambiguous throughout project delivery, project managers employed the risk reduction heuristic to overcome a gap in knowledge. Project managers for the construction company being observed attended a training session led by a senior level company employee. One of the main topics of this meeting was the proper way to release extra money from a project to the company through the course of construction. Throughout the delivery of a project, the contractor may sometimes have extra money left over from contingency or a general condition fund. As the senior level official described, project managers should wait until the very end of a project to release this money to the company. Essentially, this is one way that project managers protect themselves and mitigate risk. From the viewpoint of the project manager, this money was for risk reduction and until no uncertainty is left in the project this risk reduction measure should not be removed.

The final observation (O10) of the risk reduction heuristic was apparent in the contractor's avoidance of subcontractors with either no or a negative reputation. In this observation, the risk reduction heuristic was employed to both overcome a lack of information about competing subcontractors and to help reduce resources spent on a project by encouraging more reputable subcontractors. During an observation period in the estimating department, a lead estimator described a common practice to add an additional cost for performance and payment bonds to the bottom line of subcontractors with no or negative reputations. If the contractor received a bid from a subcontractor deemed less qualified or less reputable, they mitigated their risk by requiring a performance and payment bond.

5.3 Representativeness Heuristic

The representativeness heuristic was observed four times throughout the observation period. These observations demonstrate how individuals in the construction industry apply experiences from a small sample size to a population or larger group as a whole.

The first observation (O11) involved a welding inspection. In the face of time constraints associated with building inspections, the welding inspector employed the representativeness heuristic. When inspecting a staircase, the welding inspector relied heavily on a small sample size of welds to make a judgement about the welds on the entire staircase. The inspector reviewed welds around load bearing beams and three non-load bearing welds on stair treads, handrails, and landings, and then certified all of the welds on the staircase, leaving outs hundreds of welds in his inspection. In discussing this process with the weld inspector, he said, "by the looks of the [sample of] welds I have looked at, we are dealing with a good welder." In other words, he used the representative heuristic to determine the quality of welds throughout the stairwell. The use of the representative heuristic by the welding inspector increased his inspection speed and informed his judgement about the type of welds throughout the stair case and construction project.

The second observation (O12) of the representativeness heuristic was an observation of a companywide meeting that encouraged employees to voice their experience with subcontractors. This meeting environment provided a good indication that employees of the contractor employed the representativeness heuristic to overcome gaps in knowledge about subcontractors in the region. The company leadership wanted to announce recommendations for or oppositions against subcontractors, often making these judgements on past performance, with one or multiple crews, often from a single project. Large subcontractors with dozens of construction crews were often judged as a whole based on the performance of a single construction crew or individual. Those that performed well, were recommended by project management to the entire company. Similarly, if a subcontractor's crew or an individual performed poorly, project management would recommend that the company be avoided in the future.

For the third instance that the representativeness heuristic was observed, an earlier mentioned observation (O6) is discussed again. In this example, a senior level employee had warned new staff members of the risks associated with new and recycled products that did not have a proven track record in the industry. In this example, a lack of information or exposure to all recycled products led to the use of the representativeness heuristic. By applying his experience with one recycled product to many other recycled products, this employee indicated using the representativeness heuristic. This particular individual's exposure to faulty shingles made from recycled tires led to a negative judgment of other recycled products. In short, he applied his experience with one recycled product to an entire product line.

The final observation (O13) of the representativeness heuristic involved the design of condensate drain lines at a retirement home facility. In this example, the architect employed heuristics to arrive at a quick design solution. In response to the pressures of time associated with building design, the architect applied his experience from a sample of split HVAC systems to a much larger HVAC system, and in the process made an error in judgement about the quantity of water discharge. The facility consisted of three buildings, with twenty units per building. Once all three buildings were completed, the owners noticed the flower beds were constantly flooding. The construction management team realized that condensate lines from all the HVAC units were disposing into the flower beds, resulting in 20 gallons of water per day. Rework was required to reroute all condensate lines to a ditch.

The error occurred in underestimating the about of water discharge per HVAC unit. The amount of water for one HVAC system was minimal and the designer assumed the water discharge for multiple would also be minimal.

5.4 Reputation Heuristic

The reputation heuristic is evident when an individual place a high cognitive value on a product or company's reputation in their selection of an option over other variables like total cost. There were four instances of the reputation heuristic observed during the observation period.

The first observation (O14) was an owner's selection of a carpenter for the commercial office building. This observation demonstrated the high value placed on reputation in the industry, especially when faced with the complexities of subcontractor selection. For the commercial building project, the contractor had recommended a local carpenter with a high reputation for quality. The cost of the local carpenter was more than the other received bids. While the owner's construction team had intended to use the reputable carpenter, the owner's financing committee selected the carpenter with the lowest bid to perform the work. Once this had been realized by the owner's construction team in a meeting with the contractor and designer, the owner decided to award the remaining wood work to the reputable carpenter regardless of the high price. In this example, the lack of information about competing carpenters and the abundance of variable weighting that may be accounted for in subcontractor selection motivated heuristic use, particularly to ensure the owner's construction of a quality end product.

The second instance of the reputation heuristic is a reference to an earlier observation (O11) of the representativeness heuristic during the welding inspection. The welding inspector only inspected a sample of critical welds and applied the representative heuristic to these welds. But, the reputation heuristic was also evident in this example, as the inspector also weighed reputation in his decision to quickly pass the stair case. During the inspection, the inspector mentioned that he knew the welder who was performing work on this particular construction site, and knew that he performed quality work. Since the welder had built a reputation of good welding practices with this inspector in the past, and in an attempt to expedite the inspection under the pressures of time, the inspector described feeling less obligated to check each weld. Thus, the reputation heuristic and representativeness heuristic seemed to contribute to the judgement about passing the welding for the construction project.

The third instance of the reputation heuristic revisits the observation of a weekly company-wide meeting (O12). One of the topics discussed in these meetings was subcontractor performance. This discussion allowed all employees to gain a sense about company reputations across the region. To overcome a gap in knowledge about subcontractors, these meeting suggested use of the reputation heuristic in subcontractor selection. In this context, project team members often utilized the input on subcontractors in that meeting to assist in their subcontractor selection on other jobs. These meetings helped the company determine which subcontractors would be shortlisted on other jobs, and which subcontractors to avoid based on their reputation.

The fourth instance of the reputation heuristic revisits the observation of the estimating department (O10). In this observation, the contractor clearly utilized the reputation heuristic to help influence subcontractor selection. The contractor had the option of requiring a performance or payment bond for subcontractors. In response to either a lack of information about subcontractors or the unknown variables associated with predicting construction quality and completion dates, the contractor placed a price on company reputation by requiring bonds of less reputable subcontractors. Reputable companies with an outstanding record weren't required to be bonded, which resulted in lower bottom line price and increased their chances of receiving the contract.

5.5 Anchoring Heuristic

The use of the anchoring heuristic was apparent in four instances of observations. Construction stakeholders often anchored to a known salient value, then adjusted that value to make decisions.

The first instance (O15) involved a delay in delivery of precast concrete quoins. On one particular construction site, the mason foreman employed the anchoring heuristic to overcome a lack of information about a material lead time when planning the installment of brick on the building's exterior walls. The foreman had planned his schedule around the typical lead time of decorative precast concrete quoins, which were designed to be installed with the brick. Unfortunately, the 4-6-week typical lead time for this item was actually 7-9 weeks for this project. Unbeknown to the foreman at the time, the material vendor was experiencing an excess in orders, resulting in longer lead times. The mason hadn't called ahead of time to confirm a lead time for this item, and instead had used a material lead time for the same item from a past project. In other words, he anchored to past delivery estimates without checking if these numbers were appropriate today. The result was an order placed three weeks too late, pushing the critical path beyond completion date.

The second example of the anchoring heuristic refers back to the instance (O14) of a carpenter selection. In this observation, the owner initially anchored to cost in subcontractor selection to help reduce resources invested in this project. In this example, when faced with the complexities of extensive variable weighing in subcontractor selection, the owner's financial committee fixated on the lowest bid to hire a carpenter. The increase in bid price from the carpenter recommended by the project management team was greater than the perceived value in quality of work, hence the owner's financial committee decided on the low bid carpenter. Not until after the carpenter was awarded phase one, did the owner realize this decision was a mistake. The casework in this particular building was intricate, and the owner recognized the decision should have been made based on reputation not cost.

The third instance (O16) of the anchoring heuristic involved the installation of a building's exterior insulation finishing system (EIFS). To allow for a quicker installation process and in reaction to the pressures of time associated with material installment, the EIFS foreman utilized the anchoring heuristic. EIFS is a foam molded trim intended to replicate wood for the exterior finish of a building. It is cheaper and easier to install than traditional wood trim. The installer first produced an initial set of EIFS pieces that were manufactured per the construction drawings. He then placed the EIFS system against the building frame and marked the foam in several places, indicating needs in size changes. The EIFS subcontractor then returned to the shop and manufactured enough foam EIFS for the entire building. The foreman said this measuring practice was common practice. By anchoring to the construction documents, and adjusting per the actual framework, the EIFS foreman utilized the anchoring heuristic to reduce the amount of onsite fabrication.

The final instance of the anchoring heuristic revisits the observation (O8) of the owner's door order for the interior buildout of the commercial office building that had not yet been fully designed. The owner's representative employed the anchoring heuristic to overcome a lack of information about the interior buildout of this building. The owner's representative described how he used a very similar building as a starting point, counted roughly how many doors were in that building in his head, and added extra doors as a safety. No quantity takeoff method was used (the design was not even complete yet). But, the team needed to order the doors to stay on schedule. In this observation, the owner's representative calculated a rough estimate for a long lead time item door order by anchoring to a past project.

6.0 Discussion

Heuristics are used frequently throughout a construction project by project management and field staff. Heuristics save time and increase decision efficiency. For example, the use of the representativeness heuristic by the welding inspector allowed for a faster certification process. By inspecting only the critical welds, he reduced the inspection time from multiple days to a couple hours. Using heuristics in some instances led to detrimental outcomes. For example, referencing the construction documents instead of relying on the familiarity heuristic could have saved the plumber time and money when installing the cast iron rail leaders. He thus was overly reliant on the affect heuristic by only using his past knowledge for installation procedures.

These heuristics do not occur in isolation. For example, the risk reduction heuristic appears linked to the reputation heuristic. To reduce risk associated with selecting a subcontractor, a contractor or owner may opt to select a more reputable subcontractor even with a higher price. The risk of using a less well-known subcontractor could have been mitigated in other ways, for instance, by using bonds and contingency. In other words, preference for reputation is higher than time or money. Further, a contractor may rely on the familiarity heuristic when planning the means and methods for a new construction project in order to reduce perceived risk. This risk could also be mitigated in other ways, perhaps by a cost-benefit analysis to weigh alternatives (Ng and Skitmore 2001).

Project management staff can use the findings presented in this paper as a starting point for becoming more aware of decisions that affect their construction projects. For example, recognizing the use of the anchoring heuristic may have saved the critical path when waiting for the precast quoins to be installed on the façade of the commercial office building. Project management staff can also help reduce over design by recognizing design engineers use the risk reduction heuristic. As was the case with the pull box. This instance slowed project delivery and resulted in numerous hours of project staff fixating on this small detail during weekly meetings.

The biggest influence on heuristic outcomes is user awareness. Individuals who are self-aware about their decision making tendencies, tend to make less mistakes. By just educating oneself on heuristics that impact their decisions, they can improve their own decision making and make effective use of heuristics. Framing, a concept of choice architecture, can also be utilized.

To help overcome heuristics that result in negative outcomes, project management can look to framing effects (Shealy et al., 2016). For example, engineering decision makers are more likely to be motivated not to lose something than gain something of equal value (Shealy et al., 2016). Framing decisions in terms of possible loses for inaction may change motivation. Future studies could test different framing strategies in construction to test their effectiveness. For example, subcontractors can award small monetary benefits to employees who complete a task without rework. This can help encourage them to not only rely on the familiarity heuristic when performing an installation. Further, contractors can frame contingency funds as money that can be gained by the contractor, not funds that are meant to be spent. This can help change project manager's attitudes towards unspent funds in a project, and encourage them to release it sooner.

This paper can also assist individuals in calculating a decision through a normative decision model. Normative decision models require the use of user inputs on preferences and needs of the decision maker. By assigning weights to variables that impact a decision, these models help capture all variables that affect a solution. MAUT (multi-attribute utility theory) and CBA (choosing by advantages) are two popular examples of normative decision making models, and both require user weighting of variables. By using this paper, stakeholders in construction can gain a better insight into owner, contractor, and subcontractor needs and preferences. For example, if a contractor were employing a normative decision model to select a subcontractor on behalf of an owner, they would know to apply heavier weights to a factors such as 1) company reputation, 2) contract duration, and 3) perceived risk.

7.0 Conclusion

This series of observations occurred over more than 520 hours observing a contractor in the Mid-Atlantic region of the United States. More than 41 initial observations were recorded. In total, 29 instances of these 41 observations contained heuristics. The top five most frequently occurring heuristics were familiarity, reputation, representativeness, anchoring, and risk reduction. Subcontractors were observed using the familiarity heuristic during building installations, often making judgments on installation practices based on past knowledge. Reputation was observed as the most critical attribute when deciding subcontractors. The contractor also made project level decisions to ensure the company's reputation was preserved for the owner. To save time, field staff and project management would make general assessments about project level activates using the representativeness heuristic. Anchoring led to errors in schedule assumptions, but also enabled more quick judgements about quantity takeoffs. Risk reduction was a constant theme through the observations that was also attached to other heuristics.

While these heuristics often served as cognitive benefits, some also had negative effects. For example, the familiarity heuristic had primarily negative impacts on decision makers in this study, often leading to rework by a subcontractor. The risk reduction heuristic didn't always serve as a cognitive benefit either. The contractor frequently shied from risk associated with less reputable subcontractors or recycled material types. While avoiding this may protect the contractor financially in the short term, it could also cause the contractor to miss opportunities associated with subcontractor improvement or material advancements.

By studying the examples provided in this paper, project stakeholder can gain a fuller insight into the decision making behind their industry. By using this paper as an informative tool, construction stakeholders can emphasize heuristics that are beneficial, and use heuristics that have potential for negative impacts sparingly.

8.0 Limitations

There are some limitations to this observation research. Particularly the impacts of sampling and recall bias and the objectivity in heuristic labeling (Kopec and Esdaile 1990). The observations were only conducted with one contracting company, who primarily performed vertical construction with a construction manager at risk delivery method. The findings may differ given a different construction company or industry (industrial, water treatment, transportation) (Cortes et al. 2008).

The recall bias, a bias encountered when one doesn't fully recall all events observed, could also be present in the findings. The documented cases of this research were built from notes during three months of observations. To reduce the chance of recall barrier, the observers recorded observations in a notebook immediately following an instance of a project level decision. The time between observation and documentation helped reduce the chance of recall bias. The labeling of heuristics to observations was done by matching instance with the operationalized definitions of each heuristics. This matching process between instance and heuristic was done congruently with three researchers familiar with each instance and possible heuristic.

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CONCLUSIONS

The conclusions of the two studies provided an outline of heuristics employed by the stakeholders that were interviewed and observed. In interviews, employees typically discussed their use of the affect, temporal preference, risk reduction, reputation, and anchoring heuristic. In observations, employees typically demonstrated their use of the familiarity, representativeness, risk reduction, reputation, and anchoring heuristic. The results of both studies, outlined seven heuristics demonstrated by construction stakeholders.

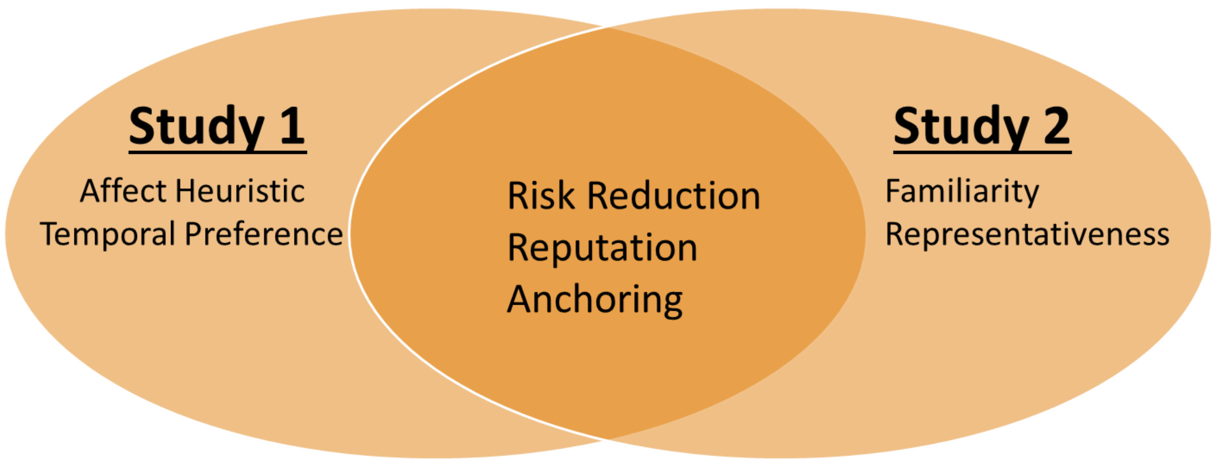

Figure 1: Heuristic Results

The results of both papers use exploratory methods to better understand how heuristics are used in construction. By studying these papers, stakeholders can gain a sense of heuristics that impact their daily decision making. For example, if a project manager were creating a schedule, he or she could reflect on the affect, anchoring, and risk reduction heuristic, the three heuristics associated with scheduling in this study. The affect heuristic was often employed when determining activity durations, by assigning optimistic deadlines. The anchoring heuristic was often employed when assigning logic and determining overall project deadlines. Lastly, by adding days to activity durations to overcome the risk of subcontractor delays, the risk reduction heuristic was employed.

In many of the observations and interviews discussed in this paper, heuristics demonstrated a positive impact on a project. For example, by anchoring to past projects during scheduling, project managers helped reduce the amount of redundancy required in the creation of a project schedule, therefore increasing efficiency. Further, by applying a large weight to reputation in their decision making, the contractor helped reduce the risk associated with less reputable or unfamiliar subcontractors.

While these heuristics demonstrated positive affects in many situations, some examples proved to have negative impacts. For example, one quote provided by a project executive demonstrates an over use of the affect heuristic. In his commentary about his overly optimistic decision making for a particular project, he said, "At the end of the day, I made a mistake in judgement. I was overly optimistic about the project forecast, even when the facts were in front of my face ... that mistake cost us an owner relationship that we are trying to reestablish." Further, while the use of the risk reduction heuristic can help protect an individual, over use can lead to risk aversion, where individuals shy away from risk altogether.

Intervention strategies such as design thinking, systems thinking, and choice architecture can help decision makers improve their use of heuristics. Future research could consider how these different types of intervention strategies can amplify the benefits of heuristics and temper the pitfalls in a construction environment. For example, active strategies such as design and systems thinking can assist a decision maker in becoming more self-aware and cognizant of how their decisions affect other people or project factors. Design thinking prescribes a five step process for creating innovative designs. These five steps include 1) Emphasize, 2) Define, 3) Ideate, 4) Prototype, 5) Test (Brown, 2010). While all five steps are not applicable to most everyday decision making environments, decision makers can still benefit from this model. By primarily focusing on step one, emphasize, they can become more aware of how their decisions affect other surrounding systems of their decision. Further, systems thinking encourages individuals to visualize how their decision impacts systems as a whole (Shankar, Haslett, & Sheffield, 2010). Systems thinking strategies encourage decision makers to draw concept maps before making a decision to demonstrate how their decision will impact other factors. By applying concept maps to everyday decisions, project stakeholders can become better decision makers.

Passive strategies can also assist individuals in their decision making, albeit unknowingly. Passive decision making strategies are nudges that help influence behavior. Choice architecture is a common passive strategy that suggests the manipulation of decision environments to encourage good choices (Harris et al., 2016). An example of choice architecture in construction could be the manipulation of default settings in scheduling software. One could test how adjusting default setting for copying over an old project could affect the schedule built by a project manager. By adjusting these setting, researchers could find the best defaults that still allow for the benefits of using a past projects schedule as a starting point but still allow for ingenuity in a new project schedule. Framing strategies, a subset of choice architecture, could also be tested. By framing different variables in terms of gains and not losses, the construction industry can help decision makers become less risk averse.

While this thesis does not provide solutions to all of the construction industries modern problems, it is one contribution among many to positively influence the industry. By providing a clearer insight into decision habits of construction stakeholders, this research aims to help further inform decision makers in construction. By encouraging strategic use of heuristics, this paper is designed to benefit the construction industry and its users at large.

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APPENDIX

Employee #:

Role: (Senior) Project Manager Superintendent Project Executive Foreman Project Engineer

Interview Questions

1. What project(s) are you currently working on? Can you briefly describe the scope?

Scheduling:

2. How do you create a schedule? (creator)
   - **a.** Do you ever use past projects as a reference?
   - **b.** How did you learn to create a schedule?
   - **c.** Do you know if everyone at your company creates schedules the same way?
   - **d.** Do you typically set aggressive deadlines?
   - **e.** How do you monitor the schedule? Square footage proximity rates? Unit rates?

3. Are the schedules provided to you for a project typically overaggressive or less aggressive? (user)

4. In your opinion, what factors typically contribute to scheduling delays on a project?

5. In your opinion, what factors typically contribute to the early completion of a project?

6. How do you prepare your submittals?

7. Can you describe the process of submitting an RFI?

8. What criteria do you use to decide if a change order will be submitted for a change to a project?

9. How do you typically select sub-contractors?
   - **a.** What advice would you give to a new project manager who is supposed to select sub-contractors but isn't aware of company reputations?

10. How do you typically select material vendors?
   - **a.** What advice would you give to a new project manager who is supposed to select material vendors but isn't aware of company reputations?
   - **b.** What are key factors in material selection? If all material vendors can provide a product that meets specifications, what other elements do you consider?

11. In your opinion, do owners equally value future maintenance costs and upfront costs?

a. Which do you think they emphasize more? How much more?

12. How frequently do you perform a cost benefit analysis and weigh out alternatives quantitatively?

13. Can you think of an instance where you had to make a big decision on a job? Describe your process for weighing alternatives.

Cost Performance:

14. Have you ever been assigned to a project that experienced cost overruns?

15. In your opinion, what factors typically contribute to cost overruns on a project?

16. In your opinion, what factors contribute to projects that finish under budget?

Quality:

17. In your opinion, what factors typically contribute to quality issues on a project?

18. How often is rework typically performed on a project?

a. What is the cause of rework?

19. How often has value engineering been employed on jobs that you have worked on?

a. How does value engineering affect a project?

Employee #:

Role: Estimator

Interview Questions

1. What project(s) are you currently working on? Can you briefly describe the scope?

Estimate:

2. Can you briefly describe how you create a detailed estimate?
    a. How did you learn to create an estimate?
    b. Do you ever use past projects as a reference?
    c. Do you know if everyone at your company creates estimates the same way?
    d. How do you decide what kind of waste factors to use?

Scheduling – Creator:

3. How do you create a schedule?
    a. Do you ever use past projects as a reference?
    b. How did you learn to create a schedule?
    c. Do you know if everyone at your company creates schedules the same way?
    d. Do you typically set aggressive deadlines?
    e. How do you monitor the schedule? Square footage proximity rates? Unit rates?
4. Are the schedules provided to you for a project typically overaggressive or less aggressive?
5. In your opinion, what factors typically contribute to scheduling delays on a project?
6. In your opinion, what factors typically contribute to the early completion of a project?

MISC Tasks:

7. How do you prepare your submittals?
8. Can you describe the process of submitting an RFI?
9. What criteria do you use to decide if a change order will be submitted for a change to a project?
10. How do you typically select sub-contractors?
    a. What advice would you give to a new project manager who is supposed to select sub-contractors but isn't aware of company reputations?
11. How do you typically select material vendors?

   - **a.** What advice would you give to a new project manager who is supposed to select material vendors but isn't aware of company reputations?
   - **b.** What are key factors in material selection? If all material vendors can provide a product that meets specifications, what other elements do you consider?

12. In your opinion, do owners equally value future maintenance costs and upfront costs?

   - **a.** Which do you think they emphasize more? How much more?

13. How frequently do you perform a cost benefit analysis and weigh out alternatives quantitatively?

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19. How often is rework typically performed on a project?

   - **a.** What is the cause of rework?

20. How often has value engineering been employed on jobs that you have worked on?

   - **a.** How does value engineering affect a project?