A Heuristic Model for Rapid and Effective Decision Making in Construction

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Heuristic decision-making is already being used to benefit several fields, such as medicine, law, business, and psychology. Heuristics are an important capability that can be used to make fast decisions. This capability is very useful in construction because it is not uncommon for a construction foreman to experience several disruptions in the course of a single workday. With Heuristic decision-making, a "work-around" decision can be rapidly and effectively made after a construction site disruption occurs. The idea of heuristic decision-making is new to the construction industry, and is the motivation behind this research. Understanding the ability of heuristics to develop rapid and effective decision-making will help the construction industry to save time and increase productivity. Therefore, research was conducted in order to develop a model for a heuristic decision-making process. Interviews with 22 sample group construction foremen regarding 88 real disruption cases were performed in order to understand how decisions were made after disruptions occurred. Conducting a survey with seven different industry foremen later validated the data. The findings indicate that construction foremen currently do use a heuristic decision-making model known as a "Determinant Decision Attribute Heuristic".

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I. INTRODUCTION

According to William Starbuck, a professor at the University of Oregon, "a decision implies the end of consideration and start of action" (Harvard Business Review, 2006). In a brief history of decision-making, Buchanan and O'Connell write, that humans have continuously searched for new tools to help them make decisions. They also mention this as an unusual and long journey through development of artificial intelligence: "The study of decision making, consequently, is a palimpsest of intellectual disciplines: Mathematics, sociology, psychology, economics, and political science, to name a few" (Buchanan and O'Connell, 2006).

The history of decision-making strategies is not one of pure progress toward perfect rationalism. There are constraints, both contextual and psychological, on our ability to make optimal choices. Complex circumstances, limited time, and inadequate mental computational power reduce decision makers to a state of bounded rationality (Herbert Simon, 1991). Simon also concluded that qualitative structure applies to physical symbol systems, such as computers and the human brain. Due to these limitations on the computing speeds and power, intelligent systems must be used approximating methods to handle most tasks. Their rationality is thus "bounded", and a method of achieving acceptable, if not optimal, outcomes has always been sought.

The human mind uses three tools to make decisions - logic, statistics, and heuristics (Gigerenzer and Gaissmaier, 2011). Each of these tools is used in a specific ways and in accordance to its suitability to the situation at hand. A logical and systematic decision-making process helps address critical elements, and results in a good decision (Mind Tools web, 2014). This process is also known as a "logical framework", a "theory of change", or a "program matrix". Engineers often use a similar process known as "simple sequential procedures" (Magee and Frey, 2006).

Statistics are used to inform many decision-making processes. The availability of statistical information does not, however, automatically result in sound decision making. In order to use statistics to make well-informed decisions, one must be equipped with the skills and knowledge to be able to access, understand, analyze and communicate statistical information (Australian Bureau of Statistics, 2010). There are other mathematical models, such as "multi-attribute utility theory", "linear models", "Bayesian networks" or "classification and regression trees". All of these decision-making tools are employed in slow-moving decision making processes. However, for a faster-moving process, heuristics are the method most often employed.

A Heuristic is a decision-making process, which ignores part of the information with the objective of making decisions more quickly, frugally, and/or accurately than more complex methods (Gigerenzer and Gaissmaier, 2011). The mathematician Gorg Polya distinguished heuristics from analytical methods in the following manner. He stated that heuristics are needed to find a proof, whereas analysis is needed for checking a proof. Evidence also shows that heuristics perform better in problems of inference, such as judgment (Hogarth and Karelaia, 2005), forecasting (Goldstein and Gigerenzer, 2009), and categorization (Martignon et al., 2008).

In the context of this research, typical construction projects involve many participants. They include the project owner, the designer and engineers, the general contractor and the subcontractors. From the first day of their involvement on a project these participants make many decisions. Many of these construction decisions manifest themselves in the project's construction phase and occur on the jobsites. These decisions often result in disruptions to the planned flow of the work. A disruption manifests itself when a construction foremen encounters a condition which prevents them from starting, continuing or completing a task. It is not uncommon for a general contractor or subcontractor foremen to experience several disruptions in the course of a single workday. Construction foremen are the personnel closest to the scheduled day-to-day jobsite activities and are the usually the first to make a decision to develop a "work-around" – a possible solution which allows the next step in the planned workflow to continue - when disruptions are discovered. Construction foremen are the "last planners" (Ballard, 1994) who decide and carry out the directives to complete a project.

Electrical foremen were the tradesmen selected for the purposes of this study. The reason for selecting the electrical trade is that these trades are involved at the start of the project and finish their work near the end of the project, and so have the most continuous presence on the jobsite. This means that their trade is the one which suffers the most disruptions. These characteristics make them the ideal trade to study at any phase of the project.

1.1. Heuristic Decision Making

The term "Heuristic" has as its origin the Greek word "heuriskein", which means " to find" or "to discover". Heuristics are involved in or serve as an aid to learning, discovery, or problem-solving by experimental and, especially, trial and error methods (Merriam Webster Dictionary, 2015). It ignores part of the available information with the goal of allowing a decision to be made more quickly, frugally, and/or accurately than more complex methods (Gigerenzer and Gaissmaier, 2011). The term heuristic is used for simple decision models, which people use (Katsikopoulos, 2011).

Many people use heuristics or rules-of-thumb while making judgment and decisions (Dhami and Harries, 2009). Gigerenzer, proposed "fast and frugal" as a simple heuristic models reasoning method to take advantage of our limited time and knowledge. These kinds of psychological heuristics are simple alternatives to optimization models, which are mathematical functions, incorporating all available information in the computation (Katsikopoulos, 2011).

"Humans do not need complex cognitive strategies to make good inferences, estimations, and other judgments; rather, it is the very simplicity and robustness of our cognitive repertoire that makes homo sapiens a capable decision maker" (Marewski, Gaissmaire, and Gigerenzer, 2010).

There are several formal heuristic models that are frequently used in different fields today. Some models that are considered include heuristics such as "recognition heuristic", "fluency heuristic", "take the best and hiatus heuristic", "matching heuristic" (Gigerenzer, 2001, Dhami and Harries, 2003). Also, "fast and frugal trees heuristics" (Gigerenzer, 2001), "determinant buying attitudes" (Myers and Alpert, 1968), and "core attributes heuristics" (Saad and Russo, 1996) are some additional alternatives.

Heuristics generally embody principles for information search, stop, and decision-making (Dhami and Harries, 2009). Decision-making problems are generally divided into two types: a) design problems and b) choice problems. In design problems, information search is focused on the sufficiency of information acquired for problem configuring and building alternatives, while choice problems focus on gathering information for a solution (Browne and Pitts, 2003). This research focuses on the choice problem, and how construction foremen make the decision about what to do next when work on their jobsite is interrupted. In addition, it looks at how foremen gather information for choosing an action to "work-around" the disruption.

Information search for design problem is done early in a decision-making process, whereas information search for choice occurs later in the process (Simon, 1981). Design problems are described by divergent thinking, in which the decision maker tries to think in a variety of directions in open inquiry (Couger, 1996). In contrast, in choice problems the decision maker collects evidence to select one or more of the available options. Choice is therefore directed by convergent thinking and the decision maker makes a choice (Couger, 1996, Guilford, 1957). Studies of information search typically use process tracing approaches, which examine patterns of search from information selection on information boards. The word "backlog" is the term used by foremen and referred to as "consideration set of alternatives" in this research. Additionally eye-movements, retrospective, concurrent verbal reports and Information Use are used to come to conclusions about the information search (Ford, Schmitt, Schechtman Hults, and Dohrty, 1989). Rieskamp and Hoffrage (1999) also observed that the information search strategies could better predict through the use of a simple heuristic model. Information search helps researchers to develop simple heuristics, which can describe and predict information search as well as judgment and decision-making behavior (Dhami and Harries, 2009).

Stop rules for information search in choice problems are used by several researchers in addition to a few examples are given here. They include: Gigerenzer and Todd, 1999; Gigerenzer, Todd, and ABC Research Group, 1999; Rapoport and Tversky, 1970; Seale and Rapoport, 1997, Schmalhofer et al., 1986. There are numerous stop rules found helpful in explaining individual behavior in choice problems situations. For example, Gigerenzer and Goldstein have suggested three simple stopping rules, which they named "The Minimalist," "Take the Last," and "Take the Best." All three of these rules focus on the examination of information attributes to make a choice. "The Minimalist" and "Take the Last" rules require the decision maker to choose an alternative based only on the first positive cue value encountered. The "Take the Best" strategy makes judgments on one good reason only, ignoring other attributes.

Finally, Saad and Russo (1996) proposed the "Core Attributes" heuristic, which states that a person will stop acquiring information and select an alternative after he finds information on all of his important attributes. These stopping heuristics are useful to choice problem situations, as all focus on the convergence to a single alternative.

1.2. Developing Heuristic Decision Model in Construction

There are several other fields, such as business, medicine, law, and psychology, where researchers have used heuristic models to make decisions. Heuristics have achieved competitive performance in applications in business (Astebro and Elhedhli, 2006), medicine (Fischer et al., 2002), and psychology (Czerlinski et al., 1999). Heuristic model is thought to be more appropriate to construction "work-around"sites, where the participants are without the luxury of time to develop and select among many alternative decisions. They often rely on experience, judgment or experimentation in a manner similar to a "heuristic" procedure.

However, no literature was found on any research performed in the field of civil engineering which used a heuristic model of decision-making. Nevertheless, engineers have been known to use other decision-making methods, such as "Failure mode and effects" analysis and "Fault tree" analysis.

The literature review suggest that heuristic decision-making methods must be investigated to achieve the research objectives and realize the project goal. Numerous models, which are used in different fields, were considered as part of this investigation. Some of the models, like matching heuristics, were close to the context of the research, but did not quite represent the way that construction foremen make decisions. Developing a simple heuristic, which follows three steps: a) the information search, b) stop, and c) decision-making, would be more appropriate to explain the process and analyze the situation (Dhami and Harries, 2009). Therefore, a heuristic model was proposed and evidence was investigated for the challenges, which face construction foremen.

The heuristic model proposed was "Determinant Decision Attributes Heuristic", which construction foremen might use to make rapid decisions to develop a "work-around" to construction site disruptions.

The term “Determinant” was first used by Myers and Alpert (1968) in their research on “Determinant Buying Attitudes: Meaning and Measurement.” Before them, Krech and Crutchfield (1948), in their research “Theory and Problems of Social Psychology”, used the term “importance”, which has the same meaning as the term “determinant”. Saad and Russo (1996) later used the term “Core Attributes” in their research for “Stopping Criteria in Sequential Choice”. In that study, they explained when to stop acquiring more information and take the decision, which represented the leading alternative.

The same three steps as discussed before were used here:

a) Information search: Construction foremen develop a backlog list, also referred to as “consideration set of alternatives”, before their work flow starts. When the disruption happens, they start with a goal or set of goals to compare the predetermined consideration set of alternatives and decision attributes to develop a “work-around”. The foremen reduce the alternatives based on the importance of the decision attributes, which are also called determinant decision attributes, and they search for information until they acquire the determinant decision attributes.

b) Stop rule: First, foremen acquire the information for their determinant decision attributes. The information found leads them to choose the assignment of their crews, and they then stop searching for further information. Foremen perceived these determinant decision attributes as central to the making of a decision. The number of determinant decision attributes falls between three and six.

c) Decision-making rule: The decision rule is the final step in the decision-making process to implement the choice made by the foremen. Once the foremen stop acquiring information, they make a choice upon a course of action and then they implement the action.

Figure 1 below illustrates the flow chart for the proposed heuristic that construction foremen used to develop their alternative when job site is disrupted.

II. RESEARCH METHODS

a) Preliminary work: In order to study the context of the study to develop a heuristic model, six different construction sites were visited and 10 jobsite foremen were interviewed. This helped to gain an in-depth insight to their decision-making process when disruptions occurred on their jobsites. Following the jobsite visits, hypotheses and the survey research questions were developed.

b) The Sample selection: Twenty-two foremen were recruited to participate in the study. All worked for four electrical subcontractors in the Chicago, Illinois USA. As mentioned above, the electrical trade is involved at the start of the project and finishes their work near the end of the project, therefore has the most continuous presence on the jobsite. This means that their trade is the one which often suffers the most disruption. This, therefore, this makes them an ideal trade to study disruptions at various stages of a project. Since interviews were the main source of data collection, it took significant time to collect the data. This time, however, was necessary because it was important for the data to be both representative and purposive.

c) Data collection: These 22 sample foremen were interviewed face-to-face four separate times. Each interview took between 30 to 45 minutes and occurred on the same day as - or the day, which followed - a disruption, and after the foremen managed the disruption. The entire data collection occurred over a five months period, from April to August of 2014. A total of 88 interviews were conducted. The

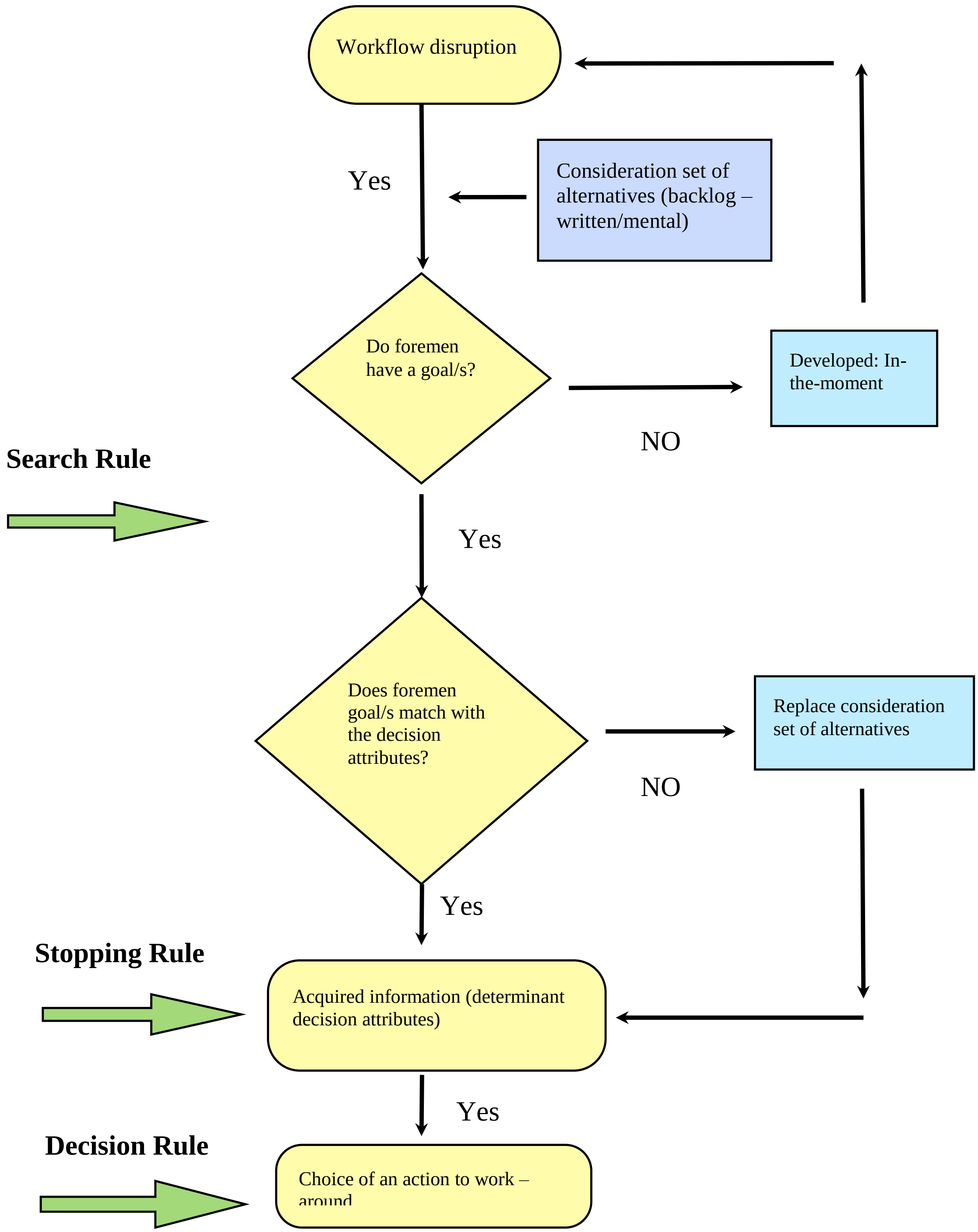


FIGURE 1. DETERMINANT DECISION ATTRIBUTE HEURISTIC FLOW CHART

units of analysis were dependent upon the 32 projects, the 22 sample foremen, and the 88 disruptions, and were based on the project characteristics, foremen characteristics, and the causes of the disruption.

There were 25 interview questions asked of the sample construction foremen. These questions focused mainly on the decision-making process, which foremen used for developing a "work-around" to a workflow disruption.

d) Data validation: Responses to the 25 open-ended questions were received back from the original twenty-two foremen, and analyzed. This analysis allowed multiple choice responses to be developed to the same twenty-five open-ended questions. These same twenty-five open-ended questions - which now sought multiple-choice responses - were then administered to a new and different group of seven similarly-situated Chicago area foremen.

III. RESEARCH QUESTIONS AND HYPOTHESES

The purpose of the research reported in this article was to find a proof that construction foremen used a particular heuristic decision model known as "determinant decision heuristic", and that this heuristic model followed the simple heuristic rules of information search, stop, and decision making.
The following working Hypotheses were used:

1. To investigate when foremen develop a consideration set of alternatives as stated in the alternative form (information search step):

> **H1**: The foremen develop a consideration set of alternatives (i.e. metal/written backlog) before a disruption occurs.
>
> **H2:** The consideration set of alternatives is updated every morning/frequently to reflect changing conditions on the jobsite.

2. To understand how foremen develop a consideration set of alternatives (information search step):

> **H3:** The foremen start with a set of backlog task characteristics to aid with choosing tasks to put on the backlog.

3. To investigate how foremen reduce the consideration set of alternatives when work is interrupted, (stop step):

> **H4:** The foremen start with a decision goal or set of goals to aid with reducing the consideration set of alternatives.
> **H5:** There is a common set of decision attributes for comparing alternatives.

4. To investigate which decision attributes were used to compare the tasks, in the consideration set of alternatives to assign or re-assign to the workmen (decision step):

> **H6a:** Foremen consider more than one alternative.
> **H6b:** Consideration set of alternatives has a leader alternative.
> **H6c:** Consideration set of alternatives is updated (replaced) "in the moment".
> **H6d:** The decision goal(s) is matched to the decision attributes in order to select an alternative task to assign or re-assign to the crew members.
> **H7:** There is a set of determinant decision attributes used by each foreman in order to select one alternative.

5. To understand how many decision attributes are used to make a choice among the alternatives:

> **H8a:** It can be predicted as to how many determinant decision attributes foremen use.
> **H8b:** It can be predicted as to which determinant decision attributes foremen use.
> **H8c:** There are between 3-6 determinant decision attributes used to make a choice.
> **H8d:** There is a match between the predicted decision attributes used and those actually used.

6. To understand how the different attributes influence the outcome of a decision:

> **H9:** There are specific decision attributes that impact the outcome of the decision.

IV. DATA ANALYSIS AND RESULTS

There were two types data collected from the interviews: a) quantitative and b) qualitative. Quantitative data were of several different types. These included 1) binary type (dichotomous frequency) with responses of yes or no; 2) nominal type by counting frequency of occurrence; 3) ordinal type by ranking the responses; and 4) interval type with continuous data. The qualitative data were collected as written and audio record of the interviews. The text data were both written and audio record of the interviews. The qualitative data was then summarized into text and the text was then distilled to generate the key themes of goals, decision attributes, and outcomes of the decision attributes. These goals, decision attributes, and outcomes of the decision attributes were counted as frequencies for the nominal data. These data sets were analyzed using the different statistical techniques such as confidence interval for proportion, chi-square contingency tabulation, mean analysis, and matching score, based on the data type. SPSS (Statistical Package for the Social Sciences), SAS (Statistical Analysis System), and Excel were the main software applications for data analysis and for the production of graphs, charts, and tables.

4.1. Results of Hypothesis Testing and Interpretation of Results

Hypothesis - H1: The foremen develop a consideration set of alternatives (mental, written, or both types in backlog format) before a disruption occurs.

When asked if they "developed consideration set of alternatives (backlog) before a disruption", 96.6% (99% CI [91.62%, 101.58%]) of respondents answered that they developed consideration set of alternatives before a disruption occurred. This means that it can be concluded with 99% confidence level and a corresponding confidence interval of ± 4.98 that foremen did develop consideration alternatives before a disruption occurred.

In answering the type of the backlog used by the foremen, 4.5% used only mental backlog, 16.2% used only written backlog, and 77.3% used both backlog types.

Hypothesis – H2: The consideration set of alternatives is updated every morning/regularly to reflect changing conditions on the jobsite.

When asked if they "updated consideration set of alternatives regularly to reflect changing conditions on the jobsite", 97.7% (99% CI [93.58%, 101.82%]) of respondents answered that they indeed updated consideration set of alternatives regularly. This means that it can be concluded with 99% confidence level and a corresponding confidence interval of ± 4.12 that foremen indeed do updates regularly.

The chi-square fitness test result also

showed that the test was statistically significant: χ^2 (3) = 28.27, $p < .0005$. Therefore, we can conclude that foremen regularly update their consideration set of alternatives. The proportion of the frequency of updates for consideration set of alternatives was as follows: 2.3% never updated, 36.3 as often as needed, 22.7 weekly, and 38.6% daily.

Hypothesis – H3: The foremen start with a set of backlog task characteristics to aid with choosing tasks to put on the backlog.

When asked if they "started with a set of backlog task characteristics (reasons for the task to be on the backlog)", 100% of respondents answered that they started with a set of backlog task characteristics.

Hypothesis – H4: The foremen start with a decision goal or set of goals to aid with reducing the consideration set of alternatives.

When asked if they "started with a decision goal or set of goals to aid with reducing the consideration set of alternatives", 96.6% (99% CI [91.62%, 101.58%]) of respondents reported that they started with a goal or set of goals. This can be concluded with 99% confidence level with a corresponding confidence interval of ± 4.98.

Hypothesis – H5: There is a common set of decision attributes for comparing alternatives.

This was analyzed in two stages. First the text data was analyzed to develop the nominal data. The nominal data were then analyzed by simple statistical technique in the second stage.

Interview data, which were basically text, were all recorded, distilled, and categorized in to key themes (referred to as "decision attributes" henceforth). There were 18 decision attributes generated from the data and then ranked based on the number of their frequency reported by the foremen. There were altogether a number of frequencies of 190 reported in order to choose those 18 decision attributes. Then this list of attributes was arranged depending on the highest to the lowest number of frequency for each decision attribute reported by the foremen. A cumulative frequency of the attributes was calculated and is presented in Table 1 below.

As shown in Table 1, 8 decision attributes out of 18 were chosen more than 70% of the time by the foremen. Similarly, Figure 2 is the graphical illustration of the Table 1 for a common set of decision attributes used by foremen. Thus, an inference can be drawn that foremen have a common list of decision attributes for comparing alternatives to make a decision.

Hypothesis – H6a: Foremen considered multiple – rather than a single – alternatives.

When asked if they "considered multiple alternatives", 87.5% (99% CI [78.42%, 96.58%]) of respondents answered that they developed consideration set of alternatives before a disruption occurs. This means that it can be concluded with 99% confidence level and a corresponding confidence interval of ± 9.08 that foremen consider multiple alternatives.

Hypothesis – H6b: Consideration set of alternatives has a leader alternative.

When asked if their "consideration set of alternatives" had a leader alternative, 87.5% (99% CI [78.42%, 96.58%]) of respondents answered that their developed consideration set of alternatives had a leader alternative. This means that it can be concluded with 99% confidence level and a corresponding confidence interval of ± 9.08 that foremen has a leader alternative.

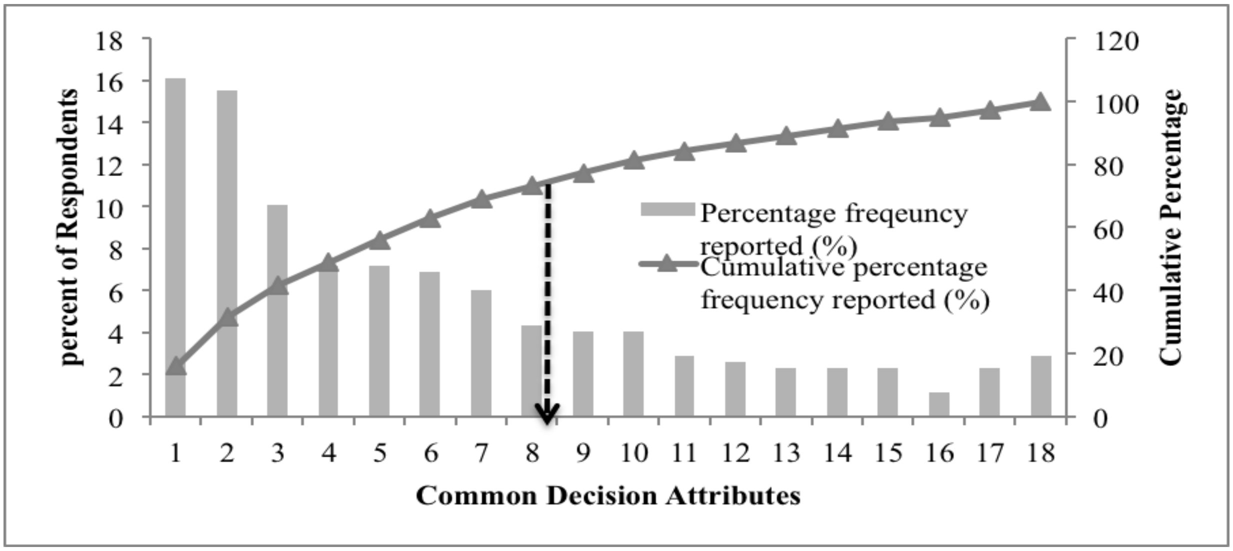
Hypothesis – H6c: Consideration set of alternatives is updated (replaced) "in the moment".

When asked if their "consideration set of alternatives was updated (replaced) in the moment", 54.5% (99% CI [40.83%, 68.17%])

of respondents answered that they replaced the consideration set of alternatives in the moment. This means that it can be concluded with 99% confidence level and a corresponding confidence interval of ± 13.67 that foremen update consideration set of alternatives in the moment.

TABLE 1. COMMON SET OF DECISION ATTRIBUTES OF FOREMEN

	Common set of decision attributes	Frequency reported	Percentage frequency reported (%)	Cumulative percentage frequency reported (%)
1	Duration for the new task	56	16.09	16.09
2	Availability of materials, tools, and equipment for the task	54	15.52	31.61
3	Workers' skills match to the task	35	10.06	41.67
4	Availability of information	25	7.18	48.85
5	Relocate workers fast	25	7.18	56.03
6	Similar task or task require same tools	24	6.90	62.93
7	Priority and/or importance of task	21	6.03	68.97
8	Task scheduled for the week	15	4.31	73.28
9	Select something on backlog	14	4.02	77.30
10	Manpower	14	4.02	81.32
11	Location factor (proximity and availability)	10	2.87	84.20
12	Productivity of the job	9	2.59	86.78
13	Decision was already made	8	2.30	89.08
14	No layoffs	8	2.30	91.38
15	Stay on or ahead of schedule	8	2.30	93.68
16	Safety factor	4	1.15	94.83
17	Coordination with other trades	8	2.30	97.13
18	Other	10	2.87	100.00
	Total Frequency Reported	**348**	**100.00**	



FUGURE 2. COMMON SET OF DECISION ATTRIBUTES CONSIDERED DURING THE INFORMATION SEARCH

Hypothesis – H6d: The decision goal(s) is matched to the decision attributes in order to select an alternative task to re-assign to the crew members.

A matching score was developed to analyze this hypothesis. The non-numeric interview data "goals" of the foremen were recorded, distilled, and generated key themes for the goals. There were two type of goals reported by the foremen: primary goals and other goals. There were 7 primary goals and 12 other goals generated from the data. These two goals types were then merged to get a final list of goals. A final list of 16 goals was then generated. There were 18 total decision attributes, as mentioned above. The goals and the decision attributes were then compared. Among the set of 16 goals and 18 decision attributes, there were 11 perfect matches, which yielded 68.75% match in goals and 61.11% match on decision attributes. Hence, an inference was drawn that decision a goal or set of goals is matched to the decision attributes in order to select an alternative task to assign or re-assign to the crew members.

Hypothesis – H7: There is a set of determinant decision attributes used by each foreman to select one alternative.

The interview data were recorded, distilled, and generated to come up key themes, which was referred to as "decision attributes" with each foreman. It was difficult to find a set of decision attributes by individual foreman with the amount of data available. However, determinant decision attributes that each foreman used was a subset of the common set of decision attributes that was generated in H5. In order to find a common set of alternatives by each foreman, more than four interviews should be conducted with each foreman.

Hypothesis – H8a: It can be predicted as to how many decision attributes foremen consider.

First 3 interviews with 22 foremen across 66 real disruption cases were grouped in stage 1. The numbers of decision attributes evaluated were counted from the survey questions to compute the mean. The analysis result showed that the number of decision attributes searched by the foremen ranged from 1 to 8 (overall mean = 4.18, SD of means = 1.97). Therefore, it can be predicated from the above mean score and SD with a confidence level of 99% that the number of decision attributes range from 3.56 to 4.80.

In stage 2, the remaining 22 interviews were conducted with 22 foremen across 22 disruption cases. The results showed that the number of decision attributes searched by the foremen ranged from 1 to 8 (overall mean = 4.27, SD of means = 1.91). This falls within the same range of 3.56 to 4.8 decision attributes which foremen were expected to evaluate from stage 1 analysis. Using this data, it can be predicted as to how many decision attributes foremen use to make a choice for an action to address the workflow disruption.

Hypothesis – H8b: It can predicted as to which decision attributes foremen use.

A matching score was developed to see how much overlap existed between decision attributes evaluated and determinant decision attributes actually used by the foremen before they selected an alternative across 88 real cases. There was a 90% (16 decision attributes out of 18) match between decision attributes considered and the determinant decision attributes actually applied to make a choice. From H8a, the average number of decision attributes searched by the foremen in stage 1 was obtained to have a mean of 4.18 decision attributes ranging from 1 to 8. Similarly, mean of 4.27 decision attributes was obtained in stage 2, which also ranged from 1 to 8. From H5, 73.28% of the times foremen selected 8 out of 18 determinant decision attributes to make a decision. Therefore, combining all of the above, an inference can be drawn that it can be predicted as to which determinant decision attributes foremen use, with a 90% confidence level.

Hypothesis – H8c: There are between 3 to 6 determinant decision attributes used to make a choice.

To test this hypothesis, the mean for the number of determinant decision attributes actually used by the foremen across 88 disruption cases were calculated. The test result showed that the number of determinant decision attributes used by the foremen ranged from 1 to 5 (overall mean = 2.25, SD of means = 1.02). This showed that foremen used between 2 to 3 determinant decision attributes to make a choice. Figure 3 also shows that the number of determinant decision attributes actually used by foremen, across 88 real disruption cases, were 2 determinant decision attributes at most.

Hypothesis – H9: There are specific decision attributes that impact the outcome of the decision.

The characteristics of good decision reported by the foremen included the following: new task completed in time (39%), workers are productive (18%), no rework is needed (11%), customer is happy (9%), no waiting, got the job done (8%), workers are safe (2%) and other (13%). Every one of the respondents reported that they had made a good decision in all 88 cases. Based on these responses, no inferences could be drawn between the decision attributes and the impact of the outcome of the decision, since none of the despondences reported a bad decision being made. Figure 4 shows the characteristics of good decisions reported by the foremen across 88 real cases.

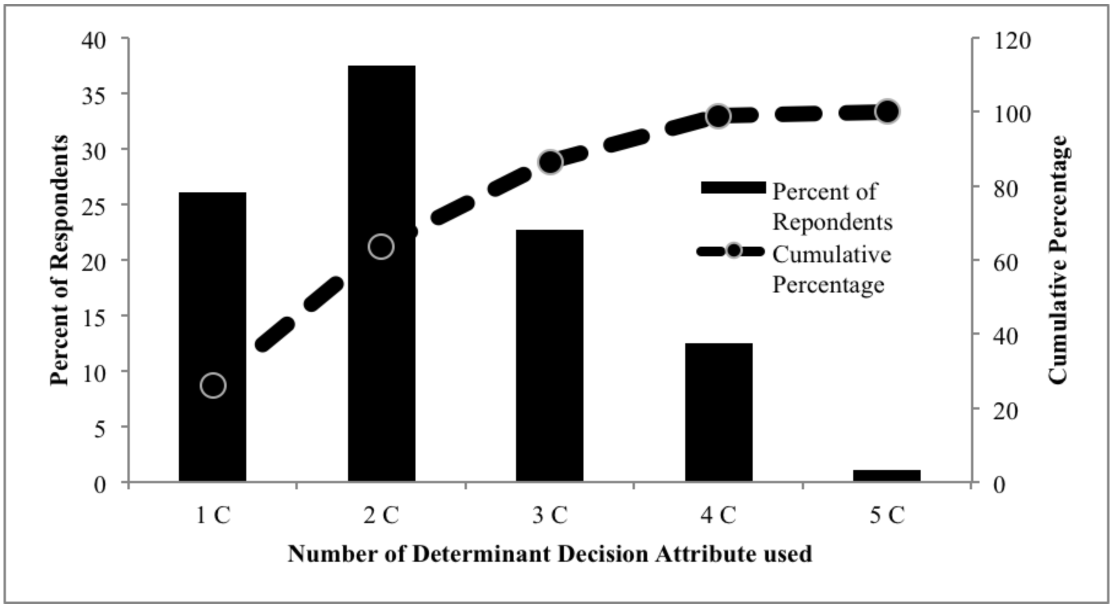
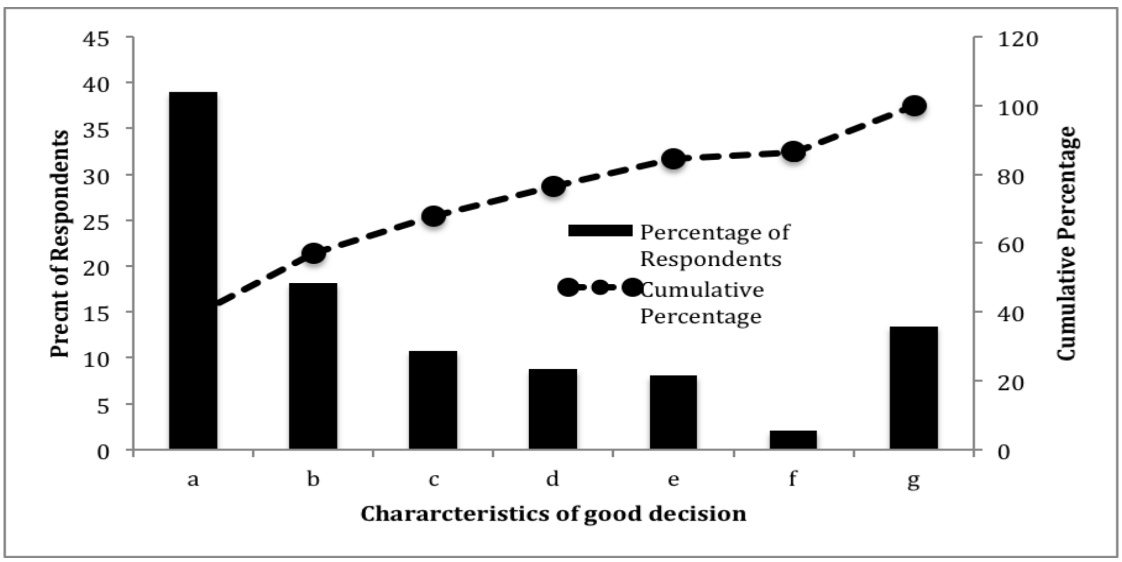


FIGURE 3. NUMBER OF DETERMINANT DECISION ATTRIBUTE USED BY FOREMEN



a) New task completed in time, b) Workers are productive, d) No Rework is needed,
e) Customer is happy, f) No waiting, get the job done, g) Workers are safe and h) Other

FIGURE 4. CHARACTERISTICS OF GOOD DECISION REPORTED BY THE FOREMEN

4.2. Further Analysis

Foremen information search characteristics and whether search characteristics follow a simple heuristic were further analyzed as presented below. This study analyzed the responses given by 22 foremen (during data collection phase) and 7 different foremen (during data validation phase). The result showed the characteristics for heuristics, such as a minimum amount of information search, stopping rule, and making a choice.

a) Information search: This study identified the average number of decision attributes searched by the foremen across 88 disruptions. The number of decision attributes searched by the foremen ranged from 1 to 8 (overall mean = 4.20, SD of means = 1.94) whereas determinant decision attributes actually used by the foremen to make a final choice ranged from 1 to 5 (overall mean = 2.25, SD of means = 1.02). None of the foremen searched all 18 decision attributes from the list. This clearly showed that the information searched by the foremen was minimal (same as concluded by Dhami and Harries 2009). The random orders of search from the list of 1 – 18 decision attributes searched were varied based on the specific type of disruption.

b) Stop rule: As shown in Table 1, most frequently 8 common decision attributes (out of 18) were searched by the foremen every time. This ranged from 1 to 5 decision attributes across 88 disruption cases every time a decision was made. It is also observed that once the foremen acquired the determinant decision attributes, they stopped searching further and were ready to make a choice. This means that the stopping rule is embedded into the determinant attribute heuristic. The process used to acquire the determinant attribute heuristic leads to a choice through the termination of information search once it is acquired (Saad and Russo, 1996).

c) Decision-making rule: Every foreman, in all 88 disruption cases, made a decision whether to assign or reassign the crew for their disruption "work-around" every time. At least 12 foremen made their decision based on only one decision attribute in 23 disruptions.

Figure 5 shows the bar chart for the number of determinant decision attributes verses actual number of decision attributes searched by foremen across 88 cases. Figure 6 shows the line graph of the number of determinant decision attributes verses actual number of decision attributes searched by the foremen across 88 cases. The graph also shows that two decision attributes were the most used by the foremen in both determinant decision attributes heuristic and actual search of decision attributes.

V. CONCLUSIONS AND RECOMMENDATIONS

The intent of this study was to trace the process of decision making in order to develop a model for heuristic decision-making in construction. The process of construction foremen making decisions on the jobsites was investigated.

The main finding of the study is that the proposed model of "determinant decision attributes heuristic" is followed by the foremen and is used to develop a "work-around" to resume the disrupted workflow. There are approximately three to five decision attributes, which are considered by foremen in their decision-making processes. These can be interpreted as empirical evidence that bounded rationality leads to a reliance upon a finite and limited set of variables in the operational context which is under study.

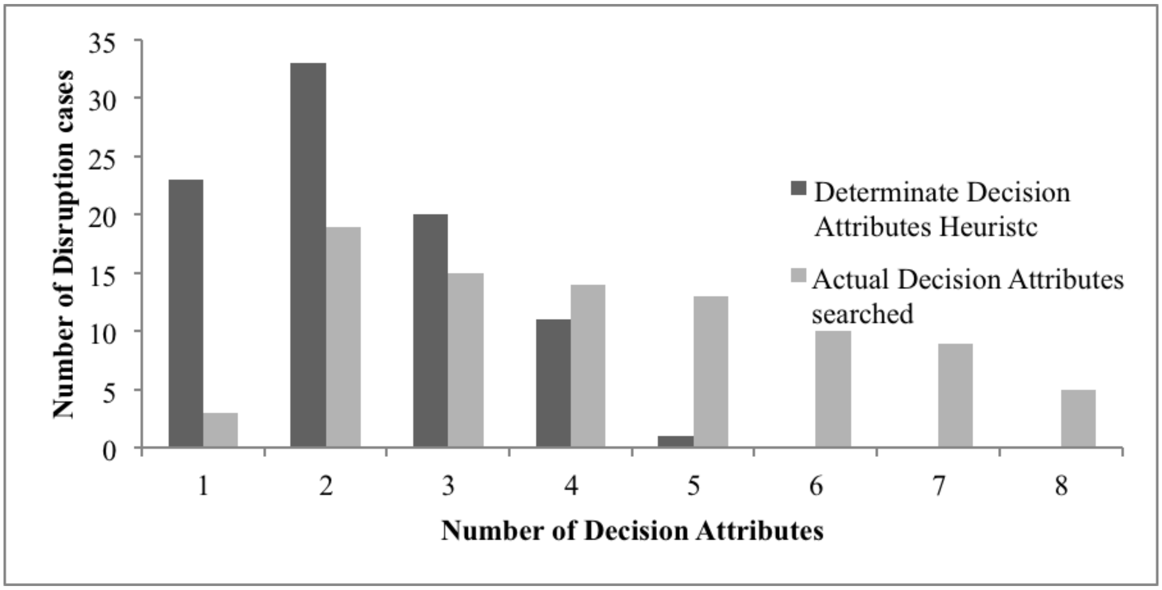


FIGURE 5. NUMBER OF DETERMINANT DECISION ATTRIBUTES VERSES ACTUAL SEARCH OF DECISION ATTRIBUTES BY FOREMEN ACROSS 88 CASES

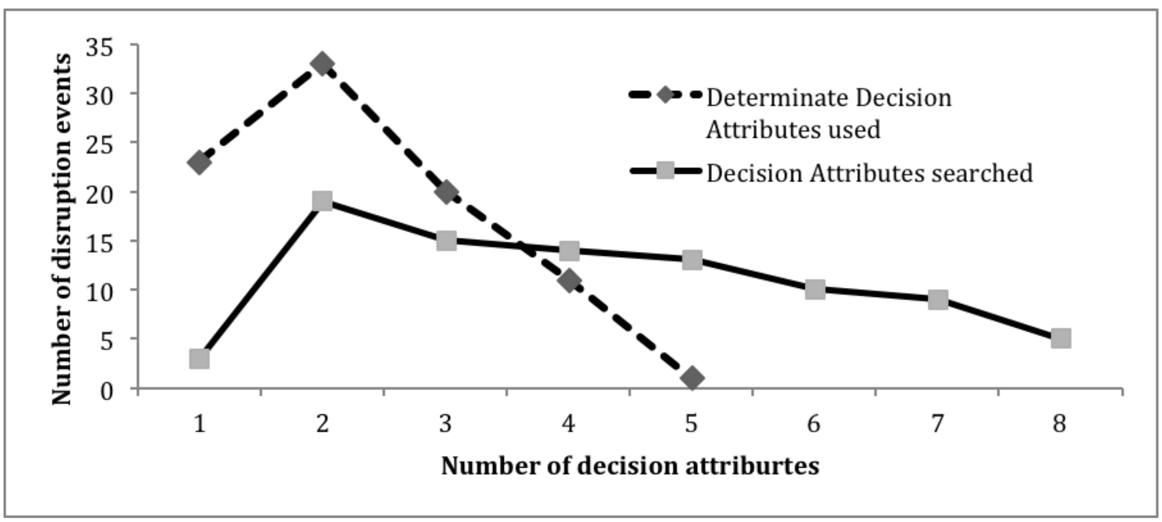


FIGURE 6. NUMBER OF DETERMINANT DECISION ATTRIBUTES USED AND ACTUAL SEARCH OF DECISION ATTRIBUTES BY FOREMEN ACROSS 88 CASES

In addition, the decision-making process that foremen follow matches well with the characteristics of determinant decision attribute heuristic (information search, stop, and decision-making). The process of decision-making follows that the foremen first develop a consideration set of alternatives to start the workflow. Then, when their workflow is disrupted, they quickly develop a goal or set of goals to reduce their consideration set of alternatives. This reduced set of alternatives is then matched with determinant decision attributes. They then stop searching once they have acquired the information in their determinant decision heuristic attributes. These determinant decision attributes lead to a choice of an action to assign or reassign the crew to "work-around" the disruption.

This study is based on only one trade in the construction industry (electrical). It is recommended to use this heuristic decision model in wider spectrums in construction industry among other trades. It is also recommended to investigate further the type of stop rule and decision rule that construction foremen use to stop acquiring the information. Because of the limitations of this study; the stop rule and decision rule used by the foremen were not investigated in enough depth.

The other areas into which the authors are extending this research include relationships between foreman personality traits (big-five and need for cognition) and heuristic decisions on construction sites, between foremen educational and experience levels and heuristic decisions on construction sites, and between project characteristics (time pressure, turbulence in various stages of the project and project organization, collaboration and coordination) and heuristic decisions on construction sites.

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