Developments in the Built Environment 14 (2023) 100129

Contents lists available at ScienceDirect

Developments in the Built Environment

journal homepage: www.sciencedirect.com/journal/developments-in-the-built-environment

Fast-and-frugal heuristics for decision-making in uncertain and complex settings in construction

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ARTICLE INFO

Keywords:
Bias
Decision-making
Ecological rationality
Heuristics
Risk
Uncertainty

ABSTRACT

Fast-and-frugal heuristics are simple, task-specific decision strategies that form part of a decision maker's repertoire of cognitive strategies for solving judgment and decision tasks. They have been shown to deliver better decision outcomes than statistical (including probabilistic and stochastic) approaches in uncertain and complex settings or where there is only a small sample from which to draw conclusions. Yet, they have received limited attention in the construction-related literature. This paper aims to raise awareness of the important role that fast-and-frugal heuristics play in decision-making as alternatives to statistical models in uncertain and complex settings or where there is only a small sample from which to conclude. Additionally, it is suggested that there is a need for research to identify and develop an adaptive toolbox of ecologically rational heuristics to enhance decision-making within varying project settings in construction. This paper's contributions are twofold: (1) challenges the prevailing reliance on statistical approaches being used when making judgments under uncertainty; and (2) identifies a new line of inquiry to harness the benefits of using fast-and-frugal heuristics for decision-making.

1. Introduction

Decision-making takes various forms in construction, ranging from those of a strategic nature (e.g., what projects to select and support) to remedial ones (e.g., how to take corrective action when projects are underperforming), and is necessary for all types of projects (e.g., relatively simple and complex). Thus, decision-making is critical for ensuring a project's success. Decisions often need to be made quickly to ensure activities are not delayed and the project's programme is met. Even though there is a need for quick decision-making in construction, there often prevails an assumption of perfect rationality (i.e., *homo economicus*, a rational economic person), which refers to the ability to generate or choose behavior that will bring maximum success, given the situation and available information (Katsikopoulos and Gigerenzer, 2013). Consequently, an inordinate number of mathematical models based on artificial intelligence, machine learning, and statistics can be found in the construction-related literature. These models seek to help improve the efficiency and effectiveness of various facets of decision-making for a wide range of construction activities (e.g., contractor selection and cost contingency determination) (Bakht and El-Diraby, 2015).

Yet, the dominant assumption that perfect rationality (i.e., rational choice theory) underpins decision-making has been challenged in fields such as business and management (Mousavi and Gigerenzer, 2014), finance (Neth et al., 2014), psychology (Gigerenzer and Gaissmaier, 2011), and economics (Gigerenzer, 2018). This questioning of perfect rationality and the subsequent ability to optimize decision outcomes, which has received limited attention in the construction literature, is supported by Simon's (1956) notions of 'bounded rationality' (human mind has knowledge, time, and computational power limitations) and 'ecological rationality' (human mind adapts to its environment). Moreover, the implications of decades of research on decision-making under various conditions (including imperfect knowledge) suggest that humans prefer to make quick, 'good enough' decisions, known as 'satisficing' behavior (Gigerenzer and Gaissmaier, 2011).

Ultimately, bounded rationality and ecological rationality offer accounts of decision-making behavior that challenge or reject the dominant view of perfect rationality and its underlying assumptions of *homo economicus* (Love et al., 2022). As a result, managerial decision-making can also adopt a vision of human nature described as *homo heuristicus* (i.

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https://doi.org/10.1016/j.dibe.2023.100129
Received 30 November 2022; Received in revised form 26 January 2023; Accepted 28 January 2023
Available online 18 February 2023

e., heuristics-using-person) (Neth et al., 2014; Love et al., 2022).

Within construction, heuristics are typically considered a liability inflicted by cognitive bias when making decisions about the risk and uncertainty of events (Ika et al., 2022). However, they are "more accurate than standard statistical models that have the same or more information" (Wübben and Wangenheim, 2008: p.453). In this paper, a heuristic is a "conscious or unconscious strategy that ignores part of the information to make better judgments. It enables us to make a decision fast, with little search for information, but nevertheless with high accuracy" (Gigerenzer, 2104: p.269). Put simply, heuristics are fast-and-frugal rules of thumb that draw on environmental cues when people make ecologically rational judgments. Such judgments focus on the fit between different decision strategies people take in varying environmental circumstances.

Despite the expectation that fast-and-frugal heuristics can yield biased decisions, scientific evidence, as mentioned above, indicates 'contained bias' can deliver a more accurate outcome than statistical approaches, notably in uncertain and complex settings or where there is only a small sample from which to draw conclusions (Gigerenzer and Todd, 1999; Gigerenzer, 2008). In this instance, by providing a less-is-more effect (i.e., less information can, under some conditions, lead to more accurate decisions), heuristics satisfy the cognition law of accuracy-effort trade-off, where less effort suggests less accuracy (Gigerenzer and Gaissmaier, 2011).

Practitioners instinctively use heuristics in their daily routines, for example, identifying rework risks during toolbox talks or while planning daily activities (Love and Matthews, 2022). But while there may be instances where heuristics appear to be more accurate, their precision "may often look like curiosities in the absence of an overarching theory," and as a result, they are not given the credence they deserve (Love and Matthews, 2022: p.453). The absence of such a theory to support the use of heuristics in formal decision-making scenarios in construction has meant that they are unreasonably treated as second-best alternatives to mathematical models, particularly in the case of statistical (including probabilistic and stochastic) approaches where frequency and probability judgments are relied upon (Love et al., 2021).

Considerable debate surrounds the comparative efficacy of the 'error-prone, second-best or biased heuristics' (Kahneman et al., 1982) and 'the success-prone, good-enough, or fast-and-frugal heuristics' (Gigerenzer and Todd, 1999) schools of thought, which customarily govern the judgment under uncertainty literature. While the former school proffers that heuristics are, in essence, irrational shortcuts and thus overwhelmingly lead to bias, the latter suggests they can be good and deliver accurate decision outcomes. Be that as it may, the intention of this paper is not to revisit this debate, as it has been addressed in detail by Kelman (2010). Instead, the paper shines a light on the important role that fast-and-frugal heuristics can play in the decision-making processes in construction as alternatives to prevailing logic and statistics-based approaches. Indeed, the construction of large-scale infrastructure projects, in many instances, is largely performed under conditions of uncertainty rather than known risks, which a fast-and-frugal heuristics approach can accommodate. Accordingly, by using fast-and-frugal heuristics, practitioners can learn to rely on them in an adaptive way to make accurate decisions.

2. Decision-making and heuristics

Decisions are made using logic, statistics, or heuristics (Gigerenzer, 2008; Gigerenzer and Gaissmaier, 2011). The rules of logic and statistics are associated with rational reasoning with "heuristics linked to error-prone intuitions or even irrationality" (Gigerenzer and Gaissmaier, 2011). Indeed, scholars such as Tversky and Kahneman (1974) and Kahneman and Tversky (1979), to name a few, have argued that "deviations from logical or statistical principles are interpreted as judgmental [cognitive] biases" (Gigerenzer and Gaissmaier, 2011: p.452). Accordingly, misconceptions about heuristics have evolved, identified in

Table 1
Six common erroneous beliefs about heuristics.

	Common Misconceptions	Clarifications
1	Heuristics produce second-best results; optimization is always better	In many situations, optimization is impossible (e.g., computationally intractable) or less accurate due to estimation errors (i.e., less robust; see investment example).
2	Our minds rely on heuristics only due to our cognitive limitations.	Characteristics of the environment (e.g., computational intractability) and the mind make us rely on heuristics.
3	People rely on heuristics only in routine decisions of little importance	People rely on heuristics for decisions of both low and high importance.
4	People with higher cognitive capacities employ complex weighting and integration of information; those with lesser capacities use simple heuristics (related to Misconception 1).	Unsupported by experimental evidence. Cognitive capacities seem to be linked to the adaptive selection of heuristics and less to executing a heuristic.
5	Affect, availability, causality, and representativeness are models of heuristics	These terms are mere labels, not formal models of heuristics. A model makes precise predictions and can be tested, such as in computer simulations.
6	More information and computation are always better.	Good decisions in a partly uncertain world require ignoring some available information (e.g., to foster robustness).

Adapted from: Gigerenzer (2008: p.21).

Table 1 with a corresponding rebuttal to clarify and put to bed these mistaken beliefs that frequent mindsets of supporters of Kahneman and Tversky's (1979) 'heuristic and bias' school of thought.

Cognizant of the likelihood of judgmental bias influencing a decision, considerable effort has gone into reducing its presence using statistical approaches, particularly in the context of mitigating the risk and uncertainty associated with estimating and managing the cost and schedule of projects (Love et al., 2021). For example, there is a general belief that cognitive and political biases are the root cause of cost and time overruns in projects and that the statistical technique of Reference Class Forecasting (RCF), which looks at the time and cost outcomes of a reference class of past projects similar to the one under consideration, can be applied to alleviate if not eliminate them (Flyvbjerg et al., 2018).

Questions surround the effectiveness of RCF as the hypothesis that biases negatively influence a project's cost and time performance has yet to be empirically demonstrated and, at best, is based on conjecture (Love et al., 2021, 2022). Moreover, RCF cannot accommodate irreducible uncertainty as it only caters to risks or 'known unknowns' where probabilities of overruns can be assessed (Love et al., 2022). Further, it treats classes of projects and their ranges of cost overrun as historically immutable; that is, not subject to change or individual analysis to break down the causes of these overrun events.

As heuristics have been inexorably linked with bias, there is a generally held belief that their use automatically results in decision-making errors; that is, the assumption that people are predictably irrational and bad at decision-making (Ika et al., 2022). While this assumption is based on a flawed and limited perspective, fast-and-frugal heuristics have received no attention in the construction literature, albeit a hypothetical example demonstrating their use to accommodate the risk and uncertainty of rework (Love and Matthews, 2022). Yet, Katsikopoulos and Gigerenzer (2013), among many others, consider heuristics as an asset rather than a liability, as they are adaptive to real-world decision problems, especially under uncertainty. In what follows, we explore the role of fast-and-frugal heuristics in decision-making in construction.

2.1. *The usefulness of fast-and-frugal heuristics*

Statistical and mathematical models can be fine-tuned and optimized to accommodate risk, but *not* under uncertainty where alternatives, outcomes, and probabilities are unknown (Nisbett et al., 1983). Applying such models to irreducible uncertainty is questionable for several reasons (Love et al., 2022). Still, it is precisely under these conditions that fast-and-frugal heuristics should become the go-to strategy for the decision-maker. As construction projects are dynamic and subject to uncertainty, fast-and-frugal heuristics can form part of a decision-maker's adaptive toolkit, a point that will be expanded on below. In the meantime, an adaptive toolbox is "a framework for non-optimizing visions of bounded rationality, emphasizing psychological plausibility, domain specificity, and ecological rationality. Heuristics in the adaptive toolbox are modeled on the actual cognitive abilities a species has rather than on the imaginary powers of omniscient demons" (Gigerenzer, 2001: p. 37). The potential usefulness of an adaptive toolbox of ecologically rational heuristics has yet to be exploited by practitioners in construction.

Notably, heuristics are ecologically rational as they can be adapted to "the structure of the environment" (Gigerenzer and Todd, 1999: p.13). In this instance, the environmental structures where heuristics have been found to succeed are: "(1) *uncertainty*: how well a criterion can be predicted; (2) *redundancy*: the correlation between cues; (2) *sample size*: number of observations (relative to the number of cues); and (4) *variability in weights*: the distribution of the cue weights (e.g., skewed or uniform)" (Gigerenzer and Gaissmaier, 2011: p.457).

Besides the 'availability', 'representativeness', and 'anchoring and adjustment' heuristics, which most readers will undoubtedly be familiar with, as a result of Tversky and Kahneman's (1974) work, a suite of others has been identified. Well-known and established heuristics include the 'recognition', take-the-first', 'take-the-best', 'fluency', 'tally (unit weight linear model)', 'satisficing', 'fast-and-fugal tree', '1/N; equality', 'default', 'tit-for-tat', imitate the successful', and 'imitate the majority'. Table 2 identifies hypothetical scenarios where a sample of well-known heuristics, whose predictive ability has been empirically validated in other domains and contexts, could be applied in construction and form part of the decision maker's adaptive toolbox. As noted by Gigerenzer (2008), "each of these heuristics can be used with and without awareness. In the latter case, each provides a potential mechanism of intuition" (p.23). Intuition is akin to a gut feeling or hunch. It refers to the capability to act or decide appropriately without deliberately and consciously balancing alternatives, without following a specific rule or routine, and possibly without awareness (Gigerenzer, 2007). A detailed overview of the heuristics mentioned above can be found in Gigerenzer (2008), Gigerenzer and Gaissmaier (2011), Katsikopoulos (2011) and Neth et al. (2014),

To date, a cursory review of the relevant literature suggests that, besides the 'satisficing' heuristic, none of the above heuristics has been applied in construction settings (Eriksson and Kadefors, 2017; Love and Matthews, 2022). In the case of the 'take-the-best' heuristic, for example, it estimates alternatives by ranking them through *cue validity* (i.e., the conditional probability that an object falls in a particular category given a particular feature or *cue*). Then the highest-ranking one is chosen. The 'take-the-best' heuristic, relative to those that rely on logic and statistical reasoning, for example, tends to perform well in uncertain environments and where high levels of redundancy prevail (Hogarth and Karelaia, 2007; Gigerenzer and Gaissmaier, 2011).

To cite just one example, consider how the uncertainty brought about by Covid-19 and the war in Ukraine in the current economic climate has adversely impacted global supply chains and the cost and availability of building materials. The supply of steel for structural frames is a case in point. Construction organizations around the world cannot predict future steel purchases. Here, redundancy is reflected in the high correlation between the purchasing intervals. An alternative to steel is engineered timber. So, if it is cheaper and available, infer engineered timber; but if not, then look for the next cue, which may be Fibreglass Reinforced Polymer (FRP).

However, it must be acknowledged that FRP is generally more expensive than steel and timber, with its benefits materializing over its life. In this example, decisions need to be made quickly and with limited information so as not to delay a build; statistical models for decision-making would be of little use in this case. To that end, ecological rationality results in comparative statements where "strategy X is more accurate (frugal, fast) than Y in environment E" (Gigerenzer, 2008: p.457).

In sum, heuristics are best used in situations where people need to

Table 2
Hypothetical examples of fast-and-frugal heuristics in an adaptive toolbox.

Heuristic	Definition	Appropriate environment	Bold predictions	Hypothetical Scenario
Recognition	If one of two alternatives - A and B is recognized, then the higher value is inferred from the criterion	Recognition validity >0.5	Contradicting information about a recognized object, less-is-more effect, if a >b, forgetting is beneficial	*Contingency*: Identify a project of a similar type experiencing a cost overrun. Add a contingency percentage based on the selected project's estimator's experience and understanding of the selected project
Satisficing	Searches through options in any order stop. As soon as the first option exceeds an aspiration level, then it is selected	Decreasing populations	Unknown	*Project schedule*: Identify a project of a similar size and complexity and use its schedule to determine the selected project.
Fluency	If both alternatives are recognized, but one is identified faster, then the one with an inferred higher value on the criterion is selected	Fluency validity >0.5	Can predict differences between two recognition latencies.	*Scope-change*: When considering likely scope changes to a project's engineering design, options a and b are put forward. Option a is selected the quickest
Take-the-best	Infer which of two alternatives has the higher values by; (a) assessing through cues in order of validity; (b) stopping the search as a cue discriminates; and (c) choosing the alternative this cue favors.	Cue validities vary highly; moderate to high redundancy, scarce information	Can predict as accurately as or more than multiple regression, neural networks, classification, and regression trees	*Procurement*: Two pre-cast systems are considered for a bridge's construction. The attribute of lead-in time is considered (i.e., cue). The option with the earliest delivery is selected.
Take-the-first	Choice from self-generated options by: (a) searching through options in order of validity; (b) stopping the search after two or three options; and (c) choosing the first option generated	Option validity varies highly; option validity is learned through feedback	Can predict limited search better than memory models	*Environment*: An estimator draws on their experience from previous projects to generate options for managing the cost associated with contaminated soil (e.g., biological treatment, chemical oxidation, or soil stabilization)
Fast-and-frugal tree (FFT)	Classify an object into two categories by: (a) searching cues according to their order; (b) stopping the search as soon as a cue allows you to do so. The object specified is selected.	Refer to take-the-best heuristic	Can predict accurately as or better than logistic regression	*Rework*: Determining how an error can result in rework and a safety incident occurring (Love and Matthews, 2022)

Adapted from Gigerenzer (2008), Gigerenzer and Gaissmaier (2011) and Raab and Gigerenzer (2015).

make quick decisions when probabilities or utilities are unknown and when ill-defined problems "prevent logic or probability theory from determining an optimal solution" (Gigerenzer, 2008: p.20). In this instance, people's minds resemble an adaptive toolbox whereby they draw upon various heuristics tailored for specific classes of problems – "much like the hammers and screwdrivers in a handyman's toolbox" Gigerenzer (2008): p.20]. With experience, people learn to select those heuristics from their adaptive toolbox to be used consciously or unconsciously for inferences and preferences. However, a weightier question in construction concerns the development of a knowledge base regarding when and under what conditions heuristics can and cannot be used, when a given heuristic succeeds or fails, and why. As noted below, current research still lags in promoting the broader use of heuristics in construction.

3. Implications for future research

While heuristics are domain-specific cognitive strategies that can be learned, they can also emerge from practice (Gigerenzer, 2014). As previously noted, an array of heuristics has been identified as part of an individual's adaptive toolbox, each fitting a specific environment. Thus, there is a need for research to focus on determining *what* and *how* heuristics are being used in practice under varying conditions (e.g., differing project types and procurement methods). Identifying and developing heuristics for every possible scenario that individuals and management may confront during the design and construction of projects is impossible (Katsikopoulos, 2011). Nevertheless, research establishing a Pareto Network for most likely construction challenges and decision nexus is inherently possible. Moreover, Gigerenzer (2014) argues heuristics are generalizable as they are simple and rely on limited information. But as construction projects are dynamic, ephemeral, and subject to uncertainty, questions surround the generalizability and relevance of existing heuristics to the varying scenarios that may confront practitioners as they go about their daily work routines (Love et al., 2022). Thus, there may be cases where new heuristics need to be constructed, enabling the adaptive toolbox to evolve over time. As such, the following building blocks will need to be used to construct them (Gigerenzer and Todd, 1999).

- *Search rules*: Specifies the direction the search extends in the search space.
- *Stopping rules*: Specifies when the search is stopped.
- *Decision rules*: Specifies how the final decision is reached.

For example, a fast-and-frugal heuristic approach to predicting cost contingency might rely on the recognition heuristic (RH) (Table 2). While several similar projects may have been constructed, decision-makers (or team members) may be familiar with only one of them, perhaps through the media, and can use its cost performance to determine the contingency. Here the RH comprises a search rule (i.e., retrieve recognition information from memory), a stopping rule (i.e., stop the search immediately), and a decision rule (i.e., go with the recognized object). To this end, the "RH is a simple heuristic, and people rely on it for various choice tasks ("go with what you know") (Raab and Gigerenzer, 2015: p.3). In situations where people cannot rely on recognition, they may switch to using other heuristics such as "take-the-best" (Table 2).

Only one heuristic can be applied to each situation, so how an individual selects it from those available in an adaptive toolbox is another issue that remains unclear (Gigerenzer and Todd, 1999). Further, two equally trained and professional construction managers may select alternative heuristics depending on personal preferences. Over time, however, as a person's knowledge base grows and their awareness of the comprehensiveness of the adaptive toolbox expands, developing heuristics from repeated scenarios (e.g., rework events) should help decision-makers select the most appropriate strategy (Love and Matthews, 2022). Again, research is needed to examine the nature of scenarios and how fast-and-frugal heuristics can be effectively used in the decision-making process that confronts practitioners. As Gigerenzer and Gaissmaier (2011) point out, "a heuristic is not good or bad, rational or irrational; its accuracy depends on the structure of the environment (ecological rationality)" (p.475).

4. Conclusion

Fast-and-frugal heuristics have a proven track record of providing accurate decision-making results in several fields (e.g., business and management) under conditions of uncertainty. Yet, in the construction literature, the important role that fast-and-frugal heuristics can play in the decision-making process of uncertain and complex construction projects has been ignored.

Thus, the goal of this paper has been to raise awareness around the effectiveness of heuristics so researchers can begin to examine and demonstrate their benefits to practitioners. However, if the benefits of fast-and-frugal heuristics are to be realized in construction, there is a need for future research to focus on three salient issues: (1) developing an adaptive toolbox (i.e., understanding what heuristics are being used and needed, their building blocks and the evolved capacities they exploit), (2) ensuring the heuristic is ecologically rational (i.e., it works in its environment) and (3) fostering their intuitive design (i.e., how can heuristics and environments be designed to improve decision-making?). The authors hope this paper will act as a catalyst for motivating future research to examine the role of fast-and-frugal heuristics in the decision-making processes of construction.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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