

Working Paper Proceedings

15th Engineering Project Organization Conference
with
5th International Megaprojects Workshop
Stanford Sierra Camp, California
June 5-7, 2017

Removing Certainty from the Equation: Using Choice Architecture to Increase Awareness of Risk in Engineering Design Decision Making

Tripp Shealy, Virginia Tech, USA

Dalya Ismael, Virginia Tech, USA

Andreas Hartmann, University of Twente, the Netherlands

Marc van Buiten, University of Twente, the Netherlands

Proceedings Editors

Ashwin Mahalingam, IIT Madras, Tripp Shealy, Virginia Tech, and Nuno Gil, University of Manchester



© Copyright belongs to the authors. All rights reserved. Please contact authors for citation details.

REMOVING CERTAINTY FROM THE EQUATION: USING CHOICE ARCHITECTURE TO INCREASE AWARENESS OF RISK IN ENGINEERING DESIGN DECISION MAKING

Tripp Shealy¹, Dalya Ismael², Andreas Hartmann³, and Marc van Buiten⁴

ABSTRACT

The mediated model of determinants for risky decision making theorizes that decision making is influenced by a decision makers risk propensity and risk perception. Risk propensity is an individual's tendency to take or avoid risks. Where as risk perception is the decision makers' assessment of how risky a situation is in terms of probabilistic estimates. Risk perception is also influenced by risk representation, which is the way risk is presented to the decision-maker. Modifications were made to the choice architecture of a trade-off matrix to test whether representing risks as embedded characteristics of design options influences engineering choice. Senior civil engineering students (n=98) were asked to consider trade-off matrices for two design options using criteria provided in a decision scenario. Half of the participants randomly received the control version of the trade-off matrix where risk was shown as an additional sixth criteria. The other half of participants received the modified tradeoff matrix where risk shown as a confidence interval. Illustrating risk as a separate criteria appears to significantly ($p=0.04$) influence users decision making leading participants to discount risk. Nearly 70% chose the more risky option. Yet, when risk was shown as a confidence interval participants were evenly split between the high and low risky option. The risk representation seems to mediate or counter balance those with a high propensity for risk. When controlling for risk propensity the results are even more significant ($p=0.02$). Meaning, those with high risk propensity more frequently choose the risky choice given the control version (as expected) but that did not hold true for the modified version, when shown as a confidence interval. Understanding how decisions are influenced by risk representation can lead to designing choice architecture that helps engineers and contractors make decisions that are in their own, or their clients' best interests.

KEYWORDS

Risk perception, engineering design, decision making, choice architecture

¹ Assistant Professor, Department of Civil and Environmental Engineering, College of Engineering, Virginia Tech, USA, tshealy@vt.edu

² Graduate Research Assistant, Department of Civil and Environmental Engineering, College of Engineering, Virginia Tech, USA, dalya88@vt.edu

³ Associate Professor, Department of Construction Engineering & Management, University of Twente, P.O. Box 217, 7500 AE Enschede, a.hartmann@utwente.nl

⁴ Researcher and lecturer, Department of Construction Engineering & Management, University of Twente, P.O. Box 217, 7500 AE Enschede, m.vanbuiten@utwente.nl

INTRODUCTION

Identifying risk and uncertainties early during the upfront planning of a construction project is beneficial to prevent unexpected cost overruns and time delays. Although with hundreds, if not thousands, of design decisions to be made during upfront planning this also creates a challenge because of the effort and time to consider all design choices. To help, trade-off matrices are frequently used to evaluate traits of engineering design options. For instance, evaluating material options based on cost, flexibility, and assembly time. Similar to financial portfolios, high returns are the goal but at the same time so is reducing risk. The subjective weight given to each choice is not a simple nonlinear probability but reflects the relative rank of the outcome in the distribution of possible outcomes (Fischhoff & Kadvany, 2011; Fox & Langer, 2005). In other words, risk is relative. Variance in judgment about risk is often due to the options presented and this is evident in the brain. Presenting options in various forms cause mechanisms in the brain to activate at different times (Gonzalez, Dana, Koshino, & Just, 2005). Therefore, the tools and process used to evaluate design options are critical to ensure options are chosen that provide high returns while appropriately managing and accurately valuing risk options in construction (Buiten et al., 2016; Shealy et al., 2016).

Indeed, poor judgment in risk evaluation and decision making can lead to significant economic outcomes, especially in an industry like construction, accredited with over \$1 billion in infrastructure put in place each year in the United States (US Census Bureau, 2017). Decision makers are prone to heavily rely on past experience and heuristics to simplify alternatives and make decisions (Tversky & Kahneman, 1974) and this can cause errors in judgment (Keller, Siegrist, & Gutscher, 2006). Engineering designers and contractors who are not aware of the uncertainties involved in their design and delivery choices may likely experience errors in judgment and cognitive biases. For instances, van Buiten & Hartmann (2013) point out that cognitive bias within public-private partnerships can lead to prematurely narrowing project scope. Another bias that may influence judgment of risk is the pseudo-certainty effect, which is a decision makers' tendency to perceive an outcome as certain while in fact it is uncertain. This can lead to decisions that underweight risk and uncertainty. The order in which, design traits are considered when using a trade-off matrix, for instance, considering potential risk separate from the potential benefits (i.e. quality, sustainability, cost) may lead to further undervaluing potential risk (Buiten et al., 2016).

Models and software can help correct these human prone errors in cognition by more accurately measuring the probability and impact of risk occurrence, but models and software can not provide insight on stakeholders' perceptions and the risk management strategies necessary for each scenario. Meaning, risky decision making at some point must be mediated by the decision makers' perceptions of risk. The mediated model of determinants for risky decision making theorizes that the effects of risk taking are influenced by a decision makers' *risk propensity* and *risk perception* (Sitkin & Pablo, 1992; Sitkin & Weingart, 1995). Both *propensity* and *perception* directly effects decision making. The direct causal effect between the variables is observed in numerous empirical and field studies (Jüttner et al., 2003; Simon et al., 2000; Weber et al., 2002; Wiseman & Gomez-Mejia, 1998).

Risk *propensity* is defined as an individual's current tendency to take or avoid risks (Sitkin & Weingart, 1995). Risk *propensity* is conceptualized as an individual trait that can change over time and thus is an emergent property of the decision maker. Where as, risk

perception is defined as the decision makers assessment of how risky a situation is in terms of probabilistic estimates of the degree of situational uncertainty, how controllable that uncertainty is, and confidence in those estimates (Baird & Thomas, 1985). Risk *perception* is influenced by risk *representation*, which is the way risk is presented to the decision-maker. The concept of risk *representation* is the focus on this research, which departs from previous research about risk in construction (Buiten et al., 2016). *Representation* is the way risk involved in a decision is presented to the decision-maker. In essence, how the risk is framed influences the choice (Shealy et al., 2016). Figure 1 depicts a modified version of Sitkin & Weingart (1995) model of determinates of risky behaviour, in which decision making is influence by risk *representation*, *perception* and *propensity*.

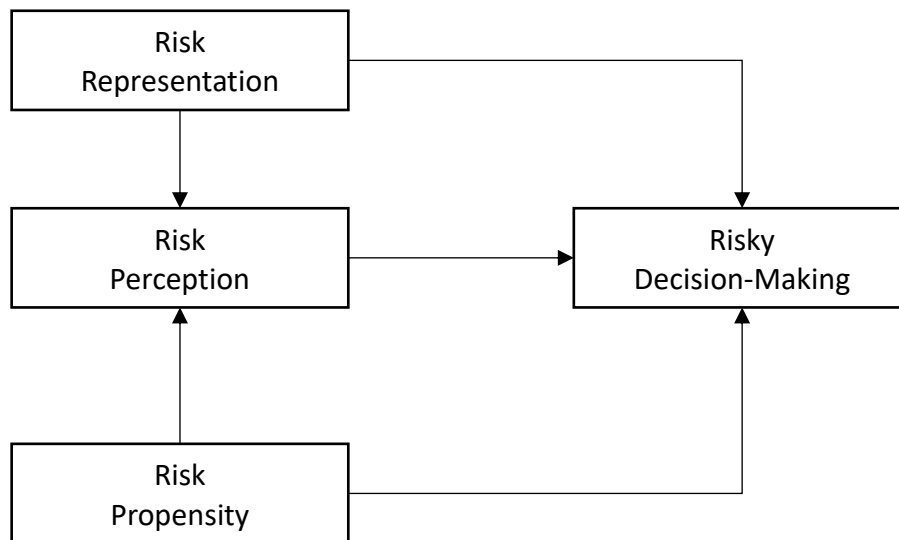


Figure 1: Modified determinants of risky decision-making behavior based on based on Sitkin & Weingart, 1995)

OBJECTIVE

The objective of this research is to measure how engineers make tradeoffs relative to the risk *representation* and their individual risk *propensity*. The research empirically measures the effects of changes in choice structures at the same time controls for individual difference in willingness to accept risk (i.e. propensity). How information is presented relative to the associate risk of each option may inadvertently influence engineers’ consideration for design options.

In this study, project constraints are controlled. Realistic scenarios are used in which decision makers were asked to make engineering design decisions, but without experiencing the actual consequences of the outcomes. Like true randomized control trials, these hypothetical decision scenarios approximate the actual decision setting and sample from the relevant population. However, because of the hypothetical outcomes, there are additional advantages: numerous and novel conditions can be examined, results are obtained quickly, and detailed process data is more easily collected.

The following section outlines the theoretical framework from behavioral decision science. The purpose is understanding how decisions are influenced by features of risk representation that should, from a normative perspective, have no effect, we can learn how to better design choice environments that help engineers and contractors make decisions that are in

their own, or their clients' best interests. In the case of retirement savings, for example, asking people to commit in advance to allocating future salary increases toward retirement has been shown to increase rates of saving (Goldstein, Johnson, & Sharpe, 2008). Similarly, to increase the use of green electricity, making renewable sources the default option has been extremely successful in field studies conducted by German utility companies (Schleich, 2009). The purpose here is to move "upstream" from consumer level decisions to decisions that effect the design and construction of our built environment, which in turn affects consumers. Much of the literature in the next section pulls from consumer and individual choice. The methods section then illustrates how these techniques scale to engineering decision making and the results provide findings that suggest a similar effect as those observed in consumers. The conclusion highlights the need for more research that bridges behavioral decision science and construction engineering management.

BACKGROUND

When decision makers are faced with alternatives that involve risk and the probabilities of outcomes are unknown, prospect theory can predict decision outcomes. Decision makers often downplay outcomes that contain risk and overly weigh outcomes that include certainty (Kahneman, Knetsch, & Thaler, 1991; Kahneman & Tversky, 1979). This is because potential losses provoke greater degrees of discomfort than potential gains provide satisfaction (Kahneman & Tversky, 1984; Schwartz, 2000). To overcome a potential loss, the gain must be roughly twice as great (Benartzi & Thaler, 1993). Decision makers, however, are not always risk averse. If a decision maker recently experienced a loss, the amount of risk they are willing to accept increases, in hopes to return to net zero or positive outcome (Tversky & Kahneman, 1981). Another variable is the decision makers risk propensity, or their individual preferences for willingness to accept risk (Hamid et al., 2014; Keil et al., 2000). Each individual's risk propensity varies based on behavior, experience, and often context (Hamid et al., 2014).

In general, Prospect theory can help explain why homeowners selling in a down market may insist on a higher asking price (Genesove & Mayer, 2001), why investors sell profitable stocks too soon and retain losing stocks too long (Odean, 1998), and why consumers generally hold failing assets longer than winning assets (Carmon & Ariely, 2000; Cummings et al., 1986; Knetsch, 1989). Prospect theory is applied to make accurate predictions about risk seeking or averse behavior in politics (Patty, 2006), international relations (Berejikian, 2002) and public support for military intervention (Nincic, 1997). Framing military involvement as a protective mediation to avoid geopolitical loss (i.e. framing to avoid loss) is viewed more favorable by the general public than a proactive intervention explained as benefiting foreign policy (i.e. framing to gain) (Nincic, 1997).

Framing choices as losses or gains in value is often more influential in decision making than the resulting end point (Kahneman & Tversky, 1979) because even when two presentation formats are formally equivalent each may give rise to different psychological processes (Thaler, Sunstein, & Balz, 2010). Decision makers do not immediately know the right choice, but rather perform an informal reasoning process referred to as preference construction. For example, medical patients given a choice between surgery or radiation preferred surgery when described as having a 90% survival rate. However when the surgery was described as having a 10% mortality rate the preference for surgery was much lower (McNeil, Pauker, Sox Jr, & Tversky, 1982).

The same type of preference construction is likely true for engineers when considering design options. Framing effects that over or under emphasize the risk associated with each choice may lead to sub-optimal decision outcomes. Choice architecture is a method to account for cognitive processing and improve judgment and decision making under uncertainty (Johnson et al., 2012; Weber & Johnson, 2009). The principle of choice architecture is that decisions can be structured to focus decision-makers on the information that matters most. For example, when presented with miles per gallon (mpg) metric, consumers wrongly assume that increases in mpg have a linear effect in fuel use and CO₂ emissions, suggesting that an increase from 10 to 20 mpg has the same benefit as going from 40 to 50 mpg. However, this is not true. The shift from 10 to 20 mpg reduces fuel use by 50%, whereas from 40 to 50 mpg, fuel use is reduced by only 20%. Restructuring the information as a linear metric, such as gallons per mile, improves decision makers ability to pick the most efficient option (Larrick & Soll, 2008). Similar choice architecture, that more closely aligns decision structures with psychological processes, is improving fields from medicine (Johnson & Goldstein, 2003) to finance (Fox & Langer, 2005), to insurance (Johnson, 1993).

Notice the purpose of the mpg is not to trick the decision maker rather remove the bias causing the error in judgment. Sometimes a further distinction is made between de-biasing and re-biasing, depending on whether efforts to align descriptive behavior with normative standards focus on eliminating underlying cognitive biases altogether or merely counteract them (e.g., Larrick, 2004; Soman & Liu, 2011).

The purpose of intentional choice architecture is to steer behavior, while retaining freedom of choice (Sunstein & Thaler, 2003). Choice architecture are small cues that are subtle and yet can assist in decision making. Sometimes referred to as libertarian paternalism: libertarian referring to the decision maker's freedom to choose and paternalism referring to the fact that the better choice has been made easier to identify. An example is when cafeterias organize healthy foods at eye level and move fattening and sugary food in a location harder to view. While the consumer still has the freedom of choice, the healthy food is most prominent and is more likely to be chosen (Sunstein et al., 2008). Another example is the default "opt-out" systems rather than "opt-in" systems to increase organ donation rates (Johnson & Goldstein, 2003).

Recent reviews (Johnson et al., 2012) highlight these and other choice architecture approaches. Such demonstrated improvements to decision making at the consumer-level holds promise that similar behavioral modifications might be of service to "upstream" decisions about design choices during project delivery (Shealy & Klotz, 2016). The expected outcome is that applying known choice architecture to design decisions about project delivery of infrastructure may better enable decision makers' awareness of risk thus influencing their choice and outcome.

HYPOTHESIS

This research builds on previous research in construction engineering management suggesting that judgment and decision making, cognitive biases, and social heuristics distort managerial decisions in complex infrastructure governance, planning, and delivery (Beamish & Biggart, 2012; Harris, Shealy, & Klotz, 2016a; Klotz, 2010; Shealy & Klotz, 2015; van Buiten & Hartmann, 2013). Understanding how engineers make decisions can help reduce these biases through more intentional choice architecture (Shealy & Klotz, 2014). The broad hypothesis is engineering decision making follows the determinates of risky decision making behavior by Sitkin & Weingart (1995). Risk propensity and risk representation mediate risk preferences,

which influence the decision outcome. More specifically, the first hypothesis is modifications to risk representation by illustrating the associated risk of each design criterion will significantly influence risk preferences and thus influence engineers' decision making. Meaning, altering the way engineers are shown risk, either as an additional criterion or as a confidence interval embedded within other criterion, will significantly influence the option they choose. Using Figure 1 as the illustrated path of influence, modifications to *risk representation*, plus individual *risk propensity*, creates *risk preferences* with less risk taking and the outcome measured in the *risky decision making* are participants more frequently choosing Option 2 than Option 1.

The control version of the decision scenarios provides design criteria (e.g. flexibility, sustainability) to consider for two construction options. Risk is presented as an additional design attribute in the control group and in the modified version risk as a confidence interval integrated into each of the other design criteria. The second hypothesis is risk presented as an additional design criteria, rather than integrated, will lead engineers to discount the value of risk. In other words, because the other design criteria have a higher positive value in Option 1 but higher overall risk, decision makers' will choose Option 1 with the highest benefit and discount the associated cumulative risk. So, more participants in the study will choose Option 1 (greatest possible outcome but higher risk) compared to Option 2 (less potential positive outcome but less risk) in the control version when risk is shown separate from the design criteria like, flexibility, delivery speed, affordability, etc. Again, using Figure 1 to illustrate the path of influence, the control version of *risk representation*, plus individual *risk propensity*, creates *risk preferences* with higher willing to accept risk, causing a more participants in the *risky decision making* to choose Option 1 over Option 2.

Although, risky decision making is not only influenced by risk representative but risk propensity. So, the third hypothesis is when controlling for risk propensity the modifications become more statistically significant. Meaning the modifications to risk representation has a statistically greater probability of influence on the decision makers' choice. The modification should more accurately depict the potential risk of each option therefore reduce discounting of risk in Option 1 and lead to more decision makers choosing Option 2. Controlling for risk propensity, those with high willingness to accept risk will select Option 1 more frequently in the control version but the opposite is true for the modified version. In essence, changing the frame of risk reduces the effect of risk propensity on the decision outcome. The path of influence for hypothesis three is similar to that described in hypothesis one. Except, now, the path of influence no longer includes risk propensity. So, the modified version of *risk representation*, *risk propensity* is controlled, creates *risk preferences* with lower willingness to accept risk causing even more participants in the *risky decision making* to choose Option 2 over Option 1.

Knowingly, these are lab experiments without real world threat to the decision maker. So, taking a risk has little negative effect after the scenario is over. Therefore, due to the experimental setup, more decision makers may likely choose the option with higher risk. Thus, this experiment is a more conservative test because it allows for high risk-propensity that may be harder to observe in reality when the performance stakes are real. Said another way, the risk is fabricated, which likely leads to more reason to consider the option with highest benefit (and higher risk), so even a small shift in decision outcome from the most risky to the least risky option in the modified version would likely be compounded in the real world where willingness to accept risk with real consequences are fewer. None the less, in hypotheses three, risk propensity is a control variable when measuring the effect on changes to risk representation. The

purpose of controlling for their willingness to accept risk to to more directly measure the effect of the modifications to risk representation.

METHODS

The core proposition is that modifications of choice architecture influence decision making. We examine if tweaking a trade-off matrix used to assess preliminary design options in a design competition can nudge decision makers away from riskier, more uncertain options, towards less risky and certain options. The purpose is to counter balance risk preferences by modifying the risk representation. To this end, an experiment was conducted that involved a hypothetical, but realistic scenario. The decision scenario allowed students to create a vivid image of an engineering design decision and at the same time was relevant in its implications to the construction industry.

Engineering students (n=98) in the civil engineering program at Virginia Tech participated in the in-class experiment. All students were seniors approximately two months away from making these types of engineering decisions in their career. They received no financial compensation for their participation. The participants were randomly assigned to receive either the the control version or the modified version of the trade off matrix.

Before distributing the decision scenario, participants were told there was no time limit, and no correct or incorrect answer. Participants were asked to imagine a hypothetical situation: a government agency wished to sponsor a new housing development construction project. Participants were told that they were part of a student team that already had two rough ideas. Option 1 was to transform existing structures and Option 2 was to build new housing complexes from scratch. Two pictures were included, one depicting an abandoned office building, the other showing a plot of land. One of these ideas had to be developed further. In order to determine which, the students adopted a structured approach in the form of a trade-off matrix. This matrix accounted for six criteria given to the students. These criteria included: flexibility, delivery speed, sustainability, affordability, spatial and social quality, and risks and uncertainties. Each of the design criteria was briefly described.

Option 1 scored high on most criteria, but entailed substantial uncertainty. Option 2, scored a bit lower on most criteria, and was slightly the safer bet. Participants were asked to consider the matrix, and to indicate their preference by choosing Option 1 or Option 2.

The modifications to choice architecture came in the display of design criteria matrix (i.e. flexibility, affordability, etc.). The score system is a point score system based on a legend provided ranging from (-2) Very Unfavorable to (2) Very favorable. An illustration of the scoring system is shown in Figure 2. Participants in the control version received a trade-off matrix with risk and uncertainties listed as an additional sixth design criteria, whereas the experimental group received a modified version with risk embedded within each design attribute. In sum, the experiment had a one-way between-subjects design with two conditions (control vs. modified). The single dependent variable was the option choice: Option 1 (remodel) vs. Option 2 (new construction).

Control (Risk shown separate)	Modified (Risk embedded)
--------------------------------------	---------------------------------

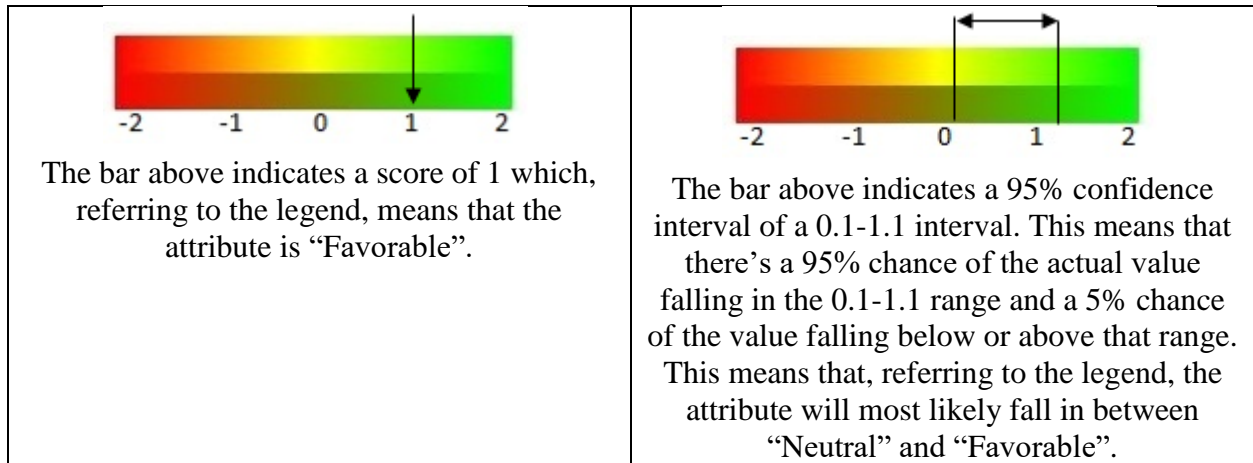


Figure 2: Scoring system of design attributes for Option 1 and Option 2.

In addition to asking which design option they would choose, a post task survey asked participants to rank their comfort with risk. The survey question specifically asked, “In general, people often have to take risks when making financial, career, or other life decisions. Overall, how would you place yourself on the following scale? Please circle a number.” The question was based on a 7-point scale (1) Extremely comfortable taking risks to (7) Extremely uncomfortable taking risks. Those who scored 1-3 were grouped as high willingness to accept risk. Those who scored 5-7 were grouped as low willingness to accept risk.

Statistical difference was measured using the Mann–Whitney *U* test. The Mann-Whitney *U* test is a nonparametric test of the null hypothesis that it is equally likely that a randomly selected value from one sample will be less than or greater than a randomly selected value from a second sample. Unlike the t-test, the Mann-Whitney *U* test does not require the assumption of normal distribution.

RESULTS

Results of the experiment are displayed in Table 1. In the control group, where risk was shown as an independent criterion, 30 out of 45 (66.66%) participants preferred Option 1 (higher risk and uncertainty) over Option 2 (less risk and more certainty). In the modified version with choice architecture that embeds risk as a confidence interval into each design criterion, the results were more evenly split: 26 out of 53 (49%) chose Option 1, whereas 27 (51%) chose Option 2.

Table 1: Number of participants who prefer Option 1 or Option 2 as a function of condition.

Options	Choice Version	
	Control (Risk shown separate)	Modified (Risk embedded)
Option 1: Renovate (Higher Risk)	30 (66.66%)	26 (49%)
Option 2: New Construction (Less Risk)	15 (33.33%)	27 (51%)
Total	45	53

The decision outcomes of the control version compared to the modified version of the decision scenario are statistically different ($p=0.04$). Meaning, the modified choice architecture appears to influence risk preferences which is represented in the decision outcome. Related to

hypothesis two, participants given the control version, where risk was shown separate rather than embedded within each criterion, were statistically more likely to choose design Option 1 with the higher risk. Therefore, the results indicate to reject null hypothesis two. Decision makers were more likely to choose the option with the highest benefit and discount the associated cumulative risk.

Related to hypothesis three, the expectation was risk propensity significantly impacts risky choice. Said another way, those who perceive themselves as comfortable with taking risks are more likely to select Option 1 no matter the choice modification or risk representation. Those in the low willingness to accept risk were expected to choose Option 2. Table 2 illustrates participants willing to accept risk and the version of decision scenario they received. The results were significant in the control version ($p=0.02$) but not in the modified version ($p=0.5$). Meaning, the choice architecture of risk representation appears to mediate the influence of risk propensity. Showing risk as a characteristic of each design criterion rather than as a separate criterion reduced the influence of individual decision maker’s risk propensity. Participants in the control group who perceive themselves as comfortable with taking risks were significantly more likely to select Option 1 but this effect was not shown in the version with the modified choice architecture.

Table 2: Number of participants who prefer Option 1 or Option 2 as a function of condition categorized by willingness to accept risk.

Design Options	Control (Risk shown separate)		Modified (Risk embedded)	
	High	Low	High	Low
Option 1: Renovate (Higher Risk)	19 (80%)	11 (51%)	15 (54%)	11 (44%)
Option 2: New Construction (Less Risk)	5 (20%)	10 (49%)	13 (46%)	14 (56%)
Total	24	21	28	25

To summarize, modifying the choice architecture by embedding the risk profile of each design criteria rather than presenting the cumulative risk as separate criteria influences the decision outcome. Comparing only those with a high willingness to accept risk given either the control or modified version, the influence of risk preferences in risky decision making is mediated by the modified risk representation. Those who view themselves as high willingness to accept risk are more likely to choose Option 1 (most risky) when risk is presented as separate criteria. But when risk is displayed as a characteristic of each criteria the influence of risk propensity dissipates. Those with high willingness to accept risk were not more likely to choose Option 1 in the trade off matrix with the modified choice architecture.

CONCLUSION

By presenting risk and uncertainty as seemingly independent criteria the relationship with other design criteria might be obscured or discounted during the decision evaluation. Representing the risk as a characteristic of each of the criteria rather than a separate criteria led to a shift in choice among participants. Those given the modified version were evenly distributed in choosing Option 1 and Option 2 whereas the majority of participants shown risk as an additional criteria chose Option 1. The risk representation seems to help overcome or counter act the risk

preferences of individual decision makers with high willingness to accept risk. The results seem to suggest that even strong overall risk propensity is mediated by the risk representation.

There are obvious limitations using a simulated decision scenario and students as the sample population but based on prior research with both students and professionals (Shealy & Klotz, 2015; Shealy et al., 2016) the expectation is that the results presented here would translate to professionals. A limitation, however, is that this research approach required isolating a single decision point, and therefore how these decisions will hold over time is not known. Certainly, the next step is to move from controlled empirical studies into the real world. Future research could include more complexity that was intentionally excluded in this study as possible confounding variables. Future work could also expand the design process over time and frequency. Obviously, designers do not make choices in isolation nor do they simply choose between two predefined design options. Moreover, path dependencies, status quo bias, and many other cognitive barriers influence the decision making process. Future research could more explicitly explore these additional real world complexities by adopting a different representation of risk in the trade-off matrix. For instances, feasibility examples are shown to influence decisions about sustainability (Harris et al., 2016b) so another choice architecture approach could also stress the potential impacts of risks by including cautionary examples of other projects. Defaults are also shown to influence both loss aversion (Shealy & Klotz, 2015) and anchoring (Klotz et al., 2010) in engineering decision making and likely to influence risk preferences.

While modifications based on behavioral decision science are applied almost exclusively at the individual consumer level, here how modifications to choice architecture impact “upstream” design and planning decisions were empirically tested. The results suggest choice modifications to the risk representation can shape upstream decisions. Compared to the costs of infrastructure itself, simply restructuring choices is an inexpensive approach to support more informed decisions. These types of modifications are also less intrusive and speedier than more formal changes or legislation, although they could be so incorporated as learning develops. Those seeking to bring more awareness to risk and uncertainty in design and construction can draw on research findings like this to design their own choice architecture. And through additional empirical studies and field experiments, the research community can begin to predict decision outcomes based on these and other cognitive biases and therefore improve decision making with the result of more informed and better managed infrastructure projects.

Surprisingly, behavioral decision science and more specifically choice architecture still remains underexplored in construction management. Perhaps, in part, because this requires interdisciplinary collaboration. Behavioral decision science offers rapidly advancing insight into how decision environments influence choices and behavior. Though, interventions can create compensating behaviors (e.g., spillover and rebound effects, single-action biases) and are not always transferrable to every culture or scenario. Ongoing evaluation and refining of interventions is a vital contribution in the future. As well as, construction engineering and management research can provide new context and decision scenarios for those in behavioral science. The take away is that those framing decisions about design and construction hold power and need to be better understood, and when appropriate, apply interventions to help guide users toward outcomes in their own best interest.

REFERENCES

- Baird, I. S., & Thomas, H. (1985). Toward a Contingency Model of Strategic Risk Taking. *The Academy of Management Review*, *10*(2), 230–243. <https://doi.org/10.2307/257965>
- Beamish, T. D., & Biggart, N. W. (2012). The role of social heuristics in project-centred production networks: insights from the commercial construction industry. *Engineering Project Organization Journal*, *2*(1–2), 57–70.
- Benartzi, S., & Thaler, R. H. (1993). *Myopic Loss Aversion and the Equity Premium Puzzle* (Working Paper No. 4369). National Bureau of Economic Research. Retrieved from <http://www.nber.org/papers/w4369>
- Berejikian, J. D. (2002). Model Building With Prospect Theory: A Cognitive Approach to International Relations. *Political Psychology*, *23*(4), 759–786. <https://doi.org/10.1111/0162-895X.00306>
- Buiten, M., Hartmann, A., & Meer, J. (2016). Nudging for Smart Construction: Tackling Uncertainty by Changing Design Engineers' Choice Architecture. Presented at the Engineering Project Organization Conference, Cle Elum, Washington, USA. Retrieved from http://www.epossociety.org/EPOC2016/papers/Buiten%20et%20al_EPOC_2016.pdf
- Carmon, Z., & Ariely, D. (2000). Focusing on the Forgone: How Value Can Appear So Different to Buyers and Sellers. *Journal of Consumer Research*, *27*(3), 360–370. <https://doi.org/10.1086/317590>
- Cummings, R. G., Brookshire, D. S., Bishop, R. C., & Arrow, K. J. (1986). *Valuing environmental goods: an assessment of the contingent valuation method*. Rowman & Littlefield Pub Incorporated.
- Fischhoff, B., & Kadvany, J. D. (2011). *Risk: a very short introduction*. Oxford; New York: Oxford University Press.
- Fox, C. R., & Langer, T. (2005). Biases in allocation under risk and uncertainty: Partition dependence, unit dependence, and procedure dependence. *Unit Dependence, and Procedure Dependence (May 10, 2005)*. Retrieved from http://papers.ssrn.com/sol3/papers.cfm?abstract_id=757787
- Genesove, D., & Mayer, C. (2001). Loss Aversion and Seller Behavior: Evidence from the Housing Market. *The Quarterly Journal of Economics*, *116*(4), 1233–1260.
- Goldstein, D. G., Johnson, E. J., & Sharpe, W. F. (2008). Choosing Outcomes versus Choosing Products: Consumer-Focused Retirement Investment Advice. *Journal of Consumer Research*, *35*(3), 440–456. <https://doi.org/10.1086/588568>
- Gonzalez, C., Dana, J., Koshino, H., & Just, M. (2005). The framing effect and risky decisions: Examining cognitive functions with fMRI. *Journal of Economic Psychology*, *26*(1), 1–20. <https://doi.org/10.1016/j.joep.2004.08.004>

- Hamid, F., Rangel, G., Taib, F., & Thurasamy, R. (2014). The relationship between risk propensity, risk perception and risk-taking behaviour in an emerging market. *International Journal of Banking and Finance*, *10*(1). Retrieved from <http://epublications.bond.edu.au/ijbf/vol10/iss1/7>
- Harris, N., Shealy, T., & Klotz, L. (2016a). Choice Architecture as a Way to Encourage a Whole Systems Design Perspective for More Sustainable Infrastructure. *Sustainability*, *9*(1), 54. <https://doi.org/10.3390/su9010054>
- Harris, N., Shealy, T., & Klotz, L. (2016b). How Exposure to "Role Model" Projects Can Lead to Decisions for More Sustainable Infrastructure. *Sustainability*, *8*(2), 130. <https://doi.org/10.3390/su8020130>
- Johnson, E. J. (1993). Framing, Probability Distortions, and Insurance Decisions. *Journal of Risk and Uncertainty*, *7*(1), 35–51.
- Johnson, E. J., & Goldstein, D. (2003). Do Defaults Save Lives? *Science*, *302*(5649), 1338–1339. <https://doi.org/10.1126/science.1091721>
- Johnson, E. J., Shu, S. B., Dellaert, B. G. C., Fox, C., Goldstein, D. G., Häubl, G., ... Weber, E. U. (2012). Beyond nudges: Tools of a choice architecture. *Marketing Letters*, *23*(2), 487–504. <https://doi.org/10.1007/s11002-012-9186-1>
- Jüttner, U., Peck, H., & Christopher, M. (2003). Supply chain risk management: outlining an agenda for future research. *International Journal of Logistics Research and Applications*, *6*(4), 197–210. <https://doi.org/10.1080/13675560310001627016>
- Kahneman, D., Knetsch, J. L., & Thaler, R. H. (1991). Anomalies: The endowment effect, loss aversion, and status quo bias. *The Journal of Economic Perspectives*, 193–206.
- Kahneman, D., & Tversky, A. (1979). Prospect Theory: An Analysis of Decision Under Risk. *Econometrica (Pre-1986)*, *47*(2), 263–291.
- Kahneman, D., & Tversky, A. (1984). Choices, values, and frames. *American Psychologist*, *39*(4), 341–350. <https://doi.org/10.1037/0003-066X.39.4.341>
- Keil, M., Wallace, L., Turk, D., Dixon-Randall, G., & Nulden, U. (2000). An investigation of risk perception and risk propensity on the decision to continue a software development project. *Journal of Systems and Software*, *53*(2), 145–157. [https://doi.org/10.1016/S0164-1212\(00\)00010-8](https://doi.org/10.1016/S0164-1212(00)00010-8)
- Keller, C., Siegrist, M., & Gutscher, H. (2006). The role of the affect and availability heuristics in risk communication. *Risk Analysis: An Official Publication of the Society for Risk Analysis*, *26*(3), 631–639. <https://doi.org/10.1111/j.1539-6924.2006.00773.x>
- Klotz, L. (2010). Cognitive biases in energy decisions during the planning, design, and construction of commercial buildings in the United States: an analytical framework and research needs. *Energy Efficiency*, *4*(2), 271–284. <https://doi.org/10.1007/s12053-010-9089-z>

- Klotz, L., Mack, D., Klapthor, B., Tunstall, C., & Harrison, J. (2010). Unintended anchors: Building rating systems and energy performance goals for U.S. buildings. *Energy Policy*, 38(7), 3557–3566. <https://doi.org/10.1016/j.enpol.2010.02.033>
- Knetsch, J. L. (1989). The endowment effect and evidence of nonreversible indifference curves. *The American Economic Review*, 79(5), 1277–1284.
- Larrick, R. P. (2004). Debiasing. In D. J. Koehler & N. Harvey (Eds.), *Blackwell Handbook of Judgment and Decision Making* (pp. 316–338). Blackwell Publishing Ltd. <https://doi.org/10.1002/9780470752937.ch16>
- Larrick, R. P., & Soll, J. B. (2008). The MPG illusion. *Science*, 320(5883). Retrieved from <http://www.waccobb.net/forums/showthread.php?38094-The-MPG-Illusion>
- McNeil, B. J., Pauker, S. G., Sox Jr, H. C., & Tversky, A. (1982). On the elicitation of preferences for alternative therapies. *New England Journal of Medicine*, 306(21), 1259–1262.
- Nincic, M. (1997). Loss aversion and the domestic context of military intervention. *Political Research Quarterly*, 50(1), 97–120.
- Odean, T. (1998). Are Investors Reluctant to Realize Their Losses? *The Journal of Finance*, 53(5), 1775–1798.
- Patty, J. W. (2006). Loss aversion, presidential responsibility, and midterm congressional elections. *Electoral Studies*, 25(2), 227–247. <https://doi.org/10.1016/j.electstud.2005.05.004>
- Schleich, J. (2009). Barriers to energy efficiency: a comparison across the German commercial and services sector. *Ecological Economics*, 68(7), 2150–2159.
- Schwartz, B. (2000). Self-determination: The tyranny of freedom. *American Psychologist*, 55(1), 79.
- Shealy, T., & Klotz, L. (2015). Well-Endowed Rating Systems: How Modified Defaults Can Lead to More Sustainable Performance. *Journal of Construction Engineering and Management*, 141(10), 4015031. [https://doi.org/10.1061/\(ASCE\)CO.1943-7862.0001009](https://doi.org/10.1061/(ASCE)CO.1943-7862.0001009)
- Shealy, T., & Klotz, L. (2016). Choice Architecture as a Strategy to Encourage Elegant Infrastructure Outcomes. *Journal of Infrastructure Systems*, 0(0), 4016023. [https://doi.org/10.1061/\(ASCE\)IS.1943-555X.0000311](https://doi.org/10.1061/(ASCE)IS.1943-555X.0000311)
- Shealy, T., & Klotz, L. E. (2014). Encouraging elegant solutions by applying choice architecture to infrastructure project delivery. In *Construction in a global network*.
- Shealy, T., Klotz, L., Weber, E. U., Johnson, E. J., & Bell, R. G. (2016). Using Framing Effects to Inform More Sustainable Infrastructure Design Decisions. *Journal of Construction Engineering and Management*, 0(0), 4016037. [https://doi.org/10.1061/\(ASCE\)CO.1943-7862.0001152](https://doi.org/10.1061/(ASCE)CO.1943-7862.0001152)

- Simon, M., Houghton, S. M., & Aquino, K. (2000). Cognitive biases, risk perception, and venture formation: How individuals decide to start companies. *Journal of Business Venturing*, *15*(2), 113–134. [https://doi.org/10.1016/S0883-9026\(98\)00003-2](https://doi.org/10.1016/S0883-9026(98)00003-2)
- Sitkin, S. B., & Pablo, A. L. (1992). Reconceptualizing the Determinants of Risk Behavior. *Academy of Management Review*, *17*(1), 9–38. <https://doi.org/10.5465/AMR.1992.4279564>
- Sitkin, S. B., & Weingart, L. R. (1995). Determinants of Risky Decision-Making Behavior: A Test of the Mediating Role of Risk Perceptions and Propensity. *Academy of Management Journal*, *38*(6), 1573–1592. <https://doi.org/10.2307/256844>
- Soman, D., & Liu, M. W. (2011). Debiasing or rebiasing? Moderating the illusion of delayed incentives. *Journal of Economic Psychology*, *32*(3), 307–316. <https://doi.org/10.1016/j.joep.2010.12.005>
- Sunstein, C. R., & Thaler, R. H. (2003). *Libertarian Paternalism Is Not An Oxymoron* (SSRN Scholarly Paper No. ID 405940). Rochester, NY: Social Science Research Network. Retrieved from <http://papers.ssrn.com/abstract=405940>
- Sunstein, C. R., & Thaler, R. H. (2008). *Nudge: Improving Decisions About Health, Wealth, and Happiness*. Penguin Books.
- Thaler, R. H., Sunstein, C. R., & Balz, J. P. (2010). *Choice Architecture* (SSRN Scholarly Paper No. ID 1583509). Rochester, NY: Social Science Research Network. Retrieved from <http://papers.ssrn.com/abstract=1583509>
- Tversky, A., & Kahneman, D. (1974). Judgment under Uncertainty: Heuristics and Biases. *Science*, *185*(4157), 1124–1131. <https://doi.org/10.1126/science.185.4157.1124>
- Tversky, A., & Kahneman, D. (1981). The framing of decisions and the psychology of choice. *Science*, *211*(4481), 453–458.
- US Census Bureau. (2017, February). US Census Bureau Construction Spending Survey. Retrieved April 20, 2017, from <https://www.census.gov/construction/c30/c30index.html>
- van Buiten, M., & Hartmann, A. (2013). Public-private partnerships: Cognitive biases in the field. In *Engineering Project Organization Conf*. Retrieved from http://www.epossociety.org/EPOC2013/Papers/VanBuiten_Hartmann.pdf
- Weber, E. U., Blais, A.-R., & Betz, N. E. (2002). A domain-specific risk-attitude scale: measuring risk perceptions and risk behaviors. *Journal of Behavioral Decision Making*, *15*(4), 263–290. <https://doi.org/10.1002/bdm.414>
- Weber, E. U., & Johnson, E. J. (2009). Mindful judgment and decision making. *Annual Review of Psychology*, *60*, 53–85.

Wiseman, R. M., & Gomez-Mejia, L. R. (1998). A Behavioral Agency Model of Managerial Risk Taking. *Academy of Management Review*, 23(1), 133–153.
<https://doi.org/10.5465/AMR.1998.192967>