5th International/11th Construction Specialty Conference
*5e International/11e Conférence spécialisée sur la construction*

Vancouver, British Columbia
June 8 to June 10, 2015 / *8 juin au 10 juin 2015*

# APPLICATION OF PROSPECT THEORY TO MANAGEMENT DECISIONS UNDER RISK ON CONSTRUCTION PROJECTS

Jean-Charles Fiolet[1,2], Carl T. Haas[1]
[1] Department of Civil and Environmental Engineering, University of Waterloo, Canada
[2] jfiolet@uwaterloo.ca

**Abstract:** Working on a construction project requires making important decisions quickly and frequently. Most of these decisions are made under risk in that the outcomes are not known, but their probabilities and impacts can be estimated, however imprecisely. Deciding to pave, given temperature predictions, is an example of such a decision. When the impacts are aggregated, they can represent a non-negligible amount compared to project budgets. Understanding project leaders' behaviour when they make such decisions under risks may create opportunities to avoid future losses that result from suboptimal choices. As those decisions are numerous on a construction project, it might be difficult for the project leaders to always make the best choice. By using a questionnaire referring to potential construction project situations, this study shows how some behavioural tendencies can influence the choices of construction leaders. This paper mainly focuses on one aspect of the study, which is the impact of the certainty effect on projects leaders' decision making. It demonstrates how project leaders are sensitive to the behavioural tendency associated with the certainty effect. This observation leads to the question of how to detect those problems and, how to correct them so as to avoid non-negligible loss of money for construction projects.

## 1 INTRODUCTION

Project leaders are required to quickly make many day-to-day decisions on their construction projects. When aggregated, those decisions can have a significant influence on cost and schedule performance. Many of those decisions are made under financial risk. An example is the decision whether to place concrete on a day for which the risk of rain has been estimated. Studies have investigated this question of decision under risk in terms of gambling and investments, and they have proven that people will illogically avoid and chase risk under different circumstances. This paper reports on an investigation of this phenomenon with respect to decisions made on construction sites.

It begins with a literature review of relevant behavioural economics principles and findings. Based on this review, a set of experiments were designed in the form of a questionnaire that would test basic hypotheses to determine sensitivity to risk and influence on judgment when day-to-day decisions are being made. Project leaders such as foremen, general foremen, superintendents, and managers were asked to answer the questionnaire.

The results of these experiments partially demonstrate the impact of risk on decisions made by project leaders. Results mostly follow the behavioural tendencies previously identified in Behavioural Economics research which indicate that risk influences judgment. For example, when the risk-option was more advantageous in terms of expected value, most people made the logically correct decision, but a significant subset made the other choice, and this represents a loss of money for companies. Also, different parameters of the project, such as the cost performance, may have influence on decisions. Respondents were less risk averse when the project was described as under budget, but many also chased risk when the project was over budget. These are expected behaviours based on behavioural economics theory. Demonstrating and understanding how some decisions made under risk can lead to a predictable non-negligible loss of money is a first step in this research. The ultimate goal is to help project leaders avoid making illogical decisions when sufficient information is available to avoid such decisions.

## 2 DEVELOPMENT OF BEHAVIOURAL ECONOMICS AND APPLICATION TO THE CONSTRUCTION SECTOR

### 2.1 Emergence of Behavioural Economics

Economics studies conducted in the second half of the last century have shown that making decisions under risk is not as easy as people might think. When people are making decisions, they are not using expected utility theory; other parameters influence their choices. This specific field in economics is called “Behavioural Economics”. It deals with the subfield of psychology which describes what guides people when they are making a decision.

The research field of behavioural economics can be classified in two categories: the process of judgment and the process of choice. Judgment deals with how people estimate probabilities, and choice is about how people select an action among others. The goal of this field is to understand how people are making their decisions, when they are facing risk.

But, some economists have also found that there are some effects which can generate problems during the phase of decision-making under risk. For example, people prefer earning an amount disproportionately more than their aversion to losing the same amount (Kahneman and Tversky 1979). Similarly, people generally give more value to what they already have compared to or referenced than to what they can have in a deal in objective and absolute terms. This effect is called reference-dependence (Knetsch 1992).

Psychologists also define different mechanisms which violate some principles of basic economics, like expected values. Such mechanisms, as “certainty effect” or “loss aversion” affect the process of choices when people are making a decision under risk. It is hypothesized that those mechanisms can also influence construction leaders when they are facing a risk and have to make a decision.

### 2.2 Factors influencing construction decisions

The decisions of construction project leaders are influenced by factors external or internal to the construction project. For instance, the experience of the decision-maker has an influence on his future choice: events that actually occurred are easier to imagine compared to ones that have not yet occurred in their experience (Kahneman and Frederick 2002).

Some factors can also influence the process of judgment such as the environment and the context. For example, if the same problem is presented or seen in two different ways, then it can lead to different answers from the decision maker. People will not react the same way if the problems are presented in terms of gains, or in terms of losses. This is called the “framing effect” (Tversky and Kahneman 1981).

Lists of parameters influencing the success of a construction project have been made numerous times in the literature (Sanvido et al. 1992, Chan et al. 2004). They can be human related, management related or process related. One objective of this study is to identify key factors and link them to a behavioural tendency to explore if the behavioural tendency will have an impact on a category of decisions made for the construction project.

### 2.3 Application of Behavioural Economics to the Construction Sector

Behavioural Economics knowledge has been applied to different sectors and to construction project management. An important area of construction project management to which it has been applied is the bidding process. As this step of the project can deal with large amounts of money, applying behavioural economics to understand how construction leaders make bidding decisions makes sense (Han et al. 2005, Chen et al. 2015).

Behavioural economics has many applications in the construction sector. Another example would be the application of social norms on typical construction project problem such as absence behaviour to understand those (Ahn et al. 2014).

This paper focuses on the application of behavioural economics to small decisions that are made frequently on projects. Taken individually, those decisions may not seem important enough to matter compared to the size of projects, however aggregated together they can represent a non-negligible amount. This paper describes an experiment applying behavioural economics to those kinds of decisions.

## 3 DESCRIPTION OF THE EXPERIMENT AND OF THE QUALITY OF MATERIALS QUESTION

### 3.1 Description of the Global Experiment

#### 3.1.1 Goal of the experiment

Creating a controlled experiment that places construction decision makers under financial risk and which observes their decision making behaviour under such conditions is, ironically, fraught with risk and not likely to receive research ethics review process approval. A reasonably close and ethically acceptable approximation of the preceding approach is to develop a research tool that implements an experiment in which decision makers are asked to make a choice as if the conditions described were real. Such a tool has been developed in the form of a questionnaire. This timed questionnaire is used to conduct the experiment.

The experiment has three goals. The first goal is to determine the sensitivity of construction project leaders to different typical risks during the decision making process. The second goal is to study the impact of key parameters on those decisions. The final goal is to estimate the financial impact that those decisions can have on a construction project when they are compared with the same decisions problem resolved following expected utility theory.

Specifically, the questionnaire contains close-ended questions, each with two possible options. The participants are asked a series of questions that describe typical construction project situations. The reasons for this choice are:

- Approximation of action based experiment: As explained above, this approach approximates adequately a controlled experiment with real consequences.
- Simplicity of analysis: Compared to an open-ended questionnaire, the answers, here called options, for this kind of questionnaire are easier to read because there are only two possible choices for each question. The question is reduced to a specific problem, and the data linked with that question can be directly interpreted.
- Simplicity for understanding and focus: All the questions built for this questionnaire are as simple as possible to maximize likelihood of understanding and to maximize consideration of externalities that might influence the respondents' decisions.
- Simplicity for answering: The close-ended questionnaire allows people to answer faster.
- Correspondence with research goals: Previous successful studies that focused on behavioural tendencies almost invariably used close-ended questionnaires (Allais 1953, Kahneman and Tversky 1979). This form of questionnaire is useful for isolating behavioural tendencies, because it forces the participant either to choose or to avoid the risk, and it makes the result easier to analyze as well using conventional statistics.

### 3.1.2 Development of the questions – Behavioural tendencies

The first problem was to determine how many questions should be in the questionnaire, what kind of questions would be included and how they should be presented to the participant. For this experiment, it was decided to build the questions around behavioural tendencies such as "certainty effect" or "loss aversion", by identifying situations on construction projects in which those behaviours might be exhibited. Thus, one of the most important parts of the development of the questionnaire was to build situations where a behavioural tendency might appear, and make it realistic for the participant. Based on this rationale, some construction situations were chosen and linked to a behavioural tendency in order to construct each question. The questions were in four groups:

- Choice between two techniques – testing for Perception of Change
- Choice between two kind of shingles (Quality of the materials) – testing for Certainty Effect
- Construction of a set of bored piles – testing for Non Compliance
- Decision to work with a risk of rain – testing for Loss Aversion

### 3.1.3 Development of the questions – External Influences

When project leaders are working on a construction project, they can be influenced by many external factors. Those factors can influence their choice in day-to-day decisions when they are facing risk. From the behavioural economics literature, it is clear that current financial position typically influences decisions made with respect to possible future gains and losses (Tversky and Kahneman 1986). Project cost performance is a good proxy for this factor as it reflects on the project leader's perception of their own situation, performance, and related future rewards or penalties. Thus, each question is framed in terms of the following three project cost performance situations:

- on budget
- over budget
- under budget

### 3.1.4 Development of the questions – Expected Values

The expected value (EV) of an option corresponds to the sum of the expected values of the possible outcomes. Expected value is calculated using equation 1.

$$[1]\ \mathrm{EV} = \sum_{i=1}^{n} P_i C_i$$

For both options to each question the associated expected value is computed and then compared to the expected value of the other option. Two cases occur:

- The expected value of both options are equal
- One option has an advantage over the other one in terms of expected value

These two cases are used in the questionnaire for different objectives. The first case, when the expected values of both options are equal, is intended to highlight the presence of a behavioural tendency, if it exists. For the second case, the option that comprises a risk is advantaged compared to the other one. This time the goal is to qualify the subset of participants who are averse to risk.

### 3.1.5 Distribution of the questions

All the questions are built to test for one behavioural tendency and one external influence. The expected values of their options are either equal or different depending on the experimental hypothesis for each behaviour. The different questions prepared for this questionnaire are shown in Table 1. The questions were mixed randomly in the questionnaire, so that two similar questions did not appear in sequence.

Table 1: Distribution of the questions in the questionnaire

| Situations – Behavioural Tendencies | Expected Values | External Influence | Number of the question |
|---|---|---|---|
| Perception of Change | Expected Values different | Under budget | Q4 |
| | | On budget | Q10 |
| | | Over budget | Q18 |
| Quality of the materials – Certainty Effect | Expected Values equal | Under Budget | Q6 |
| | | On Budget | Q15 |
| | | Over Budget | Q20 |
| | Expected Values different | Under Budget | Q22 |
| | | On Budget | Q2 |
| | | Over Budget | Q12 |
| Bored Piles – Non Compliance | Expected Values equal | Under Budget | Q11 |
| | | On Budget | Q8 |
| | | Over Budget | Q5 |
| | Expected Values different | Under Budget | Q17 |
| | | On Budget | Q14 |
| | | Over Budget | Q23 |
| Weather – Loss Aversion | Expected Values equal | Under Budget | Q1 |
| | | On Budget | Q21 |
| | | Over Budget | Q16 |
| | Expected Values different (option A advantaged) | Under Budget | Q19 |
| | | On Budget | Q13 |
| | | Over Budget | Q7 |
| | Expected Values different (option B advantaged) | Under Budget | Q24 |
| | | On Budget | Q3 |
| | | Over Budget | Q9 |

## 3.2 Construction of the “Quality of materials” Question

### 3.2.1 Materials of the question

This conference paper, due to limitations, focuses on the “Quality of the materials” questions where the construction project is on budget (Q15 and Q2). However, the distribution and experimental design of the full set of questions are presented. The “Quality of the materials” question deals with the certainty effect.

The certainty effect is the psychological effect referring to the reduction of probability from certain to probable in the perception or utility function of the decision maker. Usually, reducing a probability of winning creates some effects, such as displeasure. This displeasure leads the individual to a reaction of risk-aversion because the small possibility of not winning is perceived as a loss. This risk-aversion reaction is bigger when the probability is reduced from certain to probable than from probable to less probable (Tversky and Kahneman 1986). Conversely, extremely small probabilities are invariably overvalued, leading to behaviours such as the purchase of lottery tickets.

The "Quality of materials" question plays with this behavioural tendency of certainty effect. The question offers one option with a complete assurance of the quality that is relatively expensive and a second option where the assurance of the quality is close to complete, but it is not, and this option is less expensive compared to the first one. Here, it is important that the probability of acceptable quality for each shingle for the second option is close to 100% or else other parameters would enter in the question such as the time of replacement, cost of disposal, and shipment. The intent was for the respondent not to factor in these other issues. An example of this question is shown in Figure 1. This question deals with the installation of shingles, but no qualifications are needed to answer this question, so every project leader or decision maker should be able to answer it.

*Question 15*:

*You are working on a project which is **on time** and **on budget**.*

*We need to install many shingles, and there are 2 types of shingles A and B which match the specifications. Which shingle type are you going to choose? The differences between the 2 types are:*

- *Shingle A costs **$194** per unit and there is a probability of **97%** it will not crack or break during the installation.*
- *Shingle B costs **$200** per unit and there is a probability of **100%** it will not crack or break during the installation.*

*A* ☐ *B* ☐

Figure 1: Example of a "Quality of the materials" question

### 3.2.2 Choice of the values – Decision Trees

The "Quality of materials" question where the construction project is on budget appears twice in the questionnaire: once when the expected values are equal (Q15) and a second time when the risk option (shingle A) is advantaged in terms of expected values (Q2). The decision trees of these questions are shown in Figure 2. Both questions offer a probability of cracking of 97% during the installation of which is close to 100% and so corresponds to the criterion defined before. The price of the shingles is around $200 for both questions. It makes sense because nothing about the shingle was specified in the question.

The expected value is computed for each option. Equation 1 is used for this computation. For option B, the expected value is easy to compute because the probability linked is 100%. However, computing the expected value for option A is more difficult, because the broken shingles have to be replaced by the same kind of shingle and the operation can last infinitely in theory. However, this calculation corresponds to the sum of a series. These expected values appear in the decision trees of Figure 2.

## 3.3 Progress and methodology of the experiment

The data collection process was established within the guidelines of the Office of Research Ethics of University of Waterloo. The participants were given an information letter about this study, and they had to fill a consent form so that their data can be used. Once this first step was done, the participants were allowed to fill the questionnaire. Filling the questionnaire took approximately half an hour. To finish, after

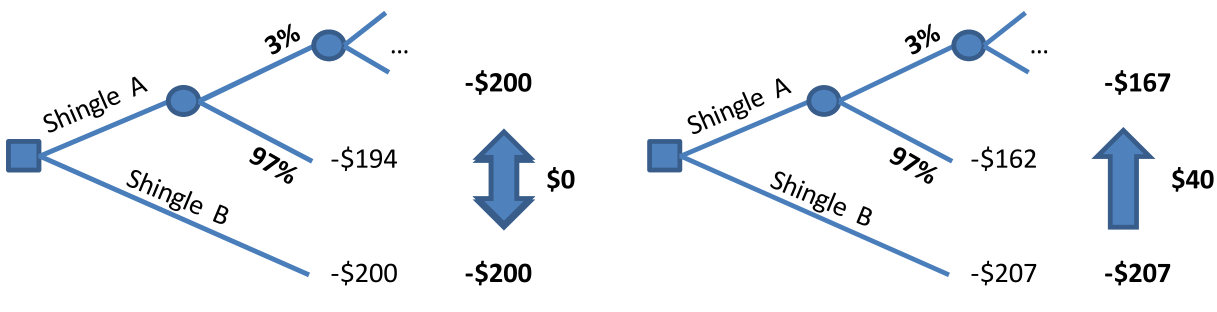


Figure 2: Decision trees of the “Quality of Materials” questions and EV of both options – EV equal Q15 (on the left) and EV different Q2 (on the right)

they gave back their questionnaire, they received a feedback letter, explaining the objectives of this experiment.

The data from the answers of the questionnaire was then analyzed, question by question, testing for the behavioural patterns explained before. It was also studied and analyzed in relation with external influences and characteristics from the participants such as their position or their age to observe how those parameters can influence their choices and their reactions facing those behavioural patterns.

In total, this study had 53 participants; they are all construction project leaders, mostly located in North America, and at different levels: foremen, project managers, executives and a few teachers and researchers. Those people were chosen randomly with respect to their age, their location and their position. The range of age is large, from the twenties to the sixties, so it results in participants with different levels of experience. Some have a whole career behind them, while others just started their job. This absence or not of experience may influence the way they make decisions under risk, so it is important to have a sample representative of the population of construction workers.

## 4 ANALYSIS OF THE RESULTS

### 4.1 Results of the “Quality of the Materials” Question

The percentages of participants who chose option A or option B for these two questions are shown in Table 2. As expected, the majority of participants chose to avoid the risk and took option B (no risk) for the question where the expected values are equal. This result shows the impact of the certainty effect on the participants’ choice. The significance of this value will be determined in the next section by computing the 95% confidence interval.

Concerning the second question where option A (risk taking) was advantageous, most of the participants made the best decision in terms of expected values. However, 28% of the participants chose to avoid the risk even if it was obviously more attractive in terms of expected values. This represents a significant number of participants, and consequently, potential non-negligible loss for companies. Computing the expected utilities linked to this question may explain this behaviour. This will be shown in the next section.

Table 2: Results of the “Quality of the materials” questions

| Options | Shingle A (Risk Taking) | Shingle B (No Risk) |
|---|---|---|
| EV equal (Q15) | 36% | **64%** |
| EV different (Q2) | **72%** | 28% |

### 4.2 Interpretation of the Results

#### 4.2.1 Computation of the confidence interval

For the question where the expected values are equal (Q15), Table 2 shows that 64% of the participants choose to take option B; this value corresponds to the mean of the participants' answers. To calculate the mean for the overall population of the construction project leaders' potential answers, an approach would be to compute a confidence interval using the binomial analysis. This confidence interval is shown in equation 2:

$$[2]\ \left[\bar{X} - t * \frac{\sqrt{\bar{X}(1-\bar{X})}}{\sqrt{n}}\ ;\ \bar{X} + t * \frac{\sqrt{\bar{X}(1-\bar{X})}}{\sqrt{n}}\right]$$

Where:

- $n$ = Sample Size
- $\bar{X}$ = Sample Mean
- $t$ = Value linked with the confidence level

For this experiment, the t-value corresponding to a 95% confidence interval is equal to 1.96. So, the 95% confidence interval for this question (Q15) computed with equation 2 is 36 ±13% for option A and 64 ±13% for option B. This interval is too large to quantify the impact of this behavioural tendency but it is enough to show the pattern of certainty effect on construction leaders' choices as the confidence interval of the two options are not intersecting. It means that more than half of the population of construction project leaders makes the choice to avoid the risk when the expected values are equals, which proves the impact of the certainty effect on them when they are making a decision under risk.

Concerning the second question (Q2), the 95% confidence interval computed with equation 2 is 72 ±12% for option A and 28 ±12% for option B. This interval is also too large to quantify exactly the part of the population of construction leaders who are avoiding the risk and prefer option B. However, it is enough to prove that this non-negligible part of the population of construction leaders can engender losses, because they choose to avoid the risk taking option, even if it is more attractive in terms of expected value. Those potential losses are most likely generated by the certainty effect (Tversky and Kahneman 1986). This behavioural tendency has an impact on daily decisions made by construction leaders, and it may lead to some losses for the construction project.

#### 4.2.2 Computation of the expected utilities

Usually, when people are making a decision under risk, they are not computing expected values, but they are computing expected utilities. Following Prospect Theory (Kahneman and Tversky 1979), the expected utility represents the evaluation phase of the choice process. Following are the expression of the expected utility and the definitions of the scales used to compute it:

$$[3]\ U(x_1, p_1; \dots; x_n, p_n) = \pi(p_1)v(x_1) + \dots + \pi(p_n)v(x_n)$$

- The first scale, $\pi$ associates with each probability $p$ a decision weight $\pi(p)$, which reflects the impact of the probability.

- The second scale, $v$ assigns to each outcome $x$ a number $v(x)$, which reflects the subjective value of that outcome.

For this question, only the first scale was considered to compute the expected utilities. The outcomes of the two options are close to each other, so the subjective values of the outcomes might still be close and so, might not create any difference in the computation of the expected utilities compared to the expected values.

Two expected utilities are computed for these questions: one adding 10% to the original probability of risk and a second one adding 20%. Inversely, the same amount is subtracted from the complementary probability. As everyone considers the risk from their own point of view, and there is no general expected utility true for everybody and for each problem, people see the risk from their own perspective. Some are adding 10% to the probability of risk, some add less, and some add more. This value of 10% corresponds to the mean found from previous studies made in behavioural economics to understand the choices under risk (Tversky and Kahneman 1992).

This study is looking for trends in decision making, so using approximates values like 10% or 20% is useful to understand the decision of the participants when they are making this decision under risk. The computation of the expected utilities for the question where the expected values are equal (Q15) is shown in Table 3. It explains the choice of the participants: for either of the expected utilities n°1 or n°2, option B is more attractive, explaining why a majority of participants chose option B. Participants who chose option A, may have considered the risk of option A as zero.

Table 3: Results of the “Quality of the materials” question – EV equal (Q15)

| Options | Shingle A (Risk Taking) | Shingle B (No Risk) |
|---|---|---|
| Expected Values | -$200 | -$200 |
| Expected Utilities n°1 (+10%) | -$223 | **-$200** |
| Expected Utilities n°2 (+20%) | -$252 | **-$200** |
| Percentage | 36% | **64%** |

For the question where the expected value of option A (risk taking) was more attractive compared to the expected value of option B (no risk), the expected utilities are presented in Table 4. These computations are helpful to understand the participants’ choices. The expected utilities n°2 are close to each other, which means that if someone overvalues the probability of the risk in option A by more than 20%, option B was selected instead. This happened for 28% of the participants. Conversely, if someone undervalues or overvalues the probability of risk in option A by less than 20%, option A was selected.

Table 4: Results of the “Quality of the materials” question – EV different (Q2)

| Options | Shingle A (Risk Taking) | Shingle B (No Risk) |
|---|---|---|
| Expected Values | **-$167** | -$207 |
| Expected Utilities n°1 (+10%) | **-$186** | -$207 |
| Expected Utilities n°2 (+20%) | -$210 | **-$207** |
| Percentage | **72%** | 28% |

These computations show how the certainty effect impacts the participants’ choices. The influence of the certainty effect differs between participants. Some are not affected by this behavioural pattern, however some are influenced by it, and they increased the probability of risk of the question linked with that pattern. By reacting like this when externalities are not considered, they are avoiding the best option in terms of expected values. An aggregation of all these types of decisions could represent non-negligible losses for construction projects.

## 5 CONCLUSION AND RECOMMENDATIONS

This experiment shows the impact of one behavioural pattern, the certainty effect, on construction project leaders when they have to make a decision under risk. When this pattern is present in the question, they are in the majority risk-avoiding. This can lead to some losses on the construction project. This happens when the risk-taking option is more attractive in terms of expected values. Some respondents avoided the risk and took the safer option, which leads to small losses. Aggregated together, these small losses may represent significant losses for the construction project.

The “certainty effect” is not the only behavioural tendency which has been studied for its influence on decisions under risk. Other behavioural tendencies such as “loss aversion” may have an impact on construction project leaders’ decisions as well. What’s more, this impact may be more or less important depending of some critical factors for a construction project, such as the cost performance or the experience of the decision maker.

This application of behavioural economics, and more precisely of prospect theory, on common decisions made frequently and quickly by construction leaders helps to understand how these decisions are made for a construction project. Understanding them can lead to the prevention of the losses generated by illogical behavioural patterns. The final goal would be to quantify and prevent these losses by detecting those decisions and help the construction leaders when they have to deal with them.

## Acknowledgements

The writers gratefully acknowledge all the participants of this experiment who made this study feasible and NSERC for supporting it.

## References

Ahn, S., Lee, S., and Steel, R.P. 2014. Construction Workers’ Perceptions and Attitudes toward Social Norms as Predictors of Their Absence Behaviour. *Journal of Construction Engineering and Management*, **140**(5): 04013069.

Allais, M. 1953. Le Comportement de l’Homme Rationnel devant le Risque: Critique des Postulats et Axiomes de l’Ecole Américaine. *Econometrica*, **21**(4): 503-546.

Chan, A.P., Scott, D., and Chan, A.P. 2004. Factors Affecting the Success of a Construction Project. *Journal of Construction Engineering and Management*, **130**(1): 153-155.

Chen, Y.Q., Zhang, S.J., Liu, L.S., and Hu, J. 2015. Risk perception and propensity in bid/no-bid decision-making of construction projects. *Engineering, Construction and Architectural Management*, **22**(1): 2-20.

Han, S.H., Diekmann, J.E., and Ock, J.H. 2005. Prospect theory: Contractor’s Risk Attitudes in the Selection of International Construction Projects. *Journal of Construction Engineering and Management*, **131**(3): 283-292.

Kahneman, D. and Frederick, S. 2002. Heuristics and biaises: The psychology of intuitive judgment. Cambridge University Press, England.

Kahneman, D. and Tversky, A. 1979. Prospect theory: An analysis of decision under risk. *Econometrica*, **47**(2): 263-291.

Knetsch, J.L. 1992. Preference and nonreversibility of indifference curves. *Journal of Economic Behaviour & Organization*, **17**(1): 131-139.

Sanvido, V., Grobler, F., Parfitt, K., Guvenis, M., and Coyle, M. 1992. Critical Success Factors for Construction Projects. *Journal of Construction Engineering and Management*, **118**(1): 94-111.

Tversky, A. and Kahneman, D. 1981. The framing of decisions and the psychology of choice. *Science*, **221**(4481): 453-458.

Tversky, A. and Kahneman, D. 1986. Rational Choice and the Framing of Decisions. *The Journal of Business*, **59**(4): S251-S278.

Tversky, A. and Kahneman, D. 1992. Advances in Prospect Theory: Cumulative Representation of Uncertainty. *Journal of Risk and Uncertainty*, **5**(4): 297-323.