Behavioural Economics:

Application to Quotidian Construction Decisions

by

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AUTHOR'S DECLARATION

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

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 whether to pave a road, given temperature predictions, is an example of such a decision. When the impacts are aggregated, they can represent a non-negligible amount relative to project budgets. Understanding project leaders' behaviour when they make such decisions under risk may create opportunities to avoid future losses that result from suboptimal choices. As these decisions occur frequently in 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 certain behavioural tendencies can influence the choices of decision-makers. This experiment focuses on behavioural tendencies such as the certainty effect and loss aversion. It demonstrates how project leaders are sensitive to these behavioural tendencies by evoking reactions of risk aversion or risk chasing in the experiment's participants by presenting them with situations involving risk. These observations lead to the question of how to detect such decision-making problems and how to correct them so as to avoid non-negligible losses of money for construction projects.

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Chapter 1
Introduction

Construction project leaders are required to make numerous decisions every day on their construction projects, which may be referred to as quotidian decisions. The most important decisions are not made directly on the construction site but are already discussed and decided before the project starts. Meanwhile, day-to-day decisions have to be made; they are smaller in terms of cost than the most important ones but they appear frequently. Construction project leaders make these decisions quickly, and often by themselves. Even if each of these decisions seems to be negligible compared to the cost or the schedule performance, when they are aggregated, they can have a significant influence. Among these decisions, many are made under financial risk.

An example of these kinds of decisions would be the choice to place concrete on a day for which the risk of rain has been estimated. Another would be to decide to pave or not, given temperature predictions. Numerous other examples can be found in which construction leaders have to choose between different options for their construction project.

In the previous century, some studies investigated this question of decision under risk in terms of gambling and investments, and they have proven that people will illogically avoid or chase risk under certain circumstances. These studies, conducted mainly by Kahneman and Tversky, deal with the impact of certain behavioural patterns on people's way of making decisions. They have developed a model, called "prospect theory" (Kahneman and Tversky, 1979), which became "cumulative prospect theory" (Tversky and Kahneman, 1992), whereby people's decisions can be understood by taking into account their reaction when they are facing a risk. On account of this work, Daniel Kahneman received the Nobel Memorial Prize in Economics in 2002. The objective of this thesis is to investigate this phenomenon with respect to decisions made on construction sites.

This thesis begins with a literature review of relevant behavioural economics principles and findings. The literature review goes through the different stages of the development of behavioural economics and the theory explaining the behaviour of people when they have to make decisions under risk. Those studies lead into the theory of prospect theory and cumulative prospect theory. The literature review also deals with the different behavioural patterns which can influence decisions when people are facing risk. Moreover, it considers studies concerning critical factors for construction projects and studies which applied the abovementioned behavioural economics principles to the construction sector.

Based on this review, a set of experiments were designed in the form of a questionnaire that would test basic hypotheses to determine people's sensitivity to risk and how that influences their judgment when day-to-day decisions are being made. The questions of the questionnaire are based on the key behavioural patterns discovered by researchers as described in the literature review. Project leaders such as foremen, general foremen, superintendents, and managers were asked to answer the questionnaire. Their common characteristic is that they are the on-site decision-makers.

This set of experiments 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 the decisions made by the project leaders. The final goal is to estimate the financial impact that making illogical decisions can have on a construction project by comparing the financial outcome of such decisions with that of decisions resolved logically according to the expected monetary value. Expected monetary value is widely understood to yield the most logical choice, unaffected by behaviour.

The results of these experiments partially demonstrate the impact of risk on decisions made by project leaders. The 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 monetary 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 chased risk when the project was over budget. These are expected behaviours based on behavioural economics theory. Demonstrating and understanding how decisions made under risk can lead to a predictable non-negligible loss of money is the initial goal of this research. The ultimate goal is to help project leaders avoid making illogical decisions when sufficient information is available to avoid such decisions.

Chapter 2
Literature Review

2.1 Behavioural Economics

For decades, research has been conducted and applied towards reducing the cost of construction projects. The materials, the techniques, and the organization of construction projects are continually being improved in terms of reducing the cost and increasing the quality of the work. As a result of these improvements, many construction sites are well-organized such that all of the work is carried out at optimal efficiency. However, there are still some uncertainties that cannot be controlled. And these uncertainties, which can be considered as a risk, have to be considered by foremen and project managers.

Some economic studies, conducted in the second half of the last century, have shown that making decisions under risk is not as easy as people may think. In actuality, when people make decisions, they do not use the expected monetary values; rather, other parameters influence their choices. These studies pertain to a specific field in economics called “behavioural economics,” which deals with the psychological processes that guide people when they are making decisions.

The research field of behavioural economics can be classified into two categories: (1) the process of judgment, and (2) the process of choice. Judgment deals with how people estimate probabilities, and choice is about how people select an action amongst a set of possible actions. The goal of this field is to understand how people make decisions when they are facing risk.

2.1.1 Heuristics in Judgment

2.1.1.1 Influence of Experience

When risk is involved in decision-making, two parameters need to be considered: the likelihood of the risk and the economic value of the outcome. These factors are important because they are the main reasons motivating decisions. Most of the time, the principles used in economics to model the economic values of the outcomes are based on the concept of statistical sampling, in which Bayes' rule is used to update the probability: the last events will have a greater influence than the older ones. However, Bayes' principle is difficult to use, as there is no general rule to define the prior. People can misjudge events by not using these principles correctly.

Some psychologists define various mechanisms which violate the abovementioned principles. For example, events that actually occurred are easier to imagine than ones that did not occur (Kahneman and Frederick, 2002). Another significant problem pointed out by these psychologists is how well the data represent the events. Sometimes, the prior has been given too much influence and people will misjudge the probability of a future event to make the data fit the reality. If a coin is tossed and lands as heads five times in a row, people will be more likely to bet on tails for the next toss; this judgmental bias is called the law of small numbers. Conversely, another misjudgment can lead to the opposite conclusion: people may feel lucky or unlucky, and judge accordingly. Studies about betting on games demonstrate such behaviours (Gilovich et al., 2002).

Another problem linked with probability judgment is the fact that people can misunderstand a set of hypotheses or encode it incorrectly. If people already have an idea about the probabilities while they are collecting the information, they will tend to make them correspond to their preconceived ideas (Rabin and Schrag, 1999).

2.1.1.2 Influence of the Environment and Context

Once the probabilities of an event are evaluated, the next step is to make the choices based on the options that are presented. The standard preference theory is based on certain principles that guide people when they are making their decisions, but some of these principles are violated in actual practice (Slovic, 1995). For example, one such principle is that people's decisions should not vary according to the way the event is described, but this does not hold true in reality.

Certain phenomena that challenge this standard preference theory have been identified. One such phenomenon is the "framing effect": the kind of decision a person makes will be different depending on whether the problem is presented in a "positive frame" or in a "negative frame"; in other words, in terms of gains or in terms of losses (Tversky and Kahneman, 1981).

Another phenomenon which undermines the standard preference theory is the "anchoring effect." This effect describes how people can be influenced by a random value, given before the moment they are making their decision. This value, called an "anchor," has an influence on the final choice, even if the value is chosen randomly (Tversky and Kahneman, 1974).

Moreover, the context has a great influence on the decision-maker: the choice between options can depend on which other options are available. This phenomenon is called the "context effect" (Simonson and Tversky, 1992). These effects show how the environment in which the decision-makers operate can influence their decisions.

2.1.1.3 Loss Aversion and Risk Aversion

Some economists have also found that there are certain psychological effects which can generate problems during decision-making facing risk. One of the effects that is easiest to understand is the fact that people are going to dislike losing an amount to a greater degree than they are going to like earning the same amount (Tversky and Kahneman, 1991). Indeed, people in general will give more value to what they already have compared to what they can potentially have in a deal. This phenomenon can be called reference-dependence (Knetsch, 1992). It has significant consequences when a deal is considered, such as the “endowment effect”: people will want to buy something at a lower price than they would sell it (Kahneman et al., 1990). Another aspect of the endowment effect is the fact that people are not going to consider in the same way goods which are for resale rather than to be utilized. This effect leads to loss aversion.

One of the greatest contributors to problems in decision-making is loss aversion. Loss aversion refers to people's tendency to strongly prefer avoiding losses to acquiring gains (Kahneman and Tversky, 1984). In other words, people will lose more satisfaction if they forfeit a certain amount of a prized commodity than they will gain if they acquire this same amount.

Loss aversion is directly connected to risk aversion. In effect, risk aversion is a phenomenon that undermines the validity of expected utility theory, which posits that the utility of a risky distribution of outcomes is a probability-weighted average of the outcome utilities. This theory may sound logical, but in reality it often fails to describe actual behaviour because of factors such as risk aversion. On account of the demonstrated reality of risk aversion in the psychology of judgments and choices, expected utility theory is no longer valid.

Although some studies have shown that loss aversion does not always occur, this can be explained by certain psychological principles. The main idea of these principles is the fact that if there is an exchange of goods in parallel to the loss, it will cancel the loss aversion effect (Novemsky and Kahneman, 2005).

Furthermore, some intentions can affect the perception of loss aversion and moderate it. The perception of loss aversion can be moderated by both emotional attachments to the good being forfeited and cognitive focus during evaluation. Being attached to an item alters the perception of loss aversion, whereas changes in cognitive perspective explain why an item is perceived as a loss to a greater or lesser degree (Ariely et al., 2005; Novemsky and Kahneman, 2005).

Moreover, some studies have shown that the loss aversion effect can actually be reversed when it deals with small outcomes. In this case the pattern is reversed, and gains appear larger than losses. This reversal can be explained in terms of the hedonic principle – individuals are motivated to maximize pleasure and to minimize pain – as well as by the assumption that small losses are more easily discounted cognitively than large losses (Harinck et al., 2007).

From this loss aversion effect, some principles can be derived in terms of reactions to losses vs. non-gains and non-losses vs. gains (Liberman et al., 2005). This study confirmed the prediction that non-gains would be perceived as less intensely negative than losses, but did not confirm that gains would be perceived as less positive than non-losses. The results contradict the prediction of loss aversion, as non-losses were perceived as less intensely positive than gains. So, the loss aversion effect is not sufficient to explain why losses are perceived as more averse than gains.

2.1.2 Choices: Prospect Theory and Cumulative Prospect Theory

Prospect theory (Kahneman and Tversky, 1979) takes into consideration these phenomena related to risk aversion. The way it differs from expected utility theory is the addition of a probability weighting function and a value function. These two functions help the theory to fit the experimental results and take into consideration phenomena such as risk aversion.

Prospect theory is the basis of behavioural economics. Kahneman and Tversky pointed out some problems with expected utility theory and developed prospect theory to remedy these problems. This new theory takes into consideration loss aversion and other behavioural tendencies such as the certainty effect, the reflection effect and the isolation effect.

2.1.2.1 Behavioural Tendencies

The certainty effect refers to when “people overweight outcomes that are considered certain, relative to outcomes which are merely probable” (Kahneman and Tversky, 1979). For example, the difference between 90 and 100 percent will appear more important than the difference between 40 and 50 percent. When people deal with probabilities which are close to 100 percent, they do not react the same way as expected utility theory would suggest. This phenomenon was demonstrated by Allais (1953) and it was the first behavioural tendency to be pointed by economists.

The reflection effect refers to the fact that “the preference between negative prospects is the mirror image of the preference between positive prospects” (Kahneman and Tversky, 1979). This means that for all the different effects described above, what is going to happen if the problem is inversed needs to be considered: people are going to change their preference when they are dealing with negative prospects instead of positive ones.

The isolation effect refers to the observation that when people try to simplify the choices between options, they will “disregard components that the alternatives share, and focus on the components that distinguish them” (Kahneman and Tversky, 1979). This approach can lead to different and inconsistent preferences: depicting a problem differently can ultimately lead to different preferences.

2.1.2.2 Choice Process: Prospect Theory

Prospect theory divides the choice process into two parts: (1) the editing phase and (2) the evaluation phase. The editing phase regroups different operations defined by Kahneman and Tversky (1979) as follows:

- Coding: People normally perceive outcomes as gains and losses, rather than as final states of wealth or welfare. Gains and losses are defined relative to some neutral reference point. The reference point usually corresponds to the current asset position, in which case gains and losses coincide with the actual amounts that are received or paid.
- Combination: Prospects can sometimes be simplified by combining the probabilities associated with identical outcomes.
- Segregation: Some prospects contain a riskless component that is segregated from the risky component in the editing phase.
- Cancellation: The essence of the isolation effect is the discarding of components that are shared by the offered prospects.
- Simplification: This refers to the simplification of prospects by rounding probabilities or outcomes.
- Detection of dominance: This involves the scanning of offered prospects to detect dominated alternatives, which are rejected without further evaluation.

Next comes the phase of evaluation:

- The first scale, π, associates with each probability p a decision weight π (p), which reflects the impact of p on the overall value of the prospect (Figure 1). However, π is not a probability measure, and $\pi (p) + \pi (1 - p) < 1$.

- The second scale, v, assigns to each outcome x a number v (x), which reflects the subjective value of that outcome (Figure 2). Recall that outcomes are defined relative to a reference point, which serves as the zero point of the value scale. Hence, v measures the value of deviations from that reference point, i.e., gains and losses.

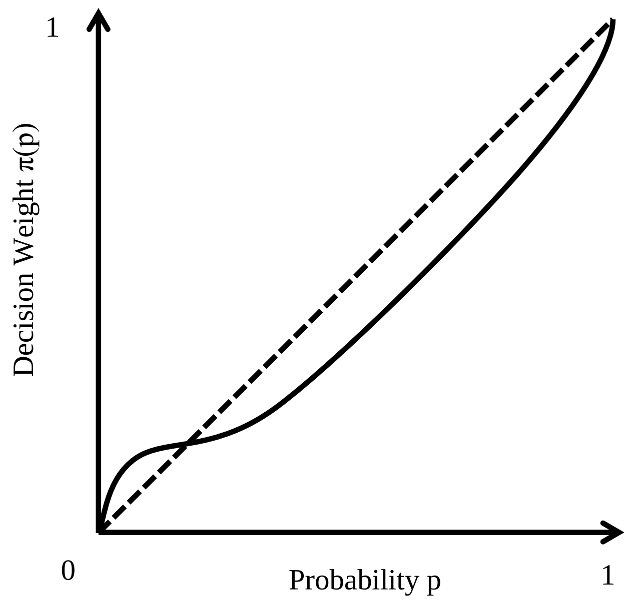

Figure 1: Typical Weighting Function following Prospect Theory

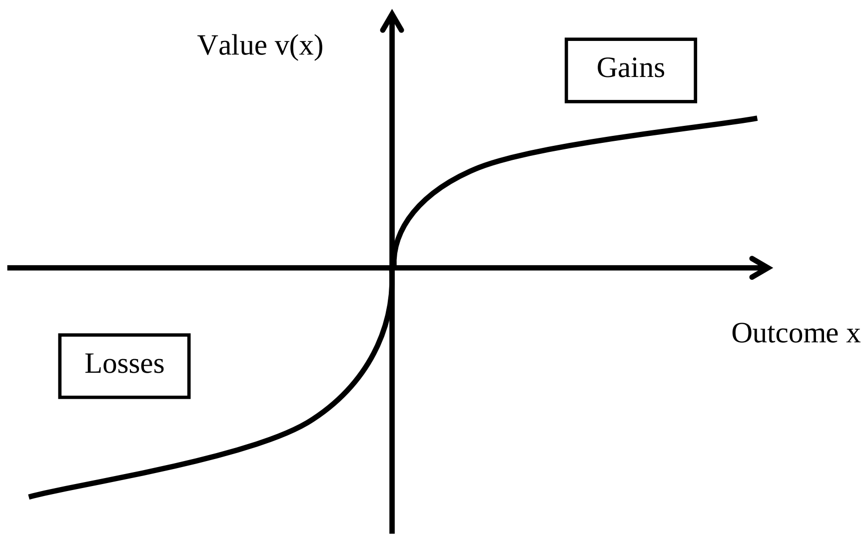

Figure 2: Typical Value Function following Prospect Theory

2.1.2.3 Cumulative Prospect Theory

Cumulative prospect theory (CPT) is also a model for describing decision-making under risk (Tversky and Kahneman, 1992). This theory is an extension of prospect theory. The two theories are very close as they both consider that people are making their decision using a reference point rather than considering their final state; however, for CPT, the expected utilities follow a model called rank-dependent expected utility (Quiggin, 1992). This model of computing expected utilities only overweights events with small probabilities and extreme outcomes, whereas prospect theory overweights all events with small probabilities, including the ones with lower outcomes.

From the two functions introduced in the last section (Figure 1 and Figure 2), only the weighting function is modified with CPT. It is illustrated in general and exaggerated form in Figure 3.

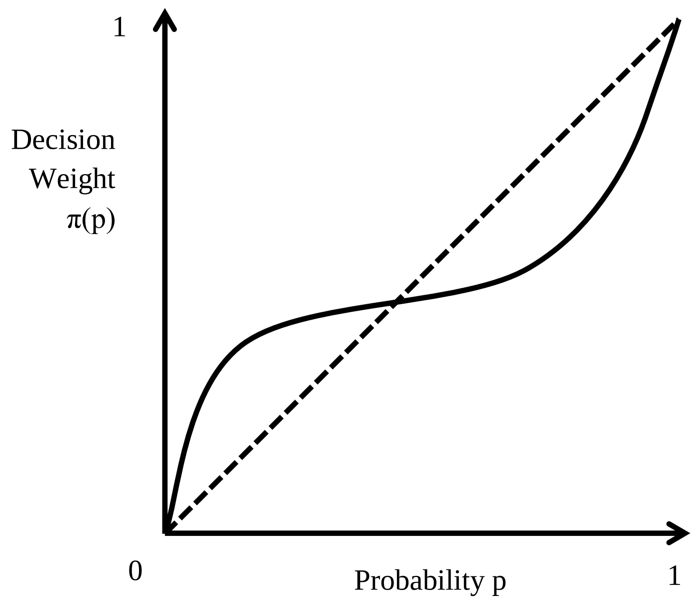

Figure 3: Exaggerated Typical Weighting Function following Cumulative Prospect Theory

The development of behavioural economics in the past few decades has had a huge impact on the understanding of decision-making. This work has been applied in many fields, mainly in finance and in macroeconomics, but also in the construction sector as introduced in the following section.

2.2 Application to the Construction Sector

2.2.1 Factors Influencing Construction Decisions

The literature review has already pointed out that the experience of the decision-maker has an influence on his future choices: events that have actually occurred are easier to imagine than ones that have not yet occurred in one's experience (Kahneman and Frederick 2002). Decisions made under risk can be influenced by various parameters. Accordingly, decisions made by construction project leaders can be influenced by factors external or internal to the construction project. Experience is one of the factors, but not the only one.

Some studies have listed parameters influencing the success of a construction project, and it might be surmised that these parameters influence decisions as well. For instance, some researchers have defined a set of conditions about some factors, and the success of the building project is ensured if those conditions are maintained (Sanvido et al., 1992). Based on these studies, a list of factors that support the success of construction projects can be created.

For many studies, the critical success factors of a construction project depend on its particular situation. Most of the specifications are connected to the country in which the construction project is carried out (Kaming et al., 1997; Li et al., 2005). The culture of each country is unique, and particular cultural factors will have a certain degree of influence on decision-making. Other studies focused on some specific part of the construction project such as partnering (Chan et al., 2004a) or bidding (Chua and Li, 2000).

To synthetize the studies conducted around this question, some researchers built a list of critical success factors, which can be grouped into certain categories, such as project related factors, human related factors or external environmental factors (Chan et al., 2004b). These factors, which are critical to the success of construction projects, are considered likely to influence the decisions of construction project leaders when they have to make decisions under financial risk.

2.2.2 Decision-making Tools

To deal with these critical factors affecting the construction performance, certain tools of different decision-making theories were explored to model and manage these risk factors. Some researchers have discussed the application of decision-making tools, such as decision support system (DSS) or fuzzy set theory technologies, in modelling risk management (Baloi and Price, 2003). Many different multi-criteria decision-making methods exist and can be applied to construction situations (Jato-Espino et al., 2014). These decision-making tools have their particular strengths and weaknesses; they have their own specificities which make them applicable in certain environments. However, they mainly focus on certain important decisions. For instance, they may focus on assessment of a project (Singhaputtangkul et al., 2013) or bidding strategy (Chou et al., 2013).

These tools are built for important decisions which include many criteria and are, by consequence, complex and very difficult decisions for construction project leaders. However, the study described in this thesis focuses on simple decision problems, i.e., with a minimum of parameters, so as to make the problem and the related decision easier to understand. Furthermore, the developed tools are not used for small decisions, such as the ones which are made quickly and frequently on a construction project. Nevertheless, certain factors and parameters can create some risks around these small on-site decisions, and construction project leaders have to deal with them. Behavioural economics can be applied to the construction sector to analyze such situations, so as to understand how construction project leaders are making their decisions when dealing with risk.

2.2.3 Application of Behavioural Economics to the Construction Sector

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

Behavioural economics has also been applied to specific construction problems. Uncertainty about the weather can lead to delays in the construction, so it becomes a risk for construction project leaders. When they have to price this risk, certain behavioural patterns are going to influence them (Chan and Au, 2007).

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

This thesis project focuses on the application of behavioural economics to small decisions that are made frequently on projects. We call these "quotidian construction decisions." Taken individually, these decisions may not seem important enough to matter compared to the overall scope of projects; however, aggregated together they can represent a non-negligible amount of cost. This paper describes an experiment involving the application of behavioural economics to those kinds of decisions.

Chapter 3
Methodology

3.1 Introduction to the Experiment

3.1.1 Goals of the Experiment

While project leaders are working on a construction project, they are required to make many day-to-day type decisions. These kinds of decisions may be considered "small" compared to the overall scope of the construction project. Nonetheless, these decisions are often made under financial risk, and, when aggregated, they can have a significant influence on the project cost and schedule. Construction project leaders use their experience and common sense when dealing with these kinds of decisions. As these decisions are made frequently, it is important to consider if construction project leaders are always able to make the most logical decisions. For instance, the literature review showed that, when people are facing financial risk, the way they make decisions changes. One might expect such people to make decisions according to the expected monetary value, but they do not do so in every case. It is thus appropriate to investigate whether project leaders working on construction projects are influenced by financial risk in similar ways when they are making their decisions. An example of such a decision made under risk would be construction project leaders having to decide whether to place concrete for the next day, knowing the chance of rain. Thus, the behavioural phenomena highlighted in the literature review might also happen in construction projects, and an experiment was designed to test for the existence of such phenomena in construction projects.

The experiment has three goals. The first goal is to determine the sensitivity of construction project leaders to different typical financial risks during the decision-making process. The second goal is to study the impact of key parameters on those decisions. It has been noted that certain parameters influence the decisions made by construction project leaders, often leading to them to act irrationally. The final goal is to estimate the financial impact that such illogical decisions can have on a construction project by comparing their financial outcomes with those of decisions made according to the expected monetary value.

The results expected from this experiment include important insights into how construction project leaders make their decisions when they are working on a construction project, and an understanding of how the environment influences the way they make those decisions. It is hoped that this new knowledge will lead to useful outcomes for construction projects in the real world, which can be anything from a set of tips on how project leaders can mitigate their biases when making decisions, to something akin to a calculator on a handheld device to help them stop chasing or avoiding risk illogically.

3.1.2 Form 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.

Various kinds of studies have been carried out to evaluate the reaction of people when they are facing risk. In most cases, when the subject of risk analysis is investigated, it is with a questionnaire survey about the construction industry’s perception of risk in their work environment. Previous studies asked construction leaders to classify and rate the risks as a function of their importance and of their impact on a construction project. The goal of these previous projects was to identify the key factor of a specific construction project in certain case studies, or some important financial aspect of a construction project such as the bidding process.

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 the risk or to avoid the risk, and it makes the result easier to analyze using conventional statistics.

The questionnaire used in this thesis 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 adequately approximates a controlled experiment with real consequences.
- Simplicity of analysis: Compared to an open-ended questionnaire, the answers, called options here, 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 the question can be directly interpreted. If the same questions are asked with an open-ended questionnaire, the results would be more difficult to interpret and analyze. It would require a different tool to analyze the data such as the ANOVA analysis, which would require more participants in the study. Giving only two possible options for each question simplifies the analysis of the answers, and it does not compromise the results. The multiple options system would not allow the possibility of attaining exact knowledge regarding whether the participants are avoiding the risk or not.

- Simplicity for understanding and focus: All the questions created for this questionnaire are as simple as possible in order to maximize the likelihood of understanding and to maximize the isolation of externalities that might influence the respondents' decisions. The situations described in every question are understandable for each participant in the project, so every participant is able to answer the questions of this experiment. The questions do not give too many details so as to not overwhelm the participants and to allow them to answer the questionnaire quickly. The use of close-ended questions, providing only two options, also helps the participants to focus on the risk linked to each question and forces them to deal with it by making a decision.
- Simplicity for answering: The close-ended questionnaire allows people to answer faster, and that is very important, because most of the participants respond to this questionnaire during work time, and it cannot take too much time. Moreover, more questions can be included if the participants do not need to spend a lot of time answering each question.
- Simplicity to build: The choice to simplify the questions, by not giving too many details in each question, makes the questions easier to create. The questions have a lot of associated criteria to account for (Section 2.2.1), so using only two possible options for answering each question makes it less difficult to formulate the questions.

Hence, the reasons for choosing a close-ended questionnaire rather than another kind of questionnaire are numerous. However, there are nevertheless certain disadvantages in using this kind of questionnaire for this experiment. One possible drawback would be that the simplification of the situation and the possible answers make the problem difficult to answer for some people. Project leaders, when they are making their decisions, are used to considering all possibly relevant parameters as well as the context of the construction project. So, when they are addressing these questions, if they do not find all the elements they normally use when they are making their decisions, they may add their own externalities. This can compromise the results of the questionnaire.

However, if the questions provided numerous details for each situation, it would be difficult to understand the interpretation and the choice of the participants, if they do not explain their choices. It would be impossible to know the reason for the participant's decision for each question, so it would be too difficult to link the answers with particular behavioural tendencies. With questions dealing with only a few parameters, on the other hand, the choice is easier to interpret, and it is less difficult to test for the behavioural tendencies which underlie the choices. These kinds of questions allow the participant to focus on only a few details, which facilitates analysis of their reaction about these details. These are the reasons why a close-ended answers questionnaire has been chosen for this experiment.

3.1.3 Participation in the Experiment

3.1.3.1 Sample Size

For this experiment, construction project leaders working on construction projects are targeted to answer the questionnaire. The term "construction project leader" refers to each participant of a construction project who has to make quotidian decisions on a construction project: from the foremen, who make their decision directly from the construction site, to the project managers.

As the potential participants of this experiment represent a population of more than 100,000 people, it is impossible to ask everybody to participate in this study. Only a sample of this population will answer the questionnaire of the experiment, and then the results of the questionnaire from that sample will represent the tendency of what the global results would be. One of the first elements that needs to be determined is the sample size. While every sub-class could be considered separately, because their answers could differ, project leaders are grouped together as a class to sample, because of limited resources for the study.

To calculate the sample size, sampling errors and biases have to be taken into consideration. The sample size must be suitably selected to accurately reflect the actual population size of more than 100,000 people. The definitions for the sampling errors and biases are:

- Selection bias: When the true selection probabilities differ from those assumed in calculating the results, it is not certain that the sample accurately represents the population. The confidence interval is the probability that the sample influenced the result. The most common value is 95%. This means that there is a 95% chance of obtaining the same result if the experiment is done a second time. If the sample does not consist of people selected randomly but rather people selected according to certain representative groups, then a factor needs to be added to the sample size.
- Random sampling error (or margin of error): This refers to random variation in the results due to the elements in the sample being selected at random. The common value for this is 5%. This means, for example, that if the value found is 70%, the real answer is between 65% and 75%.

The sample mean is a point estimate. It is useful because the distribution is known. However, as a point estimate it has the undesirable property that its distance from the true population mean is unknown; it is unlikely to exactly equal it. So, a confidence interval is computed from the data derived from the questionnaire, which is an estimate that combines the variability and sample size. Usually, when a confidence interval is built, it is with a 95% confidence level. In this case, on repeated sampling from the population, 95% of the numerical intervals generated are expected to contain the population mean; by chance, 5% will not.

In Figure 4, a graph is presented with a 95% confidence level for the confidence interval, linking the sample size (ordinate) and the margin of error (abscissa) by using the statistical formula introduced in Equation 1.

$$n = \frac{t^2 p(1-p)}{m^2} \quad \text{Equation 1}$$

Where:

- $n = Sample\ size$
- $m = Margin\ of\ error$
- $p = Sample\ mean$
- $t = Factor\ linked\ with\ the\ confidence\ level$

For instance, to have a 95% confidence interval with a margin of error of +/- 15 %, a minimum of 49 participants (this is the case when the sample mean is 50%) need to answer the questionnaire.

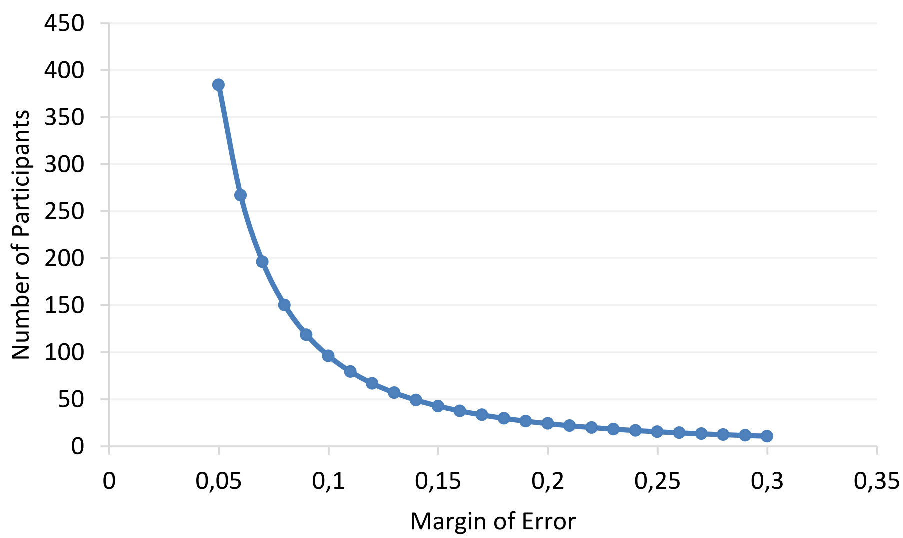

Figure 4: Graph Plotting the Number of Participants in Function of the Margin of Error

3.1.3.2 Contact with the Participants

Once the number of participants for this experiment was defined, the next step was to contact the potential participants and introduce them to the experiment. This part of the experiment involved briefly explaining the questionnaire to the potential participants. The challenge was to describe in a few lines what the experiment involves, without giving too many details, so as to not influence the answers of the potential participants.

The first participants of this study were found thanks to Dr Haas's contacts in CII and were mainly project managers. It was by e-mail that the first contact was made with the participants. In this e-mail, an information letter was sent to explain the project and what exactly was asked of the participants.

This letter was constructed according to the guidelines of the Office of Research Ethics (ORE) of the University of Waterloo. Completing the ORE form is compulsory when an experiment involves the participation of people, and this was the case for the questionnaire. The ORE asked the conductors of the experiment to follow some general ethical principles for experiments involving people. The ORE also requested the creation of certain documents, including the following:

- An information letter (Appendix B): The purpose of this document is to give all the useful information about the experiment to the potential participants to ensure that they have been adequately informed. The information letter has to include information such as the names of the investigators and how to contact them, a statement explaining the project and its purpose, and a description of the procedure used (in this case it was a questionnaire).
- A cover form (Appendix C): This document is compulsory for studies using anonymous questionnaires, such as this one. This document conveys some information from the previous

letter and asks the potential participant his or her consent to participate in the experiment. The cover letter has to be returned with the questionnaire to make sure that all the participants have read the information letter and are aware of all the pertinent details.

- A feedback letter (Appendix D): The goal of this letter is to give some feedback to the participants about the questionnaire they answered, to clarify what they have done and to explain how it is going to contribute to the field in question.

These were the different steps that were taken in contacting the potential participants for this experiment. When a survey is conducted, the participants should normally be chosen randomly. In this case, however, it was difficult to select them randomly, because the participants comprise a very dispersed, specialized and mobile population. It is mostly through personal contacts that participants were found. As the contacts list was small, it was impossible to randomly choose the participants from a list. Nevertheless, the participants for this experiment are based in different locations and are working in different companies, so they do represent the population reasonably well.

During the recruitment of participants, the proportion between foremen and project managers participating in this experiment was made as equal as possible; it was ensured that approximatively the same number of participants were foremen and project managers. In the same way, the age range of the participants was large. It was important to have both experienced and less-experienced participants for this experiment.

3.2 Construction of the Questionnaire

3.2.1 Situations for the Questions

For this experiment, a questionnaire was used with two possible options for each question. At the beginning of the project, the first problem was to know how many questions would be in the questionnaire, what kind of questions would be included and how it would be presented to the participant.

Essentially, the questions were based on the original decision-making studies. In articles such as "Prospect theory: An analysis of decision under risk" (Kahneman and Tversky, 1979), the different questions presented to the participants were also close-ended questions with two possible options, and they were linked with behavioural tendencies. Those studies showed that expected utility theory has some gaps. In every case, they were using what can be called "behavioural tendencies." These behavioural tendencies correspond to patterns shown by people when they are facing risk in a situation: they will no longer make decisions in accordance with the expected monetary value.

For this experiment, it was decided to build the questions around these behavioural tendencies, but construction project situations that might lead decision-makers to exhibit the behaviours of interest had to be found first. This was one of the most important parts of the construction of the questionnaire: creating situations in which a behavioural tendency appears, and making it realistic for the participant.

This was a difficult undertaking, because the situations had to be real, but the questions could not contain too much information for multiple reasons:

- If a question included a lot of information, it would take more time for the participant to read it, and by the same token, it would take more time to answer it, because he or she has to take all the elements into consideration while thinking of an answer. The participants, however, do not have a lot of time to answer questionnaires such as this one.

- If a question included a lot of information, it would be very difficult or impossible to understand how the participants arrived at their decisions. For this to be achievable, the participants would have to explain for each question how they arrived at their particular choice. This can take a lot of time, which most of the participants do not have. It would also be very difficult to summarize the answers, because people can make the same decision for different reasons. So, the experiment would need more participants to have significant results, which is impossible in this case.

- If a question included a lot of information, a participant who is not specialized in the kind of area described in the question may not be able to fully understand it. The questionnaire was sent to construction project leaders (project managers, foremen, etc.) who are working in civil engineering in general, so the questions could not be too specific in one area, or else all the participants would need to pertain to this one particular area. However, it is very difficult to have a significant number of participants who are specialized in the same area answer this questionnaire.

- The goal of this experiment was to test the reaction of project leaders when they are facing risk. So, the questions have to lead them to this kind of problem. If there are too many parameters, the behavioural tendency can be lost in the amount of information. It might be from other criteria that the choice would be made.

So, the questions had to be simple, in the sense that they could not contain too much information, to ensure that the participants would have to deal directly with risk in keeping with the purpose of the experiment. This work was the prolongation of the work of another student advised by Dr Haas, Peixian Li, and it was based on her work that the first versions of the questions were created (Li, 2013). A list of the situations she used in her questions is as follows:

- Chance of rain for the day after. (This was a question pertaining to emotional influence.)
- Chance of accident on a construction site. (This was a question pertaining to accident influence.)
- Building bored piles with the possibility of using less reinforcing steel. (This was a moral question to determine if respondents would choose to "cheat.")
- Choice between a contractor you know and another unknown but cheaper one. (This was a question about the trust put in someone known versus unknown.)

The questionnaire evolved out of this preliminary work. The idea of an "accident question" was abandoned, because this previous study involved Chinese participants, and this one is targeted to North American project leaders. The policy pertaining to accidents is not the same throughout the world. In North America, as in some other places, people will always take zero risk if one of the construction workers would be in danger of hurting himself or worse. So, this question was abandoned.

Other questions were kept but with a few changes. The idea of dealing with the weather was kept, but the emotional influence was abandoned. Also, the idea of non-compliance or "cheating" was kept for the new questionnaire. The question dealing with the choice of the contractor could not be kept because it was asked from a different point of view. The original question asked about which contractor the participant wants to choose, but, as the new questionnaire involved project leaders as participants, the question could not be kept this way. However, the idea of trust was kept and transferred to another question, which will be introduced later in this chapter.

All the questions in the questionnaire should represent realistic scenarios which could potentially happen on a construction project. Moreover, the questions should pertain to day-to-day decisions that project leaders deal with regularly while working on a construction project. Furthermore, the questions should involve small amounts of money compared to the project cost performance.

Other questions were added to Peixian Li's list (2013) to expand the set of questions:

- A question dealing with quality of materials. This question was built around a specific behavioural tendency, the certainty effect. The material chosen for this question is shingles.
- A question about the completion time. This was a question involving the time to install a system with one proposition more attractive but with a risk. Due to the limit in the number of questions, this question was not retained in the end. Also, the behavioural tendency pertaining to this question was already present in another question, so this question was less important than the other ones.
- A question about the perception of change. This one deals with the preference that people have towards taking an option they are familiar with, rather than a new one. (This is the same idea as the trust question introduced before, but this time it is dealing with construction methods and not contractors, and the amounts involved are much smaller.)

In the end, four situations were chosen for use in the questions:

- Weather (chance of rain)
- Quality of materials (shingles)
- Construction methods (perception of change)
- Non-compliance to specifications (bored piles)

The next step was to link the situations with a behavioural tendency.

3.2.2 Associated Behavioural Tendencies

For each of the situations introduced above, a behavioural tendency had to be connected with it. Each question had to evoke a behavioural tendency so as to study the reaction of the participants when they are facing risk.

As was shown by the literature review, various behavioural tendencies, such as certainty effect or loss aversion, can create illogical reactions when people are facing risk. Different behavioural tendencies will be used in this questionnaire once, each one associated with one question. However, each of these questions is repeated with different project conditions modifying them, so question sets are created, which are described later.

Some behavioural tendencies were difficult to apply. In fact, building a realistic situation with simple positive or negative outcomes was challenging. Each question should represent a situation which can happen often on a construction project, so the questions mainly deal with losses or spending.

This part of the questionnaire design, linking a situation with a behavioural tendency, is delicate. Kahneman and Tversky (1979) have found that people react differently to a situation depending on whether the question involves positive or negative prospects. Moreover, in some construction situations, the questions deal with both kinds of prospects. Thus, linking the questions to a particular behavioural tendency is not an easy task, and this step has to be done carefully.

3.2.2.1 Construction Methods – Perception of Change

This question set is different than the other ones which follow. In this question set, two options are offered to the participants in each question. One option involves something that they are familiar with, while the other option is cheaper but is something completely new to them.

This question set deals with the fact that people are afraid of change. People feel safer doing or using something they know than something unknown. In this question, the risk is not represented by a percentage like the other questions, but only by the fact that the option is new to the participant. This new option does not require any special competence, so the only risk of this option is the novelty of the technical method offered.

An example of a question used in this question set is shown in Figure 5. The costs chosen for this question will be explained later in this chapter (Section 3.2.4.1).

Question 10:

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

You face a problem on a construction site, and there are 2 technical ways (A and B) to fix it. Which one are you going to choose? The differences between the 2 ways are:

- *Decision A: This is a technical way that you are used to. You have always done things this way. It costs **$20,000**.*

- *Decision B: This is a new way for you. You have never done this way but you know that some colleagues often do this way, and there is no special competence required. It costs **$19,000**.*

A ☐ *B* ☐

Figure 5: Example of a "Construction methods – Perception of Change" Question

3.2.2.2 Quality of Materials (Shingles) – Certainty Effect

The certainty effect is a psychological phenomenon 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 evokes certain 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 (Shingles) – Certainty Effect" question set deals with this behavioural tendency. The questions offer one option that involves complete assurance of quality but that is expensive, and a second option in which the assurance of quality is very close to, but not quite, total, and this option is less expensive than the first option. Here, it is really important that the assurance of quality for the second option is close to 100% or else another parameter would enter into the question such as the time of replacement or shipment.

An example of a question used in this question set is shown in Figure 6. The probabilities and costs chosen for this question set will be explained later in this chapter (Section 3.2.4.2).

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 6: Example of a "Quality of the Materials (Shingles) – Certainty Effect" Question

This question set deals with shingles, but no specification is needed to answer it. Furthermore, the probability for the option varies between 93% and 97%. The participants, when they are answering this question set, should be attracted by Option B, because the absolute certainty of 100% evokes a sense of certitude and people feel more confident when they are making this kind of decision.

3.2.2.3 Bored Piles – Non-Compliance

This question set offers the possibility to project managers to save money by getting around the rules, but it gives them a large penalty if they are caught. The goal of this question set is to see if people will ignore the rules to gain money. This question set deals with the morality of the participants by offering as one option a usual choice, and as the other option a more rewarding choice, but this option contains a high penalty with a small probability.

An example of a question used in this question set is shown in Figure 7. The probabilities and costs chosen for this question set will be explained later in this chapter (Section 3.2.4.3).

<u>Question 8</u>:

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

You are constructing a set of bored piles and there are two ways for finishing them. Which decision are you going to make?

- *Decision A: Do as designed. This way it will cost **$3,000**.*

- *Decision B: Use less reinforcing steel. It will be safe, and it will only cost you **$2,500**, but it does not meet design specifications. There exists a **2%** possibility of being found using less reinforcing steel by the client. If found, you will lose **$25,000**. But, there is no risk that you will be fired by your company.*

A ☐ *B* ☐

Figure 7: Example of a "Bored Piles - Non-Compliance" Question

As is explained in the second option shown in Figure 7, if the client discovers that the bored piles do not meet design specifications, the person who has made this decision will not be fired, which would be the case if it was a company decision to make this choice. The participant has only to focus on the risk of getting a fine with this option. For this question set, the percentage of getting caught varies between 1% and 5%, which is a very small probability.

3.2.2.4 Weather – Loss Aversion

This last question set deals with loss aversion. An important concept in economics and decision theory, loss aversion refers to people's tendency to strongly prefer avoiding losses to acquiring gains. Some studies suggest that losses are twice as powerful, psychologically, as gains.

The behavioural tendency of loss aversion is associated with the chance of rain question set. The fact that it may rain the next day corresponds to potential losses for the construction project.

An example of a question used in this question set is shown in Figure 8. The probabilities and costs chosen for this question set will be explained later in this chapter (Section 3.2.4.4).

Question 21:

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

You must decide whether to work tomorrow on a large concrete placement exposed to the weather. There is a ***80%*** *chance of rain. Which decision will you make?*

- *Decision A: You decide to work tomorrow. If it rains, you will experience net losses of* ***$4,170****. If it does not rain, you will experience net earnings of* ***$880****.*
- *Decision B: You decide to not work tomorrow. As a result, you will experience net losses of* ***$3,160*** *whether it rains or not.*

A ☐ *B* ☐

Figure 8: Example of a "Weather – Loss Aversion" Question

With all the tools available on a construction site, it is possible to predict the chance of rain and price the risk linked to it (Chan and Au, 2007). In this question set, both options contain losses: one small but sure to happen, and the second one bigger but with a chance of not happening.

For this question set, the chance of rain is between 50% and 80%, because if the probability of rain is small, every project leader would decide to work, whereas if the chance of rain is close to 100%, people would never choose the option of working without considering the potential gains and losses. The risky option for the decision-maker is to choose to work the next day and the safe one is to decide to not work the next day.

After designing the questions, the next step was to put them together so as to create the questionnaire.

3.2.3 Layout of the Questions

3.2.3.1 Parameters – External Influence

When project leaders are working on a construction project, they can be influenced by many parameters. Those parameters can influence their choice in day-to-day decisions, and affect their decisions when they are facing risk. The literature review showed some classifications for key parameters, which may influence project leaders' decisions (Chan et al., 2004b).

For this experiment, it was decided that each question set would be asked in different conditions:

- On budget and on schedule
- Over budget
- Under budget
- Ahead of schedule
- Behind schedule

As the most important parameters of a construction project are the budget, the time schedule and the quality of materials (Chan et al., 2004b), asking the participants the same kind of question while changing the state of the project cost performance or the time schedule could cause them to make a different decision.

Due to a limitation in the number of questions in the questionnaire, the time schedule parameter was abandoned.

In the end, three budget conditions were chosen, and each of the questions is asked three times, one time per state. These conditions can be seen as an external influence on the decisions the participants have to make, which represent classic day-to-day situations project leaders face. From a strictly financially logical point of view, their decision should not change because of this external influence; they should act according to the computation of expected monetary values, as is assumed by standard preference theory. However, as explained earlier, some gaps have been revealed in this theory, and the question asked in this part of the experiment is for the purpose of knowing if an external influence such as the cost performance can increase or decrease these gaps.

For each of the three external influences, the question is introduced by a short sentence that sets the cost performance:

- *You are working on a project which is **on time** and **on budget**.*
- *You are working on a project which is **on time**, but you are **25% over budget**.*
- *You are working on a project which is **on time**, but you are **25% under budget**.*

The choice was made to not put an amount when the construction project is under or over budget; either an amount for the budget or an amount of the difference with the budget. The goal of each of the statements is to put the participant in a particular kind of situation. If an amount was used in the statements, this would prompt people to take this value into consideration when they are making their decision; however, it is only the situation of working on a construction project that is over or under budget which is intended here. The choice of the value of 25% was made to put the construction project in a significant state of under or over budget. The point of this value is that, it is not so small as to be considered as negligible, but not so large as to be irrecoverable.

3.2.3.2 Expected Monetary Values of the Options

The expected monetary value of an option corresponds to the sum of the cost and the probability that it can occur (Equation 2).

$$EV = \sum Cost * Probability \quad \text{Equation 2}$$

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

- The expected monetary values of both options are equal.
- One option is more advantageous than the other one.

These two cases are used in the questionnaire for different objectives. The first case, when the expected monetary values of both options are equal, is for the purpose of highlighting the presence of a behavioural tendency. As shown by the case studies presented by researchers in decision-making under risk (Allais, 1953; Kahneman and Tversky, 1979), if from two equivalent options in terms of expected monetary values one is preferred to a second one, this suggests a behavioural tendency in the answers of the participants. People will be averse to the risk-taking option, so they will try to avoid it if possible. If a behavioural tendency can be quantified, and it represents utility, then a utility function can be used to calculate expected utility, which is more relevant than expected monetary value, in some cases, but not typically more economically efficient.

The second case, in which the expected monetary values are different, has a different goal. This time the riskier option is advantageous compared to the other one. The objective of this question is to discover how many people will choose to avoid the risk and then compute how much money is lost on account of avoiding the risk. For the remainder of this thesis, the expected monetary values will be called more simply expected values.

This principle is not applicable to every question set. For the “Construction methods – Perception of Change” question set, no probabilities are involved, and if the two options had the same expected values, the question would not make sense. So, for this question set, only the case in which the expected values are different was used in the questionnaire.

For the question sets “Quality of the materials (Shingles) – Certainty Effect” and “Bored piles – Non-Compliance,” the two cases were applied. In each of these situations, the two options have the same expected value for the first case; and in the second case, the risk taking option will be more advantageous. So, for the “Quality of the materials (Shingles) – Certainty Effect,” the option in which the probability is close to 100% but that is inferior was advantageous; and for the “Bored piles – Non-Compliance,” the option that does not meet the design specification was advantageous in terms of expected value.

Lastly, the “Weather – Loss aversion” set is also different. Since in this question, people are expected to be loss averse, it was decided that a third case would be added for this question, such that both options have a case for which they are the preferred choice. The reaction of construction project leaders is difficult to predict, as they might be more risk averse than people in general. The decision to use three cases for this question set has for its objective to facilitate an understanding of how this specific population of project leaders would consider this risk.

3.2.3.3 Layout of the Questions

All of these question sets appeared in the questionnaire. The layout of the questions in the questionnaire was done carefully so as to avoid the answering of a question influencing the following one. Accordingly, the questions were mixed randomly in the questionnaire, so that two similar questions did not appear in sequence, and of course, the values involved were different for each question. The goal was to hide, for instance, the fact that two questions are similar in terms of expected value but different in terms of their external influence.

The layout of the questions in the questionnaire is shown in Table 1. The questions are defined by the criteria introduced earlier: behavioural tendency, external influence and difference between associated expected values. The questionnaire is shown in Appendix A.

It took approximatively 20 to 30 minutes for the participants to answer the questionnaire. The questionnaire was kept relatively short, because they were responding to it during their work hours, and it would have been more difficult to find participants if the questionnaire took more time to answer.

Table 1: Distribution of the Questions in the Questionnaire

Situations – Behavioural Tendencies	Expected Values	External Influence	Question number
Construction Methods – Perception of Change	Expected values different	Under Budget	Q4
		On Budget	Q10
		Over Budget	Q18
Quality of the Materials (Shingles) – 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

3.2.4 Choice of the Values – Decision Trees

Now that the question sets had been selected, values needed to be chosen to make the scenarios credible. When the participants were answering the questionnaire, it was important for them to have the impression that these scenarios could possibly happen in the project they were working on at that time, or in an earlier project. Also, as some questions were repeated, the values had to be different to ensure that the participants were not comparing the questions before answering them.

In order to show the expected values linked to the different options of each question, which would help clarify subsequent analysis, a decision tree was made for each of them, as shown in the following section.

3.2.4.1 Construction Methods – Perception of Change

There are no probabilities in this question set, so the goal for this question set is to establish the difference between the amounts of the two options. This difference should be not too large or else the participants would be more inclined to choose the smaller amount. However, if the difference between the amounts is negligible, all the participants would have the opposite reaction, thereby negating the objective of the question set. The difference between the two amounts was decided to be within 5 to 10%.

Furthermore, the proportion of the difference for the three questions should be constant or else it would be difficult to compare the results of the three questions. So, the goal was to make the values different but with a constant proportion of difference.

The decision trees for the three “Construction methods – Perception of Change” questions are shown in Figure 9, Figure 10 and Figure 11.

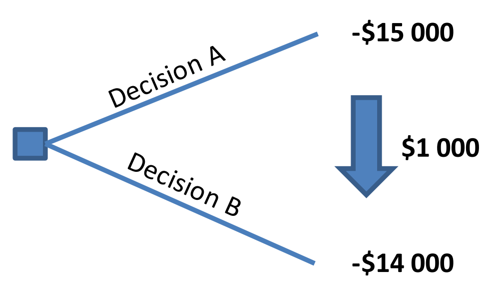

Figure 9: Decision Tree – Question 4 – Construction Methods – Perception of Change – Expected Values Different – Under Budget

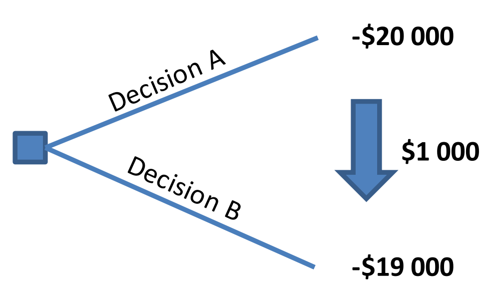

Figure 10: Decision Tree – Question 10 – Construction Methods – Perception of Change – Expected Values Different – On Budget

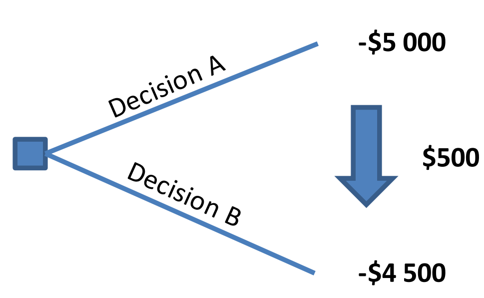

Figure 11: Decision Tree – Question 18 – Construction Methods – Perception of Change – Expected Values Different – Over Budget

In these three questions, the amounts of the costs are round numbers, so the participants can clearly see which of the options has the best expected value. The difference between the amounts of the two options varies between 5 and 10% in terms of proportion, and between $500 and $1 000 in terms of amounts. The three questions deal with different values, but they are still equivalent in terms of the ratio between the two options.

3.2.4.2 Quality of the Materials (Shingles) – Certainty Effect

This time, there are probabilities in the question set, so the values have to be chosen more carefully. The probabilities for a shingle to not crack or break during the installation vary between 93 and 97%. This interval has been chosen according to the following criteria: the probability of the shingles breaking cannot be too low, or else whatever the price, the participants are never going to choose the higher cost shingles; if the probability is close to 100%, it will be very difficult to find realistic amounts for the price of the shingles – the reliable shingles will become exorbitantly expensive and the question will not be credible.

The prices of the shingles vary between $80 and $300. Since no specific information is given about the shingles, this price range was found to be credible. For each option, the expected value is computed. For Shingles B, computing the expected value is easy because the associated probability of not cracking or breaking is 100%. However, computing the expected value for Shingles A is more difficult because the damaged shingles have to be replaced by the same kind of shingles, which could also become damaged. Although this process can in theory be infinite, the answer does converge to a value. It is this value which appears in the decision tree shown in Figure 12.

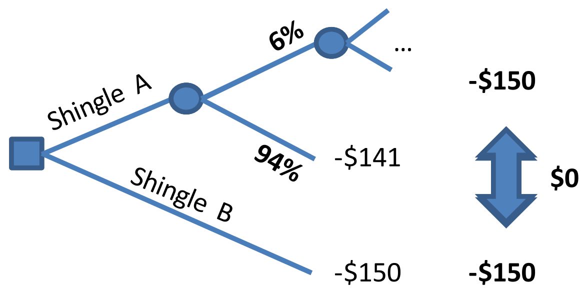

Figure 12: Decision Tree – Question 6 – Quality of the Materials (Shingles) – Certainty Effect – Expected Values Equal – Under Budget

To compute the exact expected value of the cost of Shingle A, a sequence of the cost of the different possible cases is created. The first term (u_0) will correspond to the fact that the shingle will not crack during the installation (Equation 3). The second term (u_1) will correspond to the fact that the shingle will crack in the first installation but not in the second installation, and so on. The general term is shown in Equation 4.

$$u_0 = 0.94 * -\$141 \qquad \text{Equation 3}$$

$$u_n = u_0 * n * \beta^n \qquad \text{Equation 4}$$

β corresponds to the probability of breaking during the installation, which is 0.06 here.

The expected value of this option corresponds to the sum of the terms of this sequence. So, the series $\sum u_n$ is considered (Equation 5).

$$\sum_{n=0}^{+\infty} u_n = \sum_{n=0}^{+\infty} u_0 * n * \beta^n = u_0 * \sum_{n=0}^{+\infty} n * \beta^n \qquad \text{Equation 5}$$

The series $\sum_{n=0}^{+\infty} n * \beta^n$ is convergent if $\beta < 1$, as is the case here. The math has shown that this series converges to $\left(\frac{1}{1-\beta}\right)^2$ (Equation 6).

$$\sum_{n=0}^{+\infty} u_n = u_0 * \left(\frac{1}{1-\beta}\right)^2 \quad \text{Equation 6}$$

In the case of this question, the expected value for this option is shown in Equation 7.

$$\sum_{n=0}^{+\infty} u_n = 0.94 * -\$141 * \left(\frac{1}{1-0.06}\right)^2 = -\$150 \quad \text{Equation 7}$$

This demonstration can be used for all the questions built around this situation. Their associated decision trees are shown in Figure 12, Figure 13, Figure 14, Figure 15, Figure 16 and Figure 17.

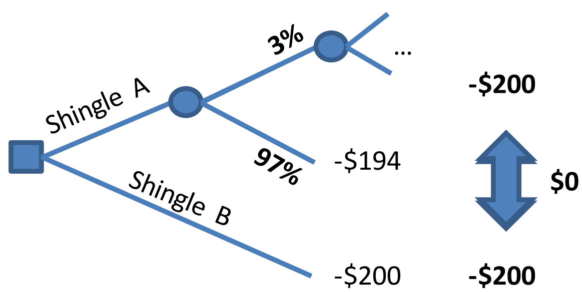

Figure 13: Decision Tree – Question 15 – Quality of the Materials (Shingles) – Certainty Effect – Expected Values Equal – On Budget

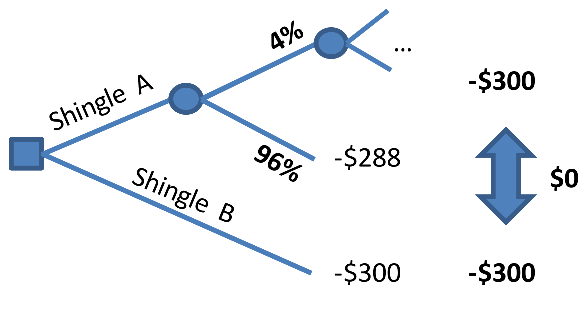

Figure 14: Decision Tree – Question 20 – Quality of the Materials (Shingles) – Certainty Effect – Expected Values Equal – Over Budget

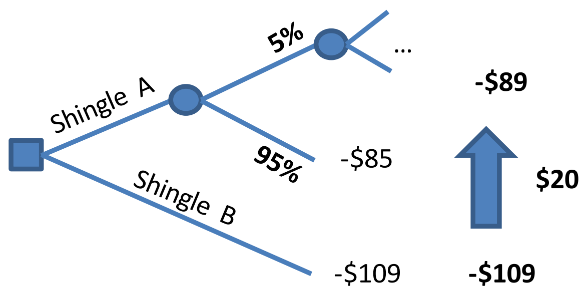

Figure 15: Decision Tree – Question 22 – Quality of the Materials (Shingles) – Certainty Effect – Expected Values Different – Under Budget

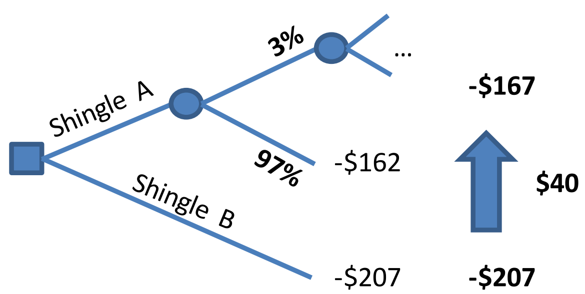

Figure 16: Decision Tree – Question 2 – Quality of the Materials (Shingles) – Certainty Effect – Expected Values Different – On Budget

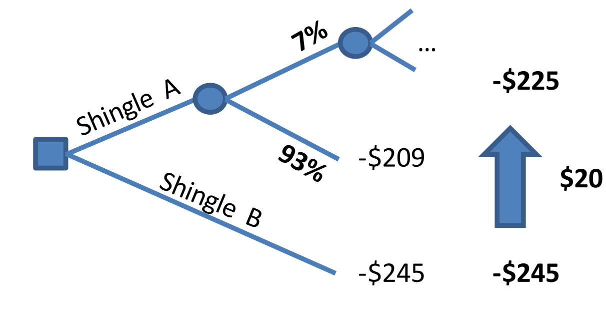

Figure 17: Decision Tree – Question 12 – Quality of the Materials (Shingles) – Certainty Effect – Expected Values Different – Over Budget

For two of the three questions in which the expected values are different, the difference between the amounts of the two expected values is $20. This amount represents approximatively 10 to 20% of the price of shingles in each question. This amount is not negligible compared to the price but it is still small, so it is not obvious that Shingles A are more advantageous than Shingles B. This is why, in the case in which the construction project is on budget, the difference between the two amounts is $40. For this question set, the participants do not need to do any calculations or reasoning to distinguish the best option. This question is defined as an "obvious" question, a question in which the best answer is obvious in terms of expected values. Its objective is to detect if some participants will avoid the risk anyway, even if the risky option appears more advantageous in terms of expected value.

3.2.4.3 Bored Piles – Non-Compliance

As with the previous question set, the values for the percentage chance of being discovered to be using less reinforcing steel and the amount of the cost difference have to be chosen. This question set deals with a very high risk but with a very low probability. So, it was chosen that the percentage chance of being found using less reinforcing steel would be small, from 1 to 5%. The cost of the bored piles varies between $500 and $10 000. For each question in the set, Option B offers a smaller price which can be half of the price of Option A. While the risk has a low probability, its impact is high. The fine associated with Option B is between 5 and 10 times the price of the bored piles.

To compute the expected value of Option B, the cost of the fine times its probability is added to the price of the bored piles which is in any case paid. The decision trees associated with the "Bored piles – Non-Compliance" questions are shown in Figure 18, Figure 19, Figure 20, Figure 21, Figure 22 and Figure 23.

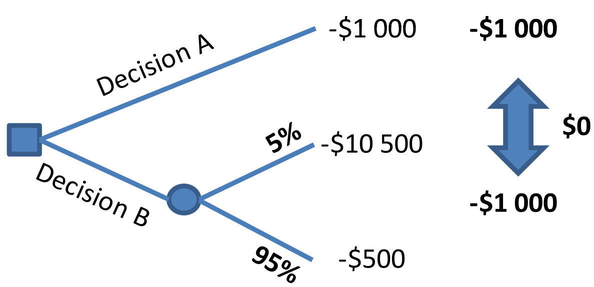

Figure 18: Decision Tree – Question 11 – Bored Piles – Non-Compliance – Expected Values Equal – Under Budget

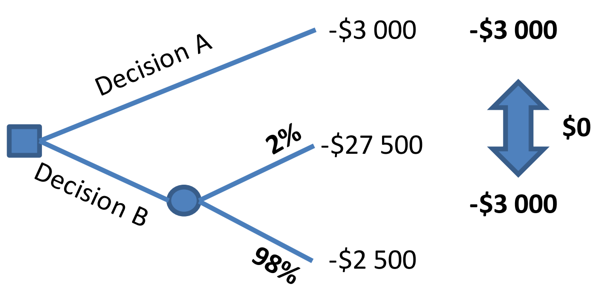

Figure 19: Decision Tree – Question 8 – Bored Piles – Non-Compliance – Expected Values Equal – On Budget

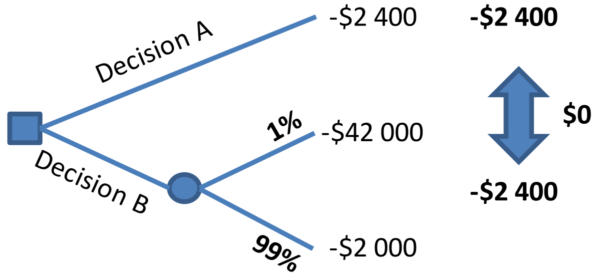

Figure 20: Decision Tree – Question 5 – Bored Piles – Non-Compliance – Expected Values Equal – Over Budget

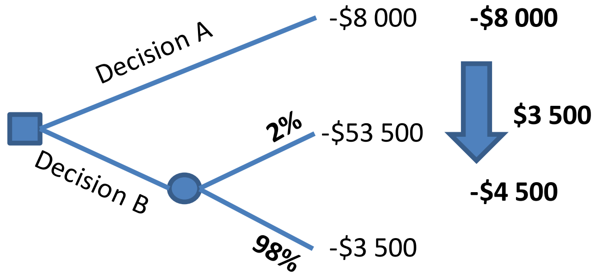

Figure 21: Decision Tree – Question 17 – Bored Piles – Non-Compliance – Expected Values Different – Under Budget

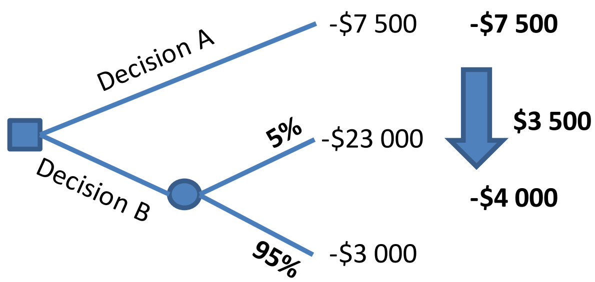

Figure 22: Decision Tree – Question 14 – Bored Piles – Non-Compliance – Expected Values Different – On Budget

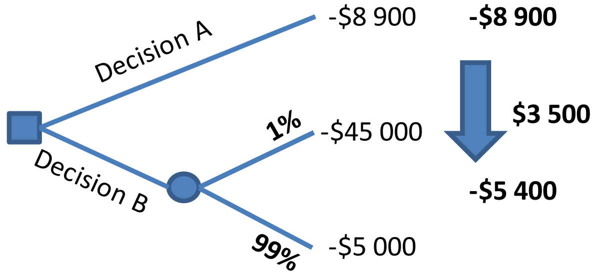

Figure 23: Decision Tree – Question 23 – Bored Piles – Non-Compliance – Expected Values Different – Over Budget

For the three questions in which the expected values are different, the difference between the amounts of the two expected values is $3 500. This amount is the same for the three questions to make it easier to compare the results. This amount represents approximatively half of the value of the bored piles when they are as described in Option A. For this kind of question, there is no need to build one "obvious" question, because all three questions, with a difference in their expected values, are already "obvious".

3.2.4.4 Weather – Loss Aversion

In this scenario, the uncertainty relates to the chance of rain the next day, which could affect planned work. The chance of rain was set to vary between 50 and 80%, as explained above. This question set has the particularity of being the only one to have, at the same time, positive and negative incomes in the options of their answers. So, this kind of question will be more difficult to analyze in terms of expected values for the participants. Additionally, in this kind of question, the amounts are not round as in other questions; this was to maintain the difference between the expected values of the options.

The amounts vary between approximatively $1 000 and $5 000 for the potential losses, and between $500 and $2 000 for the potential earnings.

To compute the expected value for Option A, the expected incomes are added by taking into consideration the probability linked to them. The decision trees of the nine "Weather – Loss Aversion" questions are shown in Figure 24, Figure 25, Figure 26, Figure 27, Figure 28, Figure 29, Figure 30, Figure 31 and Figure 32.

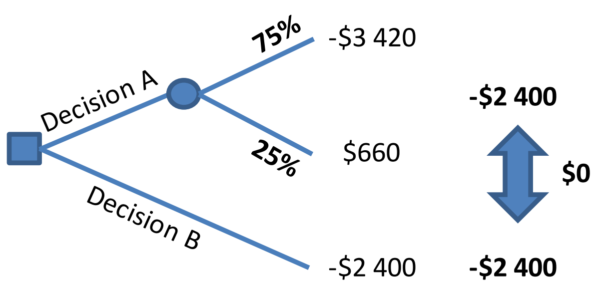

Figure 24: Decision Tree – Question 1 – Weather – Loss Aversion – Expected Values Equal – Under Budget

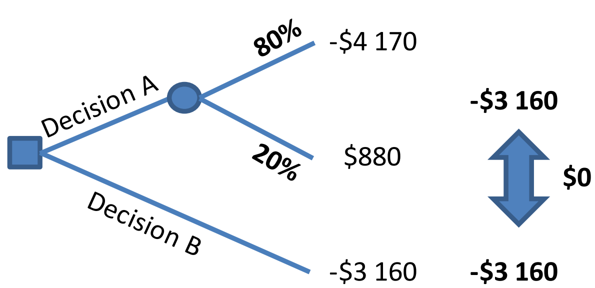

Figure 25: Decision Tree – Question 21 – Weather – Loss Aversion – Expected Values Equal – On Budget

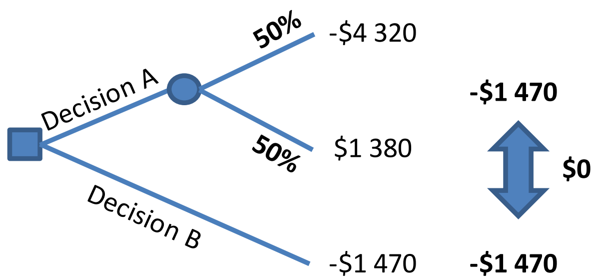

Figure 26: Decision Tree - Question16 – Weather – Loss Aversion – Expected Values Equal – Over Budget

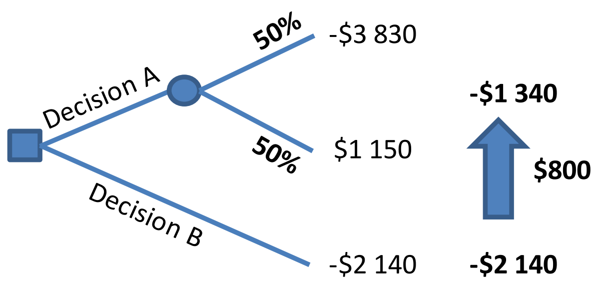

Figure 27: Decision Tree – Question 19 – Weather – Loss Aversion – Expected Values Different (A Advantaged) – Under Budget

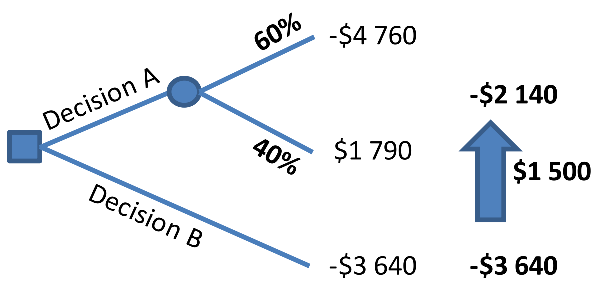

Figure 28: Decision Tree – Question 13 – Weather – Loss Aversion – Expected Values Different (A Advantaged) – On Budget

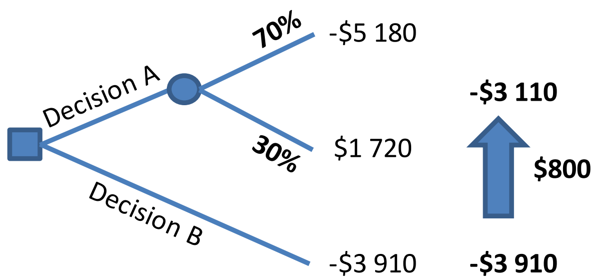

Figure 29: Decision Tree – Question 7 – Weather – Loss Aversion – Expected Values Different (A Advantaged) – Over Budget

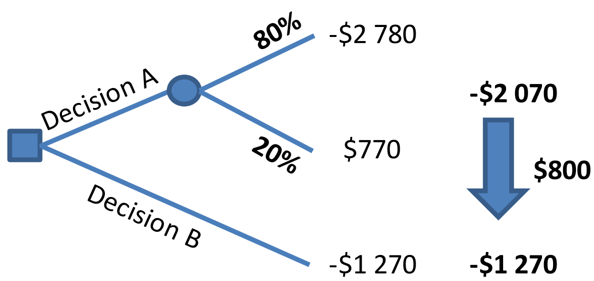

Figure 30: Decision Tree – Question 24 – Weather – Loss Aversion – Expected Values Different (B Advantaged) – Under Budget

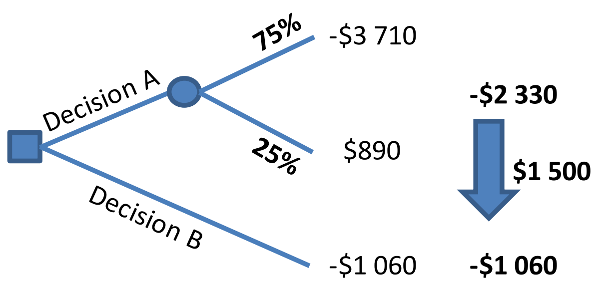

Figure 31: Decision Tree – Question 3 – Weather – Loss Aversion – Expected Values Different (B Advantaged) – On Budget

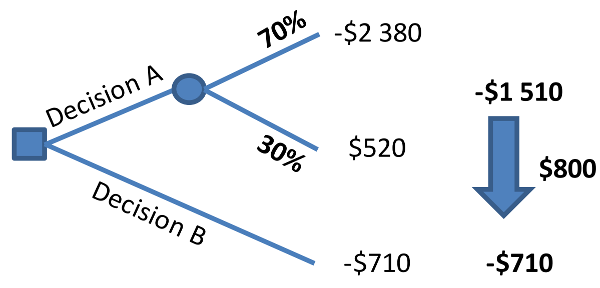

Figure 32: Decision Tree – Question 9 – Weather – Loss Aversion – Expected Values Different (B Advantaged) – Over Budget

For the six questions in which the expected values are different, the difference between the expected values is $800, except for the question in which the construction project is on budget, where the difference is $1 500. Since this time the participants were expected to be loss averse, it was unknown if they were going to choose to work or not, so the choice was made to have two cases and have a different option be advantageous for each case. The difference between the expected values is the same for each case.

Following the same principle as the “Shingle – Certainty Effect” question set, an “obvious” case was made in which the construction project is on budget. The difference is twice as large in this situation. As in the shingle question, in this specific question, it is very difficult not to perceive the answer with the best expected value in this question. The goal of this question is to discover the percentage of people who will avoid a risk even if the other option is clearly more advantageous in terms of expected value.

Before finalizing the questions that would be on the questionnaire, some tests were carried out to attain insight into how people were answering the questionnaire, so that adjustments could be made to it if necessary.

3.2.5 First Test of the Questionnaire

The question sets introduced so far were the final questions that were chosen for the questionnaire. However, before obtaining this final form of the questionnaire, some trials were conducted to assess the questionnaire and suggest ways to improve it.

Since for this experiment, the number of potential participants that were accessible was small, the trials were carried out with the cooperation of graduate students working in the Department of Civil Engineering at the University of Waterloo. All of the students had some kind of experience in construction, even if it was not exactly the same as that of the project managers or foremen who answered the final questionnaire for the experiment. These trials were very useful, because they showed whether a question had the expected impact or not. For instance, in the initial version of the questionnaire, the percentage chance of the shingles breaking for the shingle question was clearly not sufficient and this trial was a good occasion to detect this problem.

Moreover, on account of the questionnaire trial results, some of the wording of the questions was changed to make the questions clearer and more effective. For example, for the "Bored piles – Non-Compliance" question, the word "cheat" was initially used in the questions; however, since this word had a very negative impact on the participants, it was decided to replace it with the words "using less reinforcing steel," which is less direct: an ethical framework is required to interpret it as "cheating."

The main goal of these trials was to make sure that the participants correctly understood the questions. As explained before, the questions cannot have too many details; however, sometimes the participants would say that they needed more details to make a decision. Furthermore, they were asked how they made their choice so as to understand which parameters were influencing them. It was useful to know if a parameter could interfere in the choice of the participants. Changes were made based on this feedback. Once these changes were implemented in the questionnaire, it was ready for use in the experiment.

3.3 Progress of the Experiment

3.3.1 Feedback from the Participants

After the trials, the experiments using the final questionnaire were launched. Feedback was provided by some of the participants after they had answered the questionnaire. Among the comments, some indicated that not enough details were provided to answer the questionnaire. The main criticism was about the cost performance of the construction project. This indicates that the cost performance is a parameter which influences the decision of the project leaders when they have to make a decision on a construction project. There is a chance that they would not have chosen the same answer if the budget was greater than the amounts used in the questions. So, the size of the project and the relative amounts (expected monetary values) associated with the quotidian decisions are going to influence project leaders when they are making decisions on a construction project. Nevertheless, for this experiment, it was decided not to provide a hypothetical project size to the participant, as adding new parameters would complicate the analysis of the data. To do this correctly, another set of questions would need to be added to the questionnaire, making it longer to answer. This is the reason why the budget and the size of the project are not given a precise amount in any of the questions of the questionnaire.

Concerning the "Weather – Loss Aversion" question set, some adjustments were made regarding the confidence given to the weather forecast. No details about the construction project or construction site were provided; in the case of rain, these parameters would of course interfere with the decision of the project leader. Actually, the construction project can be isolated or scattered, but in this question set those details were not provided for the same reason mentioned earlier: too many details will complicate the analysis of the results. Thus, the questions need to be simple and cannot introduce a lot of details. With this question set, it is crucial that the participant approaches the problem as simply as possible and considers only the risk of rain. Furthermore, one participant added: “Never trust the weather forecast, especially when there is a chance you can make up time/budget short falls if you don’t.” This clearly means that his choice would depend on the state of the construction project: his decision would likely be different if he had some shortfalls in time or budget to make up. As proven in general risk studies, people are more willing to take a risk if the potential gains can make up previous losses. So, if taking a risk can cover their previous losses, people will be more willing to take it than they normally would. The same phenomenon appears when a decision is made at the beginning or at the end of a construction project. Project leaders will be more likely to take risks if there is a possibility to finish the construction project on time while staying within the initial budget. So, those data are additional details that can be added to the list of parameters which may influence the decision of project leaders when they are making decisions under risk on their construction project.

The “Bored piles – Non-Compliance” question set engendered some reactions as well. The main problem for this question set, as numerous participants noticed, is the fact that the risk cannot be limited to the fine. Even if the question claims it was going to be the only consequence, the participants were not able to think this way. In reality, a lot of other consequences are linked with that risk, which increases the value of it. If it is found that less reinforcing steel was used, of course they would receive a fine, but as some participants noted, they would also diminish their reputation. In the construction business, partnership and reputation are of course extremely important, and they cannot be put at risk for the sake of saving some money. When this question set was created, the goal was only to focus on the amounts of money involved, but obviously, it was impossible for the participants to overlook the potential losses of reputation and partnership. Nevertheless, this question set remains useful for the study, as a part of the participants did answer those questions by only taking account of the values involved in the question set.

3.3.2 Data Collection

The data collection process was established within the guidelines of the Office of Research Ethics of the University of Waterloo. The participants were given an information letter about this study, and they had to fill out a consent form so that their data could be used. Once this first step was done, the participants were allowed to complete the questionnaire. To finish, after they gave back their questionnaire, they received a feedback letter, explaining the objectives of the experiment.

The data from the answers of the questionnaire were then analyzed, question by question, testing for the behavioural patterns explained above. The data were also studied and analyzed in relation to external influences and characteristics pertaining to the participants, such as their position or their age, to observe how those parameters influence their choices and reactions in terms of bringing about those behavioural patterns.

3.3.3 Approach to the Statistical Analysis of the Data

The last step in the preparation of this experiment was to determine how the data would be analyzed. Each question was treated separately; for each one a confidence interval was computed. As explained earlier, the confidence interval gives more information than the sample mean. To compute the confidence interval, Equation 8 was used.

$$\bar{X} \pm t * \frac{\sqrt{\bar{X}(1 - \bar{X})}}{\sqrt{n}}$$ Equation 8

Where:

- $n = Sample\ size$
- $\bar{X} = Sample\ mean$
- $t = Factor\ linked\ with\ the\ confidence\ level$

In Equation 8, the t-factor is equal to 1.96, so as to have a 95% confidence level interval. This formula shows the importance of the sample size of this experiment. The larger the sample size, the more precise the confidence intervals will be. So, the sample size is a key factor for obtaining useful and accurate results in this experiment.

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 with construction experience. These people were chosen randomly with respect to their age, their location and their position. The range of ages is large, from the twenties to the sixties, which means that the participants have different levels of experience. Some have a whole career behind them, while others just started theirs. The amount of experience of the participants may influence the way they make decisions under risk, so it is important to have a sample representative of the population of construction workers. Once all the confidence intervals were computed for each question, the comparison and analysis between the question sets could be commenced.

Chapter 4
Analysis and Interpretation of the Results

4.1 Statistical Description of the Data

The experiment took place from April 2014 to November 2014. During that period, 53 construction project leaders participated and answered the questionnaire of this project. These construction project leaders were found via the process described earlier in this thesis (Section 3.3.2).

4.1.1 Description of the Sample

While the construction leaders were answering the questionnaire, some personal information was asked of the participants to facilitate the analysis of the data. As the participants do not share the same experience, do not work in the same environment, and do not occupy the same position in their company, it is possible that these parameters influenced the results. It is also very important that the sample represents the entire population and not only a part of it.

First, some general information about the participants is related below. The following information was not asked directly of the participants, and was not used to analyze the data; it merely serves to describe the sample of participants.

The first type of information described here is the sex of the participants of this study. In the construction sector, the population is mostly composed of men, especially in the case of the people working on the construction site. As shown in Figure 33, the data fit the expected gender proportions, as most of the participants of this study are men.

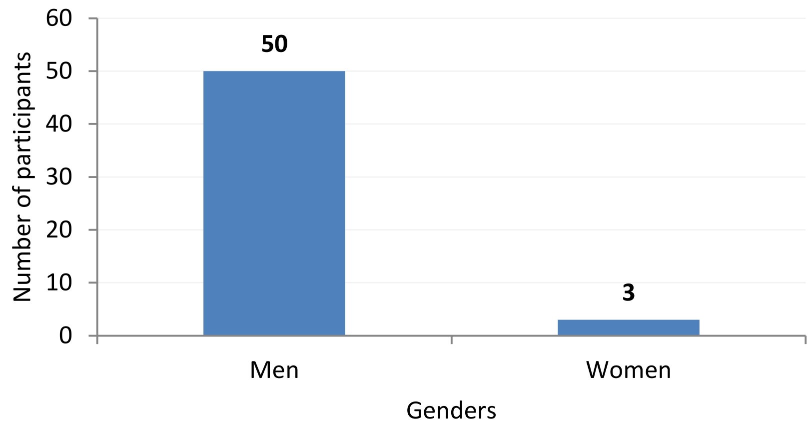

Figure 33: Distribution of the Participants' Gender

This study is aimed at people working in North America, so the participants of this experiment are mostly located in the United States and Canada. Only three of the participants work outside of North America. The remaining participants are distributed roughly equally between Canada and the United States. The distribution with respect to location is shown in Figure 34.

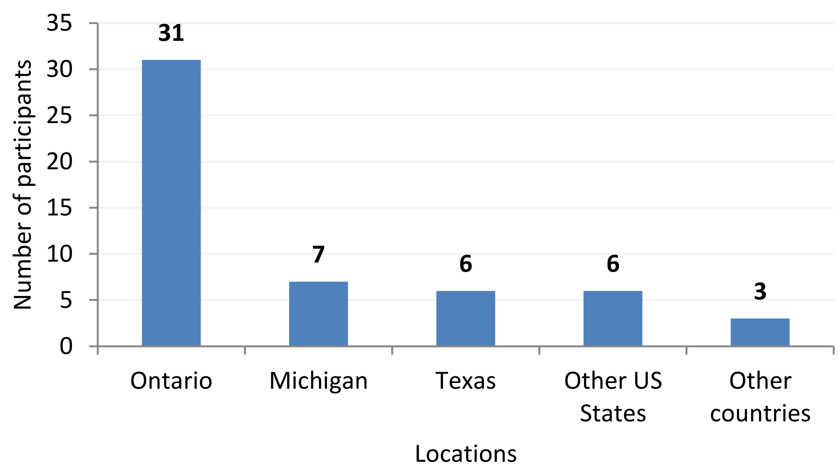

Figure 34: Distribution of the Participants' Location

Most participants are from the industrial sector. Some participants work in the educational system as researchers, but they also have experience in the industrial sector and in construction as non-academics. The distribution of the participants with respect to sector is shown in Figure 35.

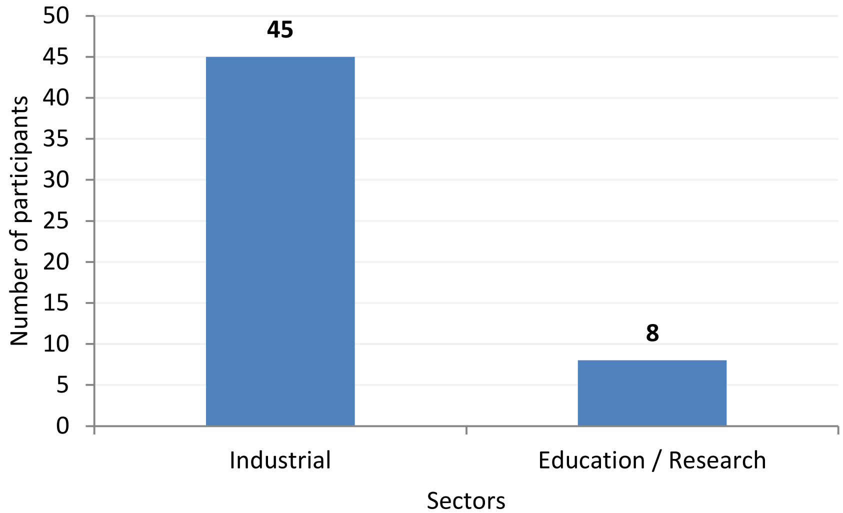

Figure 35: Distribution of the Participants' Sector

These graphs merely describe the participant population from a general point of view. In the next section, other details, such as age and position, will be described and those details will be used to analyze the data.

4.1.2 General Information

In this section, further information about the participants will be described, which will be analyzed to determine if it has an influence on the participants' answers for the questionnaire. Here, the parameters involved are the age, the experience and the position of each participant.

Concerning the age of the participants, the youngest is 22 and the oldest is 65. The age distribution is shown in Figure 36.

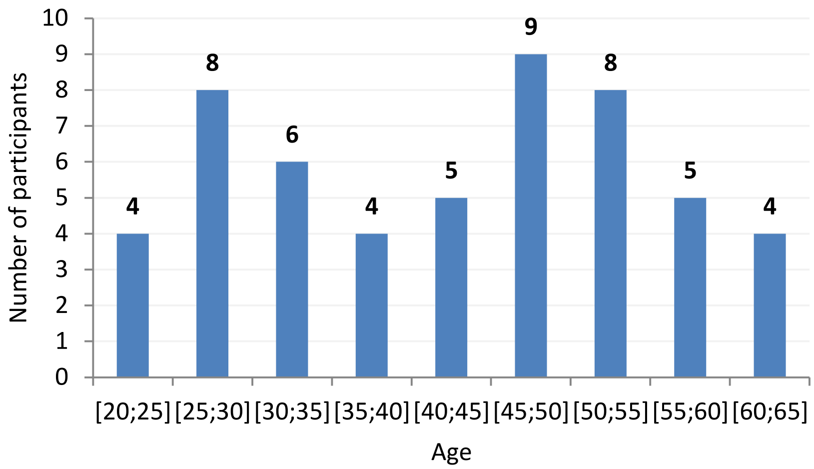

Figure 36: Distribution of the Participants' Age

The histogram shows two peaks around 30 and 50 years old. The mean of this population is approximatively 45 years old. To compare the results in function of the participants' age, two groups were made: one with the participants over 45 years old, and the other with those under 45 years old.

The next parameter is the amount of experience. The distribution of this parameter does not exactly follow the same trend as the previous graph as may be expected, since participants have their own unique background in the construction industry. The experience of the participants is shown in Figure 37.

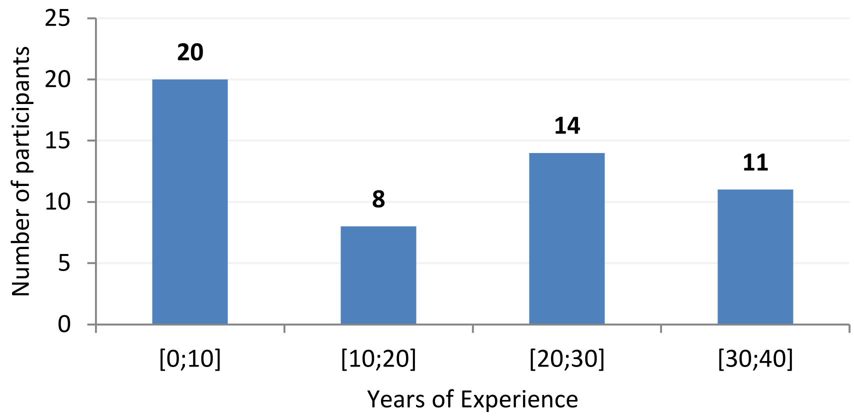

Figure 37: Distribution of the Participants' Years of Experience

This graph shows that there is a fairly even distribution of participants among all the categories, except that there are fewer participants who have between 10 and 20 years of experience. For some later analyses, the participants were divided into two groups: older than 45 years old and younger. This division corresponds to a division at 20 years of experience for this graph: the group of younger participants has less than 20 years of experience, while the older group has more than 20 years of experience. Use of either criteria results in the same two sets.

The last parameter presented in this section is the position of the participants of this experiment. When they answered the questionnaire, the participants gave their actual position, but it is also important to take into consideration that they have occupied other positions earlier in their career. The distribution of the participants' position is shown in Figure 38.

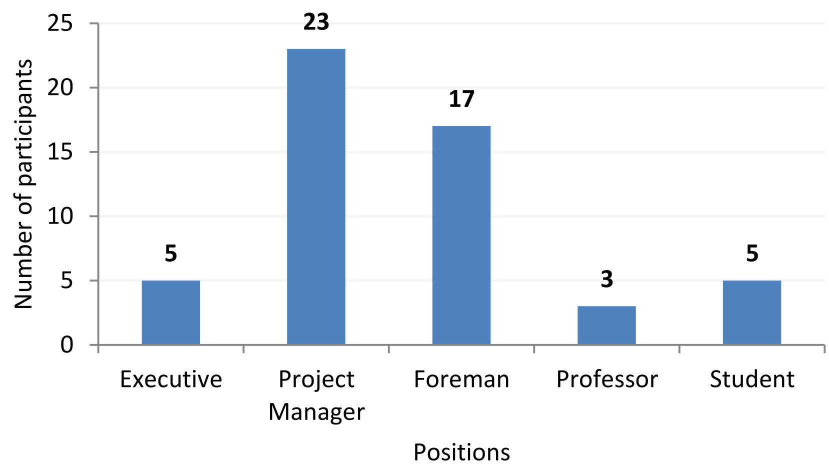

Figure 38: Distribution of the Participants' Position

Since the majority of the participants are project managers, analyzing the data is difficult. However, higher-level professions (executives, project managers and professors) can be grouped together, and the students and foremen can form a second group.

Parameters associated with the decision-makers may also potentially influence their decision-making process and risk-chasing behaviour. The decision-makers' experience is one of these potential parameters. To examine this hypothesis, the responses of the participants of this experiment were divided into two groups according to the age and experience of the participants. The grouping is based on the observation that in the data set, age is positively correlated with experience. The groups were divided so that one group was older than 45, and had more than 20 years of experience. The younger group all had less than 20 years of experience. There are 26 and 27 participants, respectively, in the groups of oldest and youngest participants.

The same operation could be carried out with respect to the position of the participants; however, it was decided not to do so, because there is not enough data for some positions. Moreover, professionals who were consulted about the research placed more of a focus on comparing the construction project leaders based on level of experience than comparing them based on position.

These graphs conclude this section of the description of the participants. When selecting participants for the study, it was important to ensure that the participants were chosen randomly, without considering their position, their location, their company, their age, etc. This was to make sure that the sample collected accurately represents the population of construction leaders.

4.2 Analysis of the Results – Question by Question

In this section, the results are shown in different tables, regrouped with the same difference of expected values in each case. In each table, only the parameter of the influence of the budget will vary. So, each table will show the results of three questions sharing the same behavioural tendency and the same difference between expected values but with different budget positions (under budget, on budget and over budget). The results are shown entirely in Appendix F.

For each question, a confidence interval will be given. This means that the percentage given represents the mean for the sample, and there is a 95% chance that the mean for the population falls within this confidence interval.

4.2.1 Construction Methods – Perception of Change

The first results discussed in this section are those for the "Construction methods – Perception of Change" question set. An example of this question is shown in Figure 39.

Question 10:

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

You face a problem on a construction site, and there are 2 technical ways (A and B) to fix it. Which one are you going to choose? The differences between the 2 ways are:

- *Decision A: This is a technical way that you are used to. You have always done things this way. It costs* ***$20,000****.*

- *Decision B: This is a new way for you. You have never done this way but you know that some colleagues often do this way, and there is no special competence required. It costs* ***$19,000****.*

A ☐ *B* ☐

Figure 39: Example of a "Construction Methods – Perception of Change" Question

This question set refers to the behavioural phenomenon that people are, in general, resistant to change. In this question set, the possibility to spend less money is offered by using a new technique, with which the decision-maker is not experienced, but which is proven to be efficient and described as risk free. Participants were expected to be risk averse and choose Option A, which is the old technical method (safe option), rather than Option B, which is the new approach (risky option). The difference between the two expected values is around 5 to 10%. Project cost performance was expected to influence responses as well.

4.2.1.1 General Analysis

For these questions, there is only one case. It is when the expected values are different, because it would not make any sense if both answers would have the same expected values. The results for these questions are shown in Table 2.

Table 2: Results for the "Construction Methods – Perception of Change" Question

Q	Project Cost Performance	Percentage of Participants Choosing Option A (Perceived Safe)	Expected Value of Option A	Percentage of Participants Choosing Option B (Perceived Risky)	Expected Value of Option B	95% Confidence Interval
4	Under Budget	**60%**	-$15 000	40%	-$14 000	+/- 13 %
10	On Budget	**55%**	-$20 000	45%	-$19 000	+/- 13 %
18	Over Budget	43%	-$5 000	**57%**	-$4 500	+/- 13 %

Taken individually, each question would seem to indicate a sort of weak trend either toward risk aversion (in the first two cases) or toward a strictly logical decision (in the last case). It is not possible to reach a conclusion regarding a tendency as the confidence interval includes the percentage of 50%, and also because of the fact that the mean is close to 50%.

Even if it is not possible to define a clear majority for each question, these results are still intriguing. Approximatively half of the population will not take the risk to use the new technique, even if they can save money by using it. Some of the participants said that they took into account the fact that the working team will need some time to learn this new technique (despite the wording and intent of the question), and it might thus cost money and time for the construction project. However, if an option can generate a positive B/C ratio and good payback period, it is better to start it as soon as possible, because it will have positive repercussions for the following construction projects as well.

Thus, for this question, half of the participants would prefer avoiding the risk of using a new option and favour paying a little more by using a technique they know. This can lead to small losses for a construction project; however, if a large company oversees many construction projects, and this kind of decision appears in some of them, the loss linked to that problem increases significantly.

Results are also inconclusive when pair-wise comparisons of the questions are made in terms of risk-chasing or risk-avoiding behaviour. However, a trend can be observed by synthesizing the results of these three questions. They all offer essentially the same dollar value for the new technology. The only difference is the situation of the project cost performance. It is therefore surmised that the difference between the results is only due to the influence of this external parameter. When the project is over budget, more participants choose to take some risk. That is, they choose to "chase" risk. This is what one would expect based on the literature.

The fact that the project cost performance is poor pushes some participants to take some risk that they would not have taken in a normal situation. In contrast, if the project cost performance is on or under budget, a small tendency towards risk aversion or what might also be interpreted as aversion to change is observed.

4.2.1.2 Age Comparison

As explained in the previous section, from the sample of participants, two groups of people can be formed, divided by their age or experience. Both criteria result in the same two groups. This section will compare the results between the two groups.

The results of the first group, which includes participants under 45 years old (with less experience), are shown in Table 3. The results of the second group, which includes participants over 45 years old (with more experience), are shown in Table 4.

Table 3: Results for the "Construction Methods – Perception of Change" Question – Younger Participants

Q	Project Cost Performance	Percentage of Participants Choosing Option A (Perceived Safe)	Expected Value of Option A	Percentage of Participants Choosing Option B (Perceived Risky)	Expected Value of Option B	95% Confidence Interval
4	Under Budget	**56%**	-$15 000	44%	-$14 000	+/- 19 %
10	On Budget	44%	-$20 000	**56%**	-$19 000	+/- 19 %
18	Over Budget	22%	-$5 000	**78%**	-$4 500	+/- 16 %

Table 4: Results for the "Construction Methods – Perception of Change" Question – Older Participants

Q	Project Cost Performance	Percentage of Participants Choosing Option A (Perceived Safe)	Expected Value of Option A	Percentage of Participants Choosing Option B (Perceived Risky)	Expected Value of Option B	95% Confidence Interval
4	Under Budget	**65%**	-$15 000	35%	-$14 000	+/- 18 %
10	On Budget	**65%**	-$20 000	35%	-$19 000	+/- 18 %
18	Over Budget	**65%**	-$5 000	35%	-$4 500	+/- 18 %

These tables show interesting results: there are some clear differences between the two groups of participants. The younger and less experienced construction leaders chose mostly to use the new technique, whereas the older and more experienced participants chose to avoid the risk.

In summary, the group composed of the younger construction leaders chose to take more risks and mostly chose Option B. Of course, the 95% confidence interval has to be considered to interpret these data. So, only a trend can result from the data. Concerning the external influence of the budget, the younger group is very sensitive to it, twice more than the older participants. Furthermore, as expected, they were more willing to take a risk when the construction project is over budget than under budget.

Conversely, the group composed of the older construction leaders took less risk relative to the younger group. Moreover, this group was not sensitive to the external influence of the budget. For the three questions, the mean of the answer is exactly the same. Of course, this is an average, but the budget has clearly less influence on this group than it does on the group of younger participants.

To conclude the analysis of this first question set, the results show that different parameters can influence the choice of the construction leaders when they are making their decision. The level of experience of the construction leader who is making this decision also has an impact. From an overall point of view, half of the population will avoid the risk of using a technology they have never experienced, even if the expected value is more attractive.

4.2.2 Quality of the Materials (Shingles) – Certainty Effect

The second question to be analyzed is the "Quality of the materials (Shingles) – Certainty Effect" question. An example of this question is shown in Figure 40.

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 40: Example of a "Quality of the Materials (Shingles) – Certainty Effect" Question

This question set deals with the certainty effect. As in the previous question set, a reaction of risk aversion is expected because the certainty effect creates an attraction to safe options over almost-safe options. In this question, participants have the possibility of choosing between two kinds of shingles. The shingles in Option A (risky option) are almost perfect, but with a very small chance of cracking during installation. The singles in Option B (safe option) are perfect, with no chance of cracking during installation but with greater cost compared to Option A. The certainty effect is expected to have more of an impact in this situation. For this kind of question, six questions were in the questionnaire. Three had expected values for the two options which were equal, and in the three others, option A, the more risky, was advantaged.

4.2.2.1 Expected Values Equal

This section deals with the results of the "Quality of the materials (Shingles) – Certainty Effect" questions when the expected values are equal. The results are shown in Table 5. As expected, participants are risk averse when they are answering this question. Most of them choose to avoid the risk and take Option B, the safe option.

Table 5: Results for the "Quality of the Materials (Shingles) – Certainty Effect" Question – Expected Values Equal

Q	Project Cost Performance	Percentage of Participants Choosing Option A (Perceived Risky)	Expected Value of Option A	Percentage of Participants Choosing Option B (Perceived Safe)	Expected Value of Option B	95% Confidence Interval
6	Under Budget	25%	-$150	**75%**	-$150	+/- 12 %
15	On Budget	36%	-$200	**64%**	-$200	+/- 13 %
20	Over Budget	**53%**	-$300	47%	-$300	+/- 13 %

Globally, there is a tendency towards risk aversion, except for the question in which the project cost performance is over budget. In this specific case, the answers are shared between both options. The phenomenon of risk-chasing seen in the "Construction methods – Perception of Change" question set is even more pronounced in this question set. The fact that the project cost performance is over budget reduces the risk-aversion behaviour normally exhibited in this kind of question, and by consequence creates a risk-chasing behaviour. Here, it is possible to notice, in the question in which the project cost performance is under budget, a more prominent risk-aversion reaction, compared to the "on budget" question. However, this difference is less pronounced than the difference between the "under budget" and "over budget" questions.

Once again, the project cost performance noticeably influences the participants' decision-making process. In the case in which the project cost performance is over budget, the participants feel pressured while making their decision, which pushes them to be risk chasing. Noticeable to a lesser degree, the opposite phenomenon appeared when the project cost performance is under budget. In this situation, participants feel comfortable enough to take less risk.

4.2.2.2 Expected Values Different

This section deals with the results of the "Quality of the materials (Shingles) – Certainty Effect" questions when the expected values are different. This time, Option A, the risk-taking option, has a better expected value in each of the questions. The results are shown in Table 6.

Table 6: Results for the "Quality of the Materials (Shingles) – Certainty Effect" Question – Expected Values Different

Q	Project Cost Performance	Percentage of Participants Choosing Option A (Perceived Risky)	Expected Value of Option A	Percentage of Participants Choosing Option B (Perceived Safe)	Expected Value of Option B	95% Confidence Interval
22	Under Budget	**64%**	-$90	36%	-$109	+/- 13 %
2	On Budget	**72%**	-$168	28%	-$207	+/- 12 %
12	Over Budget	**60%**	-$226	40%	-$245	+/- 13 %

This time, a majority of the participants chose to take Option A. This choice makes sense because when they were facing these questions, the participants could clearly see that Option A is more advantageous in terms of expected values. So, overall, 65% of the construction leaders selected the option with the best expected value. This means, however, that 35% of them took Option B. There are two possibilities to explain the decision adopted by the latter group. The first is that they did not notice that Option A has a better expected value; and a second possibility is that they did notice that Option A is more desirable, but they still wanted to avoid the risk and therefore chose Option B. Whatever the reason may be, for both the case in which the expected values are equal and the case in which they are different, for this part of the population, when they computed the expected utility before making their choice, they found Option B to be more attractive for them.

Concerning the influence of the external factor, the cost performance, the impact is clearly less important than in the questions in which the expected values are equal. The question in which the construction project is on budget was qualified as "obvious." For this question, the difference between the two expected values was double that of the other two questions. This may explain why more people take the risk for this question than for the other two questions.

However, this difference is still small, around 10%, and it would mean that the 35% of the population who chose Option B made that choice to avoid the risk even though they noticed that Option A is more desirable. It is difficult to believe, however, that 35% of the population chose the less desirable option even when they noticed the difference. So, in the next section, a computation of the expected utilities is carried out to understand the choices of all the participants for the six "Quality of the materials (Shingles) – Certainty effect" questions.

4.2.2.3 Computation of the Expected Utility

As explained in the literature review, when people in general are facing a choice, they are either not computing or using the expected values (otherwise, 100% would choose Option A in the questions in which the risk-taking option is advantageous). They are, however, computing and using expected utilities (Equation 9).

$$EU(x_1, p_1; \ldots; x_n, p_n) = \pi(p_1)v(x_1) + \cdots + \pi(p_n)v(x_n) \qquad \text{Equation 9}$$

Here is a reminder of those scales:

- The first scale, π, associates with each probability p a decision weight $\pi(p)$, which reflects the impact of p on the overall value of the prospect.
- The second scale, v, assigns to each outcome x a number v(x), which reflects the subjective value of that outcome.

For this kind of question, as the risk is mainly in probabilities and the outcomes are close to each other, some choose to compute the expected utilities. Only the first scale is taken into account, the decision weight; the amounts of the outcomes are close, so there will not be any difference in the subjective values that they are representing.

To model the decision weight function, a coefficient α_n is introduced to compute the decision weight of probability of shingles not breaking or cracking (Equation 10):

$$\pi_n(p_n) = \alpha_n * p_n \qquad \text{Equation 10}$$

The probabilities of not breaking or cracking are high (from 0.93 to 0.97), so in this case the coefficient α_n is inferior to 1 such that the decision weight is inferior to the probability (Figure 43). Following this, different tests were carried out: for each question, the decision weight, and by consequence the expected utility, were computed by using a coefficient α_n equal to 0.9 and 0.8. This increases the original probability of risk. The decision weights associated with the probabilities of breaking or cracking are complementary to the decision weights of the probabilities of not breaking.

Everyone considers the risk from their own point of view and a general expected utility that is applicable to everybody does not exist. Each person sees the risk his or her own way. This is why the answers are split between the two possible options. The coefficient α_n is going to be different for everyone. These chosen values are just the mean from previous studies that were conducted in behavioural economics to understand choices made under risk. When the project leaders are computing the expected utilities, they are using their intuition to "calculate" them.

The computations of expected utilities for the first three questions, in which the expected values are equal, are shown in Figure 41. For these questions, only one expected utility is computed, using the coefficient α_n equal to 0.9. This increases the probability of breakage by approximatively 10% in the presumed process of judgment of this experimental sample of decision-makers.

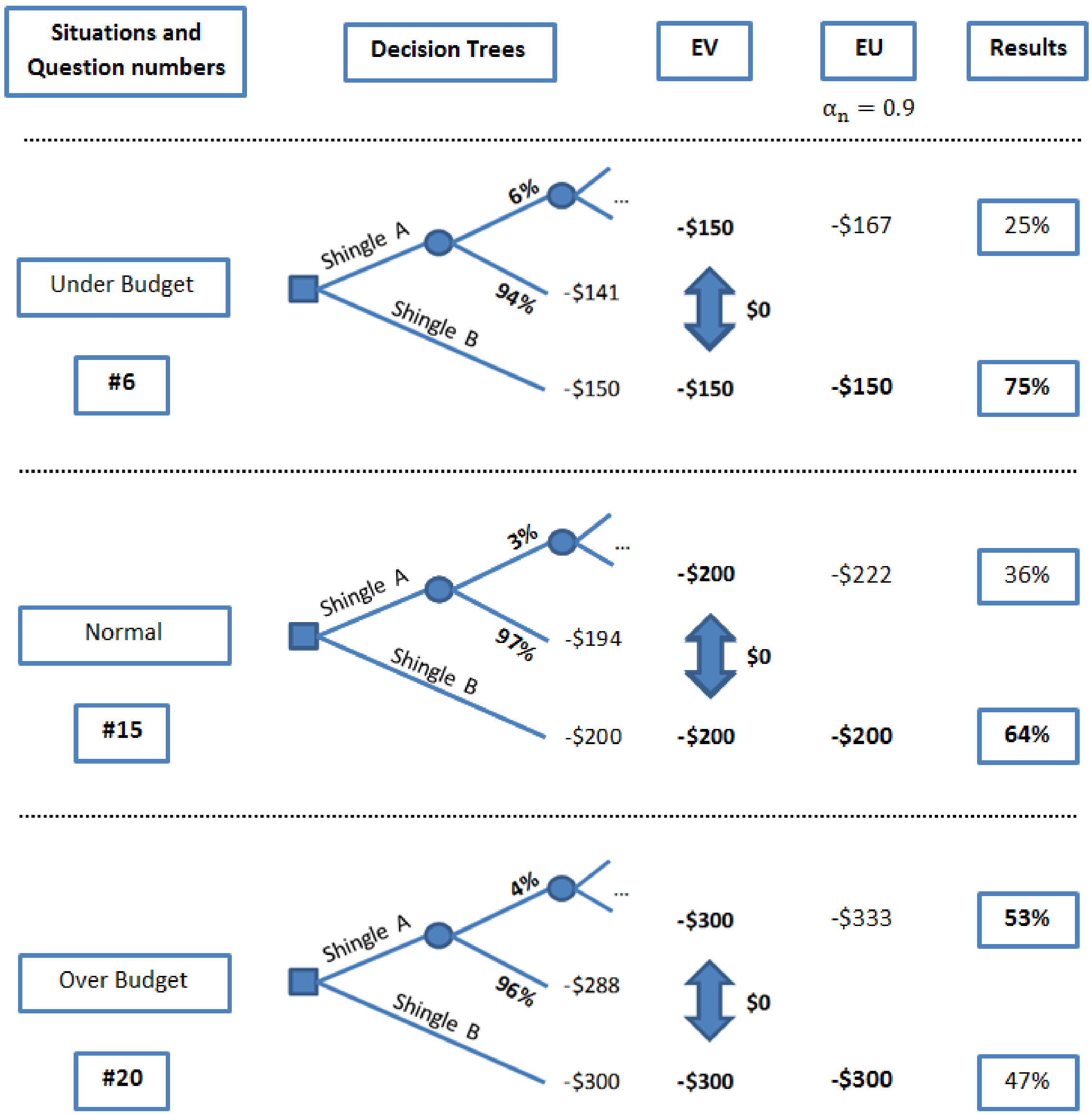

Figure 41: Computations of the Expected Utilities – "Quality of the Materials (Shingles) – Certainty Effect" Questions – Expected Values Equal

Examining the computed expected utilities facilitates an understanding of the decisions of the participants. For each of the three questions, when the expected utilities are computed, Option B, the one without risk, becomes more attractive for most participants. This is why for the questions in which the construction project is under budget or on budget, construction leaders prefer to avoid the risk and chose Option B.

However, for the question in which the construction project is over budget, the majority of participants do not follow this computation of expected utility. This is because of the influence of the cost performance. The fact that the construction project is over budget pushes them to take a risk even if when they computed the expected utilities, they found Option B to be more attractive.

Thus, the answers for these questions make sense when the expected utilities are estimated using α_n equal to 0.9. The computations of expected utilities for the last three questions, in which the expected values are different, are shown in Figure 42. For these questions, two expected utilities are computed to understand the choice of the participants. The first set of computations, 'EU1', uses the same coefficient α_n seen before, equal to 0.9 (which can be interpreted as adding approximatively 10% to the chance of breakage or as subtracting 10% from the probability the shingles will not break). The second set of computations, 'EU2', uses a coefficient α_n equal to 0.8 (which can be interpreted as adding approximatively 20% to the chance of breakage or as subtracting 20% from the probability the shingles will not break). It also results in a good explanation of the results of the second phase in the decision process, which is the process of making a choice. That is, it explains the choices made by the majority of the participants in this experiment.

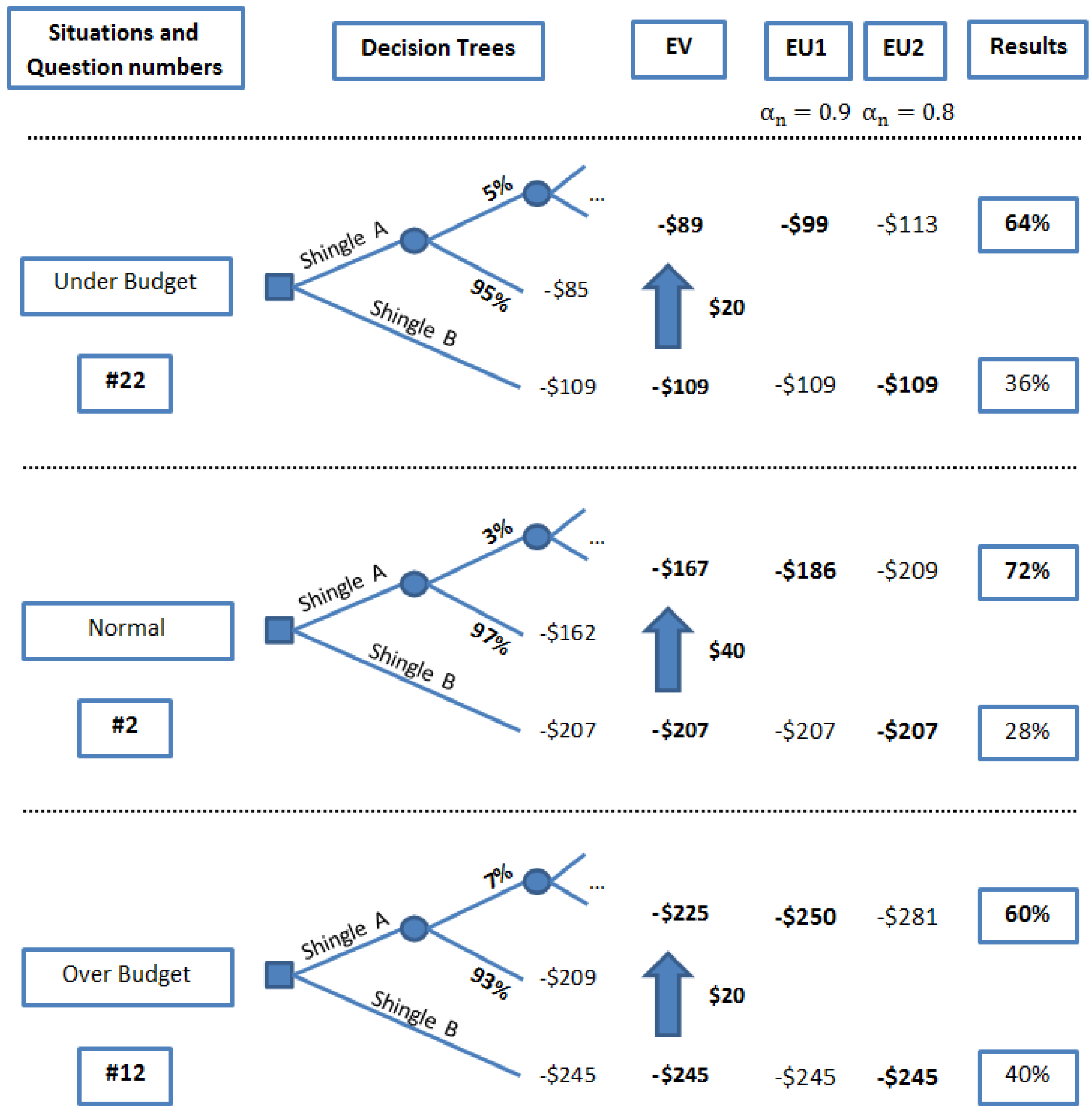

Figure 42: Computations of the Expected Utilities – "Quality of the Materials (Shingles) – Certainty Effect" Questions – Expected Values Different

For these three questions, the expected values for Option A are more attractive than the expected values for Option B. However, the expected utilities lead to different results. The first set of expected utilities, 'EU1', shows that the construction leaders would prefer to take the risk and choose Option A (except for the case in which the construction project is over budget but the values are close; and people are more able to take risks with those conditions anyway). But the second set of expected utilities, 'EU2', shows that the construction leaders would prefer to avoid the risk and choose Option B.

To understand the participants' answers, considering the computation of the two sets of expected utilities is useful. The first set of expected utilities explains the choice of most of the participants, the ones who chose to take the risk. And the second set explains the choice of the remaining participants, the ones who chose to not take any risks.

Concerning the influence of the budget, it is clear that it is less important compared with the questions in which the expected values are equal, but there is still an impact, which appeared mostly in the question in which the construction project was on budget. However, it was expected that more participants would take a risk when the construction site was over budget. It is true that the 'on budget' question was "obvious," so it is difficult to compare it with the 'over budget' question. However, if it is compared with the 'under budget' question, the amount of participants taking Option A should be more important; or else it would mean that the budget no longer has any influence when the expected values are not equal, which is difficult to believe. Of course, the influence is less important, but it should still be there. This result for the 'over budget' question might be explained by the different computations of the expected utilities.

As observed earlier, the first expected utility showed that Option A is more attractive, and the second expected utility showed that Option B is more attractive. Concerning the difference between the two expected utilities, it is not the same for each case. Actually, it can sometimes be considered equal when the two values are close to each other. This happened for the cases in which the construction project is under budget and on budget for the second expected utility (-\$113;-\$109 and -

$209;-$207). It happened also for the case in which the construction project is over budget, but this time for the first expected utility (-$250;-$245).

Taking the foregoing information into account may explain why only 62% of the participants chose Option A for the ‘over budget’ question. For the other questions, it was the participants adding 20% or more to the risk who were avoiding the risk and choosing Option B. However, for the ‘over budget’ question, it was the participants adding 10% or more to the risk who were avoiding the risk and choosing option B. This may explain why fewer participants chose Option A in the ‘over budget’ question.

A representation of these potential expected utilities can be carried out by considering the graph of the typical weighting function in accordance with prospect theory. For the three questions in which the expected values are different, the decision weights for the probabilities of no breakage associated with the computation of the two expected utilities are shown in Figure 43. The crosses connected with each probability of the questions, show the decision weight used to compute the associated expected utility (blue for ‘EU1’ and green for ‘EU2’).

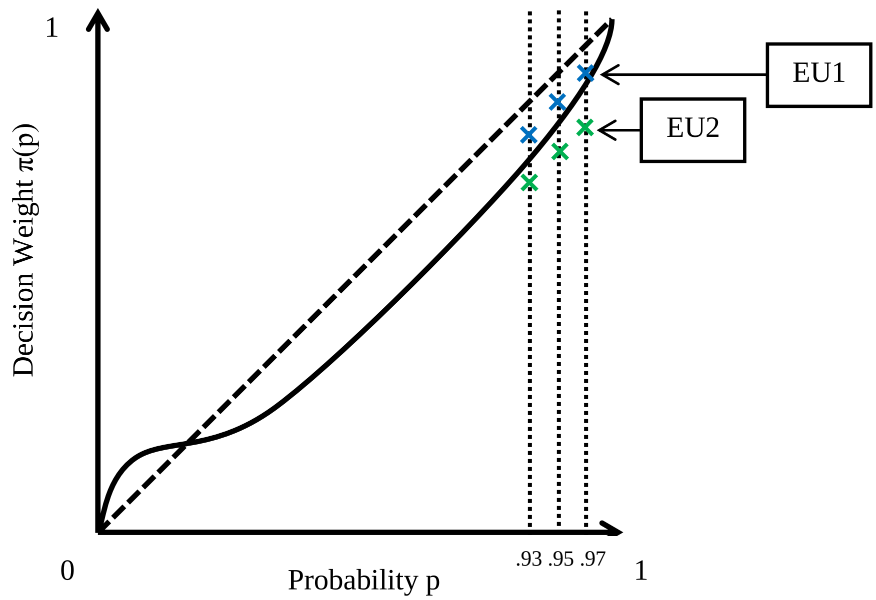

Figure 43: Decision Weights for the Probabilities of No Breakage Associated with the Computation of Expected Utilities EU1 and EU2 for Questions #22, #2 and #12 – Expected Values Different

Thus, for a given probability, the participants have a large spectrum of potential expected utilities. Some weight the probability correctly (that is, logically), a few underestimate the associated risk, and most overvalue it. However, they do not overvalue it uniformly: some add 10% to the chance of cracking, while others add more than 20% to the chance of cracking. This computation shows that the reaction to risk is not uniform and cannot be summarized solely based on the value taken from the decision weight graph (Figure 43). All these differences can engender losses when the expected values are different. For instance, when the risky option is advantageous, some participants still avoid the risk. Conversely, if the safe option is advantageous, a few participants would still take the risky option. All these situations engender losses for the companies and need to be fixed by helping the construction leaders make better decisions.

4.2.2.4 Age Comparison – Expected Values Equal

For this analysis, the sample is divided into two groups based on age and experience. The comparison is first made when the expected values are equal, and it will be followed by the questions in which the expected values are different (Section 4.2.2.5).

The results for the first group, participants under 45 years old (with less experience), are shown in Table 7. The results for the second group, participants over 45 years old (with more experience), are shown in Table 8.

Table 7: Results for the "Quality of the Materials (Shingles) – Certainty Effect" Question – Expected Values equal – Younger Participants

Q	Project Cost Performance	Percentage of Participants Choosing Option A (Perceived Risky)	Expected Value of Option A	Percentage of Participants Choosing Option B (Perceived Safe)	Expected Value of Option B	95% Confidence Interval
6	Under Budget	19%	-$150	**81%**	-$150	+/- 15 %
15	On Budget	30%	-$200	**70%**	-$200	+/- 17 %
20	Over Budget	44%	-$300	**56%**	-$300	+/- 19 %

Table 8: Results for the "Quality of the Materials (Shingles) – Certainty Effect" Question – Expected Values Equal – Older Participants

Q	Project Cost Performance	Percentage of Participants Choosing Option A (Perceived Risky)	Expected Value of Option A	Percentage of Participants Choosing Option B (Perceived Safe)	Expected Value of Option B	95% Confidence Interval
6	Under Budget	31%	-$150	**69%**	-$150	+/- 18 %
15	On Budget	42%	-$200	**58%**	-$200	+/- 19 %
20	Over Budget	**62%**	-$300	38%	-$300	+/- 19 %

For both of these tables, the confidence interval is large, so it is not possible to make conclusions regarding the exact proportion for each question, but it is still possible to observe a trend. For the questions in which the expected values are equal, it is mainly the influence of the certainty effect which is interesting for this study. Here, the construction leaders with less experience, the younger participants, are more sensitive to this behavioural tendency and avoid the risk more than the construction leaders with more experience. It is possible that the older participants accept breakage as inevitable in practice, so tend toward the lower price, because they are not able to accept the premise that none of the shingles will break.

Both categories are influenced by the budget, slightly more for the younger participants. The range between the means of the 'under budget' and 'over budget' questions is 37% for the group of younger participants and 31% for the older group.

These results are in contradiction with the results of the first question, in which the younger construction leaders took more risk than the older and more experience construction leaders. However, it is difficult to compare these two behavioural tendencies. They are not referring to the same type of risk, so it is possible that the two different groups are not sensitive in the same way to these behavioural tendencies.

4.2.2.5 Age Comparison – Expected Values Different

This section has the same objective as the previous section, but this time, it is conducted with the questions in which the expected values are different and the risky option is more attractive in terms of expected value. The results of the first group, participants under 45 years old (with less experience), are shown in Table 9. The results of the second group, participants over 45 years old (with more experience), are shown in Table 10.

Table 9: Results for the "Quality of the Materials (Shingles) – Certainty Effect" Question – Expected Values Different – Younger Participants

Q	Project Cost Performance	Percentage of p Participants Choosing Option A (Perceived Risky)	Expected Value of Option A	Percentage of Participants choosing Option B (Perceived Safe)	Expected Value of Option B	95% Confidence Interval
22	Under Budget	**67%**	-$90	33%	-$109	+/- 18 %
2	On Budget	**74%**	-$168	26%	-$207	+/- 17 %
12	Over Budget	**56%**	-$226	44%	-$245	+/- 19 %

Table 10: Results for the "Quality of the Materials (Shingles) – Certainty Effect" Question – Expected Values Different – Older Participants

Q	Project Cost Performance	Percentage of Participants Choosing Option A (Perceived Risky)	Expected Value of Option A	Percentage of Participants Choosing Option B (Perceived Safe)	Expected Value of Option B	95% Confidence Interval
22	Under Budget	**62%**	-$90	38%	-$109	+/- 19 %
2	On Budget	**69%**	-$168	31%	-$207	+/- 18 %
12	Over Budget	**65%**	-$226	35%	-$245	+/- 18 %

Unlike the questions in which the expected values are equal, the group composed of the younger construction leaders may be more willing by a very small margin to take a risk than the other group. Except for the 'over budget' question, the percentages are close. For all those values, only a global tendency can be observed from them, because the 95% confidence intervals overlap each other.

One interesting aspect of this result is the fact that the construction leaders with more experience, the older participants, are less sensitive to the external influence of the budget. When the expected values are different, their choice is almost independent of the budget. The younger construction leaders, on the other hand, are more sensitive to this influence. This result is in line with that of the previous question, in which the older construction leaders were not sensitive to the budget.

To conclude the analysis of this question, it is clear that construction leaders are sensitive to the behavioural tendency of “certainty effect,” and the budget still has a non-negligible impact. A significant segment of the construction leaders (30%) still take the less attractive decision to avoid risk. This choice represents a potential loss for construction companies. This is an important outcome of the study.

4.2.3 Bored Piles – Non-Compliance

The third question to be analyzed is the “Bored piles – Non-Compliance” question. An example of this question is shown in Figure 44.

Question 8:

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

You are constructing a set of bored piles and there are two ways for finishing them. Which decision are you going to make?

- *Decision A: Do as designed. This way it will cost **$3,000**.*

- *Decision B: Use less reinforcing steel. It will be safe, and it will only cost you **$2,500**, but it does not meet design specifications. There exists a **2%** possibility of being found using less reinforcing steel by the client. If found, you will lose **$25,000**. But, there is no risk that you will be fired by your company.*

A ☐ *B* ☐

Figure 44: Example of a “Bored Piles – Non-Compliance” Question

The “Bored piles – Non-Compliance” question set offers the participants the possibility to not meet design specifications and use less reinforcing steel for the construction of a set of bored piles. The scenario is constructed such that normally, the only consequences are lower costs, but there is also a small possibility of being caught and having to pay an expensive fine, though there would be no adverse career consequences. The participants have to choose either to respect the design and take Option A (safe option) or use less reinforcing steel and take Option B (risky option). For this set of questions, six questions were included. In three of the questions, the expected values are equal, and in the three other questions, Option B, the risky one, is obviously advantageous.

4.2.3.1 Expected Values Equal

The results for the "Bored piles – Non-Compliance" question set in which the expected were equal are shown in Table 11.

Table 11: Results for the "Bored Piles – Non-Compliance" Question – Expected Values Equal

Q	Project Cost Performance	Percentage of Participants Choosing Option A (Perceived Safe)	Expected Value of Option A	Percentage of Participants Choosing Option B (Perceived Risky)	Expected Value of Option B	95% Confidence Interval
11	Under Budget	**96%**	-$1 000	4%	-$1 000	+/- 5 %
8	On Budget	**94%**	-$3 000	6%	-$3 000	+/- 6 %
5	Over Budget	**96%**	-$2 400	4%	-$2 400	+/- 5 %

The results shown by this table are unequivocal: the majority of construction leaders avoid the risk of being found using less reinforcing steel. Only 5% of the construction leaders chose to take the risk and selected Option B.

This result can be explained by many different factors. The first one would be, of course, that the participants are afraid of the risk in Option B. The fine is a considerable amount of money, so if they are caught and penalized, they will have a big loss in their budget that they cannot afford. Also, if it is discovered that they are not using enough reinforcing steel, their employer may incur a loss in reputation on top of the fine.

Thus, this question did not work as expected. Of course, the results show clearly that the behavioural tendency affects the choice of the participants, but it is in the direction of the moral and financial risk. So, even if the expected values are mathematically equal, the expected utilities will never be equal. The risk of losing their reputation is too important and the values have less importance in this question.

For these three questions, the risk is so overwhelming that the budget has no influence on the decision. The next section deals with the same questions, but this time, the risky options are advantageous.

4.2.3.2 Expected Values Different

The results for the "Bored piles – Non-Compliance" question set in which the expected are different are shown in Table 12. This time, the risky option has an obviously better expected value. For this question set, the participants have the possibility to save some money by getting around the rules; they are expected to be strongly risk averse.

Table 12: Results for the "Bored Piles – Non-Compliance" Question – Expected Values Different

Q	Project Cost Performance	Percentage of Participants Choosing Option A (Perceived Safe)	Expected Value of Option A	Percentage of Participants Choosing Option B (Perceived Risky)	Expected Value of Option B	95% Confidence Interval
17	Under Budget	**91%**	-$8 000	9%	-$4 500	+/- 8 %
14	On Budget	**96%**	-$7 500	4%	-$4 000	+/- 5 %
23	Over Budget	**85%**	-$8 900	15%	-$5 400	+/- 10 %

Even if, this time, the risky option is advantageous, the results are globally the same as those of the previous series of questions. The majority of construction leaders avoided the risk. In this series of questions, all the questions were considered as “obvious,” but the percentages are still the same compared with the questions in which the expected values were equal. This means that when the constructions leaders computed their expected utilities, they obtained the same results. The proportion of the loss of reputation is much more important in the computation of the expected utilities than the proportion of the potential losses for this question.

Thus, the results are consistent with the first series of questions. Since the risk of loss of reputation is very strong, the computation of the expected values is not affected by the values of this question.

However, even if the results unquestionably show risk-aversion behaviour, it is noticeable that when the project cost performance is over budget, this behaviour is less common. Again, making decisions with the knowledge of working on an over-budget project pushes some participants to be risk chasing. This time the difference is small, and this risk-chasing behaviour appears for approximately 10% of the participants. Similar to the “Construction methods – Perception of Change” question, almost no difference can be observed between the “on budget” and “under budget” questions.

The risk-chasing behaviour present for the question in which the project cost performance is over budget is likely due, similar to the previous question, to the pressure that this situation puts on the decision-maker. The risk-chasing behaviour is more difficult to observe in this question set, because of the perceived potential loss of reputation which can be harmful to the employing company. This potential loss is clearly important to the participants, perhaps because of their innate ethical nature, and it reduces the risk-chasing behaviour with respect to the “over budget” question. In related behavioural economics studies, this ethical behaviour is observed to a lesser or greater extent, depending on the nature of the experiment in terms of the framing of the question and description of the situation. In some experiments, people do cheat when the expected value is preferable and the risk is low (Mazar et al., 2008), or when the expected value of cheating is much higher than not cheating. It would be interesting to repeat this study under such conditions.

4.2.3.3 Age Comparison – Expected Values Equal

The division of the participants into two groups according to their age is repeated for this question. The questions with equal expected values are treated in this section.

The results for participants under 45 years old (with less experience) and participants over 45 years old (with more experience) are shown, respectively, in Table 13 and Table 14.

Table 13: Results for the "Bored Piles – Non-Compliance" Question – Expected Values Equal – Younger Participants

Q	Project Cost Performance	Percentage of Participants Choosing Option A (Perceived Safe)	Expected Value of Option A	Percentage of Participants Choosing Option B (Perceived Risky)	Expected Value of Option B	95% Confidence Interval
11	Under Budget	**93%**	-$1 000	7%	-$1 000	+/- 10 %
8	On Budget	**89%**	-$3 000	11%	-$3 000	+/- 12 %
5	Over Budget	**93%**	-$2 400	7%	-$2 400	+/- 10 %

Table 14: Results for the "Bored piles – Non-Compliance" Question – Expected Values Equal – Older Participants

Q	Project Cost Performance	Percentage of Participants Choosing Option A (Perceived Safe)	Expected Value of Option A	Percentage of Participants Choosing Option B (Perceived Risky)	Expected Value of Option B	95% Confidence Interval
11	Under Budget	**100%**	-$1 000	0%	-$1 000	+/- 1 %
8	On Budget	**100%**	-$3 000	0%	-$3 000	+/- 1 %
5	Over Budget	**100%**	-$2 400	0%	-$2 400	+/- 1 %

As expected, both groups chose to avoid the risk and took Option A. However, the participants who chose to use less reinforcing steel in this question solely pertained to the group with less experienced construction leaders. This means that when construction leaders compute their expected utilities, the ones with more experience will give more importance to their reputation than the other group. Because of their experience, they give more importance to the risk of losing reputation; this is why all of them did not take the risk. Some participants in the other group are less experienced and therefore give less importance to their reputation. The budget still has no influence on the choice of the construction leaders, both those with less experience and those with more experience.

4.2.3.4 Age Comparison – Expected Values Different

This section has the same objective as the previous section, but this time the questions in which the expected values are different are analysed.

The results for participants under 45 years old (with less experience) and participants over 45 years old (with more experience) are shown, respectively, in Table 15 and Table 16.

Table 15: Results for the "Bored piles – Non-Compliance" Question – Expected Values Different – Younger Participants

Q	Project Cost Performance	Percentage of Participants Choosing Option A (Perceived Safe)	Expected Value of Option A	Percentage of Participants Choosing Option B (Perceived Risky)	Expected Value of Option B	95% Confidence Interval
17	Under Budget	**81%**	-$8 000	19%	-$4 500	+/- 15 %
14	On Budget	**93%**	-$7 500	7%	-$4 000	+/- 10 %
23	Over Budget	**74%**	-$8 900	26%	-$5 400	+/- 17 %

Table 16: Results for the "Bored piles – Non-Compliance" Question – Expected Values Different – Older Participants

Q	Project Cost Performance	Percentage of Participants Choosing Option A (Perceived Safe)	Expected Value of Option A	Percentage of Participants Choosing Option B (Perceived Risky)	Expected Value of Option B	95% Confidence Interval
17	Under Budget	**100%**	-$8 000	0%	-$4 500	+/- 1 %
14	On Budget	**100%**	-$7 500	0%	-$4 000	+/- 1 %
23	Over Budget	**96%**	-$8 900	4%	-$5 400	+/- 1 %

The results show the same tendencies as the questions in which the expected values are equal. As before, all of the experienced construction leaders chose to not use less reinforcing steel, whereas a few of the less experienced construction leaders chose to use it. This time, however, the fact that the expected values are different has an impact on the decision of the latter group. When they are computing the expected utilities, the less experienced construction leaders are more likely to take a risk, whereas the more experienced construction leaders still make the choice of not taking any risk. This is further evidence that the potential loss of reputation has a lesser impact on construction leaders with less experience.

Furthermore, the budget has more of an impact on the choice made by the less experienced group. This time, there are around 25% of them who chose to take the risk for the 'over budget' question, whereas there are only 10 to 15% for the two other questions. So, once again, the budget has a bigger impact on participants with less experience; however, in this case this trend is also due to the fact that these participants are less sensitive to the potential loss of reputation.

To conclude the analysis of this question, even if the results were not as expected, some interesting results can be extracted. The potential loss of reputation is, for the construction leaders, much more important than a potential gain of money. Moreover, this tendency is much stronger for construction leaders with more experience than for those with less experience. Furthermore, the group composed of younger construction leaders is still more sensitive to the budget, and it is when the construction project is over budget that they are more likely to take some risk.

4.2.4 Weather – Loss Aversion

The last question to be analyzed is the "Weather – Loss Aversion" question. An example of this question is shown in Figure 45.

Question 21:

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

You must decide whether to work tomorrow on a large concrete placement exposed to the weather. There is a ***80%*** *chance of rain. Which decision will you make?*

- *Decision A: You decide to work tomorrow. If it rains, you will experience net losses of* ***$4,170****. If it does not rain, you will experience net earnings of* ***$880****.*
- *Decision B: You decide to not work tomorrow. As a result, you will experience net losses of* ***$3,160*** *whether it rains or not.*

A ☐ *B* ☐

Figure 45: Example of a "Weather – Loss Aversion" Question

The "Weather – Loss Aversion" question set lets the participants decide if they want to work the following day, given a certain weather forecast. The participants can choose to take the risky option and choose to work (Option A) or to be safe and not work but ensure a loss (Option B). For this last behavioural tendency, nine questions were asked to the participants: three where the expected values are equal, three where Option A is advantageous in terms of expected values, and three where Option B is advantageous in terms of expected values.

4.2.4.1 Difficulty in Analyzing this Question

The results for the "Weather – Loss Aversion" questions in which the expected are equal are shown in Table 17.

Table 17: Results for the "Weather – Loss Aversion" Question – Expected Values Equal

Q	Project Cost Performance	Probability of Rain	Percentage of Participants Choosing Option A	Expected Value of Option A	Percentage of Participants Choosing Option B	Expected Value of Option B	95% Confidence Interval
1	Under Budget	75%	**51%**	-$2 400	49%	-$2 400	+/- 13 %
21	On Budget	80%	26%	-$3 160	**74%**	-$3 160	+/- 12 %
16	Over Budget	50%	**66%**	-$1 470	34%	-$1 470	+/- 13 %

This question is the most difficult to analyze. There actually exist some risks in both answers for the participant who has to make this decision. Additionally, several parameters can influence the decision of the construction leaders in this question:

- How the participants are over-evaluating the losses.
- If the participants are over-evaluating the losses in different ways (a small loss will be more overvalued compared to a big one).
- How the participants perceive the probability of rain.
- Influence of the budget.

There is no obvious tendency for this question. For the "on budget" question, the participants choose mostly to not work, and for the questions in which the construction project is over budget, the participants choose mainly to work. Furthermore, when the construction project is under budget, no trend appears. The values used for each questions are different, and this has a huge impact on the participant's choice. It has an influence on all the parameters introduced above, and it makes each question different and very difficult to compare.

Accordingly, to understand the participants' answers, each question needs to be analyzed separately, because one model cannot fit all of them. Therefore, a global model was built in which some parameters can be modified to better understand the answers of the participants. Then it will be possible to return to the analysis of the results to address this question.

4.2.4.2 Construction of a Model for the Expected Utilities

The model is built the same way it was for the "Quality of the materials (Shingles) – Certainty effect" questions. It begins with the computation of expected utility shown in Equation 11.

$$U(x_1, p_1; \dots; x_n, p_n) = \pi(p_1)v(x_1) + \cdots + \pi(p_n)v(x_n) \qquad \text{Equation 11}$$

Here is a reminder of those scales:

- The first scale, π, associates with each probability p a decision weight π(p), which reflects the impact of p on the overall value of the prospect.
- The second scale, v, assigns to each outcome x a number v(x), which reflects the subjective value of that outcome.

This time, all the scales will be used to compute the expected utilities, and as explained in the previous section, there are numerous variables to take into consideration when using this equation. For each outcome, a subjective value has to be estimated; and for each probability, a decision weight is estimated as well. Two methods were used for this modeling. A description of the first one is shown in Equation 12. This equation shows the computation of the expected utilities for each option.

$$\begin{cases} U(A) = LossA * X * (P + Z) + GainA * Y * (1 - P - Z) \\ U(B) = LossB * X \end{cases} \qquad \text{Equation 12}$$

With:

- P = Probability of rain
- X = Coefficient of overvalue of the losses
- Y = Coefficient of undervalue of the gains
- Z = Percentage added to the probability of rain

All of these parameters can then be adapted to each question to understand the participants' choices. Doing so provides a general analysis which will provide plausible insight into the overall tendencies. Since three parameters (X,Y,Z) are too many to compute the expected utilities, it was decided that Y, the coefficient of undervalue of the gains, will be fixed at 1.0 for all the questions. This value came from the various studies about behavioural economics found in the literature.

A range is chosen for the other two parameters. The coefficient of overvalue of the losses, X, will vary between 1 and 3 with a step of 0.5. This range also reflects values found in the literature. The goal is only to understand the tendency of the answers, so there is no need to use precise values for these coefficients. The same holds true for Z. The percentage added to the probability of rain will vary between -0.15 and 0.15 with a step of 0.05. These added percentage points can be negative or positive because it is assumed that the participants may not all react the same way to the questions. Some participants increase the probability of rain in their judgement phase, while others decrease it.

The second model is close to the first one but takes into account one additional parameter discussed in the literature review, which is that people are more likely to overvalue small losses than large ones. To include this factor in the model, 0.5 will be added to the "coefficient of overvalue of the losses" for the smallest loss. So, in this second model, the model of the expected utility becomes Equation 13.

$$\begin{cases} U(A) = LossA * X * (P + Z) + GainA * Y * (1 - P - Z) \\ U(B) = LossB * (X + 0.5) \end{cases}$$ Equation 13

With:

- $P = \text{Probability of rain}$
- $X = \text{Coefficient of overvalue of the losses}$
- $Y = \text{Coefficient of undervalue of the gains}$
- $Z = \text{Percentage added to the probability of rain}$

These two models will now be used to understand and analyze the results of the participants. When the ratio between the two losses is high (>1.5), the second model will be used to compute the expected utilities, and when this ratio is low (<1.5), the first model will be used.

4.2.4.3 Expected Values Equal

The table discussed in the previous section concerning the results of the "Weather – Loss Aversion" questions in which the Expected Values are equal, is repeated in Table 18.

Table 18: Results for the "Weather – Loss Aversion" Question – Expected Values Equal

Q	Project Cost Performance	Probability of Rain	Percentage of Participants Choosing Option A	Expected Value of Option A	Percentage of Participants Choosing Option B	Expected Value of Option B	95% Confidence Interval
1	Under Budget	75%	**51%**	-$2 400	49%	-$2 400	+/- 13 %
21	On Budget	80%	26%	-$3 160	**74%**	-$3 160	+/- 12 %
16	Over Budget	50%	**66%**	-$1 470	34%	-$1 470	+/- 13 %

The tables with the computation of the two expected utilities for each question are shown in Appendix E. These are helpful for understanding the participants' answers. No obvious logic is apparent when looking at the results in this table, but considering each question separately, and taking into account all the parameters, the results make sense.

Considering the question "under budget," the results are around 50-50. The following analysis considers the parameters of the question. The probability of rain is high (0.75), so the participants may increase this value when they are computing the expected utilities. The ratio between the two losses of this question is 1.425, which is close to the 1.5 ratio limit, fixed earlier, so both models can be taken into consideration in explaining the results of this question. The first model shows that the expected utility of Option B is more attractive, and the second model shows the opposite result: Option A is more attractive. This makes sense, as the results were supposed to differ between the two models.

For the "on budget" question, the majority of participants chose Option B. The probability of rain is high for this question (0.8), so the participants may subconsciously increase this value when they are computing intuitively the expected utilities. The ratio between the two losses of this question is 1.320, so the first model seems the most appropriate for approximating the computation of the expected utilities. This shows that Option B is more attractive in terms of expected utilities, which can explain the results for this question. The 23% of the participants who have chosen the other option may not have increased the probability of rain but may have in fact reduced it.

Finally, for the "over budget" question, a majority of the participants chose to take Option A and to work. Once again, the same analysis considering the parameters of the question is made. This time the probability of rain is medium (0.5). It is impossible to say if the participants will overvalue or undervalue it. The ratio between the two losses of this question is 2.939, so clearly the second model is preferable to estimate the expected utilities computed by the participants. The second model shows that when the participants increased the probability of rain, they found Option B more attractive in terms of expected utilities. In contrast, if they decreased the probability of rain, Option A became more attractive in terms of expected utilities. Another way to understand the choice of the participants for this question would be to consider the reaction of the participants when they are facing a decision in which the construction project is over budget. The previous sections show that participants were more able to take some risks with this situation; and here, the risk is present in Option A, because there is one chance out of two of a significant loss. This might also explain why around 70% of the participants chose to make the choice of working (Option A).

These analyses serve as the basis of the series of computations of the expected utilities by the two models shown earlier; those two models are approximate and merely provide and explain tendencies for the results. This is enough to show the expected pattern when the project leaders answer this questionnaire.

It is not possible to make a global analysis for this series of questions; they are too different to understand globally, but each of them gave important information. This is why no real conclusion about the influence of the budget will be made for this series of questions.

4.2.4.4 Expected Values Different – Option A Advantaged

The results for the loss aversion questions in which the expected values were different, with Option A being advantageous, are shown in Table 19.

Table 19: Results for the "Weather – Loss Aversion" Question – Expected Values Different (Option A Advantaged)

Q	Project Cost Performance	Probability of Rain	Percentage of Participants Choosing Option A	Expected Value of Option A	Percentage of Participants Choosing Option B	Expected Value of Option B	95% Confidence Interval
19	Under Budget	50%	**77%**	-$1 340	23%	-$2 140	+/- 11 %
13	On Budget	60%	**89%**	-$2 140	11%	-$3 640	+/- 9 %
7	Over Budget	70%	**53%**	-$3 110	47%	-$3 910	+/- 13 %

Concerning the first two questions, the "under budget" and "on budget," most of the participants chose to work and take the best option in terms of expected values. The "on budget" question has a very high level of participants choosing to work because the difference between the two expected values was double that of the other two questions, which makes this question obvious to answer. However, 10% of the participants still chose Option B.

The answers for the last question, the "over budget" one, are the most difficult to understand. Why would 50% of the participants choose Option B even if it is less attractive in terms of expected values? Some clues can be found to understand these results. The expected utilities reported in Appendix E can be used to explain the choice of the participants. As the amounts of the two losses present in this question are close (ratio of 1.325), the first model seems to be the best one to try to describe this behaviour. If the coefficient of overvalue of the losses is considered around its mean, about 1.5, and if the percentage added to the probability of rain is considered positive, because the probability of rain is high, then the expected utility for Option B becomes higher than the expected utility of Option A when the percentage added to the probability of rain is higher than 0.1. This might explain why the participants' answers for this question are around 50-50.

Thus, globally, the participants detected that Option A was more attractive for them to choose except for the question in which the project was over budget. For this question, the different factors which influence their choices had an important impact on participants' final decisions and led half of them to choose the less attractive option.

4.2.4.5 Expected Values Different – Option B Advantaged

The results for the "Weather – Loss Aversion" questions in which the expected were different, with Option B being advantageous, are shown in Table 20.

Table 20: Results for the "Weather – Loss Aversion" Question – Expected Values Different (Option B Advantaged)

Q	Project Cost Performance	Probability of Rain	Percentage of Participants Choosing Option A	Expected Value of Option A	Percentage of Participants Choosing Option B	Expected Value of Option B	95% Confidence Interval
24	Under Budget	80%	**15%**	-$2 070	23%	-$1 270	+/- 10 %
3	On Budget	75%	**19%**	-$2 560	11%	-$1 060	+/- 11 %
9	Over Budget	70%	**26%**	-$1 510	47%	-$710	+/- 12 %

This time, it was the other option which was advantageous, and most of the participants chose the most attractive option in terms of expected values. The answer to the "on budget" question was, as in the case in which Option A was advantageous, "obvious," because the difference between the two expected values was double that of the two other questions. It is therefore more complicated to have a general analysis of these three questions because the results are so close, and too many parameters enter into the equation. However, from a global point of view, 20% of the participants chose the answers with the lowest expected values for this series of questions. This means that around one construction leader out of five are not able to detect the best answer in this situation. This error in judgment represents a significant loss of money if it is repeated in several ongoing projects of a large company.

For this question, the age comparison will not be presented. An attempt has been made to carry out this analysis, but nothing meaningful could be extracted from it because there are too many confounding factors.

4.3 Discussion on the Influence of the Project Cost Performance and the Decision-maker's Experience

Usually, when on-site decision-makers are facing situations involving risk, they are expected to be risk averse. The results of these experiments show that they can also be risk chasing, depending on the context under which the question is asked. Each question in this experiment introduced an on-site construction situation in which a behavioural tendency was expected. In general, reactions of risk-aversion or risk-chasing are associated with a particular situation and behavioural tendency. However, by applying different states of project cost performance on the same questions, it can be concluded that this parameter has an influence on the decision-making process. Furthermore, for all three questions developed in the previous sections, the situation in which the project cost performance is over budget created a reaction of risk-chasing compared to when the project cost performance is on or under budget.

When decision-makers are working under the influence of an over budget cost performance, they consistently become more risk-chasing. This is explained by the fact that usually, when people are making decisions, they are thinking in terms of gains or losses. That is why for these three sets of questions, the results generally show a reaction of risk-aversion. However, when the decision has to be made under the pressure of an over budget cost performance, people no longer think in terms of gains or losses but in terms of the final state. They want to fix the problem, so they include this parameter in their reasoning while they are making their decision. This results in a reaction of risk-chasing. This experiment was tested with the influence of an external parameter, the project cost performance, but other external parameters could have been chosen and might have led to the same conclusions. Project schedule performance would perhaps have the same influence; working in a situation in which the construction project is behind schedule may lead to the same risk-chasing behaviour.

This reaction of risk-chasing is amplified or reduced based on the decision-maker's experience. The second step of this analysis compared the results between the two groups of participants divided according to their age and experience. Depending on the type of question, specifically the construction situation and the behavioural tendency applied, the responses of the two groups are different. The decision-maker's experience has an influence on the perception of the behavioural tendency and the project cost performance applied in each question. The less experienced participants are more risk-chasing with regard to the "Construction methods – Perception of Change" and "Bored Piles – Non-Compliance" questions than the more experienced participants, while the more experienced participants are more risk-chasing with regard to the "Quality of the materials (Shingles) – Certainty effect" questions than the less experienced participants. The decision-makers' experience affects their choices, and by consequence their reaction of risk-chasing or not, but each case has to be considered separately, as the results are different for each type of question.

Even if no rules can be established concerning the reaction of risk-aversion or risk-chasing according to the decision-makers' experience, as it depends on the behavioural tendency applied and the particular situation of the question, some conclusions can be drawn concerning the influence of the project cost performance. This parameter has much more of an influence on the group of less experienced participants than the group composed of more experienced participants. This fact can be seen in the "Construction methods – Perception of Change" question, for which the results are shown in Table 3 and in Table 4.

All these results have to be considered with the associated 95% confident interval. The computation of these confidence intervals is a sufficient approach to give tendencies on how decision-makers behave when they are facing risk situations.

Chapter 5
Conclusions

The experiment that was conducted for this thesis shows the impact of certain behavioural patterns on construction project leaders when they have to make a decision under risk. These behavioural patterns – perception of change, certainty effect, non-compliance and loss aversion – affect their judgment when they are making a decision, resulting in a decision of risk avoiding or risk chasing, depending on the situation.

This experiment proves, with the “Quality of the materials (Shingles) – Certainty Effect” question set, that the certainty effect creates a reaction of risk aversion when construction project leaders make decisions facing risk. This can lead to losses when the risk-taking option is more attractive in terms of expected values. Moreover, the impact of this behavioural pattern was more or less important depending of the situation of the project cost performance. Project leaders are more risk averse if the project is under budget, whereas they are more risk chasing if the project is over budget. More generally, for the entire set of questions, the cost performance influences the decisions made by the participants.

Consistently, for all the questions, the participants were more willing to take a risk if the cost performance was over budget. This aspect appears mainly in the “Quality of the materials (Shingles) – Certainty Effect” question set in which the expected values are equal and in the “Construction methods – Perception of Change” question set. Conversely, when the cost performance of the project was under budget, the participants took less risk. However, this impact is smaller than that of the “over budget” situation. The participants were just slightly less risk taking when the project was under budget.

Most of the participants who were affected by the influence of the cost performance were the younger (and less experienced) construction leaders. In the “Construction methods – Perception of Change” question set, only the younger participants were affected by the cost performance of the project, while the more experienced participants were consistent in their decisions and were not affected by an external influence such as the cost performance. Construction leaders approach problems differently according to their level of experience, which can have an impact on their decision-making process when they are facing risks.

Depending on the question, the younger, less experienced participants will take either less or more risk than the more experienced construction leaders. For instance, the younger participants were more risk taking in the “Quality of the materials (Shingles) – Certainty Effect” question set than the older participants, while the reverse was the case for the “Construction methods – Perception of Change” question set. So, the experience of the participants does not impact all of their decisions in the same way, but depends on the particular behavioural pattern and situation.

In the “Bored piles – Non-Compliance” question set, the least experienced participants were willing to take more risk than the other participants, but this time this result is attributed to the weight they give to sustaining their reputation. It is when the participants compute the expected utilities that the potential loss of reputation becomes a factor. The participants with less experience gave less importance to this potential loss than the more experienced ones. Thus, the experience and background of the participants has an influence on how they compute their expected utilities and how they make their decisions.

Concerning the final behavioural pattern, loss aversion, participants are loss averse, rather than risk averse, with respect to rain delays. It is not possible to determine influences from experience or from the cost performance, since this question has too many parameters involved when the participants are making their decisions for these questions. Little is therefore learned concerning whether the construction leaders would be more risk averse or risk taking if the project is over budget, for instance. That would be an example of one lead to follow to continue further in this research.

All the behavioural patterns and different factors introduced jointly create reactions of risk aversion or risk seeking more or less strongly. This can lead to losses for the construction project. For example, for the case of risk aversion, losses can occur 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 a small loss. Aggregated together, these small losses may represent significant losses for the construction project. The same holds true for the case of risk seeking.

The behavioural patterns studied in this experiment are not the only ones that can have an influence on decisions under risk. Other behavioural tendencies, such as the “anchoring effect,” may have an impact on construction project leaders’ decisions as well. Likewise, other parameters can influence the decisions of the construction leaders, such as time improvement: Would the decisions they make be affected by whether the construction project is ahead of schedule or behind schedule?

To understand the way participants deal with risk, cumulative prospect theory has been used. The model of cumulative prospect theory, created by Tversky and Kahneman (1992), fits the data from this research. Computing the expected utilities of each option of each question, by employing this model, explains the decisions made by the participants while they were facing risk. Hence, this model can be used to understand how construction project leaders make their decisions. Understanding how they are making their decisions is important, because it provides insight into which factors and which behavioural patterns influence them and how they influence them.

This application of behavioural economics, and more precisely of cumulative prospect theory, to common decisions made frequently and quickly by construction leaders facilitates an understanding of how these decisions are made for a construction project. Such an understanding 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 situations that tend to lead to illogical decisions and assisting the construction leaders in dealing with them in a more effective manner.

Appendix A
Questionnaire

Dear Participant,

We would like to thank you for taking the time to participate in this study: “Management decisions under risk on construction projects”.

A series of questions will be asked. They represent examples of typical construction situations, and you will have the possibility to choose between two ways of addressing these situations. There is no “wrong” or “good” answer. You are just simply asked to choose the answer that you would have chosen if you were working on your own construction project. You can take your time while you are answering the survey; there is no time limit.

The structure of the questions will be repeated throughout the survey, but the situations will change in every question. Please don’t use a calculator while you are answering the questions.

Please remember that any data pertaining to you as an individual participant will be kept confidential.

Thank you again for participating to this survey,

Age:

Job’s title:

Years of Experience:

Question 1:

You are working on a project which is **on time** but you are **25% under budget**.

You must decide whether to work tomorrow on a large concrete placement exposed to the weather. There is a **75%** chance of rain. Which decision will you make?

- Decision A: You decide to work tomorrow. If it rains, you will experience net losses of **$3,420**. If it does not rain, you will experience net earnings of **$660**.

- Decision B: You decide to not work tomorrow. As a result, you will experience net losses of **$2,400** whether it rains or not.

A ☐ B ☐

Question 2:

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 **$162** per unit and there is a probability of **97%** it will not crack or break during the installation.

- Shingle B costs **$207** per unit and there is a probability of **100%** it will not crack or break during the installation.

A ☐ B ☐

Question 3:

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

You must decide whether to work tomorrow on a large concrete placement exposed to the weather. There is a **75%** chance of rain. Which decision will you make?

- Decision A: You decide to work tomorrow. If it rains, you will experience net losses of **$3,710**. If it does not rain, you will experience net earnings of **$890**.

- Decision B: You decide to not work tomorrow. As a result, you will experience net losses of **$1,060** whether it rains or not.

A ☐ B ☐

Question 4:

You are working on a project which is **on time** but you are **25% under budget**.

You face a problem on a construction site, and there are 2 technical ways (A and B) to fix it. Which one are you going to choose? The differences between the 2 ways are:

- Decision A: This is a technical way that you are used to. You have always done things this way. It costs **$15,000**.

- Decision B: This is a new way for you. You have never done this way but you know that some colleagues often do this way, and there is no special competence required. It costs **$14,000**.

A ☐ B ☐

Question 5:

You are working on a project which is **on time** but you are **25% over budget**.

You are constructing a set of bored piles and there are two ways for finishing them. Which decision are you going to make?

- Decision A: Do as designed. This way it will cost **$2,400**.

- Decision B: Use less reinforcing steel. It will be safe, and it will only cost you **$2,000**, but it does not meet design specifications. There exists a **1%** possibility of being found using less reinforcing steel by the client. If found, you will lose **$40,000**. But, there is no risk that you will be fired by your company.

A ☐ B ☐

Question 6:

You are working on a project which is **on time** but you are **25% under 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 **$141** per unit and there is a probability of **94%** it will not crack or break during the installation.

- Shingle B costs **$150** per unit and there is a probability of **100%** it will not crack or break during the installation.

A ☐ B ☐

Question 7:

You are working on a project which is **on time** but you are **25% over budget**.

You must decide whether to work tomorrow on a large concrete placement exposed to the weather. There is a **70%** chance of rain. Which decision will you make?

- Decision A: You decide to work tomorrow. If it rains, you will experience net losses of **$5,180**. If it does not rain, you will experience net earnings of **$1,720**.

- Decision B: You decide to not work tomorrow. As a result, you will experience net losses of **$3,910** whether it rains or not.

A ☐ B ☐

Question 8:

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

You are constructing a set of bored piles and there are two ways for finishing them. Which decision are you going to make?

- Decision A: Do as designed. This way it will cost **$3,000**.

- Decision B: Use less reinforcing steel. It will be safe, and it will only cost you **$2,500**, but it does not meet design specifications. There exists a **2%** possibility of being found using less reinforcing steel by the client. If found, you will lose **$25,000**. But, there is no risk that you will be fired by your company.

A ☐ B ☐

Question 9:

You are working on a project which is **on time** but you are **25% over budget**.

You must decide whether to work tomorrow on a large concrete placement exposed to the weather. There is a **70%** chance of rain. Which decision will you make?

- Decision A: You decide to work tomorrow. If it rains, you will experience net losses of **$2,380**. If it does not rain, you will experience net earnings of **$520**.

- Decision B: You decide to not work tomorrow. As a result, you will experience net losses of **$710** whether it rains or not.

A ☐ B ☐

Question 10:

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

You face a problem on a construction site, and there are 2 technical ways (A and B) to fix it. Which one are you going to choose? The differences between the 2 ways are:

- Decision A: This is a technical way that you are used to. You have always done things this way. It costs **$20,000**.

- Decision B: This is a new way for you. You have never done this way but you know that some colleagues often do this way, and there is no special competence required. It costs **$19,000**.

A ☐ B ☐

Question 11:

You are working on a project which is **on time** but you are **25% under budget**.

You are constructing a set of bored piles and there are two ways for finishing them. Which decision are you going to make?

- Decision A: Do as designed. This way it will cost **$1,000**.

- Decision B: Use less reinforcing steel. It will be safe, and it will only cost you **$500**, but it does not meet design specifications. There exists a **5%** possibility of being found using less reinforcing steel by the client. If found, you will lose **$10,000**. But, there is no risk that you will be fired by your company.

A ☐ B ☐

Question 12:

You are working on a project which is **on time** but you are **25% over 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 **$209** per unit and there is a probability of **93%** it will not crack or break during the installation.

- Shingle B costs **$245** per unit and there is a probability of **100%** it will not crack or break during the installation.

A ☐ B ☐

Question 13:

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

You must decide whether to work tomorrow on a large concrete placement exposed to the weather. There is a **60%** chance of rain. Which decision will you make?

- Decision A: You decide to work tomorrow. If it rains, you will experience net losses of **$4,760**. If it does not rain, you will experience net earnings of **$1,790**.

- Decision B: You decide to not work tomorrow. As a result, you will experience net losses of **$3,640** whether it rains or not.

A ☐ B ☐

Question 14:

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

You are constructing a set of bored piles and there are two ways for finishing them. Which decision are you going to make?

- Decision A: Do as designed. This way it will cost **$7,500**.

- Decision B: Use less reinforcing steel. It will be safe, and it will only cost you **$3,000**, but it does not meet design specifications. There exists a **5%** possibility of being found using less reinforcing steel by the client. If found, you will lose **$20,000**. But, there is no risk that you will be fired by your company.

A ☐ B ☐

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 ☐

Question 16:

You are working on a project which is **on time** but you are **25% over budget**.

You must decide whether to work tomorrow on a large concrete placement exposed to the weather. There is a **50%** chance of rain. Which decision will you make?

- Decision A: You decide to work tomorrow. If it rains, you will experience net losses of **$4,320**. If it does not rain, you will experience net earnings of **$1,380**.

- Decision B: You decide to not work tomorrow. As a result, you will experience net losses of **$1,470** whether it rains or not.

A ☐ B ☐

Question 17:

You are working on a project which is **on time** but you are **25% under budget**.

You are constructing a set of bored piles and there are two ways for finishing them. Which decision are you going to make?

- Decision A: Do as designed. This way it will cost **$8,000**.

- Decision B: Use less reinforcing steel. It will be safe, and it will only cost you **$3,500**, but it does not meet design specifications. There exists a **2%** possibility of being found using less reinforcing steel by the client. If found, you will lose **$50,000**. But, there is no risk that you will be fired by your company.

A ☐ B ☐

Question 18:

You are working on a project which is **on time** but you are **25% over budget**.

You face a problem on a construction site, and there are 2 technical ways (A and B) to fix it. Which one are you going to choose? The differences between the 2 ways are:

- Decision A: This is a technical way that you are used to. You have always done things this way. It costs **$5,000**.

- Decision B: This is a new way for you. You have never done this way but you know that some colleagues often do this way, and there is no special competence required. It costs **$4,500**.

A ☐ B ☐

Question 19:

You are working on a project which is **on time** but you are **25% under budget**.

You must decide whether to work tomorrow on a large concrete placement exposed to the weather. There is a **50%** chance of rain. Which decision will you make?

- Decision A: You decide to work tomorrow. If it rains, you will experience net losses of **$3,830**. If it does not rain, you will experience net earnings of **$1,150**.

- Decision B: You decide to not work tomorrow. As a result, you will experience net losses of **$2,140** whether it rains or not.

A ☐ B ☐

Question 20:

You are working on a project which is **on time** but you are **25% over 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 **$288** per unit and there is a probability of **96%** it will not crack or break during the installation.

- Shingle B costs **$300** per unit and there is a probability of **100%** it will not crack or break during the installation.

A ☐ B ☐

Question 21:

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

You must decide whether to work tomorrow on a large concrete placement exposed to the weather. There is a **80%** chance of rain. Which decision will you make?

- Decision A: You decide to work tomorrow. If it rains, you will experience net losses of **$4,170**. If it does not rain, you will experience net earnings of **$880**.

- Decision B: You decide to not work tomorrow. As a result, you will experience net losses of **$3,160** whether it rains or not.

A ☐ B ☐

Question 22:

You are working on a project which is **on time** but you are **25% under 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 **$85** per unit and there is a probability of **95%** it will not crack or break during the installation.

- Shingle B costs **$109** per unit and there is a probability of **100%** it will not crack or break during the installation.

A ☐ B ☐

Question 23:

You are working on a project which is **on time** but you are **25% over budget**.

You are constructing a set of bored piles and there are two ways for finishing them. Which decision are you going to make?

- Decision A: Do as designed. This way it will cost **$8,900**.

- Decision B: Use less reinforcing steel. It will be safe, and it will only cost you **$5,000**, but it does not meet design specifications. There exists a **1%** possibility of being found using less reinforcing steel by the client. If found, you will lose **$40,000**. But, there is no risk that you will be fired by your company.

A ☐ B ☐

Question 24:

You are working on a project which is **on time** but you are **25% under budget**.

You must decide whether to work tomorrow on a large concrete placement exposed to the weather. There is a **80%** chance of rain. Which decision will you make?

- Decision A: You decide to work tomorrow. If it rains, you will experience net losses of **$2,780**. If it does not rain, you will experience net earnings of **$770**.

- Decision B: You decide to not work tomorrow. As a result, you will experience net losses of **$1,270** whether it rains or not.

A ☐ B ☐

Appendix B
Information Letter

Dear Potential Participant,

This letter is an invitation to consider participating in a study we are conducting as part of our research project in the Department of Civil and Environmental Engineering at the University of Waterloo. We would like to provide you with more information about this project and what your involvement would entail if you decide to take part. The following members of the University of Waterloo's Department of Civil and Environmental Engineering are conducting this research:

- Dr. Carl T. Haas, Professor of Civil Engineering
- Jean-Charles Fiolet, Master of Applied Sciences Student

Our study is titled: "Management decisions under risk on construction projects". The general purpose of the research is to study how foremen consider risk, such as weather events, in their decision making and highlight criteria which influence foremen in this kind of decision.

A series of questions will be asked. They represent examples of hypothetical construction situations, and you will have the possibility to choose between two ways of addressing these situations. There is no "wrong" or "good" answer. You are just simply asked to choose the answer that you would have chosen if you were working on your own construction project. You will be asked a few demographic questions, such as your age, your job's title and your years of experience.

Please remember that any data pertaining to you as an individual participant will be kept confidential. Once all the data are collected and analyzed for this project, we plan on sharing this information with the research community through seminars, conferences, presentations, and journal articles. If you are interested in receiving more information regarding the results of this study, or would like a summary of the results, please provide your email address, and when the study is completed, we will send you the information.

Participation in this study is voluntary. It will involve answering a survey taking less than 30 minutes. You may decline to answer any of the survey questions if you wish to do so. Further, you may decide to withdraw from this study at any time without any negative consequences by advising the researcher. All information you provide is considered completely confidential. Your name, title, designation or the name of your organization will not appear in any thesis or report resulting from this study. Data collected during this study will be retained for (3 year time period) in a locked office at the university. Only researchers associated with this project will have access. There are no known or anticipated risks to you as a participant in this study.

If you have any questions regarding this study, or would like additional information to assist you in reaching a decision about participation, please contact us at (Jean-Charles Fiolet, 519-888-4567 ext. 33929) or by email at (jfiolet@uwaterloo.ca). You can also contact my supervisor, Professor (Carl T. Haas) at 519-888-4567 ext. 35492 or email (chaas@uwaterloo.ca).

We would like to assure you that this study has been reviewed and received ethics clearance through a University of Waterloo Research Ethics Committee. However, the final decision about participation is yours. If you have any comments or concerns resulting from your participation in this study, please contact Dr. Maureen Nummelin in the Office of Research Ethics at 1-519-888-4567, Ext. 36005 or maureen.nummelin@uwaterloo.ca.

We hope that the results of our study will be of benefit to those organizations directly involved in the study, other organizations not directly involved in the study, as well as to the broader research community.

We very much look forward to speaking with you and thank you in advance for your assistance in this project.

Yours Sincerely,

Jean-Charles Fiolet

Master of Applied Sciences Student

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Dr Carl T. Haas

Professor

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Appendix C

Consent Form

By signing this consent form, you are not waiving your legal rights or releasing the investigator(s) or involved institution(s) from their legal and professional responsibilities.

I have read the information presented in the information letter about a study being conducted by (Jean-Charles Fiolet, 519-888-4567 ext 33929, email at jfiolet@uwaterloo.ca or, Professor Carl T. Haas at 519-888-4567 ext. 35492 email chaas@uwaterloo.ca) of the Department of Civil and Environmental Engineering at the University of Waterloo.

I am aware that I will be asked a few demographic questions, such as my age, my job's title and my years of experience.

I have had the opportunity to ask any questions related to this study, to receive satisfactory answers to my questions, and any additional details I wanted.

I am also aware that results from this study will be included in the thesis and/or publications to come from this research, with of course anonymity.

I was informed that I may withdraw my consent at any time without penalty by advising the researcher.

This project has been reviewed by, and received ethics clearance through a University of Waterloo Research Ethics Committee. I was informed that if I have any comments or concerns resulting from my participation in this study, I may contact the Director, Office of Research Ethics at 519-888-4567 ext. 36005.

With full knowledge of all foregoing, I agree, of my own free will, to participate in this study.

☐YES ☐NO

I agree to have my responses to the survey used in the thesis and/or publications to come from this research, with of course anonymity.

☐YES ☐NO

Participant Name: ____________________________ (Please print)

Participant Signature: ____________________________

Witness Name: ________________________________ (Please print)

Witness Signature: ______________________________

Date: ____________________________

Appendix D
Feedback Letter

Dear Participant,

We would like to thank you for your participation in this study entitled "Management decisions under risk on construction projects". As a reminder, the purpose of this survey is to study how foremen consider risk, such as weather events, in their decisions.

The data collected during the survey will be used to conduct an assessment of the foremen risk taking when they have to make decisions under uncertainty. This assessment has for objective to analyze the impact of classical variable of a construction project on the foremen decision. Results of the analysis will be presented as a series of preliminary assumptions on behavioural decision making under risk on a construction project.

Please remember that any data pertaining to you as an individual participant will be kept confidential. Once all the data are collected and analyzed for this project, we plan on sharing this information with the research community through seminars, conferences, presentations, and journal articles. If you are interested in receiving more information regarding the results of this study, or would like a summary of the results, please provide your email address, and when the study is completed, I will send you the information. In the meantime, if you have any questions about the study, please do not hesitate to contact me by email or telephone as noted below. As with all University of Waterloo projects involving human participants, this project was reviewed by, and received ethics clearance through a University of Waterloo Research Ethics Committee. Should you have any comments or concerns resulting from your participation in this study, please contact Dr. Maureen Nummelin, the Director, Office of Research Ethics, at 1-519-888-4567, Ext. 36005 or maureen.nummelin@uwaterloo.ca.

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Appendix E
Computation of Expected Utilities for the "Weather – Loss Aversion" Questions

As the "Weather – Loss Aversion" question set was difficult to analyze, two models to compute expected utilities have been created in accordance with prospect theory. The two models used to compute the expected utilities of Options A and B were defined as follows and explained in Section 4.2.4.2.

Model 1:

$$\begin{cases} U(A) = LossA * X * (P + Z) + GainA * Y * (1 - P - Z) \\ U(B) = LossB * X \end{cases}$$

Model 2:

$$\begin{cases} U(A) = LossA * X * (P + Z) + GainA * Y * (1 - P - Z) \\ U(B) = LossB * (X + \mathbf{0.5}) \end{cases}$$

With:

- $P = Probability\ of\ rain$
- $X = Coefficient\ of\ overvalue\ of\ the\ losses, X \in [1\ ;\ 1{,}5\ ;\ 2\ ;\ 2{,}5\ ;\ 3]$
- $Y = Coefficient\ of\ undervalue\ of\ the\ gains, Y = 0.8$
- $Z = Percentage\ added\ to\ the\ probability\ of\ rain,$

  $Z \in [-0{,}15\ ;\ -0{,}1\ ;\ -0{,}05\ ;0\ ;0{,}05\ ;0{,}1\ ;0{,}15]$

For each of the nine "Weather – Loss Aversion" questions, expected utilities are computed for all available cases (Model 1 or 2, with all the possible values). For each of these cases, the computation of EU(A) – EU(B) is made. If this value is positive, it means that Option A is more attractive than

Option B if the expected utilities are computed according to the condition of that case, which would explain why some participants chose Option A. Conversely, if this value is negative it means that Option B seems more advantageous with the expected utilities computed. For each of the questions, two tables show the computation of EU(A) – EU(B). The explanations are shown in Section 4.2.4.

Table 21: Calculation of EU(A) – EU(B) for Question 1 (EV Equal – Under Budget)

Model 1		Overvalue of the losses (X)				
		1	1,5	2	2,5	3
Percentage added to the probability of rain (Z)	-0,15	559,2	733,2	907,2	1081,2	1255,2
	-0,1	361,8	450,3	538,8	627,3	715,8
	-0,05	164,4	167,4	170,4	173,4	176,4
	0	-33	-115,5	-198	-280,5	-363
	0,05	-230,4	-398,4	-566,4	-734,4	-902,4
	0,1	-427,8	-681,3	-934,8	-1188,3	-1441,8
	0,15	-625,2	-964,2	-1303,2	-1642,2	-1981,2
Model 2		**Overvalue of the losses (X)**				
		1	1,5	2	2,5	3
Percentage added to the probability of rain (Z)	-0,15	1759,2	1933,2	2107,2	2281,2	2455,2
	-0,1	1561,8	1650,3	1738,8	1827,3	1915,8
	-0,05	1364,4	1367,4	1370,4	1373,4	1376,4
	0	1167	1084,5	1002	919,5	837
	0,05	969,6	801,6	633,6	465,6	297,6
	0,1	772,2	518,7	265,2	11,7	-241,8
	0,15	574,8	235,8	-103,2	-442,2	-781,2

Table 22: Calculation of EU(A) – EU(B) for Question 21 (EV Equal – On Budget)

Model 1		Overvalue of the losses (X)				
		1	1,5	2	2,5	3
Percentage added to the probability of rain (Z)	-0,15	695,9	920,65	1145,4	1370,15	1594,9
	-0,1	452,2	572,7	693,2	813,7	934,2
	-0,05	208,5	224,75	241	257,25	273,5
	0	-35,2	-123,2	-211,2	-299,2	-387,2
	0,05	-278,9	-471,15	-663,4	-855,65	-1047,9
	0,1	-522,6	-819,1	-1115,6	-1412,1	-1708,6
	0,15	-766,3	-1167,05	-1567,8	-1968,55	-2369,3
Model 2		**Overvalue of the losses (X)**				
		1	1,5	2	2,5	3
Percentage added to the probability of rain (Z)	-0,15	2275,9	2500,65	2725,4	2950,15	3174,9
	-0,1	2032,2	2152,7	2273,2	2393,7	2514,2
	-0,05	1788,5	1804,75	1821	1837,25	1853,5
	0	1544,8	1456,8	1368,8	1280,8	1192,8
	0,05	1301,1	1108,85	916,6	724,35	532,1
	0,1	1057,4	760,9	464,4	167,9	-128,6
	0,15	813,7	412,95	12,2	-388,55	-789,3

Table 23: Calculation of EU(A) – EU(B) for Question 16 (EV equal – Over Budget)

Model 1		Overvalue of the losses (X)				
		1	1,5	2	2,5	3
Percentage added to the probability of rain (Z)	-0,15	675,6	654,6	633,6	612,6	591,6
	-0,1	404,4	275,4	146,4	17,4	-111,6
	-0,05	133,2	-103,8	-340,8	-577,8	-814,8
	0	-138	-483	-828	-1173	-1518
	0,05	-409,2	-862,2	-1315,2	-1768,2	-2221,2
	0,1	-680,4	-1241,4	-1802,4	-2363,4	-2924,4
	0,15	-951,6	-1620,6	-2289,6	-2958,6	-3627,6
Model 2		**Overvalue of the losses (X)**				
		1	1,5	2	2,5	3
Percentage added to the probability of rain (Z)	-0,15	1410,6	1389,6	1368,6	1347,6	1326,6
	-0,1	1139,4	1010,4	881,4	752,4	623,4
	-0,05	868,2	631,2	394,2	157,2	-79,8
	0	597	252	-93	-438	-783
	0,05	325,8	-127,2	-580,2	-1033,2	-1486,2
	0,1	54,6	-506,4	-1067,4	-1628,4	-2189,4
	0,15	-216,6	-885,6	-1554,6	-2223,6	-2892,6

Table 24: Calculation of EU(A) – EU(B) for Question 19 (Option A Advantaged–Under Budget)

Model 1		Overvalue of the losses (X)				
		1	1,5	2	2,5	3
Percentage added to the probability of rain (Z)	-0,15	1397,5	1797,25	2197	2596,75	2996,5
	-0,1	1160	1464	1768	2072	2376
	-0,05	922,5	1130,75	1339	1547,25	1755,5
	0	685	797,5	910	1022,5	1135
	0,05	447,5	464,25	481	497,75	514,5
	0,1	210	131	52	-27	-106
	0,15	-27,5	-202,25	-377	-551,75	-726,5
Model 2		**Overvalue of the losses (X)**				
		1	1,5	2	2,5	3
Percentage added to the probability of rain (Z)	-0,15	2467,5	2867,25	3267	3666,75	4066,5
	-0,1	2230	2534	2838	3142	3446
	-0,05	1992,5	2200,75	2409	2617,25	2825,5
	0	1755	1867,5	1980	2092,5	2205
	0,05	1517,5	1534,25	1551	1567,75	1584,5
	0,1	1280	1201	1122	1043	964
	0,15	1042,5	867,75	693	518,25	343,5

Table 25: Calculation of EU(A) – EU(B) for Question 13 (Option A Advantaged – On Budget)

Model 1		Overvalue of the losses (X)				
		1	1,5	2	2,5	3
Percentage added to the probability of rain (Z)	-0,15	2285,6	3034,6	3783,6	4532,6	5281,6
	-0,1	1976	2606	3236	3866	4496
	-0,05	1666,4	2177,4	2688,4	3199,4	3710,4
	0	1356,8	1748,8	2140,8	2532,8	2924,8
	0,05	1047,2	1320,2	1593,2	1866,2	2139,2
	0,1	737,6	891,6	1045,6	1199,6	1353,6
	0,15	428	463	498	533	568
Model 2		**Overvalue of the losses (X)**				
		1	1,5	2	2,5	3
Percentage added to the probability of rain (Z)	-0,15	4105,6	4854,6	5603,6	6352,6	7101,6
	-0,1	3796	4426	5056	5686	6316
	-0,05	3486,4	3997,4	4508,4	5019,4	5530,4
	0	3176,8	3568,8	3960,8	4352,8	4744,8
	0,05	2867,2	3140,2	3413,2	3686,2	3959,2
	0,1	2557,6	2711,6	2865,6	3019,6	3173,6
	0,15	2248	2283	2318	2353	2388

Table 26: Calculation of EU(A) – EU(B) for Question 7 (Option A Advantaged – Over Budget)

Model 1		Overvalue of the losses (X)				
		1	1,5	2	2,5	3
Percentage added to the probability of rain (Z)	-0,15	1680,2	2210,7	2741,2	3271,7	3802,2
	-0,1	1352,4	1753,4	2154,4	2555,4	2956,4
	-0,05	1024,6	1296,1	1567,6	1839,1	2110,6
	0	696,8	838,8	980,8	1122,8	1264,8
	0,05	369	381,5	394	406,5	419
	0,1	41,2	-75,8	-192,8	-309,8	-426,8
	0,15	-286,6	-533,1	-779,6	-1026,1	-1272,6
Model 2		**Overvalue of the losses (X)**				
		1	1,5	2	2,5	3
Percentage added to the probability of rain (Z)	-0,15	3635,2	4165,7	4696,2	5226,7	5757,2
	-0,1	3307,4	3708,4	4109,4	4510,4	4911,4
	-0,05	2979,6	3251,1	3522,6	3794,1	4065,6
	0	2651,8	2793,8	2935,8	3077,8	3219,8
	0,05	2324	2336,5	2349	2361,5	2374
	0,1	1996,2	1879,2	1762,2	1645,2	1528,2
	0,15	1668,4	1421,9	1175,4	928,9	682,4

Table 27: Calculation of EU(A) – EU(B) for Question 24 (Option B Advantaged–Under Budget)

Model 1		Overvalue of the losses (X)				
		1	1,5	2	2,5	3
Percentage added to the probability of rain (Z)	-0,15	-321,4	-589,9	-858,4	-1126,9	-1395,4
	-0,1	-491,2	-829,2	-1167,2	-1505,2	-1843,2
	-0,05	-661	-1068,5	-1476	-1883,5	-2291
	0	-830,8	-1307,8	-1784,8	-2261,8	-2738,8
	0,05	-1000,6	-1547,1	-2093,6	-2640,1	-3186,6
	0,1	-1170,4	-1786,4	-2402,4	-3018,4	-3634,4
	0,15	-1340,2	-2025,7	-2711,2	-3396,7	-4082,2
Model 2		**Overvalue of the losses (X)**				
		1	1,5	2	2,5	3
Percentage added to the probability of rain (Z)	-0,15	313,6	45,1	-223,4	-491,9	-760,4
	-0,1	143,8	-194,2	-532,2	-870,2	-1208,2
	-0,05	-26	-433,5	-841	-1248,5	-1656
	0	-195,8	-672,8	-1149,8	-1626,8	-2103,8
	0,05	-365,6	-912,1	-1458,6	-2005,1	-2551,6
	0,1	-535,4	-1151,4	-1767,4	-2383,4	-2999,4
	0,15	-705,2	-1390,7	-2076,2	-2761,7	-3447,2

Table 28: Calculation of EU(A) – EU(B) for Question 3 (Option B Advantaged – On Budget)

Model 1		Overvalue of the losses (X)				
		1	1,5	2	2,5	3
Percentage added to the probability of rain (Z)	-0,15	-881,2	-1464,2	-2047,2	-2630,2	-3213,2
	-0,1	-1102,3	-1778,05	-2453,8	-3129,55	-3805,3
	-0,05	-1323,4	-2091,9	-2860,4	-3628,9	-4397,4
	0	-1544,5	-2405,75	-3267	-4128,25	-4989,5
	0,05	-1765,6	-2719,6	-3673,6	-4627,6	-5581,6
	0,1	-1986,7	-3033,45	-4080,2	-5126,95	-6173,7
	0,15	-2207,8	-3347,3	-4486,8	-5626,3	-6765,8
Model 2		**Overvalue of the losses (X)**				
		1	1,5	2	2,5	3
Percentage added to the probability of rain (Z)	-0,15	-351,2	-934,2	-1517,2	-2100,2	-2683,2
	-0,1	-572,3	-1248,05	-1923,8	-2599,55	-3275,3
	-0,05	-793,4	-1561,9	-2330,4	-3098,9	-3867,4
	0	-1014,5	-1875,75	-2737	-3598,25	-4459,5
	0,05	-1235,6	-2189,6	-3143,6	-4097,6	-5051,6
	0,1	-1456,7	-2503,45	-3550,2	-4596,95	-5643,7
	0,15	-1677,8	-2817,3	-3956,8	-5096,3	-6235,8

Table 29: Calculation of EU(A) – EU(B) for Question 9 (Option B Advantaged – Over Budget)

Model 1		Overvalue of the losses (X)				
		1	1,5	2	2,5	3
Percentage added to the probability of rain (Z)	-0,15	-411,8	-711,3	-1010,8	-1310,3	-1609,8
	-0,1	-551,6	-910,6	-1269,6	-1628,6	-1987,6
	-0,05	-691,4	-1109,9	-1528,4	-1946,9	-2365,4
	0	-831,2	-1309,2	-1787,2	-2265,2	-2743,2
	0,05	-971	-1508,5	-2046	-2583,5	-3121
	0,1	-1110,8	-1707,8	-2304,8	-2901,8	-3498,8
	0,15	-1250,6	-1907,1	-2563,6	-3220,1	-3876,6
Model 2		**Overvalue of the losses (X)**				
		1	1,5	2	2,5	3
Percentage added to the probability of rain (Z)	-0,15	-56,8	-356,3	-655,8	-955,3	-1254,8
	-0,1	-196,6	-555,6	-914,6	-1273,6	-1632,6
	-0,05	-336,4	-754,9	-1173,4	-1591,9	-2010,4
	0	-476,2	-954,2	-1432,2	-1910,2	-2388,2
	0,05	-616	-1153,5	-1691	-2228,5	-2766
	0,1	-755,8	-1352,8	-1949,8	-2546,8	-3143,8
	0,15	-895,6	-1552,1	-2208,6	-2865,1	-3521,6

Appendix F

Results of the experiment

#	Age	Position	Years of Experience	Sex	Location	Sector	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20	Q21	Q22	Q23	Q24
1	49	Project Manager	25	M	ON	Ind.	A	A	B	B	A	B	A	A	B	B	A	A	A	A	B	A	A	B	A	A	B	A	A	B
2	61	Program Director	21	M	TX	Ind.	B	A	B	A	A	B	B	A	B	A	A	A	A	A	B	B	A	A	B	B	B	A	B	B
3	32	PhD Candidate	1	M	MI	Edu	A	A	B	A	B	B	A	B	B	A	B	A	A	B	B	B	B	B	B	A	A	A	B	B
4	31	Management coordinator	6	F	Abroad	Ind.	B	A	B	A	A	B	A	B	B	B	A	B	A	A	B	A	A	B	A	B	A	A	A	B
5	39	Project Manager	15	M	PA	Ind.	B	A	B	B	A	B	A	A	B	B	A	A	A	A	A	A	A	B	A	A	B	A	B	B
6	39	Project Manager	14	M	Abroad	Ind.	A	B	B	B	A	B	A	A	A	B	A	B	A	A	B	A	A	B	A	B	B	B	A	B
7	54	Project Manager	28	M	DC	Ind.	A	A	B	A	A	B	A	A	A	A	A	B	A	A	B	B	A	A	A	B	B	B	A	A
8	53	Project Manager	35	M	TX	Ind.	A	A	A	A	A	B	A	A	B	A	A	B	A	A	B	A	A	A	A	B	A	A	A	A
9	30	Project Manager	6,5	M	Abroad	Ind.	B	B	B	A	A	B	B	A	B	A	A	B	A	A	B	B	A	A	A	B	B	A	A	B
10	40	Assistant Professor	15	M	MI	Edu	A	A	B	A	B	B	B	A	B	A	A	B	B	A	B	B	A	B	B	A	B	B	B	B
11	55	Project Manager	35	M	TX	Ind.	B	A	B	B	A	A	B	A	B	B	A	A	A	A	A	A	A	B	A	A	B	A	A	A
12	49	Project Manager	20	M	DC	Ind.	A	A	B	A	A	B	B	A	A	A	A	A	A	A	A	A	A	A	A	A	B	A	A	B

f

#	Age	Position	Years of Experience	Sex	Location	Sector	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20	Q21	Q22	Q23	Q24
13	60	Process Manager	37	M	TX	Ind.	B	A	B	A	A	B	B	A	A	A	A	B	B	A	B	B	A	A	A	B	B	B	A	B
14	41	Research Scientist	8	F	TX	Edu	B	B	B	A	A	B	B	A	B	A	A	B	A	A	B	B	A	A	A	A	B	B	A	B
15	58	Project Manager	34	F	DC	Ind.	B	B	B	A	A	B	B	A	B	A	A	A	B	A	A	B	A	A	B	A	B	A	A	B
16	65	CEO	45	M	ON	Ind.	A	B	B	B	A	B	B	A	B	B	A	A	A	A	A	A	A	B	B	A	A	B	A	B
17	47	Construction Manager	23	M	ON	Ind.	B	A	B	A	A	A	B	A	B	A	A	A	B	A	B	A	A	A	B	A	B	A	A	B
18	25	PhD Student	2	M	ON	Edu	A	A	B	B	A	B	A	A	B	B	A	B	A	A	B	A	A	B	A	B	B	A	A	B
19	44	Professor	20	M	CO	Edu	A	A	B	A	A	B	B	A	B	B	A	B	A	A	B	B	A	B	A	B	B	A	A	B
20	65	Project Manager	45	M	SC	Ind.	A	A	A	B	A	A	A	A	A	B	A	A	A	A	A	A	A	B	A	A	A	A	A	B
21	48	Site Superintend ent	27	M	ON	Ind.	A	B	B	B	A	B	A	A	B	A	A	A	A	A	B	B	A	A	A	B	B	B	A	B
22	28	Project Manager	5	M	ON	Ind.	A	A	B	B	A	A	A	A	B	A	A	A	A	B	A	B	B	A	A	A	B	A	B	B
23	33	Project Manager	11	M	ON	Ind.	B	B	B	A	A	B	A	A	B	A	A	A	A	A	B	A	A	B	A	A	B	B	A	B
24	52	Construction Manager	27	M	ON	Ind.	A	A	B	A	A	B	A	A	A	A	A	B	A	A	B	B	A	A	A	B	B	A	A	B

#	Age	Position	Years of Experience	Sex	Location	Sector	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20	Q21	Q22	Q23	Q24
25	49	Project Superintendent	23	M	ON	Ind.	B	A	B	A	A	B	B	A	B	A	A	A	A	A	A	B	A	A	B	A	B	A	A	B
26	49	Electrical Superintendent	25	M	ON	Ind.	A	B	A	B	A	B	B	A	B	A	A	A	A	A	B	A	A	A	A	A	B	B	A	B
27	55	Area Manager	36	M	ON	Ind.	B	A	B	B	A	A	B	A	B	B	A	A	B	A	A	B	A	B	B	A	B	A	A	B
28	43	Site Superintendent	5	M	ON	Ind.	A	A	B	A	A	B	A	A	B	B	A	A	A	A	B	A	A	B	A	B	B	B	A	B
29	58	Site Superintendent	39	M	ON	Ind.	B	A	B	A	A	A	B	A	B	A	A	A	A	A	A	A	A	A	A	A	B	A	A	B
30	48	Project Manager	12	M	ON	Ind.	B	A	B	B	A	A	A	A	B	B	A	A	A	A	A	A	A	B	A	A	B	A	A	B
31	61	Site Superintendent	42	M	ON	Ind.	A	B	A	A	A	B	A	A	A	A	A	B	A	A	B	A	A	A	A	B	A	B	A	A
32	31	Site Superintendent	4	M	ON	Ind.	A	A	B	B	A	B	B	B	A	B	A	A	A	A	A	A	B	B	A	A	B	A	B	B
33	55	Project Manager	30	M	ON	Ind.	A	A	A	A	A	A	A	A	B	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
34	44	Vice President	25	M	ON	Ind.	A	A	A	B	A	B	A	A	A	B	A	A	A	A	B	A	A	B	A	B	A	A	A	A
35	28	Contract Administration	6	M	ON	Ind.	A	A	B	B	A	B	A	A	B	B	A	A	A	A	B	A	A	B	A	B	A	A	A	B
36	55	Senior Inspector	30	M	ON	Ind.	B	A	B	A	A	B	A	A	B	B	A	A	A	A	B	A	A	B	A	A	B	B	A	B

#	Age	Position	Years of Experience	Sex	Location	Sector	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20	Q21	Q22	Q23	Q24
37	46	Project Manager	23	M	ON	Ind.	B	B	B	A	A	B	B	A	B	A	A	B	A	A	B	A	A	A	A	B	B	B	A	B
38	47	Site Superintendent	25	M	ON	Ind.	B	A	B	B	A	A	B	A	B	B	A	A	A	A	A	A	A	B	A	A	B	A	A	B
39	30	Project Manager	7	M	ON	Ind.	B	A	B	A	A	A	B	A	B	A	A	A	A	A	A	A	A	A	A	A	B	A	A	B
40	56	Site Superintendent	25	M	MI	Ind.	A	A	A	A	A	B	A	A	A	A	A	B	A	A	B	A	A	A	A	A	B	A	A	B
41	31	VDC Engineer	8	M	MI	Ind.	A	A	B	B	A	A	B	A	B	B	A	A	A	A	A	B	A	B	A	A	A	A	A	B
42	27	Project Coordinator	3	M	MI	Ind.	B	A	B	B	A	B	A	A	B	B	A	A	A	A	B	B	A	B	A	B	B	A	A	B
43	22	Project Coordinator	3	M	MI	Ind.	A	A	B	B	A	B	A	A	B	B	A	B	A	A	A	A	A	B	A	A	A	A	A	A
44	54	Executive VP	33	M	MI	Ind.	A	B	A	A	A	B	A	A	A	A	A	B	A	A	B	A	A	A	A	B	A	B	A	B
45	60	Director of Construction	37	M	TX	Ind.	B	B	B	A	A	B	B	A	A	B	A	B	A	A	B	A	A	B	B	B	B	B	A	B
46	29	Research assistant	3	M	ON	Edu	B	A	B	B	A	A	A	A	B	B	A	A	A	A	B	A	A	B	B	B	A	A	A	A
47	24	PhD Student	1	M	ON	Edu	B	B	B	A	A	B	B	A	B	A	A	B	B	A	B	B	A	A	B	B	B	B	A	B
48	33	Project Manager	6	M	ON	Ind.	A	B	A	A	A	B	B	A	A	A	A	A	A	A	B	A	B	B	A	A	A	B	B	B

#	Age	Position	Years of Experience	Sex	Location	Sector	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20	Q21	Q22	Q23	Q24
49	44	Quality Inspector	15	M	ON	Ind.	B	A	B	A	A	B	A	A	B	A	A	B	A	A	B	A	A	B	A	B	B	A	A	B
50	29	Project Designer	4	M	ON	Ind.	A	B	A	A	A	B	A	A	A	A	A	B	A	A	B	A	A	B	A	B	B	B	A	B
51	30	Site Superintendent	5	M	ON	Ind.	B	A	B	B	A	B	A	A	B	B	A	A	A	A	A	B	A	B	A	A	B	A	A	B
52	37	Project Coordinator	17	M	ON	Ind.	B	A	B	A	A	A	B	A	B	B	A	A	A	A	A	A	A	B	A	B	B	A	A	B
53	25	Mechanical Foreman	7	M	ON	Ind.	B	A	B	A	A	B	B	A	B	A	B	B	A	A	B	A	B	A	B	B	B	B	B	B

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