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NUDGING FOR SMART CONSTRUCTION: TACKLING UNCERTAINTY BY CHANGING DESIGN ENGINEER'S CHOICE ARCHITECTURE

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PREFACE

This thesis is written as part of the master program Civil Engineering and Management at the University of Twente, The Netherlands. The research has been conducted internally at the University of Twente institute under the supervision of two internal supervisors. The subject of this research is Nudging for smart construction: tackling uncertainty by changing design engineer's choice architecture. This research started in the middle of February 2016 and continued until January 2017.

Nudging is a hot topic at the moment, especially with its potential application within the construction world. Nudging has the potential to ameliorate future decision outcomes when it comes to comparing multiple design options and help steer the construction industry towards a less uncertain and safer path. The findings of this work can hopefully contribute to more understanding of nudging application in the construction world and to pave the way for further research.

I would like to thank the members of my graduation committee, Dr. Andreas Hartmann and Dr. Marc Van Buiten for their continuous support throughout my master thesis process. Being able to shadow them throughout the pilot study has equipped me with the experience needed to fuel my experiment. Their insight and knowledge was important in steering this experiment towards the right path. I would also like to extend my gratitude to Dr.Mariel Stel for her help with getting the experiment up and running.

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SUMMARY

With erratic market fluctuations, ever-increasing client demands and project complexities, a huge weight is put on the shoulders of contractors. Judging by the history records, it seems that way too often contractors find themselves in critical situations with regards to making decisions in infrastructure tenders. Tender phases pose a great deal of problems for contractors, from the abundant surplus of incomplete information provided by the client, the array of decisions needed to be taken in such short time, the need to offer the best contract while considering the MEAT (most economically advantageous tender), optimism and motivation to win the contract tends to blind contractors to some of the side effects of the designs. The inability to perceive risk and uncertainties has led to late projects, over-expenditure and in many cases, the bankruptcy of construction companies. This, in turn, calls for an intervention to help prevent this vicious reoccurring cycle and sets the basis for this research.

The main research question and its sub-questions are:

Does changing the choice architecture (nudge) of a trade-off matrix increase risk awareness and consequently change the decision outcome in infrastructure design decisions?

a) What are the factors that affect decision making under risk and uncertainty? What makes nudges so effective?

b) What suitable changes in the choice architecture (nudge) of a trade-off matrix can increase risk awareness?

c) Does presenting the risk and uncertainty in a more explicit way through nudging lead to more risk awareness and consequently change the decision outcome?

Based on the factors that affect decision making under risk and uncertainty and the understanding of the working of nudges, a nudge was developed by undergoing a nudge development process in order to find a suitable nudge for the experiment. The outcome of the nudge development process was a nudge in the form of a confidence interval and we further examined whether this nudge, once applied to a trade-off matrix used to assess design options in a student house design competition, raises risk and uncertainty awareness among participants and consequently helped steer individuals into shying away from a riskier (yet more attractive) option towards a safer (yet more average) option.

Results of this experiment are promising as they showed a statistically significant effect of the proposed nudge. The nudge served its intended purpose raising risk and uncertainty awareness levels of the participants and consequently steering the participants away from the riskiest yet more attractive option towards the more average but safer option. The presence of the confidence interval helped to explicitly focus on the risk and uncertainties pertaining to the various options. The ability of the nudge to explicitly draw attention to the risk and uncertainty has shown to cause a shift in the preferred option from the baseline form to the nudged form. Furthermore, a

priori model statistical analysis in the form of a binary logic regression indicated the effect as significant with a significance level of $p = 0.004$ (gauged on a significance level of $p = 0.05$).

In addition, four follow up questions helped to dive deeper into the decision making process understanding and identify other factors that had an effect on the choice outcome. The follow up questions followed a post hoc analysis model as the effects were only examined after the test was run. Although preventative post hoc analysis tests are usually done in order to control the type 1 error rate, it was not possible to perform these tests. The inability to perform these tests was due to the fact that in order for the tests to be run, they required a minimum of three groups, which is not the case in this experiment (only two groups are present: baseline and nudged). In order to tackle this issue, it was important to understand that the root of the post hoc tests were to detect the relationship and effect of subgroups individually. The approach done in order to best mimic the effect of these post hoc tests was to perform statistical tests to each one of the questions separately. This would enable the detection of any pattern or significant effect of each variable.

The first part of the post hoc analysis dealt with risk perception, a factor that was the outcome of the second and third questions (pertaining to the level of risk individuals perceive for each option, respectively) and helped to understand how individuals perceive riskiness in options. This risk perception helped identify perception scores as a mediator to choice outcomes. In order to test for mediation, the values of Question 2 and 3 had to be combined into one, creating the perception score. Statistical analysis testing for mediation helped identify this perception score as a partial mediator. A Significant effect ($p= 0.010$) between the independent variable and the perception score was found, a significant effect ($p= 0.004$) was found between the independent variable and the outcome, and a significant effect ($p= 0.025$) was found for the perception score in the combined analysis as well. Since the mediation didn't completely remove the effect of the independent variable in the system analysis, we concluded the perception score was a partial mediator.

The second part of the post hoc analysis dealt with two factors, risk sensitivity and risk stance (represented by Question 4 and 5, respectively). Once a positive effect of risk sensitivity and risk stance were identified on the dependent variable, but a lack of effect of the independent variable on these variables, they were thought of as moderators. Moderation statistical analysis was needed in order to test for moderation. For moderation to be significant, two analysis (for each moderator identified) needed to be significant. In the first, the dependent variable (decision outcome) was regressed on the independent variable and the moderator while in the second, the interaction between the independent variable and the moderator was entered into the analysis. The findings of both moderator analysis showed that in the first analysis, both moderator variables had a significant outcome with $p= 0.000$ for both. Nonetheless, there was no moderation effect present for any of the two variable. This is because although there was a significant effect when the first part of the analysis was made, the second analysis (where the interaction variable was included) produced a non-significant outcome. That is, after including the interaction between the independent variable and the mediator (risk sensitivity or risk stance), none of the R^2 changes were significant (which means there was no increase in the predictability of the model). Nonetheless, these factors helped consolidate the literature review findings that humans have a certain level of risk sensitivity and are by nature risk averse (they shy away from taking risks).

Based on the research results, we hope construction companies recognize the potential nudge uses in raising risk awareness within infrastructure tender processes. Nudges increase risk awareness which consequently will have an influence on the decision outcome. This risk awareness will in turn pave the way to more conscious decision making by channeling the attention towards the crucial aspects at hand, risk and uncertainty. Missing out on such an opportunity will be ill-advised, especially with the construction history records that is packed with evidence of the vicious cycle that has left many companies bankrupt which stemmed from the overlooking/lack of attention towards the risk and uncertainties associated with each design option.

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1. INTRODUCTION

1.1 Problem definition

With erratic market fluctuations, ever-increasing client demands and project complexities, a huge weight is put on the shoulders of the contractors. Unfortunately, clients have been pushing for more responsibility and risk to be accepted and taken on by these contractors. This comes mainly in the form of integrated contracts, where the contractor takes the responsibility of the project from cradle to grave, encompassing all the major phases: design, building and maintenance of projects. While these contracts might be useful in terms of enabling a better synchronization between the different phases of the project and increasing the chance of learning from experience, it also opens doors to potential problems down the line. Tender phases pose a great deal of problems for contractors, from the abundant surplus of incomplete information provided by the client, the array of decisions needed to be taken in such short time, the need to offer the best contract while considering the MEAT (most economically advantageous tender), optimism and motivation to win the contract tends to blind contractors to some of the side effects of the designs.

A study conducted by (Van Der Meer, Van Der Horst, Dewulf, & Hartmann, 2015) looked at the challenges of design decisions in large infrastructure project tenders. By realizing that systems engineering was the best way to make decisions regarding design in order to not only integrate the whole process, but also to better fulfill the client demands, a look was taken as to how tenders inhibit the optimizations of the systems engineering process. Two main challenges were noted based on that research: the first was making early design decisions, where trade-off studies were used in order to choose between alternatives. This was accomplished by applying weighting criteria based on requirements, cost and schedule (without having the relevant detail information or indicating the aleatory or epistemic uncertainty). The results of the research indicated that the choice of an alternative, without knowing the involved uncertainty, made it impossible for design managers to develop the most economically optimal design. In turn, emphasizing the importance of knowing the level of uncertainty involved in each alternative.

The second challenge was in creating an understanding of the design uncertainties. In an environment where early decisions based on limited information within a limited time frame is needed, coupled with the fact that once these decision choices are submitted in a tender, there is no going back, it was crucial to have detailed information regarding the alternatives as input for a successful trade-off in the detailed design. Since this information was lacking, the outcome was a decision which led to the increased risk evaluation for other subsystems.

One research's proposed solution was that in order to address missing or unclear information, it was important to compare its impacts on the design alternatives by incorporating a certain margin of uncertainty in the trade-offs. And that only by explicitly comparing the uncertainty in (missing) design parameters can help one hope to improve the systems understanding (Van Der

Meer, Van Der Horst, Dewulf, & Hartmann, 2015). A call for action was needed to help these contractors open their eyes to the risk and uncertainties each of the designs options possess, and what we propose comes in the form of what is called nudging.

Nudging, a theory that rose to global prominence in 2008 with the release of the book *Nudge: Improving Decisions about Health, Wealth and Happiness*, by Thaler and legal scholar Cass R. Sunstein, is gaining popularity as a means to encourage and promote a healthier, more conscious and more environmentally friendly decision making (Thaler & Sunstein, 2009). Nudging is seen as "any aspect of the choice architecture that alters people's behaviour in a predictable way without forbidding any options or significantly changing their economic consequences. To count as a mere nudge, the intervention must be easy and cheap to avoid. Nudges are not mandates. Putting fruit at eye level [to attract attention and hence increase likelihood of getting chosen] counts as a nudge. Banning junk food does not" (Kim Ly, 2013). It may be possible to apply nudging to construction (which would be attempted in this research), where design decision outcomes could be influenced through increasing risk awareness by the introduction of a nudge in the choice architecture. Risk and uncertainty awareness is crucial to not only help contractors make better design decisions regarding proposed designs within the limited tender time constraints, but also to open a door that leads to more conscious decisions on a larger scale.

Assembling all the pieces of the puzzle together, it becomes crucial to combine the knowledge acquired through literature review findings into developing an effective nudge that would enable the proper trade-off between options to be made during infrastructure tender processes and test its effectiveness on raising risk awareness.

1.2 Research objective

The objective of this research was two folds. The first objective, which was what the research aimed for, was to increase the designer's awareness of risk and uncertainties in design choices within infrastructure tenders. The second objective, which was within this research, was to:

Develop a suitable nudge based on studies pertaining to decision making under risk and uncertainty and nudge mechanisms. Determine the influence of implementing this nudge in a trade-off matrix on risk awareness and consequently on decision outcomes in infrastructure design decisions.

1.3 Questions

Based on the research objective, one main question with three sub-questions was formulated and will be answered by the end of this research:

Does changing the choice architecture (nudge) of a trade-off matrix increase risk awareness and consequently change the decision outcome in infrastructure design decisions?

a) What are the factors that affect decision making under risk and uncertainty? What makes nudges so effective?

b) What suitable changes in the choice architecture (nudge) of a trade-off matrix can increase risk awareness?

c) Does presenting the risk and uncertainty in a more explicit way through nudging lead to more risk awareness and consequently change the decision outcome?

1.4 Methodology

To investigate the factors that affect an individual's ability to make decisions under risky and uncertain situations, a thorough literature study was conducted. The various factors were looked into in order to try and paint a vivid picture to help answer the first research sub-question.

Furthermore, a look into the working mechanism of nudges and their psychological effects helps discover the reasons behind the effectiveness of nudges and thus help answer the question of what makes nudges so effective.

Once the underlying knowledge and proper understanding of the forces in play are acquired, an experiment is set up in order to test whether presenting an uncertainty in a more explicit way changes the level of risk awareness and in turn, the outcome of the decision making process. The experiment builds on a previous experiment (which will be named pilot study) conducted by Dr. Andreas Hartmann and Dr. Marc van Buiten from the University of Twente in the Netherlands (Buiten, Hartmann, & Meer, 2016). This follow up experiment was done in order to not only gain more research knowledge in the nudge domain, but also as an interest to see how different type of nudges affect risk awareness. In the pilot study, a scenario was introduced that included a student design competition as means of finding the best housing option to accommodate the refugee crisis (a topic that is very relevant and fitting) which students could relate to. Sixty students from the University of Twente took part in this experiment where they had to read a

small text explaining the competition and then choose from two options. The two options were presented in a form of a trade-off matrix. The main aim of the experiment was to see how nudges pushed students to explicitly pay attention to risks and uncertainties and study whether this would affect their decision making outcome. Students were split in two groups and handed two different versions. One version was the baseline version that included the options and score ratings for various attributes associated with each option. The second version was the nudged one, which was made by incorporating four types of nudges. These nudges came in the form of small tweaks to the trade-off-matrix and included changing the order of some attributes, include visual aids, providing examples and additional descriptions. More information can be found in (Appendix1.2). The hypothesis was that the students who took the baseline version would opt more for option 1, as it is more attractive at first sight and the students who took the nudged would opt more for option 2 after being more aware of the risk and uncertainty involved. The test did seem to provide a change in student's decisions, but a stronger manipulation was needed. Shadowing the professors during the setup, conduction and outcome verification of the pilot study helped gain insight into the world of nudging and their effects. With that in mind, this experiment hoped to build on the pilot study by tweaking a few elements to the trade-off matrix and/or incorporating a new nudge.

Although the pilot study was pencil and paper based, this experiment was computer/internet based. This was mainly done for two reasons. First, in order to reach a wider audience due to the fact that the experiment was ran during the end of the academic year where students were on summer holidays and second, people tend to be more motivated to participate in these experiments when a monetary compensation is involved. Although a paper and pencil experiment was considered, after weighing the pros and cons, the computer/online based experiment prevailed. A computer/internet based experiment did offer main advantages ranging from control, quick data availability, and motivated participants, some disadvantages were noted. Some of these disadvantages were the fact that some participants could be rushing through the experiment just to collect the monetary value (steps were taken to deal with this scenario in the data analysis by incorporating the time as an important factor).

The experimental results and analysis determined whether a positive effect was present, answering the second research sub-question. If proven effective, the combination of data collection and experimentation help determine the influence of implementing a nudge in a trade-off matrix within choice architecture on design decision outcomes in infrastructure tenders and thus, concluding the research questions.

1.5 Definition of terms

Choice architect: anyone who presents people with choices.

Choice architecture: the design of different ways in which choices can be presented to consumers, and the impact of that presentation on consumer decision making.
Integrated contracts: a contract that consists of the designing, building and maintenance of a project.
Nudge: a concept in behavioral science, political theory and economics which argues that positive reinforcement and indirect suggestions to try to achieve non-forced compliance can influence the motives, incentives and decision making of groups and individuals, at least as effectively- if not more effectively- than direct instructions, legislation, or enforcement.
Project: a temporary endeavor undertaken to create a unique product.
Systems Engineering: an interdisciplinary approach and means to enable the realization of successful systems. It focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, then proceeding with design synthesis and system validation while considering the complete problem.
Tender: a submission made by a prospective supplier in response to an invitation to tender. It makes an offer for the supply of good or services
Uncertainty: the state of being uncertain, not sure of something.

1.6 Importance of study

In an ever-changing world where constant improvements are needed not only to survive in the market, but also to help humanity move ahead, moving towards more conscious decisions based on risk awareness will enable the optimization of the resources that contractors have to offer in hopes of creating better products, all while minimizing the risks and uncertainties. This boils down to two main issues: the first is the fact that decision makers in the construction world should pay more attention to the choice architectures during infrastructure tenders while the second is the possibility of an effective nudge (change in choice architecture) to be the solution to the first issue by possibly influencing risk awareness and consequently having an effect on the decision outcome. This study will be a significant endeavor in promoting the use of nudges in infrastructure tenders. If nudges prove to be effective in the construction industry domain, this could open doors to a whole new arena of decision making, where emphasis will be made on things that matter, like risk and uncertainties, instead of the current focus on winning a contract. This will not only help break away for the current vicious cycle that revolves around short-term gratifications (winning bids) while sacrificing the future, but also pave the way to further research and exploration of nudging within the construction industry. This, in turn, would lead to better decisions, less construction company bankruptcies and lift some weight off the shoulder of contractors. The output of this study is a source material not only for researchers to witness and better understand the effect of nudges, but also for future students who wish to dive into this domain.

1.7 Report outline

The structure of this report is as follows:

- Chapter one is an introduction and lays the foundation of the paper.
- Chapter two examines the theoretical background and is subdivided into two main parts. Part one looks at the root factors that affect and determine how individuals make decisions under risk and uncertainty while part two investigates the concept of nudging.
- Chapter three introduces the nudge development process in order to find a suitable nudge to incorporate.
- Chapter four comprises of the research design. In this chapter, the design and procedure of the experiment are showcased in detail alongside the experimental setup.
- Next, the results of the experiment are presented (Chapter five).
- Discussions and further investigations are addressed in Chapter six. A look is taken into the outcomes of the experiment and statistical analysis help understand the significance of the results and their meanings.
- Conclusions are drawn in Chapter seven.

2. LITERATURE REVIEW

The literature study consists of two separate path that converge down the line. The first part lays the foundation and revolves around decision making under situations of risk and uncertainty, while the second part will be the bulk of the research, comprising of nudging: the psychological aspect of decision making.

2.1 Decision making under risk and uncertainty

Decision making is no easy task, having the responsibility to take a decision based on a wide array of attributes and not only believing that it is the best decision, but also standing by it and seeing it go through. When considering a tender, contractors have to take into account the various sources of risk and uncertainty based on imperfect observations and unknown outcomes while balancing the multiple objectives in order to reach a decision (Kochenderfer, 2015). For example, once a contractor makes a tender decision, there is no turning back; the nature of these integrated contracts make it such that whatever decision is made should be stuck with till the end, and whatever the consequences may be, the contractor bears them. “Designers of automated decision support systems must take into account the various sources of uncertainty while balancing the multiple objectives of the system “ (Kochenderfer M. , 2016). Before diving into this topic, it is important to note a key point that seems to cause a lot of confusion: the difference between uncertainty and risk. Although most of the time these two words seem to accompany one another, there is a clear distinction between them; uncertainty deals with the possible outcomes that are unknown, while risk is a certain type of uncertainty that involves the real possibility of loss which can be more accounted for than uncertainty (Boundless, 2015) (Holsinger, 2015). A heavier focus will be put on that of uncertainty which is the state of having limited knowledge of current conditions or future outcomes (as this is what contractors go through when preparing the tenders). The first instinct (and the most widespread) that individuals have when dealing with uncertainty is the tendency to delay or put off the decision until the data required to make these decision become readily available and more accessible. This path ,unfortunately, cannot be undertaken by the contractors with regards to tenders due to the fact that they need to make all the decision ahead of time (to be included in the tender) for the client to see and judge. Decision making is difficult and it’s tricky on its own, but when combined with uncertainty and risk (like in all tender phases), it becomes a whole other game on a different field. Its wide occurrence and criticality has caused a lot of research to be done into understanding what goes behind decision making under uncertain situations to the point where it developed its own name: decision theory. Decision theory can be regarded as the analysis of the behavior of an individual facing uncertainty (Gintis, 2009). Several

factors affect the ability to make decisions under uncertainty, some of these factors are: the ability to identify risks and manage them, use of probability and probabilistic models, human nature and time inconsistency. These factors are discussed in the following paragraphs.

2.1.1 ABILITY TO IDENTIFY RISKS AND MANAGE THEM

Managing uncertainty in decision making relies on identifying, quantifying and analyzing the factors that can affect the outcomes which, in turn, enable managers to identify risks and their potential impacts (Boundless, 2015). Before an emphasis on the importance of being able to manage risk is looked at, the types of risk are identified and briefly explained. There are five types of risks that should be identified in order to optimize the management of uncertainty; those risks are: strategic risks, financial risks, operation risks, legal risks and other risks (Boundless, 2015) (Roden, 2009).

Strategic risks are risks that an organization takes, usually in the form of investments, in order to pursue its missions and facilitate the fulfillment of objectives; financial risks are monetary risks that have the potential to yield economic losses that can result from either poor resource allocations, unseen fluctuations in interest rates and tax policies or unforeseen currency value fluctuations; operational risks are yielded from the choices made with regards to the processes chosen to reach the final service or goods and can come in the form of production errors, malfunctions, human or machinery errors or inferior raw materials; legal risks are one of the toughest and more crucial risks as the threat is so huge that precautions need to be taken very delicately as the risk that can arise from threat of litigation or ambiguity in the laws and regulations can put an organization in a crippling situation; last but not least, other risks include everything that is beyond control and cannot be forecasted at all and they ranges from weather disasters to earthquakes and flood (Boundless, 2015). Once all these types of risks (or most of them) are identified and quantified, it all falls back into the ability of the firm to absorb, transfer and manage these risks when they occur, whether on a miniature or critical situation (Boundless, 2015) (Roden, 2009). If managers believe that their firm has the potential to absorb the losses in the unfortunate event of an outburst, not only will they be able to better cope and react to them (such as using a hedge to deal with financial risks and unique contract languages to mitigate legal risks) but also to have a larger appetite for risk which could translate to the tender phase as contractors would be able to offer riskier designs and more attractive packages with confidence (Boundless, 2015).

2.1.2 PROBABILITY AND PROBABILISTIC MODELS

When uncertainty is a fact of life and business, probability is seen as the appropriate guide for a good life and successful business (Taghavifard, Damghani, & Moghaddam, 2009).Uncertainty is seen as the most important feature to consider in decision making, which makes the ability to represent knowledge in terms of probability, critical (Howard, 2007).Some companies such as Unilever look at decision making under uncertainty (or what they like to call DMUU) under a

different scope, as they like to see it by itself as a disciplined, methodical/structured approach to decision making, with probabilistic analyses at the heart of its logical reasoning (Roden, 2009). Probability can be seen as an instrument used to measure the likelihood of an event's occurrence and when it is used to express uncertainty leads to it having a value of zero on the deterministic side and a flat (or equal probability) on the other side (Taghavifard, Damghani, & Moghaddam, 2009). The difference between the mentioned deterministic side/model and the probabilistic one is that in the first, a good decision is judged by the outcome alone while in the latter, the decision maker is more concerned with the amount of risk that each option carries (Taghavifard, Damghani, & Moghaddam, 2009). Although the Unilever report seems to focus more on the company itself, some lessons can be learned about the importance of proper decision making under uncertainty. "The decisions are often complex in nature, have a high degree of uncertainty and can become sources of internal tension due to differences in priorities and objectives" (Roden, 2009). This can be applied directly to the case of contractors who need to make complex decisions when developing the tenders, all of which have consequences that unfold over a long period of time. Extensive use of electronic software such as RISK are on the rise, in order to not only be able identify the risks but also get a clear image of the percentage/probability of them occurring. Other famous researchers such as Blaise Pascal and Pierre Fermat see probability as the measure of the opposite of uncertainty and that the laws of probability were discovered by looking into the gambling problems and trying to figure out the ways to maximize the monetary gains (Plattner, 2015). Some of the advocates of using probability models were Morris DeGroot, James Berger and more notably John von Neuman and Oskar Morgenstern whom established that the optional decision making under uncertainty involved probabilistically weighting all possible future outcomes, which included a series of multiple regression techniques that took into consideration behavior inferred by probabilistically-weighting explanatory factors (Neumann & Morgenstern, 2004). While DeGroot and Berger rely heavily on statistical probability analysis and equations (Degroot, 1970) (Berger, 1980), other authors such as Mykel Kochenderfer rely on these probabilistic models and dive deeply in to the models as showcased in his published book called "Design Making Under Uncertainty" (Kochenderfer, 2015). Kochenderfer goes on to introduce the Bayesian networks that act as a graphical model which captures these probabilistic relationships between the various variables as well as utility theory (as a framework) to understand the optimal decision making that takes place under uncertainty. These are only some of the models touched in that book which are backed up by enough research to showcase their positive working effect as well as the reason why a lot of researchers and companies rely on them; other decision models that incorporate probability are used in accordance with the level of uncertainty. Various models exist, some of which operate under pure uncertainty, some uncertainty and pure risk (Taghavifard, Damghani, & Moghaddam, 2009) while others come in the form of decision trees, expected monetary value criterion, value utilities (which are heavily based on lengthy calculations) (Goodwin & Wright, 2004) (Baron J. , 2007) and graphs (through the use of decision diagrams (Howard, 2007)). Although a vast majority advocate and push towards these probabilistic models, few others remain skeptical and wary of their advantages.

Some of these skeptics are Andrew G Haldane (Executive director, financial stability and member of the financial policy committee) and Vasileios Madouros (economist at the Bank of England) whom argue that it is beyond one's cognitive limits to fully define future states of the world under uncertainty and probabilistically weight them (Haldane & Madouros, 2012). Their argument focused on the idea that even for super computers, evaluating things that would unfold while considering uncertainty is too limited, let alone expensive, and time consuming for the mere potential result outcomes. In such uncertain environments, where statistical probabilities are vastly unknown, these approaches to decision making are no longer suitable for the situation at hand. (Haldane & Madouros, 2012).

2.1.3. HUMAN NATURE

The nature of the human itself provides a great deal of insight into the risks taken in decision making. Usually, an individual falls under one of these three categories: risk averse (meaning the individual shies away from taking risk), risk neutral, or risk taking. Different decision makers will have a different appetite for the level of risk that they are willing to accept as a worthwhile proposition, this of course depends largely on multiple factors such as the individual's personality, the organization's culture and the individual's status within the organization (Winch, 2010). Putting the appetite for risk aside, the recommendations and solutions chosen by managers/decision-makers varies greatly depending on the degree of certainty that is usually strongly related to how much knowledge is known about the problem at hand (Taghavifard, Damghani, & Moghaddam, 2009). This can be a major factor that has a great sway with regards to the contractors setting up the tenders, different contractors might value different options and have a tendency to lean towards a certain direction based on their level of knowledge regarding the client's wishes and how to achieve them (which is also influenced by past experiences). Research into the factors that affect a decision maker's preference towards risk taking revealed a list of six important factors. The list includes: the proportion of total assets at stake, the opportunity for the laws of chance to work, sentiments, organizational culture, managerial capabilities and the human condition (Winch, 2010). Each one of these factors is described briefly in the upcoming paragraph. The proportion of the total asset at stake determines the decision maker's position with regards to the risk, if the asset in question is 5% of the total assets , then a decision maker is more likely to be risk taking than when it represents 50% of the asset; the opportunity for the laws of chance to work comes in play when there are chances of making repeated plays, this is not the case when it comes to the tenders as a decision is made once and then the decision maker has to stick with it till the end; sentiments plays on the tendency of individuals to have a sense of security in numbers, encouraging decision makers to take higher risks when their colleagues engage in similar behavior; the organisational culture creates the environment needed for decision makers to either be risk averse or risk taking; the more a decision maker is confident with their managerial capabilities, the more inclined they are to approach risk neutrality; the human condition, as seen by research, has shown that the human

nature tends to be risk averse, as they got accustomed to fearing loss more than seeking gains (Winch, 2010). In addition to one's human nature, psychologists believe that the individuals make decisions under uncertainty by determining the best option through an assessment of potential consequences and their perceived likelihood (Shafir & Tversky, 1992). Psychologists found that individuals normally abide by what they call Savage's sure-thing principle (or STP) which stated that if an individual prefers *x* to *y* given any possible state of the world, then he should prefer *x* to *y* even when the exact state of the world is not known; multiple experiment outcomes have suggested that in the presence of uncertainty, individual's various reasons and considerations are weighted differently, which, in turn, gives rise to violation of the STP (Shafir & Tversky, 1992). One such experiment was done through a game conducted on undergrad students called the Prisoner's Dilemma (or PD). The game setting can best be presented in the figure below:

		OTHER	
		cooperates	competes
YOU	cooperate	You: 75 Other: 75	You: 25 Other: 85
	compete	You: 85 Other: 25	You: 30 Other: 30

FIGURE 1 : Prisoner's Dilemma game where the cells indicate the number of points received based on the choice taken (Shafir & Tversky, 1992)

As can be seen from the figure 1 above, there are four possible options depending on whether an individual chooses to cooperate or compete. The individuals are subjected to three scenarios; the first scenario is where they are told that the opposition has chosen to compete, the second was where the opposition chose to cooperate and the third scenario is where the move of the opposition was unknown (see (Shafir & Tversky, 1992) for more detailed and complete treatment). In the first scenario, only 3% of individuals chose to cooperate when they knew that the opposition chose to compete; in the second scenario, a much larger portion of the individuals chose to cooperate (which confirms the idea that there's an ethical inclination when it comes down to cooperation); in the third scenario, they expected that the unknown action of the opposite would lead to an intermediate rate of cooperation , but actually a full 37% resulted in cooperation, showing that there's an increased tendency to cooperate and be risk averse when uncertainty is present (Shafir & Tversky, 1992).

2.1.4 LOSS AVERSION

Loss aversion is a fairly widespread concept that has been in play for quite some time. As briefly mentioned before, loss aversion is "the psychological propensity that losses loom larger than equal-sized gains relative to a reference point" (Gachter, Johnson, & Herrmann, 2007, p. 2) or in simpler terms, humans psychologically perceive a loss in a greater way than they perceive a gain (these gains/losses being of equal values). A clear illustration of this concept can be seen in Dean Buonomano's book called Brain bugs (Buonomano, 2011) where a few experimental studies were conducted to closely study the effect that these perceptions have on individuals. In a study, two scenarios were introduced to the participants; the first scenario was a case where the participants were given $50 and then asked to choose between 2 options: the first option was to keep $30 while the second option was to gamble with the $50 dollars for a 50/50 chance of either winning or losing the whole $50. Results of this first experiment showed that the majority of participants (57%) decided to be risk averse and not gamble. In the second scenario, the individuals were again presented with 2 options: the first option was to lose $20 while the second option was to gamble with the $50 with a 50/50 chance of keeping/losing the money. This time, the results indicated that 61% of participants decided to gamble. This phenomenon of loss aversion can be seen in play in that example and showcases just how uncomfortable people are with losing something, these can be translated into a lot of domains, like marketing, for example, to increase the number of people deciding to buy your product (Buonomano, 2011).

2.1.5 TIME INCONSISTENCY

Individuals usually tend to make wise decisions when they think of all the angles of a scenario and take their time, but when it comes to the tender phases that the contractors go through, with the stress and time constraints, it becomes tricky. Researchers agree that time pressure is an external factor that majorly influences the individual's behavior (Lin, Sun, Chuang, & Su, 2008) as well as constrains the quality of information that is processed (Iyer, 1989). Research has revealed that individuals can choose wisely, except when costs or the benefits are immediate, people tend to always make poor choices by sacrificing the long term payoffs in order to gain the immediate payoffs (Gintis, 2009). This applies perfectly to the scenario that unfolds as contractors develop their tenders under extreme time constraints and incomplete information (often relying heavily on negative information (Wright, 1974)) in order to win the contract. Studies have shown that individuals tend to develop three significant traits when under heavy time pressure. The individuals tend to shift from using compensatory to non-compensatory rules (Payne, Bettman, & Johnson, 1988), simplify their selection decision by relying on less effortful decision-making strategies (Svenson, Edland, & Slovic, 1990), and resolve to heuristics due to lack of choice (two experiments were conducted to test how closely the efficient processing patters for a given decision problem identified by the simulation corresponded to the actual processing behavior exhibited by the subjects and concluded that people appear highly adaptive in responding to changes in the structure of the available alternatives and to time pressure) (Dhar & Nowlis, 1999). Contractors tend to push-for and sugar-coat their developed options with an

over-enthusiastic and largely optimistic vision, which might help them gain the contract and get the immediate gratification and payoffs but might set them on the path paved with complexities, uncertainties and large risks.

2.2 Nudging

Now that a look was established into decision making under risk and uncertainty, it is quite obvious how critical some decision outcomes might be. One has to keep in mind that the way a choice is presented influences what a decision-maker chooses, something that each person can relate to on a day to day basis from experiences ranging from: fast food billboards increasing an individual's chance of craving those foods to car choices, what is the best energy saving/ environmentally friendly car.

Zooming more into the concept of nudging. The following sections will proceed as follow: an introduction into the different types of nudging is made all while showcasing scenarios where nudges have been implemented with success. Possible complications with the implementation of nudges are identified and lastly, an overall literature review summary providing answers to the first sub-question.

2.2.1 CHOICE ARCHITECT TOOLS

Choice architect, which comprises of any individual who presents people with choices, can influence choice in many ways: "by varying the presentation order of choice alternatives, the order attributes and their ease of use, and the selection of defaults, to name just a few of the design options available" (Johnson, et al., 2012, p. 488). While some people still oppose the idea of steering individuals into a desired outcome selection and accuse it of being manipulative and dishonest, the fact is that there is no neutral way, anyway a choice is presented will influence how the decision-maker chooses (Johnson, et al., 2012). An easy way to visualize this is to think of the various computer programs an individual downloads and installs, before the installation process takes place, the different options are presented for the user to freely choose from, nonetheless, there is always a pre-ticked box which is followed by "(default)" and that is what the majority of people click. This has more to do with the fact that people are either more inclined to follow the believed trend (named default) or are afraid of complicated options and thus opt for the simplest one (assuming it's the default). A choice architect's job is not easy, and a lot of preparation and thought needs to be taken in order to successfully execute their tasks. In hopes of delivering the best choices, choice architects make use of tools to aid them in establishing those choices. These tools are divided into two main categories: those used to facilitate the structuring of the choice task and those used to describe these choice options (Johnson, et al., 2012). Table 1 below shows the 2 main categories and the subcategories that comprise them.

Table 1. Available tools for the Choice Architect

Choice Architect Tools	
A. Structuring the choice task	*B. Describing choice options*
A1. Number of alternatives	B1. Partitioning options and attributes
A2. Technology and decision aids	B2. Designing attributes
A3. Defaults	
A4. Choice over time	

Each one of these categories and subcategories is explained in the upcoming sections.

A. Structuring the choice task

A1. Number of alternatives

Whether it be meal plans, tender options, or car color, a very important decision to make is with regards to the number of alternatives to present to the decision maker. While many options might give the feeling of freedom of choice and liberty when it comes to meal plans, it could also backfire with regards to let's say, car color, where the decision maker halts decision making due to the inability to choose from the countless options. Another example is with regards to the benefit plans available to US seniors now, which exceeds 100 in some states, possibly overwhelming the decision maker and the processing capacity of many elderly decision makers (Kling, Mullainathan, Shafir, Vemeulen, & Wrobel, 2011). These everyday scenarios show how increasing the number of options beyond a handful is not always beneficial, but rather leads to paralysis, poor choice and decreased satisfaction with the choice (Shwartz, Oulasvirta, & Hukkinen, 2004). Behavioral economists have studied this phenomenon for quite some time and it has been referred to as different terms, such as "choice overload" (Lepper & Iyengar, 2000) , or "tyranny of choice" (Shwartz, Oulasvirta, & Hukkinen, 2004). While psychological theory and research do affirm the positive and motivational consequence of having multiple options, at one point it becomes too much and start to have the opposite effect (Lepper & Iyengar, 2000). The result of three experiments (which were conducted on both laboratory and field settings) showed that people "are more likely to purchase gourmet jams or chocolates or to undertake optional class essay assignments when offered a limited array of 6 choices rather than a more extensive array of 24 or 40 choice" (Lepper & Iyengar, 2000, p. 995). Other experiments conducted validate and solidify the results found in the first three experiments. An experiment was conducted where the individuals were shown a search scenario and a query and had to choose the best choice within 30 seconds; the outcome showed that having to choose between six results (as opposed to 24 choices) yielded not only higher subjective satisfaction, but also to greater confidence in the correctness of the choice (Shwartz, Oulasvirta, & Hukkinen, 2004). "The choice architect needs to balance two criteria: first that more options increases the chance of offering a preference match to the consumer, and second that more options places a greater cognitive burden on consumers because of the additional need to evaluate options. One

recommendation that balances these considerations is that four or five non-dominating options may represent reasonable initial value for the choice architect given these trade-offs" (Johnson, et al., 2012, p. 490). Results of experiments showed that individuals tended to choose items appearing higher in the list, which could be an important nudge tool to use in order to give the image that the options on top are more significant (Shwartz, Oulasvirta, & Hukkinen, 2004).

A2.Technology and decision aids

As making choices can be time consuming and require a lot of focus, decision makers may rely on technology for help. More and more choices are being made with the use of some form of information technology (Murray, Liang, & Haubl, 2010). It should come as no shock that individuals rely on some form of technology to guide their choices even if one does not realize it explicitly. For example, internet websites use a record of an individual's purchases to suggest new or similar options, other websites provide an individual with the options based on their preference while yet others offer ease of comparison to heighten individual sensitivity (Lynch & Ariely, 2000) . Research has demonstrated that decision aids such as product recommendation system (available in almost every goods website) can be highly beneficial to consumers by enabling them to find products that better match their preferences all while reducing the time and effort taken in searching for them (Haubl & Trifts, 2000). Others have noted that retailers were confronted with a fundamental dilemma regarding stand-alone websites that attempted to build electronic malls for delivery of good via the internet, online services and such (Alba, et al., 1997) but that those websites provided advantage to the consumer as they meant less search costs for products and product information which ultimately led to more responsiveness to price and quality information (Lynch & Ariely, 2000) . "These technology based decision aids could be designed in order to steer consumers towards choosing products, services, or activities that are individually and/or socially desirable- i.e. healthy, environmentally friendly, etc.- without restricting their freedom of choice" (Johnson, et al., 2012, p. 491). These tools describe what nudging is intended to do, provide options and steer decision making into a desirable outcome all while maintaining the freedom of choice. Knowing that most decision makers will refer to one of these technological decision aids, choice architects could work on developing or using these tools to their advantage in order to steer the outcome towards a desired direction.

A3. Defaults:

Defaults have such a powerful effect that they are one of the most popular (and often most preferred) used tool by choice architects and ignoring them (or denying their effect) is not a sound option. "Defaults have such a powerful and pervasive effect on the consumer behavior that they could be considered "hidden persuaders" in some settings" (Smith, Goldstein, & J.Johnson, 2013, p. 159). As mentioned before about choice neutrality and the availability of defaults, it is clear that defaults appeal to a wide array of decision makers in their ability to guide their choices, while at the same time preserve their freedom to choose (Thaler & Sunstein, 2003). Defaults, also named default configurations, represent the setting or choices that apply to the individuals that do not take active steps to change them (Brown & Krishna, 2004). Seeing that the people's

preferences are often ill-formed and that their choices will be influenced by the defaults one way or the other (due to the belief that it is what the majority of other individuals choose), Thaler and Sunstein believe that people's choices should be steered (through default rules) into welfare-promoting directions without eliminating the freedom of choice (Sunstein & Thaler, 2003) . Choice architects could set up these defaults in order to promote a certain reaction through nudging by making a risk and uncertainty more explicit in a scenario. Reported in Mark Egan's collection of empirical nudges, named "Nudge database" (Egan), an extensive research was conducted by researchers aiming to see the effect of a nudge (in the form of a default choice) on organ donations in the United States. The paper published demonstrated the massive effect that default choices have on an organ donation compliance rate (Johnson & Goldstein, 2003). The experiment conducted was done by proving two options to the 161 respondents. One option was called the opt in option, where "participants were told to assume that they had just moved to a new state where the defaults was not to be an organ donor, and they were given a choice to confirm or change that status" (Johnson & Goldstein, 2003, p. 1338), the second condition was called the opt- out, where "the conditions were identical except that the default was to be a donor" (Johnson & Goldstein, 2003, p. 1338). The findings revealed that when the opt-out option was chosen, the number of donations doubled; which has also been noticed in Europe over the last two decades as they introduced the opt-in or out default options within the individual's decision making process regarding becoming an organ donor (Johnson & Goldstein, 2003). Another research conducted by (Halpern, et al., 2013) using defaults in the healthcare context was done by randomly assigning 132 seriously ill patients to complete one of three conditions of advanced directive (also named care options). The first two types had "end-of-life" care options already checked (a default choice) but the first favored "comfort-oriented" care, while the second "life-extending" care; the third type was a standard advanced directive with no options checked. Results showed that the defaults had a significant influence on the choice, as not only was "comfort-oriented" care option the most favored but that 77% of patients in the comfort-oriented choice retained that choice (Halpern, et al., 2013).

Defaults comprise of different types, with each type having its own traits and application. A description of the various types of defaults and their traits can be found in the Appendix 1.x. Each type of default can be used based on the situation at hand, all while keeping in mind and respecting the ethical aspect of freedom of choice at all times. Defaults have also had their fair share of spotlight when it came down to the ethical question. Some behavioural economists and psychologist, including Dan Ariely (who was featured in the issue of Wired Magazine) explained that this manipulation is used by sites such as Amazon and Groupon and that it is straight-up manipulation (Bjoran, 2011), while others encourage it and strongly advice it as long as it done to benefit the individuals in question and to push them towards better choices (Goldstein, Johnson, Herrmann, & Heitmann, 2008). Experiments conducted by researchers, such as Tripp Shealy and Leidy Klotz, with regards to the effect of modified defaults on the rate of sustainable performance showed that by simply modifying the defaults led to significantly higher design

goals (Shealy & Klotz, 2015). Researchers converge on the idea that defaults are very powerful tools, and that although they have different components that affect individuals in various ways, that it can direct a decision maker's decision towards a certain direction and as long as they lead to an increase in the recipient's welfare while not obstructing their freedom nor impinging on their liberties, they should be used.

A4. Choice over time

Although contractors usually make decisions over time as more and more details are revealed throughout the project life cycle, they need to have some type of overview of the choices that they will take during the tender phase. Due to the need to take these decision on a short time notice (such as the tender phase) and knowing that each one of these decisions, once taken, are not only final but have outcomes that unfold over a long period of time, the importance of these decision become critical. According to researchers, many of the choices individuals face affect choice task in three specific bias ways (Johnson, et al., 2012). First, the nature of an individual tends to be myopic (short-sighted), which makes the focus on early and quick rewards. Individuals prefer to receive positive outcomes early, leading them to yield immediate temptations and heavily discounting future outcomes (Ainslie, 2001) (Loewenstein & Elster, 1992) . Several experiments reported in the World Development Report (Bank, 2014) as well as by researcher Derek Koehler (Koehler, 1991) showcase how the majority of people's reactions tend to be short sighted. The experiment revealed some interesting results, two of which will be brought to the spotlight. The first one is that people are not able to make a difference between low probability options and thus consider that all low probability events to be equally likely (Bank, 2014). This inability of making a difference between small probabilities sends a message of indifference, which translated to sloppier option decisions, lower investments in reducing risks and the inability to properly consider trade-offs between the different low probability risks. The second outcome that the experiments revealed is that people's decisions depend on what they consider the "default situation" (Bank, 2014). This backs up the finding in section A3 regarding the effects defaults have on decision making. Second, the ambiguity of future uncertainties can change the preference individuals have for desired future outcomes as the different criteria that makeup the decision are often either under weighted or over rated. One example is with regards to global climate change where uncertainties regarding the effects of global climate change seem to reduce the political will for mitigation (Hansen, 2009). The third way should come as no shock, individuals are often overly optimistic about the future and assume that they can accomplish more than they actually do (Johnson, et al., 2012). This always seem to be the case as energy and enthusiasm over winning the tender bid and getting awarded the contract are fairly high, which leads to optimism and an over-confidence boost. Contractors then tend to over simplify the costs and time (assuming they will have more time and money in the future than the actual amounts (Zauberman & Lynch, 2005) (Kahneman & Lovallo, 1993)) of a specific position in the future as well as overestimate the probability that desired outcomes will occur as planned (Kahneman & Lovallo, 1993) (Koehler, 1991) (Shu, 2008).

Each one of these three biases discussed above could be dealt with using the various tools available to the choice architect. These "choice over time" tools range from changing the order of consideration (drawing attention to delayed options as mentioned by (Weber E. , et al., 2007)) (Weber E. , et al., 2007)), refocus towards concentrating on second best outcome (which leads to less choice deferral and higher choice satisfaction according to (Shu, 2008)) , or placing limited number of opportunities (to overcome the tendency to think that the future holds more resources and helps limit procrastination) (Johnson, et al., 2012). Choice architects need all the help they can get their hands on to facilitate their task.

B. Describing choice options

Moving on to the second category that the remaining tools fall under: describing choice options. Choosing choice options proved to be more tricky than it sounds, but it does not end there, describing and presenting the choice options is as important, if not even more important. A proper explanation and presentation might make all the difference. The tools under describing choice options are: partitioning options and designing attributes.

B1. Partitioning options and attributes

Choice architects pay close attention to the way in which the set of options and attributes are portioned into groups or categories. With the huge number of options and details, it is time consuming and inefficient to draw attention to every single aspect available. Rather, grouping and partitioning take place and light is shed on the main aspects. "Recent studies have shown that the physical portioning of a shopping cart and on-line order forms can alter the mix of products a person purchases. For instance, studies with grocers have shown that altering the amount of a shopping cart reserved for fruits and vegetables ended up altering how much was purchased" (Wansink, Soman, Herbst, & Payne, 2012). A closer look into the observations made in the experiments led to the revelation that the majority of people tend to distribute their resources (whether it be time or money) equally between the various sections (Benartzi & Thaler, 2001) (Messick, 1993) as well as have a tendency to allocate equal resources across different options (Fox & Clemen, 2005). The pervasive tendency of individuals towards an even allocation is a powerful tool that can be used by choice architects: judgements and choices can be strongly influenced by the particular groups or categories into which the set of possibilities is portioned (Johnson, et al., 2012).

B2. Designing attributes

Although a good decision tends to take into consideration all the aspects of a scenario, often that is not possible. Knowing that people usually choose between alternatives by weighting their pros and cons, choice architects can play on that by making the desired attributes more explicit/salient and other ones less explicit/salient (Johnson, et al., 2012). A scenario where this can be applied would be when car companies nudge car buyers into making more responsible purchases through

itemizing desirable/practical attributes such as gas mileage and safety while aggregating the less responsible ones such as speed and design (Martin & Norton, 2009). Due to the high number of alternatives individuals have to consider when making a choices, they might sometimes face difficulties. Choice architects should take into consideration these difficulties by limiting the number of attributes the various options have, this way the individual can manage comparing options more efficiently (Peters, Hibbard, Slovic, & Dieckmann, 2007). By making the comparison between options more efficient to the individual (could be as simple as listing a car's cost monthly versus yearly (Burson, Larrick, & Lynch, 2009)), not only makes the individual more confident about their choices but also decreases the risk of errors (Johnson, et al., 2012).

2.2.2 ISSUES IN IMPLEMENTING CHOICE ARCHITECTURE

Although nudges tend to have the desired positive effect, in some cases they can also backfire. When a decisions is taken, it starts with the individual and from there moves on to the individual's personality and risk taking levels (which are different from individual to the other) which affect the decision taken in different ways; some early nudges may not have the desired effect due to its unresponsiveness with the decision maker (Johnson, et al., 2012). One example of how individual differences can influence the outcome is through a study done by (Costa & Kahn, 2010) where a number of households were informed about their relative energy use in hopes of decreasing the average usage. The results indicated that one group (republicans) increase their use while the other (liberals) reduced their use; presumably due to the difference in the level of environmental concern about both parties (Costa & Kahn, 2010) (Gromet, Kunreuther, & Larrick, 2013). This means that the presentation of a nudge by a choice architect will not always be enough to stimulate the desired response, which pushes the need to test these choice architectures in a diverse population of interest (Johnson, et al., 2012). This is where this research steps in and provides (through experimentation) the testing needed to derive more results upon which the influence of a wider, more diverse population is tested. Some of the issues in implementing choice architecture lie in the root of nudging. Due to nudges relying to a great extent on an individual's personality (which varies between individual to another), there are cases where the individual's personality makes them unresponsive to the presented nudge or fails to provide enough stimulation to create a desired response.

2.2.3 OVERALL SUMMARY ANSWERING THE FIRST SUB-QUESTION

At this point, the two streams of literature review merge and provide the answers to the first sub-question of the main objective: *what are the factors that affect decision making under risk and uncertainty?* & *what makes nudges so effective?* Respectively.

To recapitulate, although decision making under risk and uncertainty is a risky process in itself, it is a reoccurring phenomenon in infrastructure tender processes where design decisions are

expected to be made. Since risk and uncertainty can never be completely eliminated, it should be mitigated, accounted for and understood to an extent. The main factors that affect decision making under uncertainty are:

- The ability to identify the different types of risks (strategic risks, financial risks, operational risks, legal risks and other risks) and the ability to manage them.
- The ability to represent knowledge in the form of probability and the extent of use of probabilistic models.
- The human nature of the decision maker
- The extent to which the decision maker experiences loss aversion (perceiving a loss larger than an equal-size gain)
- The extent to which the time pressure influence's a decision maker's ability to make a decision.

Keeping in mind those factors that affect decision making, a translation is made into the world of nudging where it can be seen how the factors play a role in the effectiveness of the nudge. How effective a nudge starts with the choice architect and depends on two main tools. It is crucial that choice architects take special care in using these tools to not only facilitate their jobs, but also to ensure the effectiveness of the nudge. The two categories of tools are:

- Structuring the choice task
- Describing the choice options

The main tools that facilitate the structuring of the choice task are:

- The number of alternatives should be carefully deduced. Providing too little options gives the illusion of lack choice while providing a lot created choice overload. Striking a balance between providing enough options to increase the chance of offering a preference match to the individual and making sure not to place a great cognitive burden on the individual is key.
- The use of technology and decision aids in order to both facilitate the time and effort spent in comparing between options and help steer decision making into a desirable outcome.
- The use of one of the most powerful nudges discovered: defaults. Its effectiveness stems from three mechanisms: implied endorsements, cognitive biases and effort. Different types of defaults are available, each equipped with their own traits and applications that fit to a wide array of scenarios.
- The ability to foresee the unfolding of a choice taken over time. It is made possible by ameliorating decisions taken through the use of tools such as changing the order of consideration, refocusing towards concentrating on second best outcome or placing

limited number of opportunities. These tools help tackle the three specific biases individuals face when making a decision: the myopic nature, the ambiguity of future uncertainties and the over-optimism.

The main tools that help describe the choice options are:

- Partitioning of options and attributes help draw attention to the main aspects of an option. This, in turn, helps eliminate the time consuming and inefficient attention drawing to every aspect used in conventional ways.
- Making the desired design attributes more explicit/salient and other ones less explicit/salient to not only enable individuals to compare between options more efficiently but also to draw focus on a certain desired aspect.

Balancing the structuring of the choice task and the description of choice options ensures the effectiveness of the nudge. Now that an understanding of the underlying decision making process is understood, a nudge development process is put in motion in order to find a suitable nudge and answer the second sub-question: *What suitable changes in the choice architecture (nudge) of a trade-off matrix can increase risk awareness?*

3. NUDGE DEVELOPMENT PROCESS

Nudging can take many forms and shapes. Combining the built up knowledge concerning decision making under risk and uncertainty and the concept of nudging, this section brought life to a suitable nudge by converging both literature review streams. Nudges are usually characterised based on the effect one wishes to cause. Some nudges help individuals follow through with a decision, while others influence a decision in an individual. It is important to know which nudge is best suited for the scenario at hand. More information on the form of nudges and their scenarios can be seen in Appendix 1.4. "Developing a nudge is an interdisciplinary process that is project-based and experimental in nature" (Kim Ly, 2013, p. 21). This pushed towards the experimentation with possible nudges where ideally the nudge used in the experiment presented in the next section will be of an "Activating desired behavior" nature where externally imposed nudges are being made in order to mindfully discourage (placing the uncertainty in design architecture at eye level in order to prevent the wrong/riskier decision) through raising the risk and uncertainty awareness associated with each design option. Others such as Tripp Shealy and Leidy Klotz have encouraged the used of nudges and emphasized on modified defaults in order to affect the choice architecture; this choice architecture is embedded in any rating system which is "often used as design/decision tools to evaluate, grade, and reward infrastructure projects that meet sustainability criteria such as reduction in greenhouse gas emissions, preservation of wildlife habitat, and accessibility to community cultural resources" (Shealy & Klotz, 2015, p. 1).

A lot of examples and cases attributed to nudges portray their effectiveness and simplicity, but how easy is it to develop and implement a successful nudge? To answer that, a look into the nudge development process is presented. Figure 2 (Kim Ly, 2013) below shows the four main steps that comprise the nudge development process.

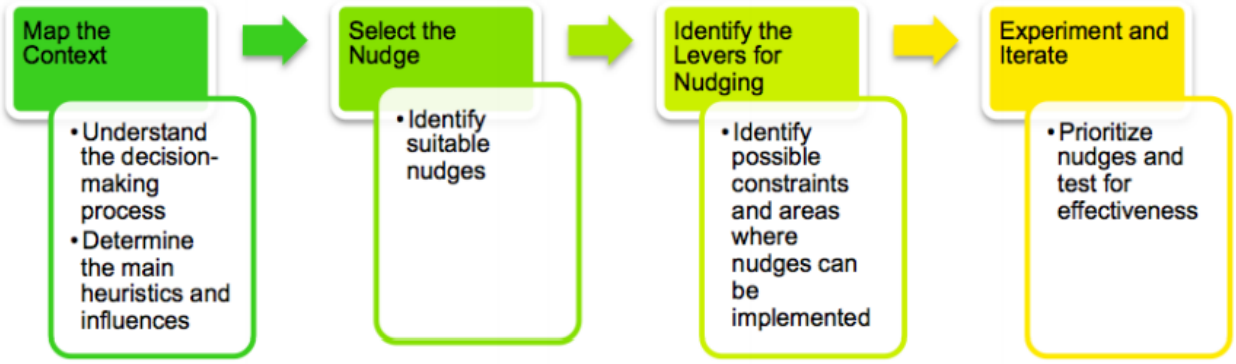


FIGURE 2. Outline of the nudge development process (Kim Ly, 2013)

This chapter maps out the nudge development process through all its stages, determines a suitable nudge and ends with an overall summary.

3.1 MAP THE CONTEXT

The first step in the development process was to Map the Context which comprised of two points. The first point was to understand the decision making process and the second was to determine the main heuristics (or approach to problem solving) and influences. This is accomplished by auditing, "Auditing the decision-making process will identify factors that prevent individuals from following through with their intentions. These factors (bottlenecks) represent area where a nudging strategy might yield quick dividends" (Kim Ly, 2013). Auditing is done through a series of questionnaires where four main aspects are looked at and addressed: (1) the properties of a decision (looks at how critical a decision is and the influencing factors that affect the decision making among the various choices), (2) information sources (the identification of the information sources needed for each part of the decision making), (3) features of the individual's mindset (how emotions, bias, experience and various individual factors influence the end decision) and (4) environmental and social factors (the effect peer pressure, length of the questionnaire, time of execution and such have on the outcome). This mapping would ultimately clearly display the critical actions that are involved in the making of a decision.

By understanding what the client wants and what the contractor aims for, mapping the infrastructure tender context would help keep an eye on the target while steering away from riskier and uncertain options. This would help clear up some of the misconceptions or expectations that the contractor had with regards to the client demands. It was important to balance the needs and goals of both parties in order to best mimic the real infrastructure tender process that takes place. The infrastructure tender processes are complicated, long, tiring and comprise a vital part of any construction project. The context of this experiment comprised of two parts.

The first part was the general context which consisted of the pre-existing context of the experimental set-up (as it builds on the pilot study) and was composed of a replication of an infrastructure tender process through a student design contest setup. Often, these tender processes revolve around limited time schedules for all parties (as contractors are rushed through coming up with a tender and clients quickly choose a winner in order to minimize time and administrative costs) and incomplete information (contractors don't have enough time to investigate all the client's wishes and their feasibility while the client might not be experienced enough to eyeball the offered tenders against critical factors). Both parties, once entered in an agreement, cannot back down (contractors need to stick with the design offered and clients decision is final). These factors (among many others) consist of the second part of the context and lead to the most crucial (and the one this experiment attempts to improve) factor, lack of risk and uncertainty awareness while making design decisions. This risk unawareness has led to many construction companies going bankrupt as well as invoking endless legal battles between parties. Thus, it becomes important to make sure that the individuals recognize the importance of the decision they are making and the potential impact it has both with relation to the decision making party, the client and the future users. As part of instilling the importance of the design

decisions individuals will be taking, it is important to make sure they can relate to the problem at hand in order to eliminate haste and indifferent decisions. This could be done in an experiment through the introduction of a topic that individuals empathize with or can relate to.

The second part of the context is the pre-chosen trade-off matrix as a choice architecture. It becomes crucial to consider a nudge in terms of its easiness of application within a trade-off matrix as well as the way the information is presented in terms of this nudge. Environmental and social factors (such as peer pressure and lengthy applications) could have an effect on the outcome and should be taken into account. These become important to consider when it comes to which type of experimental setup is made. A paper and pencil experiment might be prone to peer pressure where individuals might be inclined to answer the same as a fellow individual within their vicinity while an online computer experiment is more prone to the lengthy application effect where individuals would get bored and ultimately lose the motivation or sense of urgency in making the final decision. Some minor fixes to these two problems would be to indicate to the individuals that there are no right or wrong answers, that the only thing that matters is their preference and insight. The other fix would be to make sure that the online experiment isn't too lengthy, is made as clear as possible to the reader and by eliminating the results associated with participants whom finished the experiment in a record time (not taking them into consideration for the result analysis). Both of these parts of context need to be taken into account in order to fully understand the decision making process and to develop the first step of a nudge that is tailor fit for the environment of such an experiment.

3.2 SELECT THE NUDGE

The second step in the development process was to select the nudge. "Bottlenecks in the process are good starting places to implement a nudge" (Kim Ly, 2013). For example a bottleneck might be the capacity of the individual to assess the various design architecture options while another bottleneck might be how the individual feels the client would respond to a proposed option (maybe an innovative technique which the client might not respond to or choose to dismiss because of lack of knowledge or experience). By clearly identifying the possible nudges along the decision making process, it is easier to visualize and identify the suitable nudges needed to implement along the way.

Four suitable nudges were identified: visual effects, partitioning options and attributes, defaults and confidence intervals. Visual effects were used in the pilot study (Buiten, Hartmann, & Meer, 2016) in the form of a smiley representing the risk involved (a green smiling face to represent a low level of risk and a neutral orange face representing a fair amount of risk and uncertainty) as can be seen in the Appendix B1. Partitioning options and attributes was described in Section 2.2.1 earlier (as well as implemented in the pilot study) where a set of attributes or options are portioned into groups or categories to both help the choice architect draw attention to certain attributes and help the client by facilitating the comparison between limited attributes. Since the first two identified suitable nudges were implemented in the pilot study, they were put aside for this follow up experiment, which paved the way to the remaining two nudges (defaults

and confidence intervals). Before moving on further, it is important to establish an understanding on both these nudges, therefore, both defaults and confidence intervals are discussed in the following sub-sections 3.2.1 and 3.2.2, respectively.

3.2.1 Defaults

Due to its widespread use, popularity, and huge impact, it should come as no shock that defaults were considered as a suitable nudge. Seeing the impressive influence that defaults have, researchers looked more in depth into the reasons that caused these defaults to be so popular and effective. Three of these researchers (namely: Smith, Goldstein and Johnson) have identified the three theoretical causes that caused defaults to have such an effect. These three mechanisms were: implied endorsement, cognitive biases and effort (Smith, Goldstein, & J.Johnson, 2013), which are described briefly in the following subsections.

Implied Endorsement. Defaults can be seen by the public as the norm, or the recommendations of those who have set them (Smith, Goldstein, & J.Johnson, 2013). When it comes in the context of a policy (such as the donor example described earlier), (Mckenzie, J.Liersch, & Finkelstein, 2006) as well as (Johnson & Goldstein, 2003) agree that individuals interpret the default as the accepted and expected course of action. As much as implied endorsement could have an influence over the decision of individuals, it is a bit trickier in the market place situation. When it comes to the market place, the statue (or reputation) of a vendor plays a major role; reputable vendor's set defaults that are seen by individuals as suggestions and the best course of action, while the less reputable vendor's defaults are seen as a clear and obvious attempt to manipulate the individual (Brown & Krishna, 2004).

Cognitive Biases. Cognitive biases is the inclination or prejudice for or against someone/something (usually unfair) in the mental process of perception, memory, judgement and reasoning that an individual goes through when making a decision. Also seen as a form of social intelligence, Brown and Krishna state that how the individual responds to a default has to do with whether his social intelligence is invoked and thus, how it changes the meaning of the default (Brown & Krishna, 2004). Researchers have tried to discover the reason behind these cognitive biases in an attempt to better understand this phenomenon, and what they all agreed on is that the root cause of it all lies in loss aversion (Smith, Goldstein, & J.Johnson, 2013). Loss aversion, as described earlier, refers to "people's tendency to strongly prefer avoiding losses to acquiring gains". Studies suggest that losses are twice as powerful, psychologically, as gains" (Kahneman & Tversky, 1992). This can be linked directly to the human nature subsection (described in Section 2.1.3) and how individuals tend to be risk averse (avoiding risk) when it comes to situations that exhibit risk and uncertainty. With this loss aversion mind set, individuals will tend to fear (or shy away) from the non-default option as the impact of a loss would be more devastating than the potential gain achieved by changing to the non-default option (Smith, Goldstein, & J.Johnson, 2013). Attempting to understand this cognitive bias a bit more, Brown and Krishna conducted several experiments; one of their more relevant studies involved a questionnaire submitted to one hundred and seventy-eight undergraduate students where the

study was about mass customization on the internet and involved 3 product categories and six attributes (Brown & Krishna, 2004). Each one of the six product attributes offered three different ordered levels (low, middle and high) where for each attribute, the student would have to choose of the three options. The experiment had four conditions- no default, low option indicated default, middle option as default and high option as default). The results of the study indicated a significant positive effect on a choice when a default designation was made as opposed to the same alternative with no such designation (Brown & Krishna, 2004).

Effort. The level of effort undertaken by the individual is a major influence on the effect of a default. The low desire to put in effort by individuals can be seen as a major contributor to why defaults work in varied scenarios such as retirement program design, organ donation policies and consumer choices (Dinner, Johnson, Goldstein, & Liu, 2011). Individuals just live under that "presumed consent" because they are not willing to go through the effort of changing their decision. For example, when it comes to policies of organ donations, an individual has to go through the effort of acquiring, completing and mailing a change-of-consent form, which sets them off completely (Johnson & Goldstein, 2003) (Dinner, Johnson, Goldstein, & Liu, 2011). In order to counteract the bias caused by effort levels, it is important to make the choice between the different options in an experiment to require the same level of effort. Although effort has a big effect, different scholars agree on the idea it cannot be solely attributed to the reason why defaults work (Smith, Goldstein, & J.Johnson, 2013) (Thaler & Sunstein, 2003).

Defaults were also discussed in Section 2.2.1 earlier and are very powerful nudges that have earned the title of "hidden persuaders". Last but not least, confidence intervals made their way into the list of suitable nudges and a more in depth look into what they are and how they work is taken in the following section.

3.2.2 Confidence Intervals

Confidence intervals consist of an interval of numbers containing the most plausible values for a parameter (ucd). It is usually accompanied with a probability that the actual outcome lies within that parameter which is referred to as "the confidence level".

Confidence intervals help serve two main purposes, the first purpose is to help an entity evaluate the reliability of a particular estimate while the second purpose is used to manage risk (as they draw attention to the gravity of the risk). With regards to the first purpose, it is quite inevitable for a company to rely on probabilistic judgements nowadays in order to take decisions. "Predictions of future events necessarily revolves around subjective probabilistic judgements where a common way to obtain such judgements (in order to assess uncertainty) is to assess fractals or confidence intervals" (Bearden, Gaba, Jain, & Mukherjee, 2011, pp. 1970-1987). "Businesses rely on confidence levels to understand how likely a given risk is to occur so that it can manage the risks of a non-occurrence accordingly" (Richards & Media, 2012). Before the physiological effects of confidence intervals are drawn, a description of what a confidence interval is will be presented. "In statistics, a confidence interval gives the percentage probability

than an estimated range of possible values in fact includes the actual value being estimated" (Richards & Media, 2012).

Usually confidence intervals are relevant in three main domains: market research, risk management and budget forecasting. Each one of these domains will be discussed briefly as to get a clear image of the various possible uses of a confidence interval.

Market Research. Determining the reliability of the market research is quite important for companies especially when it comes down to estimating the level of future sales. As a company desires to have an idea of the amount of products they will eventually sell in a given period but lack the certainty of these figures, they result to confidence intervals (Richards & Media, 2012). Confidence intervals make it possible for companies to estimate the range its sales are likely to fall within a certain degree of certainty (usually around 95%); confidence intervals also provide information about variability (Shanker, 2006) .

Risk Management. Confidence intervals are important in managing risk as they allow for the management of the uncertainty or the chance of a given risk to occur (Richards & Media, 2012). For example a percentage of 90% confidence interval would mean that there still is a 10 percent chance of the actual outcome being more or less than the originally predicated value. This in turn, enables an entity to better manage these scenarios.

Budget forecasting. Every business depends heavily on budget, whether it be costs or revenues. Based on these values, companies take a wide array of decisions with regards to their processes, products, investments and much more. Important financial decisions based on the information that revolves around the range of possible values for revenues and costs are enabled by confidence intervals; these help the company make financial decisions while still allow them to prepare for the possibility of incorrect estimates (Richards & Media, 2012).

The part that was most relevant and important to this experiment was the risk management part. Here, confidence intervals enable the emphasis on risk and in turn explicitly draw attention to the uncertainties and risks associated with each design option. Each design option will have a confidence interval that allows for the visualization and better assessment of the risk at hand.

Difficulties in confidence intervals. The most common mistake that comes to hand when dealing with confidence intervals is overconfidence. Fortunately, some surveys and studies were conducted by multiple researchers in an attempt to find mechanisms that allow for the reduction of overconfidence. Some of these mechanisms include: feedback, training and incentive schemes (such as scoring rules) which seemed to yield various results (Kahneman, Slovic, & Tversky, Judgment under uncertainty: Heuristics and biases, 1982) (Arkes, Christensen, Lai, & Blumer, 1987) (Hogarth, 1975) (Koriat, Lichtenstein, & Fischhoff, 1980) .

3.3 IDENTIFY THE LEVERS FOR NUDGING

The third step was to identify the levers for nudging. "Identifying constraints such as cost and

resource availability, as well as potential levers for nudging will quicken the development process. The responses in the second step and identified constraints in step 4 might align and provide specific ideas on how the bottlenecks were "cleared up" in other situations" (Kim Ly, 2013).

The main constraints and levers identified were that the nudge needed to be suitable for implementation within a trade-off matrix, the nudge also needed to be easily implemented, understood and most importantly that its effect be noticeable. In order to test that with regards to the trade-off matrix, both suitable nudges were developed into a full experimental trade-off matrix. The following sub-sections present both nudged trade-off matrixes.

3.3.1 Default trade-off matrix

In order to develop a good default trade-off matrix, all three identified factors (implied endorsement, cognitive bias and effort) had to be taken into account. It was important to make sure that the matrix was bland that no particular aspect stood out, this was done by keeping it relatively simple. Although the trade-off matrix was kept simple, the real effect came from the text that followed. Implied endorsements, cognitive biases (which rely heavily on the concept of loss aversion) and effort could all be tackled by providing convincing enough text before the individual made their design decision. The trade-off matrix and accompanied text developed can be seen below.

Table 1. Default trade-off matrix

Trade-off Matrix		
Considerations	Option 1 "Conversion"	Option 2 "New Building"
Flexibility	4	3
Delivery Speed	4	4
Durability	5	4
Affordability	4	4
Spatial and Social Quality	5	4
Risk and Uncertainties	1	3

"After carefully taking into consideration the requirements of the agency, you notice that option 1 fits the client's requirements but that you have 40% chance of losing the competition with option 1 and lose being involved in the project. If you opt for option 2, you have a 50/50 chance of either winning the contract with some financial gains (a possible monetary reward for having a unique solution) or lose everything.

Your colleagues are optimistic about option 2 and have a strong feeling that your design is unique and that you should opt for option 2. The monetary reward would allow you and your team to go on a vacation before starting the project."

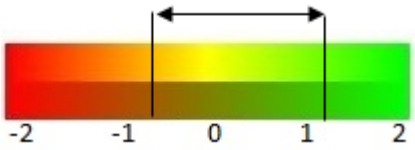
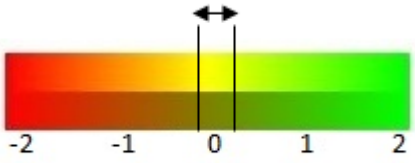
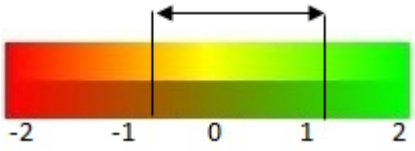
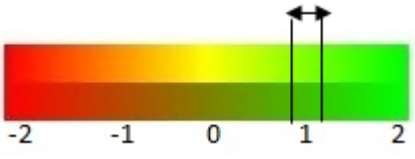
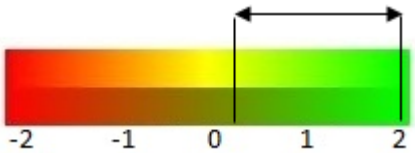
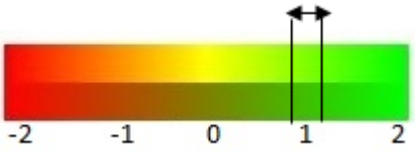
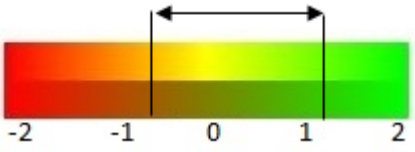
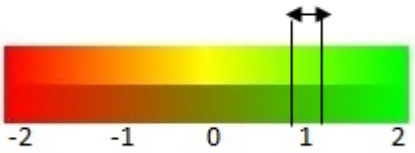
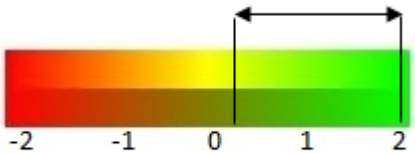
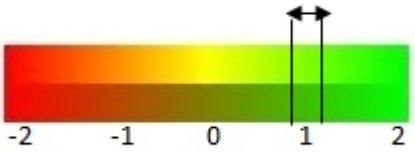
As can be seen from the text above, by wording the outcome of choosing the first option in a negative light (40% chance of losing the competition and lose being involved) while the second option in a positive one (50/50 chance of winning, allowing you and your team to go on vacation), the loss aversion principal was taken into account. Implied endorsement was taken into account by indicating that the colleagues were optimistic about the second option and had a great feeling that it was a unique design and therefore endorsed it. The combination of the cognitive bias, the implied endorsement and the blandness of the table (causing individuals to be too lazy to go and compare each attribute of each option against one another) would lead to them opting more in favor for the second option.

3.3.2 Confidence interval matrix

Incorporating confidence intervals meant making a lot of changes to the original trade-off matrix. The changes to the trade-off matrix covered four aspects. The first change was in the scoring system where the scoring system was no longer based on 0-5 scale but rather a -2 to 2 scale. This not only made it easier to portray attribute values but also to go in line with the way BAM rates attributes (would make it easier to translate and apply later on to the real world). The second change came in the form of a small visual effect where the interval was colored from red (indicating danger/caution) to green (indicating safe/conform). This helped to somehow eyeball where each design option attribute landed in relation to one another. The third change was in the way the attributes of each design option were scored. Contrary to the pilot study and the default trade-off matrixes, the confidence interval matrix was not rated on a point scale, but rather on an interval. This interval was based on a 95% confidence interval rate while the width of the interval portrayed the level of risk involved. A wide interval meant riskier attribute ranges while a narrower interval meant a safer one. The final change was to skew the intervals of the attributes. This was done in order to mimic the nature of risk and uncertainties, showcasing that although you have a chance of scoring high, you also have a high chance of scoring low (which happens most often in reality as shown by the history records of previous projects). Taking all these changes into account and applying them, the resulting trade-off matrix can be seen below.

Table 2. Confidence interval trade-off matrix

Trade-off Matrix		
Considerations	Options	
	Option 1 “Conversion” Confidence Interval	Option 2 “New Buildings” Confidence interval

Flexibility		
Delivery Speed		
Sustainability		
Affordability		
Spatial and Social Quality		

As can be seen from Table 2 above, the nudge would aim to raise risk and uncertainty awareness of both options and help individuals realize the higher risk and uncertainties associated with the first option and hopefully help them realize that the second option is a safer and sounder decision.

3.4 EXPERIMENT AND ITERATE

The fourth and final step was to Experiment and Iterate. In this step, two main points were sought after: 1) prioritizing nudges and 2) testing for effectiveness. Prioritizing the nudges was important in order to know which nudge to give more attention to while testing the effectiveness helped an entity learn from the application of such nudges.

Starting with prioritizing the nudges. As mentioned earlier, visual effects and portioning the attributes were implemented in the pilot study and thus put aside for this follow up experiment. This left the defaults and the confidence intervals as the two suitable nudges. Due to its wide spread popularity and history of effectiveness, the default nudge was carried out at first and developed into a full experiment (using the trade-off matrix developed in the previous section), but upon further analysis, proved to deviate from the original goal. Defaults are effective, but unfortunately the root cause of their effect is hard to pinpoint (the effect could be due to reasons such as loss aversion, laziness, work culture etc.). It was important to clearly see the effect of the nudge and thus defaults became questionable in that domain. More importantly, using defaults deviated from the original experiment as the main aim was to raise risk awareness of the design options whereas the default just changed the final decision outcome. This has pushed the idea of confidence intervals to make it as the prominent nudge in order to really focus on the effect of the nudge while limiting other influencing factors. The effectiveness of the chosen nudge was tested in the next chapter.

3.2 CONCLUSION

The nudge development process is comprised of four main steps:

- Map the context. In order to clearly map the context and clear any misconception, it is important to understand the decision making process and determine the main heuristics and influences, which is accomplished by auditing.
- Select the nudge. Pinpointing bottlenecks in the process helps visualize and identify suitable nudges needed to implement along the way
- Identify the levers for nudging in order to help quicken the development process and help clear up the bottlenecks.
- Experiment and Iterate. Two main points are sought after: prioritization of the nudges and testing for effectiveness through experimentation and iteration.

The end result of the nudge development process was the confidence interval nudge and can be summarized by Figure 3 seen below.

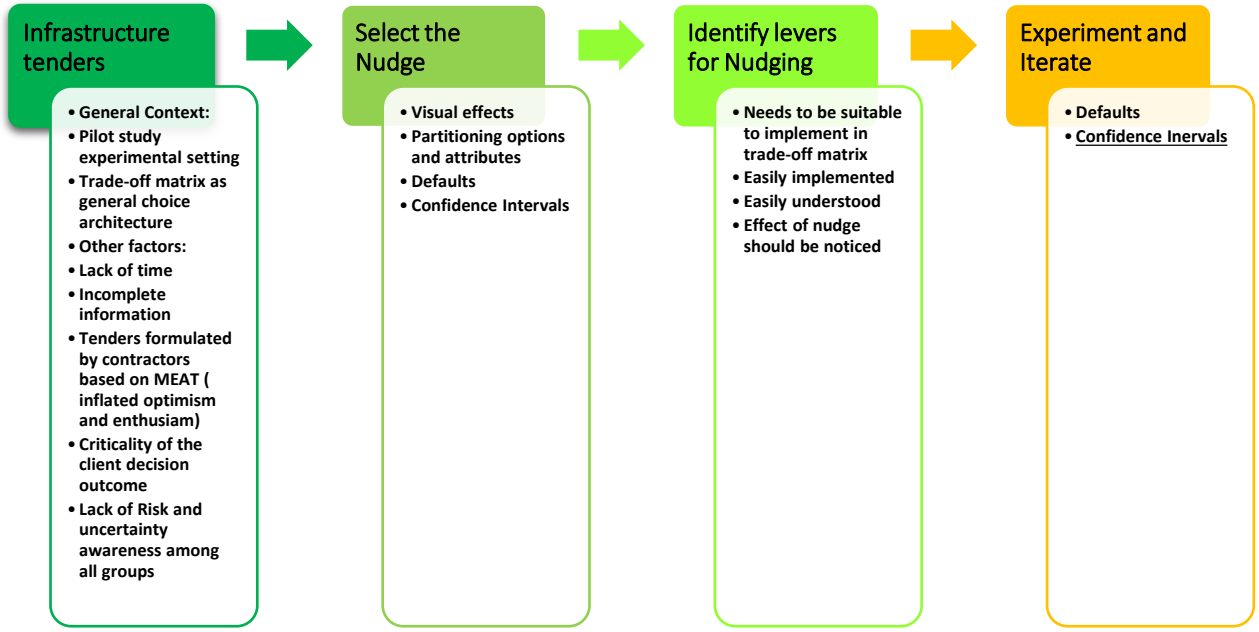


FIGURE 3. Tailored Nudge Development Process

Due to its widespread use, popularity, and huge impact, it should come as no shock that defaults were considered as a suitable nudge. Three researchers (namely: Smith, Goldstein and Johnson) have identified the three theoretical causes that cause defaults to have such an effect. These three mechanisms: implied endorsement, cognitive biases and effort (Smith, Goldstein, & J.Johnson, 2013)

- Implied endorsement: Defaults can be seen by the public as the norm, or the recommendations of those who have set them. When it comes in the context of a policy, individuals interpret the default as the accepted and expected course of action.
- Cognitive biases: the inclination or prejudice for or against someone/something (usually unfair) in the mental process of perception, memory, judgement and reasoning that an individual goes through when making a decision.
- Effort: The level of effort undertaken by the individual is a major influence on the effect of a default. The low desire to put in effort by individuals can be seen as a major contributor to why defaults work in varied scenarios such as retirement program design, organ donation policies and consumer choices.

Confidence intervals help serve two main purposes, the first is to help an entity evaluate the reliability of a particular estimate while the second is used to manage risk. Companies inevitably rely on probabilistic judgements in order to take decisions, which paves the way for confidence intervals. Not only do companies rely on confidence intervals to determine

how likely a given risk is to occur, but also in order to manage the risks of a non-occurrence accordingly. Confidence intervals are relevant in three main domains:

- Market research, where determining the reliability of the market research is quite important for companies in order to estimate the level of future sales.
- Risk management, where confidence intervals allow for the management of the uncertainty or the chance of a given risk to occur.
- Budget forecasting, where companies depend heavily on budget forecasts in order to make decisions with regards to processes, products and investments.

Both the default and the confidence intervals are developed into potential trade-off matrixes in Section 3.3. Section 3.4 ends with confidence intervals being chosen as the prominent nudge to test.

The confidence interval nudge chosen caused four main changes to the trade-off matrix:

- Changes in the scoring system from a 0-5 scale to a -2 to 2 scale. This not only made it easier to portray attribute values but also to go in line with the way BAM rates attributes (would make it easier to translate and apply later on to the real world).
- Changes in the form of a small visual effect where the interval was colored from red (indicating danger/caution) to green (indicating safe/conform). This helped to somehow eyeball where each design option attribute landed in relation to one another.
- Changes in the way the attributes of each design option were scored. Change from point scale to an interval. This interval was based on a 95% confidence interval rate while the width of the interval portrayed the level of risk involved. A wide interval meant riskier attribute ranges while a narrower interval meant a safer one.
- Changes in skewing the intervals of the attributes. This was done in order to mimic the nature of risk and uncertainties, showcasing that although you have a chance of scoring high, you also have a high chance of scoring low (which happens most often in reality as shown by the history records of previous projects).

Now that the underlying nudge mechanics was obtained and a suitable nudge was chosen, a research design is proposed next in order to build an experiment to test the nudge and provide the answer to the third sub-question: *Does presenting the risk and uncertainty in a more explicit way through nudging lead to more risk awareness and consequently change the decision outcome?*

4. RESEARCH DESIGN

To determine the effect of a nudge on the outcome of a decision making process, an experiment was setup. This chapter picks up from the previous and discusses the set-up of the experiment. Section 4.1 presents the detailed design and procedure of the experiment using the nudge developed in Chapter 3 while Section 4.2 discusses the participants and data collection method.

4.1 DESIGN AND PROCEDURE

4.1.1 Scenarios

A short instruction page presented to the participants informed them that they will be participating in an experiment that revolved around a student design competition. It was made clear that there are no right or wrong answers and that the sole purpose was to get insight on their personal preference. Everything was made as simple and clear as possible as to eliminate or optimally minimize any doubts that may arise.

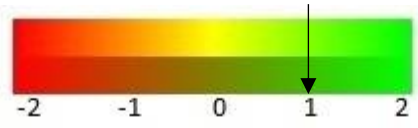
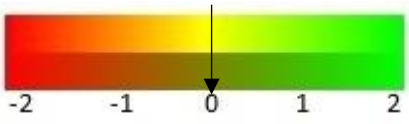
The next page of the experiment started with the introduction of the scenario that showcased a housing design competition for students. The text was introduced as to set the context of the experiment and grasp the attention of the reader. Both versions contain the same scenario and the same instructions as to ensure that the only dependant variable are the options 1 and 2. With this being said, the only change came in the form of tweaks to the trade-off matrix. The text revolved around the recent influx of refugees and how this migration has led to the search for urgent solutions to best cope with the situation. This experiment, as well as the pilot experiment, were based on an actual design contest from the central agency in the Netherlands. The central agency explored solutions to the housing problem with regards to the situation as they are "responsible for the reception, supervision and departure (from the reception location) of asylum seekers coming to the Netherlands" (COA, 2016). Participants were told that they were taking part in a student housing design competition with a team and that they had already two rough ideas developed. These two ideas were presented as can be seen below in Figure 4. The first option depicted an empty existing building to be put to use by reforming them into housings units, while the second option showed a vacant piece of land upon which new housing units would be built.

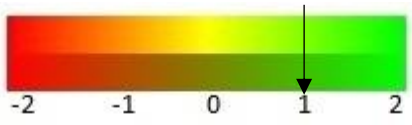
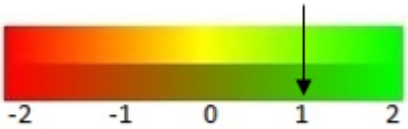
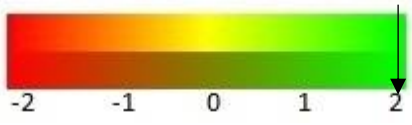
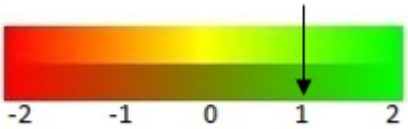
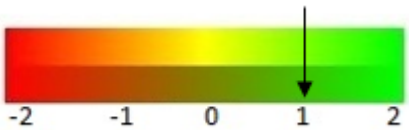
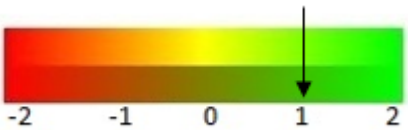
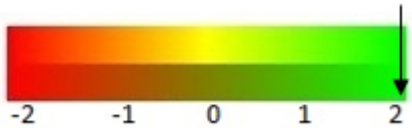
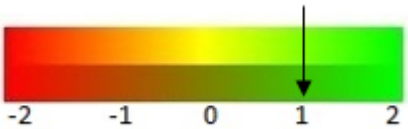
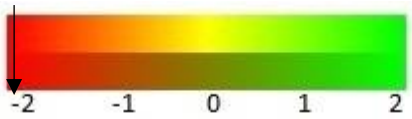
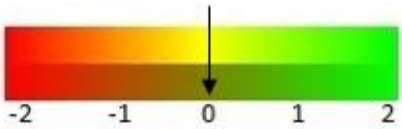
FIGURE 4. Option 1 Vs Option 2

The participant were told that they would have to choose one option to develop further. In order to help the participant take a decision with regards to the two options, criteria for both options were presented with a short explanation entailing what each criteria means. These criteria are the same for both options and are: flexibility, delivery speed, sustainability, affordability, spatial and social quality and risk and uncertainties. The only difference is in the way the criteria are rated in both versions.

In the baseline version, the trade-off matrix displayed each criteria with a point score allocation on a bar that ranges from (-2,2). (-2) being the worst case scenario while (2) being the best. Option 1 scored high on most criteria except for risk and uncertainty while option 2, although having more average scores throughout, was safer. A legend and a short explanation were presented in each version in order to facilitate the understanding and interpretation of the scores.

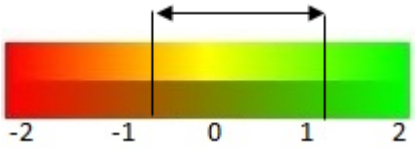
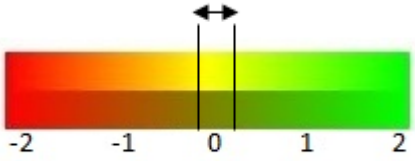
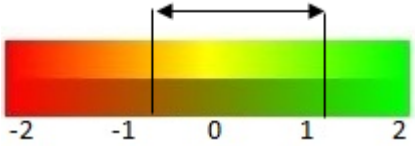
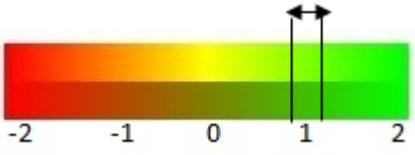
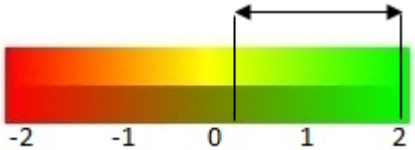
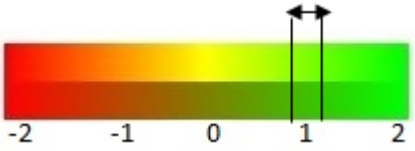
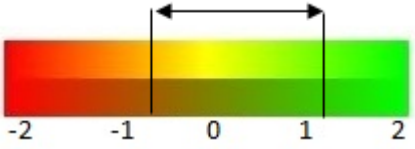
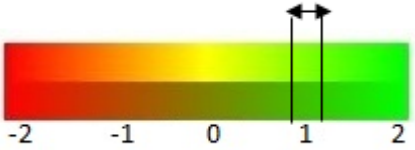
Table 3. Baseline trade-off matrix

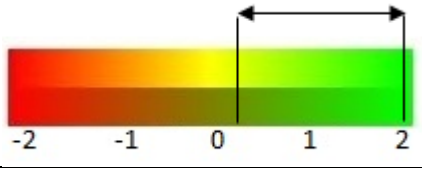
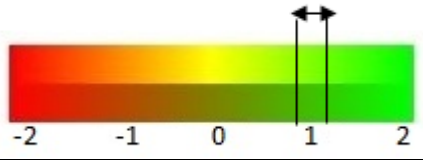
Trade-off Matrix		
Considerations	Options	
	Option 1 “Conversion” Point Scores	Option 2 “New Buildings” Point Scores
Flexibility		

Delivery Speed		
Sustainability		
Affordability		
Spatial and Social Quality		
Risk and Uncertainties		

The second version (nudged) contained the same trade-off matrix but the criteria were scored based on a 95% confidence interval. The risk and uncertainties criteria was removed and portrayed as the confidence interval. A wider interval portrayed a riskier and uncertain value while a narrower interval portrayed a safer one. The ranges vary for option 1 and option 2. Option 1 has a large range that showcased the uncertainty and risk involved in the score of each criteria, while option 2 had a narrower range, showcasing a more certain and safe option. In addition, it is important to note that the interval was skewed in order to really mimic the nature of risk and uncertainties. Taking these criteria into consideration, the participant then opt for either option 1 or 2.

Table 4. Nudged trade-off matrix

Trade-off Matrix		
Considerations	Options	
	Option 1 "Conversion" Confidence Interval	Option 2 "New Buildings" Confidence interval
Flexibility		
Delivery Speed		
Sustainability		
Affordability		

Spatial and Social Quality		

As mentioned above, five questions were asked: the first was the main question as to the preferred option and then four follow up questions (each in a page of its own) in order to shed some light on the reason why the participants chose a specific option as well as to better understand the effect of the nudge. Each question received its own page with no possibility of altering the previous answers in order to prevent participants from editing their answers once they acquired a new perspective (that risk and uncertainty should be the main focus of their decision making process). These questions are included in both versions and are as follows: If you consider the scores above, and taking the client's wishes into account, which option do you prefer? What level of risk would you associate with option 1? What level of risk would you associate with option 2? To which extent did the risk involved influence your decision? Would you consider yourself a risk taking or a risk avoiding person?

The first question was based on a binary scale and had only two possible answers (option 1 or option 2). The following three questions (Question 2,3 and 4) were multiple choice ones based on a Likert scale offering five possible answers (very risky, somewhat risky, neutral/so-so/ somewhat safe and very safe). These deal with the individual's perspective on the risk associated with each option and the extent at which risk perception played a role in their decision. The last question (Question 5) was based on a binary scale and had only two possible answers (risk taking or risk avoiding). This question dealt with personal preference and is more a reflection of the nature of the individual.

One hundred and twenty four participants were presented with the baseline experiment while one hundred and ten participants took the nudged experiment. The full experiment and figures can be seen in the appendix (Appendix 1.3).

4.1.2 General experimental design

The hypothesis was that by introducing the confidence interval, the focus of the participant will shift to the risk and uncertainty attributes, thus raising their risk awareness and helping them to think carefully about the options before making their decision. It was expected that the first version (baseline) would yield scattered answered with a slight favor towards the first option (the riskier but more attractive at first sight) while the second version (nudged) would lead to a favorable lean towards option two (the safer option) as it helps showcase the risks and uncertainties in both options. In order to fully grasp the reasons behind a participant making a decision and taking a look at the psychological aspect, few follow up questions were introduced

to give us a better understanding regarding the participant's decision making process. These follow up questions help see how participants visualize the risk of each option and understand their risk stance in order to gain insight on the mechanism of the decision making process.

The experiment contained two forms of analysis: priori statistical analysis and post-hoc analysis. The first question that tested of the effectiveness of the nudge conformed to the nature of a priori statistical analysis nature, being that a positive relationship was expected before any testing was made while the follow up questions exhibited more of post hoc analysis nature. Some sort of effect was expected to be found through the follow up questions, but the extent of the effects (or direction) was not hypothesized. Simply put, a priori model is present when a hypothesis is formulated before-hand and an effect is expected (in the case of the first question), while post hoc are effects unearthed from analysing the experiment output (as in the case of question two to five). That meant that the follow up questions followed a post hoc analysis where the relationship between the factors uncovered through the questions were examined after the analysis took place. Keeping in mind that many scientific papers are published without a post hoc control of type 1 error (when a null hypothesis is true and rejected) (Jaccard, Becker, & Wood, 1984), careful attention was taken in avoiding the error 1 error as well and avoiding any incorrect drawings of conclusions. This paved the way to post hoc control tests, or in this case, the individual analysis of questions.

The experiment was pretested in order to gain an outside insight into any aspects of the experiment that might have been missed, inaccurate or confusing. Three raters were used (Two students and one professor) took the test which helped with naming the design competition and correcting a typo (making bold the "options" in the questions)

4.2 PARTICIPANTS

Two hundred and thirty four people participated in this online experiment of whom one hundred and twenty four took the baseline form and one hundred and ten the nudged one. The experiment was run online with the use of Qualtrics and Amazon Mechanical Turk (MTurk). Qualtrics is a private research software company that enables users to do various online data collections while MTurk is a crowdsourcing internet marketplace that enables individuals and businesses to coordinate the use of human intelligence to perform tasks that computers are currently unable to do (for example: choosing the best option among several photographs). The participants did receive a small monetary compensation for their time spent taking part in the experiment.

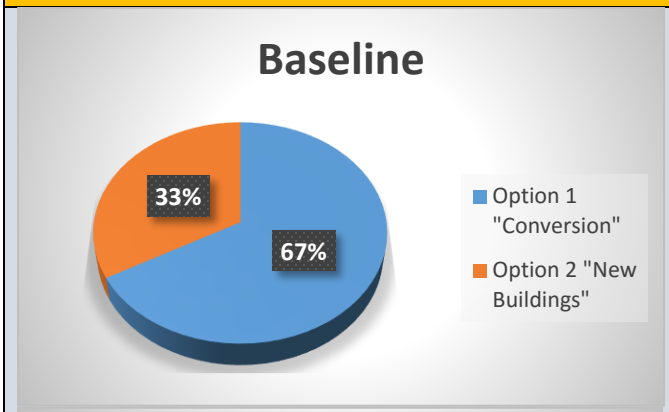
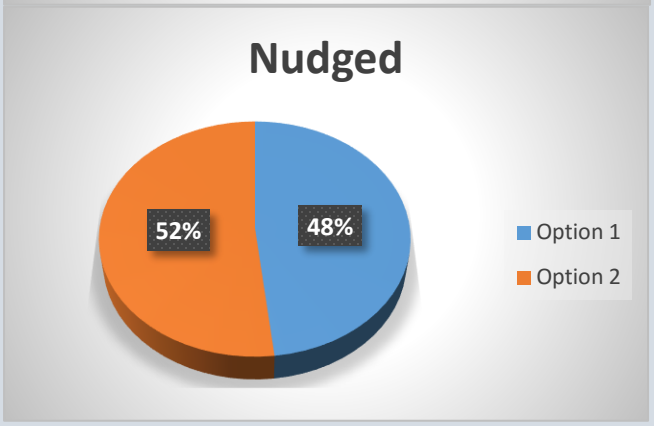
5. RESULTS

This chapter presents the results of the experiment, which are divided into four sections. Section 5.1 presents an overview of the results. Section 5.2 and 5.3 present the two different analysis models: the priori analysis (Question 1) and the post hoc model (Question 2-5), respectively, which presents the inferential data and draws conclusions based on various statistical data analysis. Finally, Section 5.4 concludes the findings.

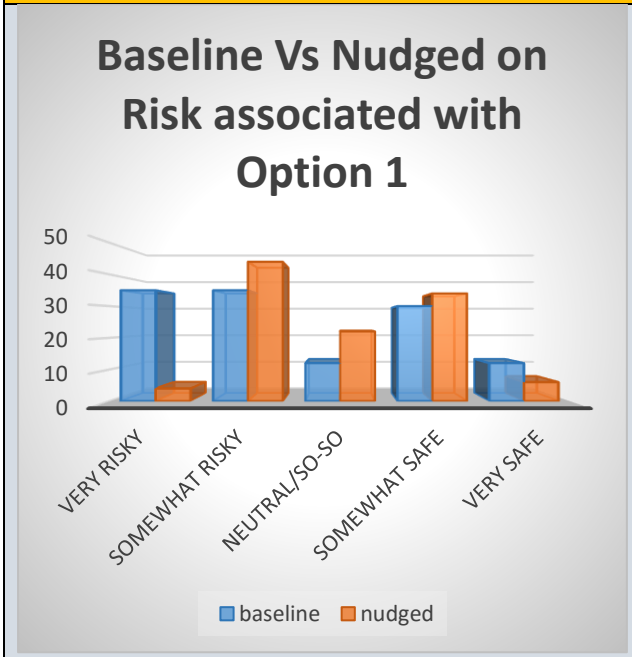
5.1. Overview of results

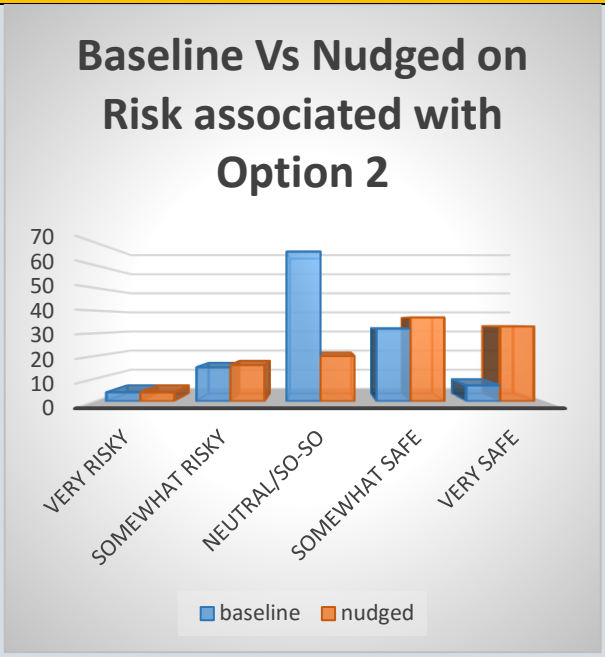
As mentioned before, five questions were asked in each version (baseline and nudged) and the results of each question are compared between the two in the table below.

Table 5. Results overview of nudge experiment

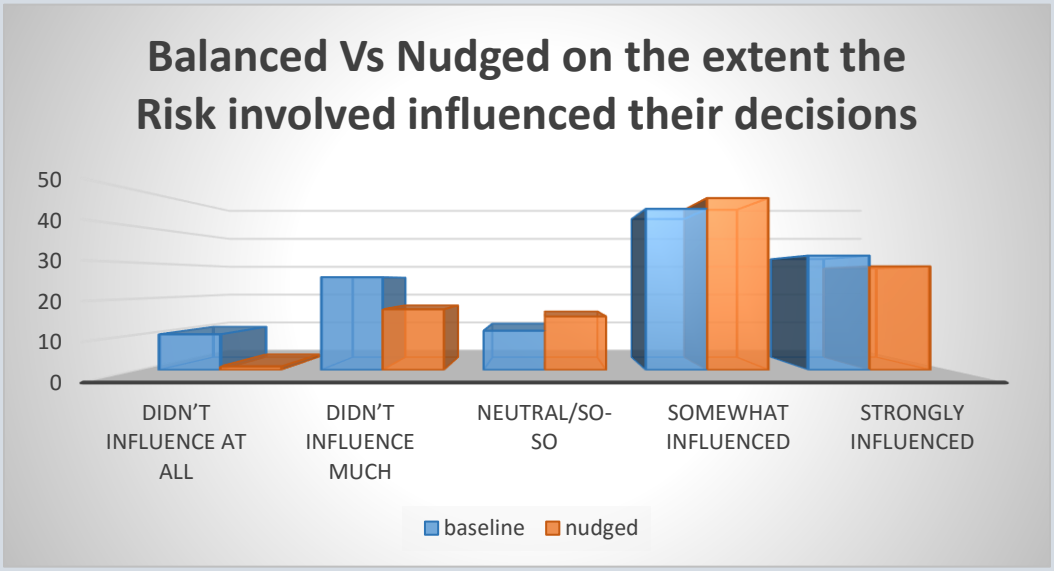
Question 1: If you consider the scores above, and taking the client's wishes into account, which option do you prefer?
   

Question 2 and 3: What level of risk would you associate with option 1? Option 2?

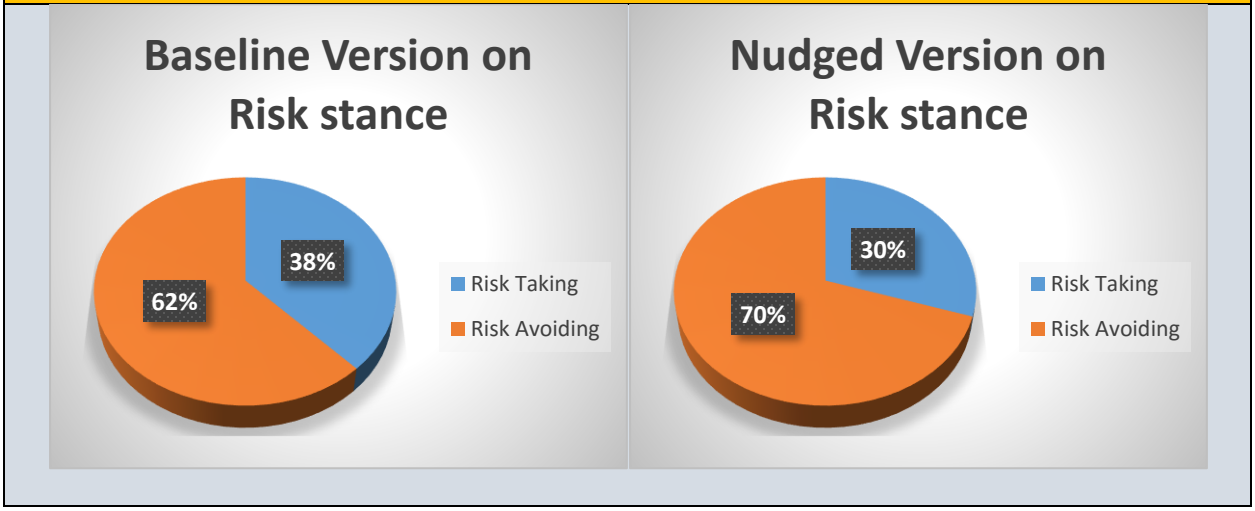




Question 4: To which extent did the risk involved influence your decision?



Question 5: Would you consider yourself a risk taking or risk avoiding person?



5.2 Nudge effect on decision outcome in the trade-off matrix

At first glance, the results of the experiment with regards to the effectiveness of the nudge (Question 1) go hand in hand with the hypothesis stated earlier. Participants who took the baseline version were drawn to the first option without paying much attention to the risk and uncertainties involved but once the risk and uncertainties were made explicit by the use of the confidence interval in the nudged version, their perspective changed, and with it, the decision on the preferred design choice. As can be seen from the results Table 6 below, in the baseline form, 83 out of 124 (67%) opted for the attractive but risky option (option 1) while in the nudged form, 53 out of 110 (48%) did in the nudged form. The shift in the preferred option chosen towards the safer option in the nudged form was statistically reliable and assed by a binary logistic regression.

Table 6. Number of participants that opted for option 1 or 2 for both forms (baseline and nudged)

Form	Options		Total
	Option 1 (Attractive but risky)	Option 2 (Average but safe)	
Baseline	83 (67%)	41 (33%)	124
Nudged	53 (48%)	57 (52%)	110
Total	136	98	234

First and foremost, question 1 was the most crucial question and tested whether the nudge actually had an effect on the participants. The analysis of this question is in line with the priori model as a relationship was hypothesised and expected to be present. The implementation of the nudge was hypothesised to increase the participant's risk and uncertainty awareness and consequently cause a significant enough shift in the choice decisions from the riskier option (option 1) towards the safer option (option 2). The relationship between the nudge and the option chosen can be seen in Figure 5 below and constitutes of a straight forward relationship between the form (baseline or nudge) and the option chosen (a.k.a choice outcome).

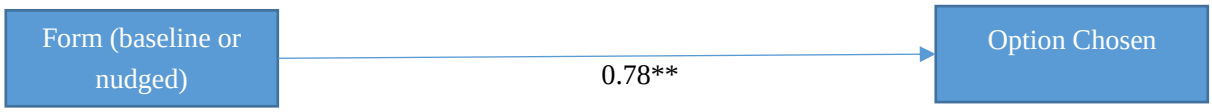


FIGURE 5. Relationship of independent variable (form) on the dependent variable (option chosen)
* $p < 0.05$
** $p < 0.005$

A binary logistic regression was performed in order to check if there was a significant relationship between the independent variable (form) and the outcome (option chosen). Table 7 reveals a statistically significant difference (on a significance level of $p < 0.05$) among the baseline version and the nudged version (p=0.004**) (the SPSS output can be seen in Appendix B3). In turn, the null hypothesis is rejected and the effect of the nudge is significant (a significant effect of the nudge on raising risk and uncertainty awareness and ultimately on the chosen option).

Table 7. Binary logistic regression of the independent variable (form) on the dependent variable (option chosen)

	Variables in the Equation					
	B	S.E	Wald	df	Sig	Exp(B)
Nudge	0.778*	0.270	8.309	1	0.004**	2.177

* $p < 0.05$
** $p < 0.005$

Now that the effect of the nudge is confirmed, the analysis proceeded to the follow up questions to gain more insight and understanding into the workings of this effect.

5.3 Mediator and Moderator models

Mediator and moderator variables (Questions 2 through 5) followed a post hoc nature as statistical analysis were run post experimentation. This was done in order to check for various effects different factors might have. It is important to note that although preventative post hoc analysis tests are usually done in order to control the type 1 error rate, it was not possible to perform these tests. In practice, post hoc analysis tests would initially adjust the p-value in order to truly test for any significance between the various groups. In essence, post hoc stems from the thought the errors in inference with regards false significance in hypothesis testing are more likely to occur when one considers a set of factors as whole (Benjamini, 2010) .In turn, several statistical techniques were developed in order to prevent this from happening by performing single comparisons. The inability to perform these tests was due to the fact that in order for the tests to be run, they required a minimum of three groups, which is not the case in this experiment (only two groups are present: baseline and nudged). In order to tackle the issue of the inability to perform a post hoc statistical analysis and the need to do single variable comparisons, it was important to understand that the root of the post hoc tests were to detect the relationship and effect of subgroups individually. The approach was done in order to best mimic the effect of these post hoc tests was to perform statistical tests to each one of the questions separately. This would enable the detection of any pattern or significant effect of each variable.

5.3.1 MEDIATOR

Question 2 and 3 dealt with the degree of risk awareness associated with individuals regarding both options and thus, help shed some light into the perceived risk. Reflecting back on Table 5, it can be noted that a high amount of participant's option for "very risky" in the baseline version with regards to the risk associated with option 1 might, theoretically, be due to the realization of the risk involved once they were asked about it (by reading the question). At this point, the question might have helped focus on the risks and uncertainties of each option, but it is not possible for participants to move backwards in the survey and change their answers.

Before jumping into the statistical analyses regarding the mediation, it was important to note whether the nudge increased the perceived level of risk awareness within participants in the nudged version. In order to investigate this effect to a larger extent, it was important to conduct a few statistical analysis.

The first set of statistical tests comprised of two independent sample t-tests. An independent sample t-test was conducted to compare the risk associated with option 1 in the baseline and nudged conditions while the second independent sample t-test was conducted for option 2. There was a significant difference in the scores for both tests. For the first t-test, baseline (M=2.59 , SD=1.37) and nudged (M=2.95 , SD=1.04); t(232)=-2.22, p=0.027. While for the second test, baseline (M=3.18 , SD=0.84) and nudged (M=3.71 , SD=1.15); t(232)=-

4.076 p=0.000. These results suggest that the nudge increased the mean and ultimately really does have the desired effect on the degree of risk awareness. Specifically, our results suggested that when participants were exposed to a nudge, their degree of risk awareness increased. This, in turn, paved the way to the next analysis.

In order to really compare between the baseline version and the nudged version, a proper ground of comparison needed to be established. Here, a perception score was calculated based on the results of both participants for both questions. This perception score (which was a difference scores of each participant based on both questions), represented the degree of risk awareness in participants. The outcome of the previous statistical analysis revealed that the perception scores exhibited characteristics of a mediator, and thus mediation testing was done. A mediator diagram was established in order to visually see the relationships and can be seen in Figure 6 below.

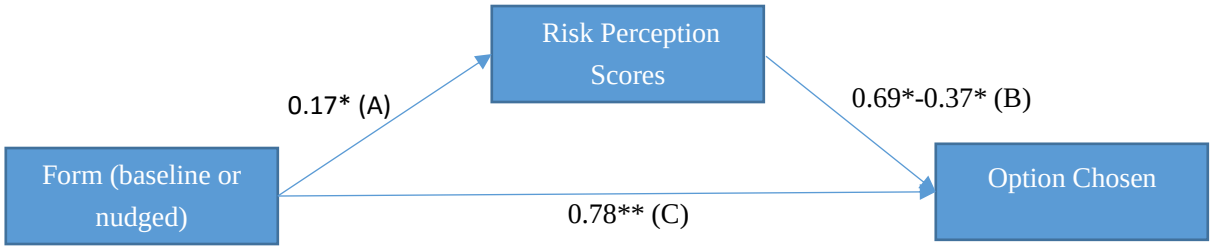


FIGURE 6. Mediator diagram
* $p < 0.05$
** $p < 0.005$

The conventional mediator diagram was adjusted to tailor fit the scenario at hand. As can be seen, three relationships are present. The first relationship, represented by “A”, demonstrated a relationship between the independent variable (form) and the risk perception scores and tests the effect of the independent variable on the perception scores. The second relationship, represented by “B”, demonstrated a relationship between the perception scores and the dependent variable (option chosen) that tests the effect of the perception scores on the dependent variable in the combined analysis (including the independent variable) while the third relationships, represented by “C”, demonstrated a direct relationship (effect) of the independent variable (form) on the dependent variable (option chosen).

In order for this mediator diagram to work, three main conditions (and therefore tests) needed to stand (Baron & Kenny, 1986).

(1) Mediator must be affected by the independent variable (Relation A).

In order for this condition to stand true, the perception score must be affected by the form. A statistical analysis in the form of an independent samples t-test was conducted for this perception score. There was a significant difference in the scores, baseline (M=1.5 , SD=0.80) and nudged (M=1.79 , SD=0.92); t(232)=-2.59 p=0.010. Pearson correlation test revealed that the coefficient was 0.167* (Appendix B.3.9). The results shown revealed that this relationship stands true and is statistically significant.

(2) The independent variable must affect the dependent variable (Relation C).

In order for this condition to stand true, the independent variable (form) must directly affect the choice outcome (dependent variable), which was tested through a binary logistic regression. The result outcome pertaining to question 1 containing the binary logistic regression revealed that this relationship stands true and is statistically significant (Table 7).

(3) Mediator must affect the dependent variable in the combined analysis (when both independent and mediator are combined) (Relation B)

In order for this condition to stand true, the perception score must affect the decision outcome in a combined analysis including the form. In order to test this, a binary logistic regression was performed including both form and perception score. The outcome of the combined analysis can be seen in Table 8, where the perception score is significant (p = 0.025*) and thus the relationship stands true and is statistically significant. (SPSS outputs can be seen in Appendix 3.2)

Table 8. Binary logistic regression containing both variables (Form and Perception score)

	Variables in the Equation					
	B	S.E	Wald	df	Sig	Exp(B)
Nudge	0.689*	0.275	6.284	1	0.012*	1.991
Perception Score	0.366	0.163	5.030	1	0.025*	1.443

* $p < 0.05$

Now that all these steps were tested and found significant, there was one more condition for the

diagram to be completed and that was to establish the type of mediation. If the effect of the form was completely gone when the combined analysis was made, then complete mediation was attained. Whereas if the effect of the form was less in the combined analysis than by itself, partial mediation was attained. The comparison of Table 7 and Table 8 revealed that partial mediation was the case as the effect of the form decreased when the combined analysis was made (from B=0.778* to B=0.689*).

5.3.2 MODERATOR

The presence of a moderator variable suggests that a variable could change the magnitude or the direction of a relationship between two variables, usually the independent variable and the dependent variable. "A moderation effect implies an interaction effect which could (a) increase the effect of the predictor on the outcome; (b) decrease the effect of the predictor on the outcome; or (c) reverse the effect of the predictor on the outcome" (Muayyad & Latefa, 2014, p. 625). Two moderators were tested for in this experiment, the risk sensitivity and the risk stance. Multiple linear regression analyses were conducted to test these relationships. Each moderator was tested separately as moderation is represented as a linear by linear interactions between the independent variable and the moderator variable (Aiken & West, 1991). In addition, in order to avoid potentially problematic multicollinearity with the interaction term down the line, it was recommended that the variables be centered for the moderation analysis (Aiken & West, 1991).

Risk sensitivity and risk stance can be seen as a reflection of the personal characteristics of the participants. The main objective of these questions was not to conduct any form of statistical analysis, but rather to gain insight on personal preferences and confirm the literature review findings, nonetheless statistical analysis were conducted. Literature review helped identify these individual personal preferences as moderators that affect the final decision outcome.

Curiosity into how these personal preferences might affect the outcome sparked the in-depth look into the effect of risk sensitivity (question 4). In the baseline version, 62% of participants scored in the influenced side, while in the nudged version, 70% indicating a shift towards larger risk influence. The results of question 5 indicated that the majority of individuals were risk averse (more so in the nudged version than the baseline) and is a perfect reflection on the literature review findings.

At first glance, results from Table 4 demonstrated that the participants do have some sense of risk sensitivity. It was important to map out the clear relationships between the independent variable, moderators and dependent variable. The relationship diagram for the risk sensitivity moderator can be seen below in Figure 7.

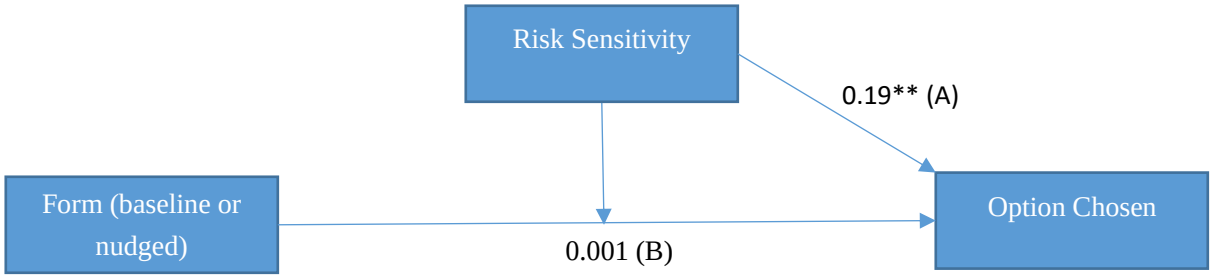


Figure 7. Risk sensitivity moderator diagram
** p < 0.005

Risk sensitivity and risk stance seemed to have an effect on the option chosen, but statistical analysis were needed to test and prove that.

In order to test for the first moderator (as shown in the figure above), two regression analyses were conducted using SPSS. In the first, the dependent variable (decision outcome) was regressed on the independent variable (form) and the moderator (risk sensitivity) while in the second, the interaction between the independent variable (form) and the moderator (risk sensitivity) was entered into the analysis. In order to computer the interaction value, first the values need to be standardized (a z-score is given to the independent variable and the moderator) and then their product is computer. This product is the interaction value which is used in the analysis.

Results of both analysis can be seen in Tables 9 and 10, respectively. As can be seen, the first analysis (relationship "A" in Figure 7) proved to be significant (p <) while the second analysis (relationship "B") was non-significant. It is safe to state that although there is an effect of risk sensitivity on the option chosen, there is no moderation effect.

Table 9. Regression of dependent variable (decision outcome) on Independent variable and moderator (Form and Risk sensitivity)

	Variables in the Equation			
	B	Coeff.Std.Err	T	Sig
Form	0.132	0.057	2.315	0.021*
Risk Sensitivity	0.19	0.24	7.9	0.000**

* p < 0.05
** p< 0.005

Table 10. Regression of dependent variable (decision outcome) on Independent variable (form), moderator (risk sensitivity) and interaction coefficient.

	Variables in the Equation			
	B	Coeff.Std.Err	T	Sig
Form	0.132	0.057	2.307	0.022
Risk Sensitivity	0.19	0.025	7.697	0.000
Interaction Coeff	0.001	0.030	0.025	0.980

* $p < 0.05$

Similar analysis was performed for the second moderator, risk stance. Results of the moderator analysis (as shown in Figure 8 below) can be seen in Tables 11 and 12 below. Similarly to the risk sensitivity moderator, risk stance proved to have an effect on the option chosen, but exhibited no moderator effect.

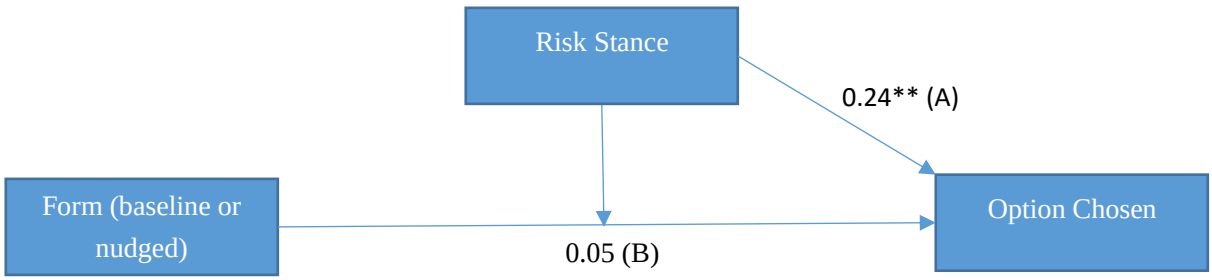


Figure 8. Risk stance moderator diagram
** $p < 0.005$

Table 11. Regression of dependent variable (decision outcome) on independent variable (form) and moderator (risk stance)

	Variables in the Equation			
	B	Coeff.Std.Err	T	Sig
Form	0.168	0.062	2.705	0.007
Risk Stance	0.242	0.066	3.690	0.000**

* $p < 0.05$
** $p < 0.005$

Table 12. Regression of dependent variable (decision outcome) on Independent variable (form), moderator (risk stance) and interaction coefficient.

	Variables in the Equation			
	B	Coeff.Std.Err	T	Sig
Form	0.167	0.062	2.690	0.008
Risk Stance	0.247	0.065	3.778	0.000
Interaction Coeff	0.046	0.031	1.482	0.140

* $p < 0.05$

The findings showed that in the first analysis, both moderator variables had a significant outcome with p= 0.000 for both. Nonetheless, there was no moderation effect present for any of the two variable. This is because although there was a significant effect when the first part of the analysis was made (that tested whether the moderator affected the dependent variable), the second analysis (where the interaction variable was included and tested for the actual presence of a moderation effect) produced a non-significant outcome. That is, after including the interaction between the independent variable and the moderator (risk sensitivity or risk stance), none of the R^2 changes were significant (which means there was no increase in the predictability of the model). The results overview can be seen in Table 13 while the full results can be found in Appendix B3.

Table 13. Moderation effects of risk sensitivity and risk stance on the relationship between the independent variable (form) and the dependent variable (decision outcome)

Model	Independent Coefficient	Moderator Coefficient	Interaction Coefficient	F
Risk sensitivity				
$R^2 = 0.241$**	0.134*	0.456**		36.68**
R^2 change= 0.01	0.134*	0.457**	0.001	24.34**
Risk stance				
$R^2 = 0.082$**	0.170*	0.232**		11.374**
R^2 change= 0.004	0.169*	0.238**	0.093	8.354**

*$p < 0.05$
**$p < 0.005$

Although no significant moderation effect was present, both variables affected the final decision outcome to so some extent, it served to consolidate the literature review findings that suggested that most individuals have some sense of risk sensitivity and are risk averse in nature with regards to decision making under risky and uncertain situations. The outcome of the participants for the baseline version vs the nudged version indicated that participants from both versions seemed to be majorly risk avoiding. It is important to note that a higher percentage of individuals

were risk avoiding in the nudged version of the experiment, 70% relative to the 62% of the baseline version.

It is also important to note that additional variables such as time were also ran in a binary logistic regression alongside the other variables in order to check for any significance. No additional variable had any significant outcome. More elaborations on each of the findings can be found in Appendix B3.

5.4 Conclusion

Results of this experiment showed a statistically significant effect of the proposed nudge in the form of a confidence interval. The nudge served its intended purpose of steering the participants away from the riskiest yet more attractive option towards the more average but safer option. The presence of the confidence interval helped to explicitly focus on the risk and uncertainties that the various options offer.

Furthermore, the follow up questions helped to dive deeper into unto the decision making process understanding and identify other factors that had an effect on the choice outcome. The results of the second and third questions helped to understand how individual perceive riskiness in options. This risk perception helped identify perception scores as a mediator to choice outcomes.

Results and statistical analysis were divided into two main parts. The first part exhibiting an a priori analysis nature with Question 1 while the second part a post hoc analysis nature with the remaining additional questions (Question 2 to 5).

The outcome helped in the rejection of the null hypothesis and the effectiveness of the nudge. The ability of the nudge to explicitly draw attention to the risk and uncertainty has shown to cause a shift in the preferred option from the baseline form to the nudged form. Furthermore, statistical analysis in the form of a binary logic regression indicated the effect as significant. A significance level of $p = 0.004$ was found (gauged on a significance level of $p = 0.05$).

The second part of statistical analysis pertained to the post hoc nature. Although preventative post hoc analysis tests are usually done in order to control the type 1 error rate, it was not possible to perform these tests. The inability to perform these tests was due to the fact that in order for the tests to be run, they required a minimum of three groups, which is not the case in this experiment (only two groups are present: baseline and nudged). In order to tackle this issue, it was important to understand that the root of the post hoc tests were to detect the relationship and effect of subgroups individually. The approach done in order to best mimic the effect of

these post hoc tests was to perform statistical tests to each one of the questions separately. This would enable the detection of any pattern or significant effect of each variable.

Perception score was formulated based on the combination of Question 2 and 3 that proved to serve as a partial mediator. Significant effect ($p= 0.010$) between the independent variable and the perception score was found, significant effect ($p= 0.004$) was found between the independent variable and the outcome, and a significant effect ($p= 0.025$) was found for the perception score in the combined analysis. Concluding the perception score as a partial mediator.

Risk sensitivity and risk stance (representing Question 4 and 5) were identified as moderators and were based on individual personal preferences. Post hoc analysis of these moderators helped shed light into the significant effect of risk sensitivity and risk stance on the final outcome. Although these factors had an effect on the dependent variable, the moderation statistical analysis proved non-significant and thus moderation is not present. Nonetheless, the findings verified some of the literature findings that the humans do have some sense of risk awareness as well as that their nature tends to be risk averse.

6. DISCUSSION

Now that the effectiveness of the proposed nudge has been tested for and proven significant, it is important to take a step back and take a look at the bigger picture. We are bombarded with nudges in our daily lives, from the fast food chains ads on TV, to the hospital organ donation forms, all the way to supermarkets as those nudges have found a way to settle among us. This of course did not happen by mistake, but rather was put into effect by individuals whom carefully studied and understood the powerful effects behind nudges and used that to steer individual decisions towards a certain "wanted" or "profitable" direction. Now although many might claim nudges to be unethical and pure manipulation, its widespread use and presence makes it inevitable to avoid. The aim of this research wasn't to change someone's decision per say, but more to apply the concept of nudging to help raise risk and uncertainty awareness with regards to the design options in hopes that by making these risk and uncertainty more explicit, decision makers will opt for a safer and more considerate choice option.

Literature findings on the effect of nudges were proven by the first main question and is a clear indication of the effect that a simple nudge has on raising risk and uncertainty awareness and consequently affecting the decision outcomes. Confidence intervals proved to be an effective nudge in raising the level of risk awareness when implemented in a trade-off matrix. The literature findings did point out that one aim which companies usually use confidence intervals is to manage risk (Richards & Media, 2012) and as such, this nudge proved the literature findings as well as showcased how it can be implemented as a nudge. Although the first question answered the main aim of the research, the literature findings sparked the curiosity into the working mechanism of nudges, which, in turn led to the follow up questions. Insight from these questions could shed light into how the effect of nudges take place.

The perception score helped shed light into the inner workings of the nudge. A clear significant effect between the individuals subjected to the baseline form and the nudge form not only showed that the nudge helped raise risk awareness, but also helped to identify it as a mediator in the relationship between the form individuals were given and the final decision outcome. The mediator diagram presented earlier helped visualize the relationship and realize the possibility that other mediators might also come at play in other scenarios whenever complex decisions are needed to be made. This could be an area discovered by future studies. The more knowledge there is with regards to raising risk and uncertainty awareness, the better the chance of increasing the magnitude of the nudge effect in the future.

Risk sensitivity and risk stance touched more on the human nature of the participants and their personal preferences. Risk sensitivity was subjected to moderation testing but although statistical analysis revealed that individuals do have a general sense of risk sensitivity and that it guides them, to an extent, in decision making but that it was not significant in the moderation model as a

whole (when the interaction variable was included). This coincided with literature findings that humans do have a certain level of risk sensitivity (sometimes called risk awareness) that helps them go through daily decisions (Hopkins, 2005). Although this risk sensitivity somewhat helped in the process of choosing an option, unfortunately it was not strong enough to instill a proper effect in conscious decision making. This might be due to the fact that individuals don't see the risk as a crucial part of decision making, or due to their over-optimism at the time of decision making (which coincides with the literature review findings (Johnson, et al., 2012)). Individuals do tend to be overly enthusiastic when coming up with a tender and that comes hand in hand with over optimism. These lead to under estimations with regards to the time and finances of a design, which essentially also falls into the domain of the unawareness of the risk and uncertainties involved with the design option. Before examining the results of the last variable, which dealt with the risk stance of individuals, all the literature studies conducted pinpointed that humans in nature tend to be risk averse (Winch, 2010). This could stems from personal factors, work environment, power of the decision maker, experience and ability to protect themselves against risk. This finding was backed up by the experiment as the majority of individuals in both versions declared themselves to be risk averse. A higher percentage of risk averse individuals was noted in the nudge version and that might be due to the effect of the nudge and the follow up questions raising the level of risk awareness and with it the notion of how important these risk and uncertainties should be valued when it comes to decision making. Risk stance also was subjected to a moderation analysis which, similarly to risk sensitivity, showed a significant outcome with regards to the relationship between this moderator and the dependent variable but a non-significant relationship in the overall model (including the interaction variable). A look at the extent of these personal preferences of risk sensitivity and risk stance affect the decision outcome might be an interesting thing to discover in future research.

The inability to clearly see the risk and uncertainties involved in each option is a huge handicap when it comes to decision making, especially in a domain such as the construction industry. The fate of people, companies and individuals are at risk and lie upon these design decision outcomes. Failing to give the risk and uncertainties the attention it deserves has been a problem present in the construction industry for quite some time. It is quite clear that these problems do stem for the nature of these infrastructure tenders that take place as the lack of time, incomplete information and raising complexities of projects and client demands are not easy to handle but it is about time that the construction industry broke free from this vicious cycle. This vicious cycle has caused many projects to be delayed, underfunded, led to companies going bankrupt and to a more critical extent, might have caused the lives of a few humans that were at the receiving end of these risk and uncertainty unawareness.

Although most participants opted for being risk averse, many of them went on to make risky choices afterwards (as can be seen from the results of the baseline experiment). This might be due to three reasons. The first one might be that the risk awareness was developed after the decision was made (upon reading the follow up question), and with no possibility to change the

option chosen (since the risk question came after the option decision) and thus help understand the discrepancy between the human nature and the chosen option. The second reason why these results might make sense in the baseline version might be due to individual's inability to perceive the risk. Which means that although their nature dictates them to be risk averse, they were not explicitly aware of the risk and uncertainties and thus fell in the trap. These mechanisms are not present in the nudged version as more synchronization between the risk stance and the choice outcome is present. The third and perhaps the most crucial reason would be knowledge about the context. It could be possible that some of the participants didn't take their chosen decision as meticulously and with as much care as individuals in a real life infrastructure tender process. The lack of sense of urgency and importance does play a role on how individuals think, behave, and possibly subconsciously affect the way they make decisions.

It is important to note that although this experiment proved confidence intervals as a significantly effective nudge, the strength of the nudge in the real world might differ. The experimental setup tried to mimic as much as possible the real life scenario, but of course there is much more at stake and many other factors in play in the real world. The fact that the effect of the nudge does somehow play on the personal characteristics of individuals, there is no telling how much it will affect each individual. Some individuals might be immune to such nudges while others might be skeptical (which might lead to the nudge having an opposite effect). It is also possible that the social pressure at the work place or while coming up with bids blinds an individual from risk and uncertainty of the design option and might prevent them from being affected by the nudge. Literature findings do indicate that in some rare cases, nudges have no effect on some individuals but that nonetheless, the majority of individuals won't notice the presence of the nudge and the nudge should fulfill its purpose and help raise risk and uncertainty awareness and consequently the decision outcome (Johnson, et al., 2012).

Future researchers and students interested in the effects of nudging could find multiple ways to improve this experiment to better asses the nudge effect. One of the main interesting things that could be looked at is (as mentioned earlier) the possible relationship between the follow up questions and if the follow up questions feed off of each other. For example, a look into whether the risk stance affects the risk sensitive by testing whether individuals who have higher risk sensitivity are more prone to be risk averse. They could also dive deeper into any one of the follow up questions and explore different factors revolving around risk sensitivity. Is it something that an individual is born with (as suggested by some literature review)? Or is it something an individual acquires through life experiences? And whether some form of nudge could subconsciously alter levels of risk sensitivity?
A second option would be to try and increase the effect of the confidence interval nudge, what other alterations and details could be added to this nudge in a trade-off matrix to better raise the levels of risk awareness to ensure an even greater response.
A third option would be to test various individuals from different backgrounds. Could it be possible that individuals from backgrounds such as the construction industry react differently to

different nudges? And if so, what would be the one the best possible nudge?
A fourth option might be to subject the experiment to a more real life setup as opposed to the online experimental setup. Individuals replying to a questionnaire from the comfort of their homes might not have the social pressure present in real life group scenarios? It would also be interesting to see how much these social pressure affect the awareness of risk and uncertainties and whether more nudges are needed to counter this effect?
As can be seen, the complex world of nudging leaves place to a lot of further research, in hopes of bettering the infrastructure tender processes.

Now that nudges are slowly starting to resurface in the construction industry, it is crucial for companies to tap into this knowledge field. The results of this experiment, alongside other experiments, showcased that nudges do have their place within the construction industry world and more importantly, within the infrastructure tender phases. In order to be able to effectively compare between design options, companies should explicitly draw attention to the risk and uncertainties that each option exhibits. This can be done through the same way that this experiment was set up. Providing each option with a confidence interval score and different skewered width spans to indicate the level of risk and uncertainty pertaining to each option. It is crucial that better decisions be taken not only to help contractors take better decisions within the limited tender time constraints, but also to open a door that leads to more conscious behavior on a larger scale. A way out of the vicious myopic and chaotic cycle that has plagued the construction industry for so long.

7. CONCLUSION

The aim of this study was to: *Develop a suitable nudge based on studies pertaining to decision making under risk and uncertainty and nudge mechanisms. Determine the influence of implementing this nudge in a trade-off matrix on risk awareness and consequently on design decision outcomes in infrastructure tenders.* Which translated to the following main research question:

Does changing the choice architecture (nudge) of a trade-off matrix increase risk awareness and consequently change the decision outcome in infrastructure tenders?

The conclusion of this thesis is given by bringing together the answers of the three sub-questions that make up the main research question: *a) What are the factors that affect decision making under risk and uncertainty? What makes nudges so effective? b) What suitable changes in the choice architecture (nudge) of a trade-off matrix can increase risk awareness? c) Does presenting the risk and uncertainty in a more explicit way through nudging lead to more risk awareness and consequently change the decision outcome?*
And then concluding with a recommendation for construction companies.

What are the factors that affect decision making under risk and uncertainty?
Although decision making under risk and uncertainty is a risky process in itself, it is a reoccurring inevitable phenomenon in infrastructure tender processes. Since risk and uncertainty can never be completely eliminated, it should be mitigated, accounted for and understood to the best of one's ability. The main factors that affect decision making under uncertainty are:

- The ability to identify the different types of risks (strategic risks, financial risks, operational risks, legal risks and other risks) and the ability to manage them.
- The ability to represent knowledge in the form of probability and the extent of use of probabilistic models.
- The human nature of the decision maker
- The extent to which the decision maker experiences loss aversion (perceiving a loss larger than an equal-size gain)
- The extent to which the time pressure influence's a decision maker's ability to make a decision.

What makes nudges so effective?
The secret behind the effectiveness of a nudge is the fact that is simple. The nature of its simplicity helped it introduce itself in our lives without us ever thinking about it. We are nudged on a daily basis whether it be on the road where billboards provide visual pleasure to promote you to indulge in a specific food or on websites where we attempt to buy products that are labelled "best sellers". This effectiveness stems from the ability of nudges to tap into two field of

knowledge and combine them into one powerful, effective tool. The two fields are: the working mechanism and the human nature.

The working mechanism is discovered by studying the workings of the most powerful nudge yet, the default. From increasing the population of donors to helping us choose the "best" software setting to download, defaults have been around for years and their power is to thank. The ability of a nudge to exploit the human nature and tendencies to steer it towards a desired decision is the source of its power. The three mechanisms are: implied endorsements, cognitive biases and effort. The concept of implied endorsements stems from the fact that individuals interpret the defaults as the accepted and expected course of action. This has been mainly used in the domain of organ donation. Cognitive biases is the inclination or prejudice for or against someone/something in the mental process of perception, memory, judgement and reasoning that an individual goes through when making a decision. Research revealed that the reason of this cognitive bias lies in loss aversion. Loss aversion (mainly a product of human nature) is the fairly widespread psychological propensity that losses loom larger than equal-sized gains. The human nature dictates that humans are lazy, they have the low desire to put in effort, which in turn helps propagate the effect of defaults (nudges).

It is hard to look at the human nature as a separate field in relation to the nudge's working mechanism, for they work hand in hand. In addition to loss aversion and effort, other human characteristics cause the nudge to have an effect. The two main characteristics are: the myopic nature and the ambiguity of the future. The nature of the individual tends to be myopic (short-sighted) which makes all the focus on the early and quick rewards and although this nature causes the individual to yield immediate temptations and heavily discounting future outcomes, it could also make them more susceptible to nudging. The ambiguity of the future can cause individuals to either underweight or over rate certain decision effects. This links back to the loss aversion concept and the fact that the nature of humans tends to be risk avoiding. The fear of the unknown makes some nudges feel like the safest option.

What suitable changes in the choice architecture (nudge) of a trade-off matrix can increase risk awareness?

The confidence interval nudge chosen caused four main changes to the trade-off matrix:

- Changes in the scoring system from a 0-5 scale to a -2 to 2 scale. This not only made it easier to portray attribute values but also to go in line with the way BAM rates attributes (would make it easier to translate and apply later on to the real world).
- Changes in the form of a small visual effect where the interval was colored from red (indicating danger/caution) to green (indicating safe/conform). This helped to somehow eyeball where each design option attribute landed in relation to one another.
- Changes in the way the attributes of each design option were scored. Change from point scale to an interval. This interval was based on a 95% confidence interval rate while the width of the interval portrayed the level of risk involved. A wide interval meant riskier attribute ranges while a narrower interval meant a safer one.

- Changes in skewing the intervals of the attributes. This was done in order to mimic the nature of risk and uncertainties, showcasing that although you have a chance of scoring high, you also have a high chance of scoring low (which happens most often in reality as shown by the history records of previous projects).

Does presenting the risk and uncertainty in a more explicit way through nudging lead to more risk awareness and consequently change the decision outcome?

Presenting the uncertainty in a more explicit way through the introduction of a confidence interval acting as a nudge to raise risk awareness and consequently change the outcome of the decision making process proved to be effective thanks to the experimental findings. The introduction of the confidence intervals helped individuals to explicitly focus on the risk and uncertainties of the presented options and better compare between them. Not being able to explicitly focus on the risk and uncertainties caused individuals to opt more for the riskier first option as can be seen from the baseline experiment. Individuals based their decision upon the first visual impression, exhibiting the clear myopic nature suggested by the literature findings. The individuals exposed to the nudge were able to focus on the risk and uncertainties and put aside the riskier but more attractive option and go with the safer second option. The nudge was able to not only move the individuals towards a desired safer option, but also helped open their eyes into the risk and uncertainty that might not have been easily spotted otherwise (such as what happened with the baseline participants). Once the risk perception was higher, individuals were able to revert back to their risk averse nature and go with the safer option, leading to more conscious behaviour.

We conclude with a recommendation.

Although nudging is slowly making its way inside the construction industry world, it should happen at a faster rate. The proper use of a nudge offers another dimension to infrastructure tender processes and it is crucial for companies to tap into this knowledge field. The results of this experiment, alongside other experiments, showcased that nudges do have their place within the construction industry world and more importantly, within the infrastructure tender phases. In order to be able to effectively compare between design options, companies should explicitly draw attention to the risk and uncertainties that each option exhibits. This can be done through the same way that this experiment was set up. Providing each option with a confidence interval score and different skewered width spans to indicate the level of risk and uncertainty pertaining to each option. It is crucial that better decisions be taken not only to help contractors take better decisions within the limited tender time constraints, but also to open a door that leads to more conscious behavior on a larger scale. A way out of the vicious myopic and chaotic cycle that has plagued the construction industry for so long.

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APPENDIX A (EXTENDED LITERATURE)

A.1 Default categories

It has been noted that there are generally seven types of defaults which fall under 2 main categories: the Mass defaults and the personalized defaults (Goldstein, Johnson, Herrmann, & Heitmann, 2008). Each category and its subcategories, as shown in the table below, will be discussed briefly in the following section.

TABLE A.1. Main categories of Defaults and their subcategories

Mass Defaults	**Personalized Defaults**
Benign defaults	Persistent defaults
Forced choice	Smart defaults
Random defaults	Adaptive defaults
Hidden options	

The first category of defaults is Mass defaults, also referred to as simple defaults (Johnson, et al., 2012), is where the defaults apply to all customers of a product or service without taking the individual customer's preference or characteristics into account (such as an online retailer using a standard shipping service unless the customer opts by himself to the rush delivery service) (Goldstein, Johnson, Herrmann, & Heitmann, 2008). The main goal behind these mass defaults is for companies to maximize their profits without restricting freedom or jeopardizing customer satisfaction.

Benign defaults. Absent preference information, these defaults are a company's best guess, one that not only seems to bring about the less risk but also the potential to be most accepted by customers. An example of a benign default is with regards to the shoulder strap in car seats; two options are available: one where the hole is on the top and the other where the hole is on the bottom; knowing that the hole on the top would be more efficient for older children while the one of the bottom for newborns, one has to think about the reason behind customers purchasing that car; once a company realizes most of its customers purchase that car for newborns, the bottom hole is chosen (other reasons also include the issue of safety vs discomfort, where safety is clearly the logical choice) (Goldstein, Johnson, Herrmann, & Heitmann, 2008).

Forced choice. Sometimes used by companies to arrive to a benign default configuration, forced choices are tested on potential customers where they are required to make an active choice on an option/product/service or suffer the consequence of being denied use of the product (Goldstein, Johnson, Herrmann, & Heitmann, 2008) (Johnson, et al., 2012). The majority of forced choices are used in recreational setting, for example in vacations, where vacationers would like to go horseback riding. A company's mind state would be that it would be wiser for them to deny customers this service (unless a liability waiver is signed in advance) than to risk

having potential costs (damage equipment or horse) generated by customers who fail to agree to the terms (Goldstein, Johnson, Herrmann, & Heitmann, 2008).

Random defaults. Another default used when there's a lack of information regarding personal individual preference. In this type of default, a configuration is assigned at random from the various default configurations (Goldstein, Johnson, Herrmann, & Heitmann, 2008) (Johnson, et al., 2012). These type of defaults can be used when conducting an experiment (Johnson, et al., 2012) or by the government to assign senior citizens prescription drug plans (from the many plans available) (Goldstein, Johnson, Herrmann, & Heitmann, 2008).

Hidden options. Usually used in the computer industry, these defaults first appear to be the customer's only choice unless further digging is done to uncover the other options (Goldstein, Johnson, Herrmann, & Heitmann, 2008). For example when it comes to gaming, where games usually come with default skins and options regarding the quality, sound, and sensitivity, there usually is no clear indication of how (or even if it's possible) to change these settings; only after the user looks thoroughly through the settings does he uncover the options (Goldstein, Johnson, Herrmann, & Heitmann, 2008). Although a company uses these defaults in order to avoid some risks and mainly minimize costs, they should be cautious as it could cause to customer dissatisfaction and that could lead to a major backlash.

The second category of defaults is the personalized defaults. These are the opposite of the mass defaults, where the individual differences of the various customers are reflected and used in order to better meet the customer needs and increase satisfaction (Goldstein, Johnson, Herrmann, & Heitmann, 2008). As the Table A1 suggests, personal defaults comprise of 3 subcategories: persistent defaults, smart defaults and adaptive defaults.

Persistent defaults. This default is based on the idea that a customer's past choices are the best predictor for the future preference, such as when airlines automatically assign seats located in the aisle to the customers who usually or previously select those seats (Goldstein, Johnson, Herrmann, & Heitmann, 2008). The use of these defaults usually capitalize on attributes desired by the company, such as customer satisfaction and loyalty.

Smart defaults. These defaults take what is known about the individual (for example geographical or demographical information) into account in order to customize settings that would better fit him/her. Smart defaults are used usually in small adjustments, such as filling out the country code in an online form based on the individual's IP address, to facilitate or make the process more efficient for the individual (Goldstein, Johnson, Herrmann, & Heitmann, 2008).

Adaptive defaults. These type of defaults are dynamic, run on real time customer decisions and usually serve as advisers that help individuals identify desirable sets of features (Goldstein, Johnson, Herrmann, & Heitmann, 2008). Also termed sensory defaults, these are often used in websites that for example change the language of the website based on the location of the user (Johnson, et al., 2012) or by car companies websites where they suggest sporty steering wheels to customers who earlier on chose high horsepower engine as a preference (Goldstein, Johnson, Herrmann, & Heitmann, 2008).

A.2 Nudge examples

The various form of nudging is better visualized by providing a table that portrays each type. Table A.2 (Kim Ly, 2013) below shows the various types of nudging. As can be seen from the table, there are four different dimensions: 1) Boosting self-control vs Activating a desired behavior, 2) Externally-imposed vs Self-imposed, 3) Mindful vs Mindless and 4) Encourage vs Discourage.

Boosting self-control usually "help individuals follow through with a decision" (Kim Ly, 2013) , Activating a desired behavior "influences a decision that an individual is indifferent or inattentive to" (Kim Ly, 2013), Externally-imposed nudges " do not require people to passively seek them out, but rather they passively shape behaviour because of the way they present available options without constraining them" (Kim Ly, 2013), Self-imposed nudges are "voluntarily adopted by people who wish to enact a behaviour or standard that they feel is important" (Kim Ly, 2013), Mindful nudges "guide individuals towards a more controlled state and help people follow through with a behavioural standard that they would like to accomplish but have trouble enacting" (Kim Ly, 2013), Mindless nudges" includes the use of emotion, framing, or anchoring to sway the decision that people make", Encouraging nudges " facilitate the implementation or continuation of a particular behaviour" (Kim Ly, 2013), while Discouraging nudges " hinder or prevent behavior that is believed to be undesirable" (Kim Ly, 2013).

TABLE A2. Examples of Nudges

		MINDFUL		MINDLESS	
		ENCOURAGE	DISCOURAGE	ENCOURAGE	DISCOURAGE
ACTIVATING A DESIRED BEHAVIOUR	EXTERNALLY-IMPOSED	Simplifying tax rules to make tax filing easier.	Placing signs to remind people not to litter.	Advertising that most people are recycling to increase recycling efforts.	Using fake speed bumps to discourage speeding[9].
BOOSTING SELF-CONTROL	EXTERNALLY-IMPOSED	Simplifying application processes for college grants to encourage higher-level education[10].	Installing car dashboards that track mileage to reduce gas usage[11].	Automatically enrolling for prescription refills to encourage taking medication.	Placing unhealthy foods in harder to reach places[12].
	SELF-IMPOSED	Maintaining an exercise routine by agreeing to pay a small penalty if a gym session is missed[13].	Avoiding drunk driving by hiring a limo service beforehand[14].	Joining a peer savings group to encourage saving money[15].	Channelling money into a separate account to reduce the likelihood of it being spent[16].

In order to be able to visualize the potential of nudging, a look into three cases about nudging techniques will be illustrated in order to help individuals make better decisions.

The first case deals with “Using descriptive social norms to increase voter participation”. A lot of countries suffer from the number of voters making their way to the voting stations. Whether it is due to the perceived indifference among the participants or personal circumstances, the voting campaigns develop techniques in order to increase the voter turnout. An experiment was conducted by Alan Gerber and Todd Rogers comparing the effects of two strategies on voter intentions. “a phone campaign was developed using two sets of telephone scripts- one

emphasizing that voter turnout was expected to be low (low-turnout script), and another emphasizing that voter turnout was expected to be high (high turnout-script). The results showed that the high turnout-script increased the likelihood or receiving a 100% likely to vote response by 7%" (Kim Ly, 2013). These results show that by incorporating a nudge, a desired effect (increasing voter turnout) was accomplished. Taking a look at the type of nudge taken, it can be noted that the type of nudge used was "activating a desired behavior" (increasing voter turnout) through using a mindless (framing that a lot of people will be voting) encouragement technique (to increase people's reaction).

In the second case study, a research team from Roskilde University in Copenhagen tested a nudge to help pedestrians avoid littering. "The team placed green footprints that led to various garbage bins in the city and handed out caramels to nearby pedestrians. After handing out the caramels, they observed how many pedestrians would follow the footprints to the garbage bin and dispose of the caramel wrapper. The results showed that there was a 46% decrease in littering" (Kim Ly, 2013). Another case where a nudging technique was successful; taking a look at the technique used in this scenario reveals that although it is also an "activating a desired behavior" like the last case study, it exhibits "discouraging" behavior (using the green steps to discourage littering).

The third case study aimed to "increase post-secondary enrolment among low-income families", where a team from researchers partnered with H&R Block- a tax filing service company. Although governments tend to offer financial help for lower income families in order to enable the access to higher education, these financial helps come with tedious and endless procedures that often discourage individuals from either starting or finishing these processes. "Researchers designed a software that worked with H&R Block's tax filing software to extract information from an individual's income tax form and use the information to automatically fill in the FAFSA form. Results show that recent graduates were 40% more likely to submit a FAFSA application" (Kim Ly, 2013). The aim of this nudge was to help individuals follow through with their decision (boosting self-control) which was externally imposed (by the researchers and the company) in order to encourage (facilitate the implementation of the forms) through mindful nudge (help individuals follow through with an act they would like to do but have trouble enacting).

APPENDIX B (FULL EXPERIMENTS)

B.1 Pilot study

The general idea of this pilot study included the introduction of two scenarios that vary slightly in description. The students were divided into two groups and given a small text and then had to pick an option (in the form of a trade-off matrix) based on what they found more attractive. The first group received the normal matrix and the second group received the nudged matrix. The text talked about a student competition with regards to affordable and flexible housing as part of dealing with the influx of refugees that has been occurring over the last few months. The choice of text was suitable due to the fact that not only did it tackle a problem which needs a live solution, but also one which students can relate to and have seen happening as well and one that might push students to be more careful about their decision making which would ultimately lead to quality decisions. After the students read the text, they are faced a trade-off matrix between two possible options. Both the options had a list of attributes represented by a "+" for positive, "++" really positive,0 (neutral) "-" negative, "—" really negative as can be seen from Table B1 below (extracted from the pilot study). The hypothesis here is that the students will pick option 1, as it seems to be the most attractive one upon first glance.

TABLE B1: Scenario 1: Normal Matrix

Trade-off matrix		
	Option	
Criterion	**OPTION 1 ("Conversion")**	**OPTION 2 ("New development")**
Flexibility	+	0
Time-to-market	+	+
Sustainability	++	+
Affordability	+	+
Spatial and social quality	++	+
Risks and uncertainties	--	0

Moving on to the second scenario. Students are again faced with an almost similar scenario but are then faced with a nudged trade-off matrix. This time, four nudges are introduced in order to steer the decision outcome. The first nudge applied was moving the last criteria (risk and uncertainty) up to the top of the list (subconsciously trying to give it more importance by changing its order), the second nudge was detailing the risk and uncertainty attribute (giving

three examples more details about an attribute captures the importance of an attribute and helps the reader dive more into the consequences), the third nudge was a visual one, where a smiley face was inserted (with colors depending on where the attribute ranked on the bar) which showed a frowning red-colored emoticon for the double negative scenario (option 1) and a yellow emoticon with a semi-smile for the neutral (0) scenario (option 2). Last but not least, the fourth nudge was providing additional descriptions regarding the risk and uncertainty in the text and title of the matrix. The nudged Table B2 can be seen below (extracted from the pilot study).

TABLE B2: Scenario 2: Nudged Matrix

Trade-off matrix for decision making under great uncertainty

Criterion	**Option**	
	OPTION 1 ("Conversion")	**OPTION 2 ("New development")**
Risks and uncertainties such as • Difficulties during site preparation • Failure to obtain permits • Objections residents	-- 	0 
Flexibility	+	0
Time-to-market	+	+
Sustainability	++	+
Affordability	+	+
Spatial and social quality	++	+

The hypothesis here is that, seeing the nudges, students will be more inclined to opt for the second option (shift from the more attractive yet more uncertain options towards the less attractive yet less uncertain option).

The results of the experiment showed that from the sample of 30 students who were given scenario 1 (the baseline normal matrix), 24 had opted out for option 1 (good but uncertain), which went hand-in-hand with the hypothesis. For the second scenario, 33 students were given this form and 23 opted out for option 1 as opposed to option 2 which was expected to prevail. Nevertheless, the Z score calculations places both the responses for scenario 1 and scenario 2 as significant.

B.2 Full Experimental Setup

Dear participant,

You are about to participate in a short experiment about design in construction. You are asked to put yourself in a certain situation. Make sure you read the scenario carefully in order to better imagine the scenario and answer the questions.

Please remember that there are no right or wrong answers, we are just interested in your personal preference.

In the space provided below, please provide your MTurk ID number.
Thank you in advance for your time and cooperation, it is much appreciated.

Form 1: (baseline condition)

Housing Design Competition

Suppose you are participating in a design competition for students. With a group of students, you would like to respond to a recent call by the Dutch Central Agency for the Reception of Asylum Seekers (COA). In response to the increased influx of asylum seekers in recent times, COA is looking into innovative solutions for maximum flexibility in the supply of temporary housing units.
After some brainstorming, you come up with two rough ideas on paper of which you will choose one to develop further. Option 1 concerns the conversion of vacant buildings and option 2 concerns realizing new housing units from scratch. Both options can be seen below.

Option 1 (“Conversion”)

Option 2 (“New buildings”)

Due to the criticality of the situation and your large interest in the matter, you decide to take the design competition seriously and adopt a structured approach to determine which idea you should develop further. When deciding, you use criteria and concerns that were stressed by the agency as their guide to evaluate designs. These criteria include:

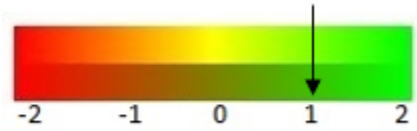
• Flexibility: Is it possible to use the units not only for asylum seekers and later for status holders, but also for other target groups?
• Delivery Speed: In order to respond to rapid and unexpected changes, can the units be produced quickly? and will they be readily available.
• Sustainability: Minimize waste in manufacturing and building. Does the design provide residents with efficient energy usage? and is it recyclable after short-term or long-term use?
• Affordability: Is it financially and economically viable? (Taking into account cost of the property and additional costs (transport, storage, connection costs, etc.)?
• Spatial and Social Quality: How is it ensured that the units are an asset to the environment, both spatially and socially?
• Risks and Uncertainties: What are the risks and uncertainties, and how big are they? Choosing riskier options has caused a lot of companies to go bankrupt over the past few years.

By taking into account the criteria above, you can meet the wishes of the COA. In addition to that, you want to determine if the design is feasible in case you win the contract and be involved in the realization. Winning this competition would mean a lot to you and your team.

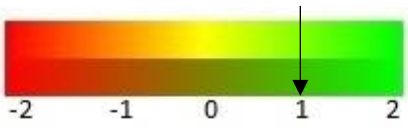
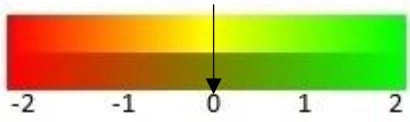
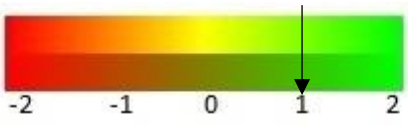
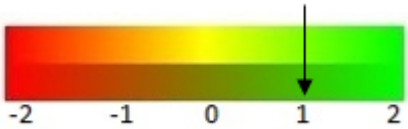
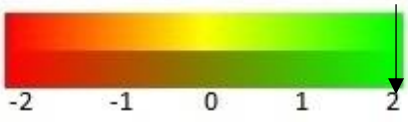
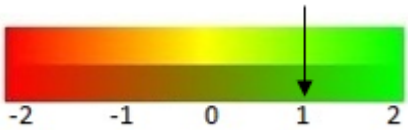
The points scored for both options are shown below in a so-called trade-off matrix.

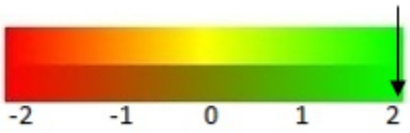
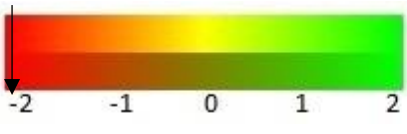
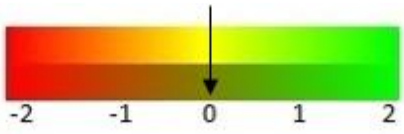
Note: The score system is a point score system based on the legend provided below ranging from -2 to 2.

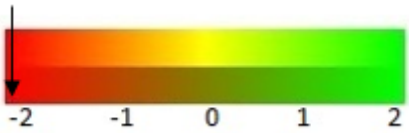
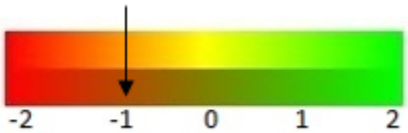
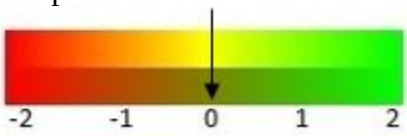
For example:

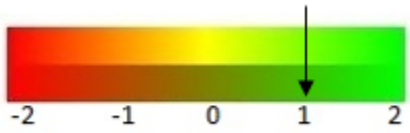


The bar above indicates a score of 1 which, referring to the legend, means that the attribute "meets standard/ favorable/none".

Trade-off Matrix		
Considerations	Options	
	Option 1 "Conversion" Point Scores	Option 2 "New Buildings" Point Scores
Flexibility		
Delivery Speed		
Sustainability		

Affordability		
Spatial and Social Quality		
Risk and Uncertainties		

Legend	
-2	Doesn't meet the standard/ bad/ large 
-1	Meets standard provided some conditions/ unfavorable / medium 
0	Complies to standard/ neutral/ small 
1	Meets standard / favorable / none

	
2	Meets standard / very favorable / none 

Q1) If you consider the scores above, and taking the client's wishes into account, which option do you prefer?

Option 1 "Conversion"	
Option 2 "New Buildings"	

Q2) What level of risk would you associate with **Option 1**?

Very Risky Somewhat Risky Neutral/So-So Somewhat Safe Very Safe

Q3) What level of risk would you associate with **Option 2** ?

Very Risky Somewhat Risky Neutral/So-So Somewhat Safe Very Safe

Q4) To which extent did the risk involved influence your decision?

Didn't Influence At All Didn't influence Much Neutral/So-So Somewhat Influenced Strongly Influenced

Q5) Would you consider yourself a risk taking or a risk avoiding person?

Risk Taking __ Risk Avoiding___

Form 2: (nudged)

Housing Design Competition

Suppose you are participating in a design competition for students. With a group of students, you would like to respond to a recent call by the Dutch Central Agency for the Reception of Asylum Seekers (COA). In response to the increased influx of asylum seekers in recent times, COA is looking into innovative solutions for maximum flexibility in the supply of temporary housing units.
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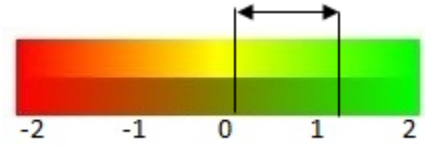
• Sustainability: Minimize waste in manufacturing and building. Does the design provide residents with efficient energy usage? and is it recyclable after short-term or long-term use?
• Affordability: Is it financially and economically viable? (Taking into account cost of the property and additional costs (transport, storage, connection costs, etc.)?

• Spatial and Social Quality: How is it ensured that the units are an asset to the environment, both spatially and socially?

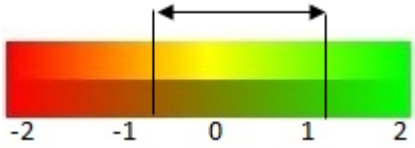
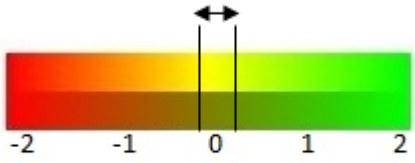
By taking into account the criteria above, you can meet the wishes of the COA. In addition to that, you want to determine if the design is feasible in case you win the contract and be involved in the realization. Winning this competition would mean a lot to you and your team.
The points scored for both options are shown below in a so-called trade-off matrix, both options have a confidence interval of 95%:

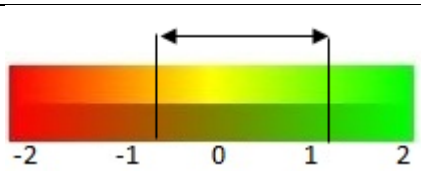
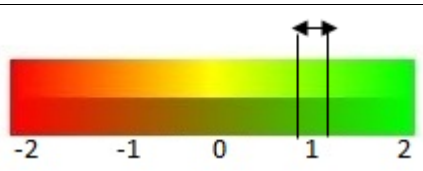
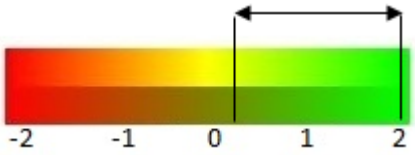
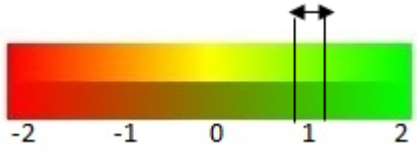
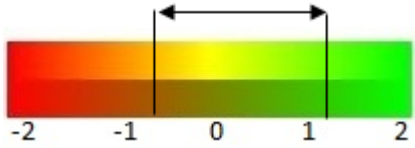
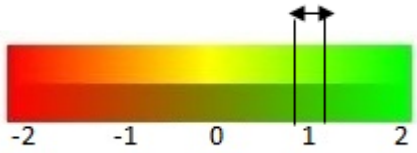
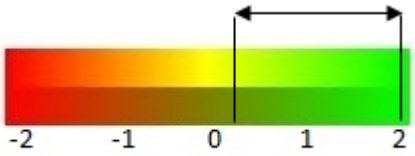
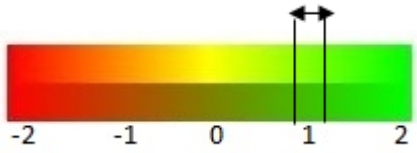
Note: The score system is a confidence interval system based on a legend provided below ranging from -2 to 2.

For example:



The bar above indicates a 95% confidence interval of a 0.1-1.1 interval. This means that there's a 95% chance of the actual value falling in the 0.1-1.1 range and a 5% chance of the value falling below or above that range. This means that, referring to the legend, the attribute will most likely fall in between "Complies to standard/neutral/small" and "Meets standard/favorable/none"

Trade-off Matrix		
Considerations	Options	
	Option 1 "Conversion" Confidence Interval	Option 2 "New Buildings" Confidence interval
Flexibility		

Delivery Speed		
Sustainability		
Affordability		
Spatial and Social Quality		

Q1) If you consider the scores above, and taking the client's wishes into account, which option do you prefer?

Option 1	
Option 2	

Q2) What level of risk would you associate with **Option 1**?

Very Risky Somewhat Risky Neutral/So-So Somewhat Safe Very Safe

Q3) What level of risk would you associate with **Option 2** ?

Very Risky Somewhat Risky Neutral/So-So Somewhat Safe Very Safe

Q4) To which extent did the risk involved influence your decision?

Didn't Influence At All Didn't influence Much Neutral/So-So Somewhat Influenced Strongly Influenced

Q5) Would you consider yourself a risk taking or a risk avoiding person?

Risk Taking __ Risk Avoiding___

B3. Full experiment SPSS outcomes

The SPSS table outputs pertaining to all the questions can be found in this section.

TABLE B3.1 SPSS output Logistic regression outcome for question 1

Classification Table[a]

			Predicted		
			Q1Decision		Percentage Correct
	Observed		1.00	2.00	
Step 1	Q1Decision	1.00	83	53	61.0
		2.00	41	57	58.2
	Overall Percentage				59.8

a. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	Form	.778	.270	8.309	1	.004	2.177
	Constant	-1.483	.427	12.078	1	.001	.227

a. Variable(s) entered on step 1: Form.

TABLE B3.2. SPSS output for binary logistic regression containing both variables

Classification Table[a]

Observed			Predicted		
			Q1Decision		Percentage Correct
			1.00	2.00	
Step 1	Q1Decision	1.00	109	27	80.1
		2.00	60	38	38.8
	Overall Percentage				62.8

a. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	Form	.689	.275	6.284	1	.012	1.991
	DifferenceScore	.366	.163	5.030	1	.025	1.443
	Constant	-1.959	.487	16.175	1	.000	.141

a. Variable(s) entered on step 1: Form, DifferenceScore.

TABLE B3.3 SPSS output for the binary logistic regression including form and Risk sensitivity

Classification Table[a]

Observed			Predicted		
			Q1Decision		Percentage Correct
			1.00	2.00	
Step 1	Q1Decision	1.00	99	37	72.8
		2.00	26	72	73.5
	Overall Percentage				73.1

a. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	Form	.773	.309	6.265	1	.012	2.165
	Q4Likert	1.106	.177	39.204	1	.000	3.023
	Constant	-5.715	.903	40.045	1	.000	.003

a. Variable(s) entered on step 1: Form, Q4Likert.

TABLE B3.4 SPSS output for the binary logistic regression including form, risk sensitivity (referred to as Q4 Likert in the table) and Risk stance (referred to as Q5 in the table)

Classification Table[a]

Observed			Predicted		
			Q1Decision		Percentage Correct
			1.00	2.00	
Step 1	Q1Decision	1.00	109	27	80.1
		2.00	30	68	69.4
	Overall Percentage				75.6

a. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	Form	.761	.310	6.015	1	.014	2.140
	Q4Likert	1.048	.181	33.560	1	.000	2.853
	Q5Risk	.488	.350	1.946	1	.163	1.630
	Constant	-6.302	1.016	38.445	1	.000	.002

a. Variable(s) entered on step 1: Form, Q4Likert, Q5Risk.

Table B3.5 SPSS output for Moderator Risk Sensitivity (Without interaction effect)

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.491[a]	.241	.234	.43259

a. Predictors: (Constant), Q4Likert, Form

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	13.729	2	6.864	36.681	.000[b]
	Residual	43.229	231	.187		
	Total	56.957	233			

a. Dependent Variable: Q1Decision

b. Predictors: (Constant), Q4Likert, Form

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.533	.117		4.554	.000
	Form	.132	.057	.134	2.315	.021
	Q4Likert	.190	.024	.456	7.900	.000

a. Dependent Variable: Q1Decision

Table B3.6 SPSS output for Moderator Risk Sensitivity (With interaction effect)

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.491[a]	.241	.231	.43353

a. Predictors: (Constant), Mod_Ind_Q4, Form, Q4Likert

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	13.729	3	4.576	24.348	.000[b]
	Residual	43.228	230	.188		
	Total	56.957	233			

a. Dependent Variable: Q1Decision

b. Predictors: (Constant), Mod_Ind_Q4, Form, Q4Likert

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	.533	.119		4.477	.000
	Form	.132	.057	.134	2.307	.022
	Q4Likert	.190	.025	.457	7.697	.000
	Mod_Ind_Q4	.001	.030	.001	.025	.980

a. Dependent Variable: Q1Decision

Table B3.7 SPSS output for Moderator Risk Stance (Without interaction effect)

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.299[a]	.090	.082	.47378

a. Predictors: (Constant), Q5Risk, Form

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	5.106	2	2.553	11.374	.000[b]
	Residual	51.851	231	.224		
	Total	56.957	233			

a. Dependent Variable: Q1Decision

b. Predictors: (Constant), Q5Risk, Form

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.770	.140		5.518	.000
	Form	.168	.062	.170	2.705	.007
	Q5Risk	.242	.066	.232	3.690	.000

a. Dependent Variable: Q1Decision

Table B3.8 SPSS output for Moderator Risk Stance (With interaction effect)

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.313[a]	.098	.086	.47255

a. Predictors: (Constant), Mod_Ind_Q5, Form, Q5Risk

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	5.597	3	1.866	8.354	.000[b]
	Residual	51.361	230	.223		
	Total	56.957	233			

a. Dependent Variable: Q1Decision

b. Predictors: (Constant), Mod_Ind_Q5, Form, Q5Risk

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	.759	.139		5.446	.000
	Form	.167	.062	.169	2.690	.008
	Q5Risk	.247	.065	.238	3.778	.000
	Mod_Ind_Q5	.046	.031	.093	1.482	.140

a. Dependent Variable: Q1Decision

Table B3.9 SPSS output for Mediator correlation between Independent variable and mediator

Correlations

		Form	DifferenceScore
Form	Pearson Correlation	1	.167*
	Sig. (2-tailed)		.010
	N	234	234
DifferenceScore	Pearson Correlation	.167*	1
	Sig. (2-tailed)	.010	
	N	234	234

*. Correlation is significant at the 0.05 level (2-tailed).