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Decision making in Engineering Projects.

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Abstract

Even though risk management is a vital aspect of project management, the way that risk-based decisions are taken in projects is not well documented. Economic theory employs the concept of utility and assumes that decision makers are rational. Behavioural economics and prospect theory challenge this idea, making a number of specific claims about how decision-making behaviour deviates from rationality in practice. Based on a focus group discussion with project managers, this research highlights the importance of risk management in underpinning decision making and investigates the extent of rationality and applicability of prospect theory in an engineering project context. Prospect theory's claims of reference dependence and loss aversion are found to be important, but the claims of diminishing sensitivity and probability weighting appear to be less relevant.

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1. Introduction

Projects are vital for the growth of any organisation, industry, or country. They play a significant role in being the vehicle for change, providing employment, and delivering value. When taking on new projects, it is essential to be

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able to employ techniques that will lead to a positive outcome on the selected project deliverables. Despite the vast experience, skill and project knowledge currently available, a significant number of projects still fail. According to the Gartner Group, as at 2012, 61% of technological projects were classified as 'unsuccessful.' A study by McKinsey & Company in conjunction with the University of Oxford in 2011 also reveals that 17% of projects go so badly wrong that they can threaten the existence of a company, and on average 45% of projects run over budget and 7% are delivered late, while providing 56% less value than predicted [1]. As new projects have higher complexity and risk, Pinto and Selvin [2] argue that factors such as cost, time and technical performance are not the only key areas to focus on to improve success. Research is needed to help provide an understanding as to how decision makers make choices in projects; understanding this may give some insight into why so many projects go wrong.

In the context of engineering projects, this research investigates the question of whether project participants approach risk management rationally. The concept of expected utility and rationality have been a major foundation for standard economic decision making. But research has now established that expected utility does not always explain the decisions taken in many contexts [3, 4, 5, 6, 7, 8, 9]. Looking at projects such as the British Petroleum (BP) Macondo well disaster [10], St Helena airport construction project [11], and NASA's Space Shuttle Challenger [12] there is a general behaviour that suggests that the importance of risk management is not treated seriously and approached in a rational manner in projects.

According to expected utility theory, the decision maker chooses between risky or uncertain prospects by comparing their expected utility values [13]. In this sense, expected utility theory should be at the heart of risk-based decision making [14]. Looking at the cases above, however, we know that expected utility does not always apply in practical contexts [3, 4, 5, 6, 7, 8, 9]. Even though the textbook approach to risk management tends to assume rationality, behaviour in the real world seems to be different [12, 15, 10, 11, 16]. This research paper aims to understand the extent of this rationality. Prospect theory has been presented as providing a better explanation of individuals' decision-making behaviour than expected utility theory. Prospect theory describes how individuals make choices between probabilistic alternatives where risk is involved, and the probability of different outcomes is either known or unknown [17]. It is not yet known whether prospect theory generally works better than expected utility theory in engineering projects, where decisions may not reflect just a single individual's preferences, but also the preferences of other stakeholders.

2. Background Literature

Making decisions is an essential part of the management of projects. There is currently an abundance of literature that provides guidance on rational decision-making process [18]. Even with the various tools, methods and research in behavioural decision making the actual decision behaviour deviates from the rational choice.

Behavioural decision-making aims to understand or elaborate the actual influences on decision-makers on making choices [19]. Decision making in projects have been recently researched and is gaining more momentum. Examples of recent works include research on over-optimism in project forecast [20, 21], escalation of commitment [22, 23], or ineffective risk management [24, 25].

Powell et al. [26] presented three schools of thought on organising the research on behavioural strategy. They drew from several works of literature and based on their onto-epistemological foundations they identified three separate schools. These schools are fundamentally different in philosophy and adopt different methodologies. The three methodologies are namely Reductionist, Pluralist and Contextualist. Researchers Powell et al. [26] present the notion that the identification and acknowledgement of the paradigmatic differences of these three schools of thought where a necessary starting point to adopt a policy of methodological pluralism and multimethod research.

EUT was developed by Neumann & Morgenstern [27] in an attempt to explain rational behaviour when people are confronted with decision making. The theory states that a person faced with a decision scenario with unknown outcomes will evaluate the options based on the probability of the outcome and the expected utility of the outcome.

EUT is based on the four elementary axioms of rationality. Which are (i) complete, (ii) transitivity, (iii) continuous, and (iv) independence. EUT is based on the decision maker considering the different choices they face in terms of final wealth and choosing the outcome that gives the highest expected value. This is simply calculated as the multiplication of the utility of an outcome with the probability that the outcome will occur.

Decision making in risky situations can be viewed as a choice between prospects and gambles [28]. A prospect can yield an outcome x_1 with probability p_1 ($x_1, p_1; \dots; x_n, p_n$). According to EUT, the most preferred outcome does not only depend on the highest expected wealth but also on the decision makers risk preference. Decision makers have different preferences, and these preferences are grouped into three, namely, risk aversion, risk seeking and risk neutral.

EUT has been applied to decision making in projects with the aim of explaining how decision makers should make/opt for choices however various studies suggest that EUT cannot explain all decisions in the project management context [29, 30, 31, 32, 33, 34].

Due to the violations of EUT [3, 4, 5, 6, 7, 8, 9], alternative theories have been developed and aimed at better explaining how humans behave. The dominate theory developed is prospect theory developed by Kahneman and Tversky [35]. The theory is based on experimental findings of actual behaviour. There are two main differences between EUT and PT which are (i) PT uses weights instead of probabilities to measure risk, and (ii) in PT the decision maker estimates gains and losses from a reference point instead of the final outcome. In order to describe the behaviour of people faced with a decision choice and capture the different systematic behavioural biases [36, 35, 37].

3. Research Methodology

The research was implemented using a focus group. It was designed in particular to get the participants to give the reasons/justifications as to why they may sometimes not opt for the rational choice in the face of uncertainty in projects. The main question areas are summarised in Table 1.

The focus group discussion consisted of 12 participants. This focus group's responses enabled the researcher to gain a causal understanding of why project participants behave the way they do. The participants work and deliver various engineering projects. They are mostly current project managers (58%) with 58% having masters or doctorate level education. 75% of the respondents have more than five years of project experience and all have some project management experience (66% have managed more than five projects).

Table 1: Focus group question areas

No	Focus Group Questions areas
Q1	Importance of risk management in project management.
Q2	Do you make decisions with only the data at your disposal?
Q3	What drives your decision making in projects in the context of risk management?
Q4	Does your approach to risk management depend on the type of project you are undertaking?
Q5	What factors do you consider?
Q6	Explore whether it would make a difference if they were managing their own project or someone else's (principal-agent problem).
Q7	How do the four elements of prospect theory work in a project management context?
	Q5.1 Reference dependence
	Q5.2 Loss aversion
	Q5.3 Diminishing sensitivity
	Q5.4 Probability weighting
Q8	How does willingness to take a risk vary depending on the current projected cost at completion of the project?

4. Results and Discussion

4.1. Importance of risk management in project management

The focus group concluded that, for engineering projects, project risk management should be considered as a critical success factor and as a top 5 critical success factor [38]; it should be considered as one of those key areas of activity in which favourable results are absolutely necessary for a manager to reach his/her goals [39]. The implementation of CSFs in project key areas ensures success is made explicit [40]. This outcome supports the existing literature that highlights the importance of risk management [41, 42, 43]. Looking at project risk management, the focus group believes that the soft side of project risk management (constituting "communication & culture" and "monitoring and review") is deemed of greater importance than the hard side. It seems that the soft side

of risk management supports the hard side and as such to fully implement the hard side of risk management one must rely on the soft side of risk management. This is in line with the works of Carvalho & Rabechini [44] who investigate the impact of risk management on project performance.

4.1.1. Extent of rationality

Participants believed that project participants behave irrationally and the further away you are from remaining within the initial project budget, the more risk averse project participants become. The focus group felt that this was irrational but normal when delivering projects.

4.1.2. Causes of irrationality

After various discussions with the group, participants were able to highlight in descending order (most important first) the key justifications for deviating from the rational choice in general. As such the key reasons are: 1) relying on intuition drawn from experience, 2) fear of worsening project state, 3) interference from direct stakeholders, 4) government interference, 5) having the wrong information, 6) assuming that everything is under the control of the project manager, 7) instability of project materials (market instability), 8) change of project scope/deliverable, and 9) lack of understanding and knowledge.

Research looking at why people deviate from the rational choice when it comes to decision making is gaining momentum in the project management context [20, 21, 22, 23, 25]. This research gives an insight of the possible reasons behind such deviation and explores the correlation between past research in decision making and the results found in this research.

In the literature, deviations from the right decision are labelled as biases and errors, and their causes are investigated. Simon [45]) suggest that roots are found in the decision makers bounded rationality. Shore [46] and McCray et al. [47] provide a theoretical analysis of the relevance of cognitive bias in project decisions. Shore [46] looks at 8 case studies of failed projects and links them with nine systematic biases obtained from generic literature while the work of McCray et al. [47] is conceptual.

There are two main project phenomena studied in the project management context with regards to individual biases. These are firstly overoptimistic plans and forecasts [20, 48, 49], and secondly escalation of commitment [50, 51, 52, 53, 54, 55, 56]. Other areas of individual bias are inefficient resource allocation [57], gold plating [58], lack of learning [59], or failure to communicate early warning signs [60] .

4.1.3. Risk management process

The next step in the discussions involved discussing with the group to determine if the risk management process they normally go through when working on their projects is approached rationally. The consensus was that the participants agreed that this is not always the case, as even though they do implement the risk management process from the onset of the projects. They rarely update the risk register and tend to handle risk as they arise. Their implementation of risk management is a firefighting-style approach as even though they agree that risk management was an important aspect in projects its implementation is mostly as an afterthought or for documentation purposes. However, the bigger the project, the more time is dedicated to risk management. This means that the type of risk management approach implemented in a project is dependent on factors such as size, complexity, focus and level of risk.

This led to a further discussion as to whether the project participants would make the same decision or implement risk management in a similar way if they were managing their own personal project. This question explores the notion of the principal-agent problem [61] The group agreed that if it was their personal investment in a project, they would be more risk-averse. They would therefore be less likely to take a particular risk as the financial implication or burden would be carried by them, and with personal projects they are few instances when one adopts or uses insurance. This suggests that there is a real financial implication of success/failure even though this was already stated in the decision survey context “This is an important project for your company, and your ability to deliver

within budget (and under budget if possible) is likely to affect your future career prospects". This suggests that to the focus group participants this was seen as more indirect than losing your own money. This verifies the existence of the principal-agent effect as they are more willing to take risk with the company's money than they would be with their own.

4.1.4. Predictions of prospect theory

The second phase of the discussion was to focus on how the predictions of prospect theory apply in the project management context. As such, each of the four elements of prospect theory were discussed. The four elements are 1) reference dependence, 2) loss aversion, 3) diminishing sensitivity, and 4) probability weighting.

4.1.4.1. Reference dependence

In the aspect of reference dependence, the consensus was that reference dependence does play a vital role in projects as project managers are always concerned about the current state/financial position of a project. As such, project managers are very aware and look at a project in terms of what the current position is, how the project can be completed with what is disposable, what measures can be taken, etc. Researchers Hardie et al. [62] suggest that consumer choice is influenced by the position of brands relative to multi-attribute reference points, and that consumers weigh losses from a reference point more than equivalent sized gains (loss aversion). The role of reference dependence was investigated to see how it affects communication strategy and how reference dependence gives rise to credible information transmission [63]. Bhatia and Golman [64] present a model of reference dependence for riskless choice, they assume that reference points affect choice by directing the decision makers attention towards the attributes associated with the reference object. The model generates a type of loss aversion and can explain behavioural anomalies related to reference dependence. Wakker [65] provides a formalisation of reference dependence as a concept that is central to prospect theory and shows that utility of income is part of prospect theory and not expected utility. Köszegi & Rabin [66] study preferences over monetary risk and they present specific ways by which environmental influences attitudes towards modest scale risk.

From the discussion, the focus group believed that, when faced with a risky decision in an ongoing project, decision makers are influenced by two distinct reference points, the 'break-even' point, which is the baseline budget against which performance will ultimately be judged, and the latest projection of the project's cost at completion. However, the further away (the better) the position of the project (under budget), the more willing they would be to take on a risk which would better the position of the project. This indicates that decision makers have the 'maximise profits' objective in mind [67, 68]. The further away they get from the break-even point (over budget), the more they become disillusioned that the break-even objective is not possible and as such the internal weight they give to the break-even point reduces. This makes them weigh the projected cost at completion reference point more than that of the break-even point.

The participants believed that the cost at completion and break-even point (baseline cost) were considered throughout the stages of the project lifecycle, as in every stage/task there is an estimated approved cost for that task; as such, decision makers are always aware of the current project state and projected cost at completion. Once they see the project moving towards overbudget threshold, they are keener to implement more cost cutting measures and would be willing to take on more risky decisions that have the possibility to bring the project back on track. However, as the projected cost at completion worsens, you get to a point that the willingness to proceed with a risk reduces, since the project is already seriously over budget. Decision makers are then less likely to make a decision that worsens the state of the project, as this would have a negative effect on the company and their individual prospects in the future. This finding is evidence that the predictions of prospect theory are not fully supported because prospect theory suggests risk-seeking behaviour should be seen as decision makers' position in a project worsens. This reduction in the willingness to take a risk as the project performance reduces can be explained by recognising that (1) decision makers have multiple reference points, (2) decision makers worry about audit, scrutiny and justification of decisions; this increases as the project goes into a weaker position (over budget). The decision makers have to have a level of confidence in the state of the project before a risky decision is taken. This can be seen

as a form of status quo bias as when decision makers face a mixed prospect (either a win or a loss is possible) they would have an emotional bias where their preference would be for maintaining the current state [69]. Conservativeness leads to this status quo effect for risky decision making in projects that seem to outweigh the desire to deliver on budget.

From the discussions, the focus group believed that the break-even point was important and they did consider it as an objective for project delivery. That said, they also believed that decision makers looked at initial estimates at all times, and when they were over budget and risk-based decisions had to be taken, they would lean towards taking the risk because of the possibility of returning the project to break even. When the project was going well and a risk presented itself with a high probability, they would also be very willing to take the risk because of the state of the project and the possibility to better position the project.

4.1.4.2. Loss aversion

Looking at loss aversion, the participants believed that it played a role in the delivery of projects in the project management context, as project managers always wanted to reap the rewards of successful project delivery. This competing nature makes project managers believe that losses are bigger than gains as it seems to them that the only outcome acceptable is the successful delivery of the project. As such, project managers would tend to avoid making risky decisions that can lead to losses even when the potential of acquiring an equivalent amount of gain is high; the project manager would generally tend to prefer making risky decisions when the conditions are favourable, i.e. when the project is underbudget. Hartono et al. [70] investigate project risk and stakeholder perspectives. Their finding is that risk is widely viewed by practitioners from a negative perspective. This view is not consistent with the theory based on utility maximisation, which would suggest a more neutral perspective. This position is consistent with the finding of Novemsky & Kahneman [71], who consider both emotional attachment to the good and cognitive focus during evaluation as potential mediators of the effects of intentions on loss aversion. Camerer [72] looks at the psychological, theoretical and empirical implications of loss aversion where the researcher uses loss aversion to explain the St Petersburg paradox. The St. Petersburg paradox presents a situation where a naïve decision criterion which takes only the expected value into account predicts a course of action that no sensible person would be willing to take [73].

4.1.4.3. Diminishing sensitivity

The third aspect of prospect theory is diminishing sensitivity. Diminishing sensitivity suggests that the further you get from the reference point (perhaps the break-even point), the less you care about the possibility of further gain/loss – i.e. the utility vs cost position curve has a reducing gradient as you go away from the break-even point (positive or negative). The flattening gradient corresponds to risk aversion to gains and risk seeking for losses.

As suggested in the context of reference dependence, focus group participants believed that this aspect of prospect theory was not really applicable in project management, as project managers tend to be more willing to take risks (risk seeking) if the project is going well (under budget), as even if the risky decision does not work out, the odds are that the project would be delivered on budget or slightly over budget. In positions of loss, however, decision seem to become more risk-averse, contradicting the predictions of prospect theory. This finding complements the work in other industries/sector such as that of Wakker et al. [74] who studied the changes in intrinsic value while keeping numbers constant and changes in numbers while keeping intrinsic value constant during the introduction of the euro in Belgium.

4.1.4.4. Probability weighting

The fourth aspect is the probability weighting function. Decision makers weight the probabilities of the outcomes instead of using statistical probabilities and underweight average events, but overweight events with low probabilities [69]. Here, the participants believed that in projects this was sometimes applicable as project managers do not always stick to statistical probabilities and sometimes tend to underweight risks that they believe are not

applicable and tend to overweight risks with low probabilities. The participants believed that probabilities were not applied in an objective way. It was also felt that the estimates of probabilities could themselves be poor, and that people could make both errors at the same time. This would compound the deviation from rationality in the decision-making process. This occurs psychologically, as even when decision makers are given the probability, they still would tend to overweight things that are particularly salient to them or, as they do not understand the probabilities, they may apply experience-based heuristics which would in turn cause them to overweight or underweight given properties. This suggests that if people were rational with no diminishing marginal utility, the mapping from objective probability and decision weights would be a straight 45-degree line.

Looking at the explanation from the focus group and the characteristics of probability weighting it would explain why people overweight when they are above the 45-degree line and underweight the probabilities when they are below the 45-degree line. This creates a certainty effect when the probability of 1 is over-weighted. To overweight risk with low probabilities gives the perception that they are able to deliver the project or manage the project in the right direction. This shows how the respondents' underweight outcomes with high probabilities relative to actual certainty. However, if the decision makers were to make a rational choice, they must conform to the expectation principle which states that values are weighted by their probability and nothing else [69]. The certainty effect highlights how decision makers reduce the probabilities from certainty to probable. A reduction in the probability of winning creates a psychological effect which leads to the perception of loss from the original probability as such this would incline the decision makers to be risk averse. Conversely, a similar reduction results in a larger psychological effect when it is done from certainty than from uncertainty. The possibility effect, on the other hand, looks at low probability environments, where people tend to value or weight events that are remotely possible to a greater degree than they should [69].

4.1.5. What drives decision making?

In the aspect of decision making the respondents believe that, before making a decision, they consider things like the organizational values (how each outcome affects the organization), and the project owner (whom the project belongs to). However, in the aspect of cost, the aim is to minimise the risk of exceeding the original approved budget. As such, they are more prone to make risky decisions that, if successful, would bring the project closer to its original budget, and are not keen to take a risky decision that would put the project in a worse state, especially if the calculated probabilities are not favourable towards success. The respondents suggest that in the decision-making process they solely base their decision on the drive to deliver the project. The reward/impact of the project is known to them as they believe both are intertwined, but the level of impact is not actually realised until after the project has been delivered.

When it comes to risk-based decision making, the focus group suggests that in an ongoing project they believe that the project would be exposed to more risks as the project goes on and mitigating would be costlier. As such, they believe that they won't be able to make further savings later in the project as the project goes. However, a key area the respondents believe they can save cost in is at the point of purchase/supply of materials for the project. This belief is questionable, however, as risk can occur at any stage of a project and the impact may also vary at any stage [75, 76, 77, 78, 79]. The respondents believe that in decision making the current performance of the project does affect decision making. They believe that more inexperienced project managers are more prone to fall victims and more experienced managers are less likely to be affected when it comes to decision making, as they believe that more experienced decision makers are more rational and intuitive. This belief is similar to the findings of other researchers who suggest that the two groups implement very different processes when making the same strategic decision [80, 81, 82, 83].

Finally, at the end of the discussion with the group, they believed that overall, the results of the discussions are plausible and applicable to engineering projects. The respondents believed that prospect theory appears to be partly applicable to engineering project as discussed, and that comparisons can be carried out across sectors to see if sector-specific solutions need to be developed or the results of this study are applicable to other sectors.

5. Conclusion

The successful delivery of projects is important because of various benefits that can be utilised from delivery. The need to improve current project management techniques can lead to better utilisation of the workforce and provide strategic advantages to project professionals and organisations. The results of the focus group show that project risk management should be considered a critical success factor. This outcome supports the existing literature that highlight the importance of risk management [41, 42, 43]. The research also suggests that prospect theory's key assumptions of loss aversion and reference dependence are useful in understanding decision making of project managers, although prospect theory's predictions of diminishing sensitivity and probability weighting were not supported in this study.

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