Different disciplinary perspectives on uncertainty

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The purpose of this paper is to discuss in more detail a number of other disciplinary perspectives on the notion of uncertainty. These perspectives range from philosophy, economics and psychology to the physical sciences, engineering and mathematics. My aim is to enrich your understanding of the multi-faceted nature of uncertainty and provide an inter-disciplinary framework within which to wrestle more deeply with what managing uncertainty means in practice for project managers

Perspective One: Probability theory

Up until the last 30-40 years the dominant lens through which uncertainty was viewed was that of probability theory (Smithson, 1989). Indeed, one of the central aims of statistics is to quantify numerical uncertainty, whether through probability theory, distributions or inferences (Attewell, 2009). Historically, uncertainty was treated *"as a form of incompleteness in information or knowledge"* (Smithson, 1989,p.1), which could only be addressed through the development of the field of probability. Probability theory is concerned with assigning numbers to the likelihood of a particular event occurring. For example, an event that is certain to occur has a probability of one and an event which will never occur is assigned a probability of zero (Loosemore, Raftery, Reilly, & Higgon, 2006). There are a number of competing schools of probability: the relative frequency school, the logical school, subjective or Bayesian theory and classical theory (Smithson, 1989). The basic mathematics of probability arose from the classical school in the 1600's, but has been overtaken in popularity today by the relative frequency school; a normative paradigm that defines probability as the relative frequency of a single event in a finite series of trials (Smithson, 1989). In its simplest sense, relative frequentist theory articulates objective probabilities based on pure likelihood of occurrence. Bayesian probability theory is more subjective in nature, defining probability in the language of degrees of belief and quantifying these degrees of belief to allow them to be treated mathematically. The final school, logical probability, is concerned with the logical relationship between a proposition and a given body of evidence (Smithson, 1989; Winch, 2010).

The application of probability theory to the management of uncertainty is most appropriate when the uncertainties can be quantified (Smithson, 1989). Consequently, probability theory has found many uses in the management of risks in projects, where the likelihood of occurrence can in some way by quantified, either objectively or subjectively. For example, the probability of a particular event occurring can be quantified and combined mathematically with the impact of that event to make a judgment on the risk to the project of that particular event occurring. As uncertainty is vague, ambiguous and often manifests itself through lack of knowledge or information it can, however, be a non-trivial matter to meaningfully use probability theory in the management of project uncertainty. The use of techniques such as fuzzy set theory (Zadeh, 1965) has, in part, addressed these limitations in applying probability theory to subjective probabilities. More recent and project management specific approaches by Chapman and Ward (see for instance: Chapman & Ward, 2000, 2002, 2011) have also made useful steps in this direction.

Perspective Two: Economics

The treatment of "uncertainty" has permeated the discipline of economics from Knight (1921) and Keynes (1937) through Von Neumann and Morgenstern's exposition of expected utility theory in 1944 (von Neumann & Morgenstern, 1980), and Kahneman & Tversky's (1979) identification of prospect theory which in turn led to the emergence of the behavioural school of economics.

Knight (1921) is most famous for differentiating risk and uncertainty into events with measurable probability (risks) and events for which assigning a numerical probability is impossible (uncertainties). The simplicity of this divide remains seductive to scholars in the field of project management (c.f. Hillson, 2002; Perminova, Gustafsson, & Wikström, 2008; Sanderson, 2012). In his seminal text "Risk, Uncertainty and Profit", Knight (1921) makes two further contributions to the understanding of uncertainty in the context of projects. First, that risk is commonly viewed as negative or undesirable, and that uncertainty is more positive, being concerned with the seizing of opportunities, from which one may profit. This distinction stands in contrast to much of the project management literature on risks and uncertainties with both APM and PMI bodies of knowledge (Association for Project Management, 2006; PMI, 2008) and scholars on uncertainty (Chapman & Ward, 2002; Cleden, 2009; Perminova et al., 2008) broadening the definitions of both risk and uncertainty to incorporate both threats and opportunities. Knight's final contribution to the debate on uncertainty and risk concerns the perception of uncertainty by individuals. He contends that uncertainty is a subjective phenomenon, experienced in different ways by different people. This has profound implications for the management of uncertainty in projects, for if uncertainty is to some extent based on perception, then different project managers will perceive and respond to it differently, as will their project teams and sponsors and other key stakeholders.

One of the giants of economics, (Keynes, 1937), similarly defined uncertainty as a state in which reasonably definite probabilities cannot be attached to different outcomes. For example, the outcome of a spinning roulette wheel is not an uncertainty in the sense that it may be estimated using probability theory. In contrast, a classic example of uncertainty that Keynes quotes is that

"*in which the prospect of a European war is uncertain, or the price of copper and the rate of interest twenty years hence…About these matters there is no scientific basis on which to form any calculable probability whatsoever"* (Keynes, 1937, p.214).

A number of implications for project management follow from these descriptions of uncertainty. First, that uncertainty is a fact of economic and, therefore, of project life (see also Atkinson, Crawford, & Ward, 2006). Secondly, that risk, as it is more easily quantified is perceived as being less threatening to economists as well as to project managers (see also Perminova et al., 2008). Project managers should resist the temptation to focus on risks, ignoring uncertainties due to their intangibility and ill-defined nature (Saunders, Sherry, & Gale, 2016). And thirdly, that the presence of uncertainty is no excuse for inaction. To quote Keynes again:

"Nevertheless, the necessity for action and for decision compels us as practical men to do our best to overlook this awkward fact and to behave exactly as we should if we had behind us a good Benthamite calculation of a series of prospective advantages and disadvantages, each multiplied by its appropriate probability, waiting to be summed" (Keynes, 1937, p.214).

In other words, project managers must constantly make assumptions, rely on experience and intuition and the advice of other colleagues and move forward on projects, making decisions and taking actions in spite of the inevitable presence of uncertainty.

Von Neumann and Morgenstern's 1944 seminal work on expected utility theory (von Neumann & Morgenstern, 1980) is foundational to the treatment of uncertainty in economics. They argued that different outcomes can be evaluated according to their expected utility, where utility (or in non-economic terms, usefulness) is the probability of receiving a particular outcome multiplied by the value of that particular outcome. One significant challenge to utility theory is that of articulating specific and well-defined preferences and probabilities in real life situations of uncertainty. This limitation was addressed by Kahneman and Tversky's (1979) Prospect Theory which has emerged as an alternative to expected utility theory. Prospect theory states that outcomes that are possible or probable are given less weight in comparison to outcomes to which certainty can be attached. In the context of managing projects, prospect theory dictates that actions taken by project managers that have certain outcomes will be valued more highly than those in which a residual uncertainty remains. Prospect Theory led to both a Nobel Prize and the nascent field of behavioural finance – whose key tenets of faith include the fallacy of rational decision making, the absence of full and perfect information, and the inadequacy of markets in assessing risk and assigning probabilities (Quiggin, 2009).

Contemporary economists are divided into those who hold that uncertainty is irreducible, and those who think it can be tamed if information is carefully chosen and individual preferences identified (Quiggin, 2009). As an example of the former, Tomas Sedlacek (Sedlacek, 2011) traces the development of economic thinking from 2000BC to the present day. He warns against the modern day obsession with complex mathematical models to explain economics, and argues that economists must reconnect with the historical, philosophical and psychological aspects of their discipline that are so key to how we as humans produce, distribute and consume goods and services (Sedlacek, 2011). Mathematics should be viewed as less of an "engine of enquiry" and more **one** language of description amongst others. Neither is the complex world in which we live a purely deterministic one, in which future states or outcomes can be predicted mathematically from previous and current states. Uncertainty in projects may seem similarly unpredictable, and can be at the mercy of the perceptions and the often less than rational behaviours of project actors. The lesson for managing uncertainty here is a clear one: As a project management community we need to acknowledge the limitations in striving for perfect mathematical modelling of risk and uncertainty, and move more towards a holistic, enquiring, learning, more messy but uniquely human approach to the management of uncertainty.

Perspective Three: Philosophy

Definitions of uncertainty within the discipline of philosophy are sparse, perhaps because uncertainty or the unknown is a meta-narrative in philosophy. Bubbling beneath the surface of many matters of philosophy is the notion of uncertainty: who are we? why are we here? what is reality? and how do we make sense of it? Underpinning each of these questions is a disquieting sense that as human beings we are not omniscient; rather there remain sizeable lacunas in our present understanding of the world in which we live. As a consequence, there are many matters about which we remain uncertain. One of the few philosophers to have explicitly wrestled with the notion of uncertainty is Wittgenstein, who argued that to be uncertain about a particular situation requires that we have certainty about something

"If you tried to doubt everything you would not get as far as doubting anything. The game of doubting itself presupposes certainty."(Wittgenstein, 1969, p.18).

This quotation may appeal to the project management practitioner who knows that even in the messiest, most ill-defined stages of a project's gestation there will be moments and markers that are certain. Indeed a much loved quotation attributed to Voltaire states that "*Doubt is not a pleasant condition, but certainty is absurd.*"– an early and prescient exhortation to project managers to test assumptions and question everything.

Smithson (1989) argues that Western intellectual thought has been dominated by the pursuit of knowledge and that ignorance, and uncertainty has been neglected

"ignorance is usually treated as either the absence or the distortion of true knowledge, and uncertainty as some form of incompleteness in information or knowledge" (Smithson, 1989, p.1).

This argument could apply equally to the domain of project management, by replacing Western intellectual thought with project management. Thus project management has been dominated by the pursuit of knowledge and that ignorance, and uncertainty has been neglected as a field of study.

Perspective Four: Psychology

Another rich seam of ideas on uncertainty can be obtained from the field of psychology, where there are broadly speaking three traditions of uncertainty response by individuals. First, there is the 'knowledge seeker' tradition, which advocates that individuals are comfortable in exploring new horizons, and exploiting new opportunities even if their outcome may be somewhat uncertain. Such individuals have a high tolerance of uncertainty. Secondly, there is the 'certainty maximiser' tradition, which focuses on the negative implications of uncertainty on our cognition and physiology, and thirdly, the 'intuitive statistician economist' tradition, which reflects the information processing view of uncertainty and encompasses how we make decisions under uncertainty (Bammer & Smithson, 2009).

Kahneman, Slovic, & Tversky's (1982) seminal work on heuristics, biases and judgement under uncertainties has emerged from this third tradition. It argues that human beings are irrational creatures, vulnerable to flawed reasoning and mental shortcuts, known as heuristics. Notable examples of these heuristics, that lead to biases are representativeness (the probability that an object A belongs to class B is assessed by the degree to which A is representative of or similar to B), availability (the probability of particular events is assessed according to how easily an instance of such an event can be re-called) and anchoring (where an estimate is made by starting from a particular initial value and this value is then adjusted to provide the final answer) (Tversky & Kahneman, 1982). March & Simon's (1958) theory of bounded rationality is another key part of the psychology canon; arguing that we are rational only to the extent that time, information and cognitive capacity permit when making decisions under uncertainty.

Kahneman and Tversky also usefully subdivide uncertainty into that attributed to the external world and that attributed to our own internal state of knowledge (Kahneman & Tversky, 1982). Some examples may help contextualise this in the field of project management. Imagine a project to order an aircraft engine test bed. Uncertainties in the external environment may be the availability of design resource for the project, or a shifting project completion date. Uncertainties in our own state of mind may arise from our lack of experience on this type of projects, or through a lack of knowledge of important project information such as unknowns in the lead time of key components. Echoing Knight (1921), we sense here that uncertainty is as much a state of mind as it is an objective view of the world. Head (1967) shares this view, arguing that uncertainty exists *"in the mind of the person who doubts"*(Head, 1967, p.206) and that this doubt is due to a lack of information or knowledge about the outcomes of a particular event. Indeed, as project uncertainty increases, the ways in which we seek to reduce and control it may become *"just as much a factor of our perceptions of the environment and our capabilities as it is of the actual characteristics of the environment and our actual capabilities*" (Osman, 2010, p.178).

Cognitively individuals can attempt to control uncertainty through how they *"perceive it, attend to it, remember aspects of it, learn about it, reason from it, make decisions about it and of course try to control it"* (Osman, 2010, p.180). There are two main schools of thought governing how individuals achieve this: instance-based theories (c.f. Gonzales, Lerch, & Lebiere, 2003) and hypothesis testing and decision making theories (c.f. Burns & Vollmeyer, 2002) There are a number of common features of these two schools of thought, namely that human beings have a propensity to try to reduce the uncertainty they are confronted with, that humans constantly try to make predictions about the future and that goal directed behaviours are employed in pursuit of these objectives. Instance-based theories state that because our environment is so complex we cannot process all the information that we are presented with, so much of the information processing happens at a subconscious level. In contrast, proponents of hypothesis and naturalistic decision making theories argue that the very fact that we are interacting with an uncertain environment requires us to think consciously about what we are doing, and monitor the impact of those changes on the environment.

How we respond to uncertainty is also guided by our individual beliefs, desires and motivations. The comic playwright, Terence, writing in the Roman republic alludes to this in his play Andria *"when the mind is in suspense it is swayed by a slight impulse either side"* (Terence, n.d.). In delivering projects, practitioners should be mindful that their actions will be shaped by their wants, needs and desires, and indeed that these wants, needs and desires may have a more powerful influence on the actions taken to control uncertainty than the characteristics of the project itself (Osman, 2010).

Perspective Five: Strategic Management

The strategy literature has much to contribute to the definition and categorisation of uncertainty in the context of organisations. At the heart of strategic choice lies the challenge of making good decisions in the absence of perfect or complete knowledge (Harrison, 1992; Porter, 1980; Sutcliffe & Zaheer, 1998). These *"strategic choices require commitments of scarce resources in the presence of incomplete or imperfect information and are therefore fraught with varying degrees of uncertainty along with attendant management of risk*" (Harrison, 1992, p.114). Strategic decisions may range from the decision to relocate manufacturing capability from the UK to Singapore, pursuing a new product range, or changing relationships with supply chain partners. Writing in the Harvard Business Review, Nitin Nohria contends that decisions today are increasingly being made under conditions of uncertainty, for four key reasons:

1. many of the simpler decisions have been made or are now passed down to subordinates
2. behavioural research by Kahnemann and Tversky (1982) has exposed the fallacy that we make rational economic decisions
3. due to the butterfly effect: the notion that the global economy is so interlinked and interdependent that fluctuations in one part of it have sizeable impacts on other parts
4. business outcomes in a service economy are arguably harder to measure than traditional measures of manufacturing efficiency. (Nohria, 2006)

Courtney, Kirkland, & Viguerie (1997) describe three types of uncertainty: Information that is available and known, information that is currently unknown but will emerge and become known if the right analysis is done, and thirdly residual uncertainty – that which remains even when the analysis is complete. Examples of residual uncertainty could include future decisions by industry regulators or future changes in the political landscape. This residual uncertainty is further subdivided into four levels of uncertainty, depending on the number, range and distribution of possible outcomes, from level 1, where the future is clear enough to point to a single course of action, to level 4, where the future environment is beset by a multiplicity of uncertainties and the future is virtually unpredictable. Milliken (1987) provides an alternative typology of uncertainty; describing three categories of uncertainty; *state uncertainty, effect uncertainty and response uncertainty*. State uncertainty is that associated with a lack of information about the environment, its components and how they might interact with each other. Effect uncertainty reflects a lack of ability to assess the impact of changes in the environment on an organisation, and response uncertainty is concerned with understanding what strategic responses an organisation has at its disposal and what the consequence of those choices are. These two typologies are complementary to each other: Courtney et al. (1997) reflect the objective nature of uncertainty, whereas Milliken's approach acknowledges that individual perception and subjectivity sit at the heart of much strategic uncertainty.

Two final contributions to strategic approaches to managing uncertainty emerge from major studies on serial entrepreneurs (Schlesinger, Kiefer, & Brown, 2012) and high-performing companies (Collins & Hansen, 2011) respectively. Schlesinger et al. (2012) draws on a study of 27 serial entrepreneurs, as experts in managing under circumstances of high uncertainty, finding that *"instead of starting with a predetermined goal these entrepreneurs allowed opportunities to emerge; instead of focussing on optimal returns they spend more time considering their acceptable loss and instead of searching for perfect solutions, they look for good enough ones."* (Schlesinger et al., 2012, p.155).

Their prescription for success in starting highly-uncertain projects is to follow an iterative Act-Learn-Build process. Here action is taken, small steps in the desired direction made, from which learning emerges, upon which the project may build. These three steps are followed iteratively until the desired goal is achieved. Of course, there are two other potential outcomes of this process; the goal may change as this process runs its course, or the project may be abandoned if it is no longer feasible.

Jim Collins' most recent research study was based on high-performing organisations: defined as organisations that achieved spectacular returns relative to the stock-market and their competitors during the period 1970-2002 (Collins & Hansen, 2011). The premise of their study is that in today's turbulent economic environment turbulence and uncertainty there may be some key features of certain corporations that can help them weather these storms more effectively than their competitors. The findings of the study are somewhat counter-intuitive, but hold lessons relevant for project managers, in that high-performing organisations "*Embrace(d) a paradox of control and non-control"* (Collins & Hansen, 2011, p.19). These organisations realise that uncertainty cannot always be controlled and predicted but that managers are in charge of their own destiny and that they can stack the cards in their favour. Three other key insights stand out. First, high-performing organisations demonstrate almost *fanatical discipline*, underpinned by relentless consistency of action. They are not derailed by events and are less likely to follow the crowd. Secondly, high performing organisations display *empirical creativity*: they carry out rigorous research, and prepare thoroughly so that they are able to make the best possible decisions. And thirdly, these organisations and in particular their leaders suffer from productive paranoia. They never relax and worry constantly about the competition. Rather than paralysing them though, this fear is channelled into action to ensure that the company remains high-performing. There are parallels in this study with High Reliability Theory's (c.f. La Porte, 1988; Mannarelli, Roberts, & Bea, 1996; Roberts & Bea, 2001; Weick, Sutcliffe, & Obstfeld, 1999) ideas of preoccupation with failure and the notion of fanatical discipline, and the study serves as a good manifesto for a high performing project manager.

Perspective Six: Physical Sciences and Quantum Physics

Buckman (2009) argues that *"uncertainty in the physical sciences is a pervasive notion. It both underpins the most successful theory of matter, quantum mechanics, and governs almost every important conclusion that physics reaches regarding the nature of things*" (Buckman, 2009, p79). This quotation embodies the two types of uncertainty that exist in the domain of the physical sciences – quantum uncertainty and measurement uncertainty. Both of these can be explored through Heisenberg's uncertainty principle, which is grounded in the weird and wonderful world of quantum mechanics. Heisenberg's uncertainty principle states that the more certain we are of a quantum particle's location at a particular time, the less certain we may be of its momentum and vice versa (Cox & Forshaw, 2011). This theory can be expressed mathematically as:

$$\Delta x \, \Delta p \sim h$$

Where Δx is the uncertainty in the particle's position, Δp the uncertainty in the particle's momentum and h is Planck's constant.

First articulated in 1927, Heisenberg's theory is foundational to our understanding of the quantum world, and since all matter comprises quantum particles, it is also foundational to our physical world. Physicists seem comfortable with the inherent uncertainty in the physical world (Buckman, 2009). Heisenberg's uncertainty principle is required to make sense of experimental observations at the quantum (sub-atomic) level, and so physicists have learned to sit comfortably with the notion of uncertainty, however counterintuitive it may seem on first examination. This is not to say that Heisenberg is arguing that everything is uncertain, rather that there are limits to uncertainty, at least in the physical world (Cassidy & American Institute of Physics, 2002). The impact of Heisenberg's uncertainty principle on the world of science and engineering should not be underestimated, undermining as it did the principles of determinism and causality in science. According to Smithson (1989) it has helped begin a renaissance in thinking about uncertainty and ignorance as opposed to certainty and knowledge in intellectual thought.

Perspective Seven: Applied Sciences: Control engineering, cybernetics and artificial intelligence

The applied sciences, specifically control engineering, cybernetics and artificial intelligence proffer a number of useful perspectives on uncertainty. *Control engineering* is concerned with the objectives of an engineering system and optimising the engineering system so that it can operate with minimum error and maximum reliability (Osman, 2010). For example: how does the system fluctuate? what impact do changes in the inputs have on the system outputs? over which time period? There are two elements to control in such an engineering system. First, monitoring that the system is operating in the required manner, and secondly, controlling the system to ensure it continues to behave as we, the designers, expect. In theory this sounds relatively simple. However at the heart of all engineering system lie uncertainties caused by feedback loops, inherent instability and emergent system properties (Osman, 2010). These emergent properties are a particular cause of uncertainty given that they are *"unexpected behaviours that stem from interaction between the components of an application and their environment"* (Johnson, 2006, p.3). The uncertainty in these engineering systems is generally dealt with by estimating possible future states of the system. This is done by making a number of assumptions that are often underpinned by probability theory. Those responsible for the system must then determine whether to treat the different forms of uncertainty in a similar manner, or whether to translate them into more manageable problems or whether to ignore the uncertainty. A systems view of projects would treat a project in an analogous manner to an engineering system, but whereas emergent properties in an engineering system might occur due to interactions between component engineering or software parts, in a project emergent properties may arise through the interaction of different stakeholders.

There are two methods of control in control engineering – formal and applied. The formal method develops a description and analysis of how a system may behave, even if that analysis is always incomplete. In contrast an applied approach implies that the system is not autonomous, but ultimately under human control in terms of scheduling changes, system adaptations and information monitoring (Osman, 2010).

The language of control engineering also speaks of resilient systems, where we might speak of resilience in projects. A resilient control system is one which is "*stable over a range of parameter variations, that its performance continues to meet the specifications in the presence of a set of changes in the system parameters*" (Osman, 2010, p.72). The essence of a resilient organisation is "*the intrinsic ability of an organisation to maintain or regain a dynamically stable state which allows it to continue operations after a major mishap and/or in the presence of the continuous stress*" (Hollnagel, Woods, & Leveson, 2006, p.16). Resilient projects would therefore be able to deal with surprises both in terms of anticipating and responding to them in a way that enables project activity to continue towards the desired outcome.

Cybernetics and artificial intelligence both extend control systems theory to enable deeper understanding of complex systems – whether engineering based or complex biological or organisational systems (Wiener, 1961). They also offer solutions as to how complex systems might be able to predict and control their future states and how complex systems might start to learn autonomously and hence improve their performance (Osman, 2010). Wiener set out the core concepts for understanding complex systems – feedback, information, causal structures, input-output associations, mechanisms, state change, regulation and autonomous behaviour. His work centred on utilising feedback and developing accurate predictive techniques (Wiener, 1961). There remains however a dichotomy at the heart of cybernetic and artificial intelligence's attempts to improve the control of systems. A system must be both robust, so it can operate without human intervention and also flexible, so that the system can learn. It is likely that this learning will be occurring in an uncertain environment. And so having learnt and adapted from one uncertain environment the system must try to develop decision making capability (using decision trees or Bayesian algorithms) so that it can then transfer that learning to a new uncertain and unfamiliar environment (Osman, 2010). As artificial intelligence systems deal with uncertainty, this enables us to develop an awareness of how we as humans manage many different sets of often uncertain and incomplete information. We achieve this by processing incoming information from our environment, and adapting our behaviour in response, a process that we do automatically and often subconsciously many times a day.

Further Reading

The aim of this paper was to introduce a number of other disciplinary perspectives on the notion of uncertainty to help illuminate further the multi-faceted nature of uncertainty. The chapter considered uncertainty from the perspective of seven different disciplines – probability, economics, psychology, philosophy, strategy, physics, cybernetics and artificial intelligence. Whilst in no sense exhaustive, the consideration of these differing perspectives has developed our understanding of what uncertainty is and approaches that we can take to better understand and manage it. For further reading the following two books are a good place to start:

1. Bammer, G., & Smithson, M. (2009). *Uncertainty and Risk: Multidisciplinary Perspectives*. London, UK: Earthscan.

2. Osman, M. (2010). *Controlling Uncertainty: Decision Making and Learning in Complex Worlds*. Chichester, UK: Wiley-Blackwell.

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