Technology Strategic Decision Making (SDM): an overview of decision theories, processes and methods

Leonidas Aristodemou (CTM-IIPM, University of Cambridge) *
Frank Tietze (CTM-IIPM, University of Cambridge)

* Please contact the corresponding author for feedback: la324@cam.ac.uk
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Leonidas Aristodemou\textsuperscript{1,2} (la324@cam.ac.uk)
Dr. Frank Tietze\textsuperscript{1} (frank.tietze@eng.cam.ac.uk)

\textsuperscript{1}Centre for Technology Management, Institute for Manufacturing, Department of Engineering, University of Cambridge, Cambridge, UK
\textsuperscript{2}The Alan Turing Institute, London, UK

Research Background

Technology Strategic Decision Making (SDM) requires a fair amount of information regarding the field in which the technology is to be selected for (Kalbande and Thampi, 2009) due to the nature of technological uncertainty (Grant, 2012). The literature argues that different methods can be applied to these SDM processes, with the most common being the qualitative scorecard approach (Cooper, 2007; Goffin and Mitchell, 2016; Mitchell et al., 2014, 2017). In addition, these SDM processes should have unique selection criteria, due to the risky and uncertain nature of early stage technology projects (Ajamian and Koen, 2002; Koen et al., 2002) and due to the different outcomes each decision gate leads to (Cooper, 2006). In this paper, we contribute to the growing literature on technology strategic decision making by producing a narrative literature review on strategic decision making processes, decision theory and strategic decision making methods.
Methodology

The paper aims to contribute to the growing literature on technology strategic decision making via a narrative literature review (Cronin et al., 2008). The articles on SDM decision theory, SDM processes and methods are identified from databases to find the most relevant published articles or in press articles, using a research strategy and a snowball effect, with relevant literature (Creswell, 2013).

We search within the title, abstract and key words for various terms such as "Decision making", "Decision theory", "Strategic decision makings", "Strategic decisions", "Decision making criteria", "Decision making factors". These are then narrowed to the field of technology and innovation management using the following terms: "technology development", "innovation", "innovation management", "technology", "stage gate", and limited to the areas of business and management. The following sections provide the readers with a summary of the results.

Strategic Decision Making Process

A decision, usually taken at the gate of a stage gate process (Fig. 1), is a commitment to mobilise resources (Cooper, 2006; Edwards, 1954; Ullman, 2002). SDM is the process of steps of identifying and choosing strategic alternatives to reduce uncertainty, and arrive at rational decision (Ahmed et al., 2014; Dewey, 1911; Mintzberg et al., 1976; Simon, 1961, 1993).

Fig. 1 Stage Gate Strategic Decision Making Process Commitment, source: Cooper (2007)

Following the value of information pyramid, a decision is based on the judgement of knowledge gain, which has been composed by the behaviour of the models, which have analysed the relationship of data (Fig. 2a). Thus, for a given issue, a decision arises, when a number of criteria are used to specify the issue, and the information measuring alternatives is evaluated relative to these (Fig. 2b). Papadakis et al. (1998) argues that the importance of SDM is based on the characteristics and understanding of the long term nature of the effects of the
decision and the bridge between deliberate and emerging strategy, and organizational learning, similar to Grant (2012); Mintzberg and Lampel (1999). There are several SDM process models in the literature that are summarised in Table 1, with Fig. 3 showing the basic features of these.

![Decision and Evaluation Diagram](image)

(a) The value of information

(b) Decision making information

Fig. 2 Strategic decision making knowledge-information classes, and the value of information, source: Ullman (2002)

<table>
<thead>
<tr>
<th>Model</th>
<th>Author</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classical decision making process</td>
<td>Dewey (1911)</td>
<td>Rational-Analytic approach. Sequential Model. The model assumes certainty conditions in the decision making process arising from intelligence, design and choice. The models assumes that the causal relationships are known and knowable.</td>
</tr>
<tr>
<td>Military model</td>
<td>Nickols (2015)</td>
<td>Goal setting objective approach. Sequential Model. The model is based on the classical decision making process and have the same limitations as above. Iterative decision making process using feedback loops.</td>
</tr>
<tr>
<td>Mintzberg’s General Model</td>
<td>Mintzberg et al. (1976)</td>
<td>Three phase and seven routine approach. Non-sequential model. There are three phases the identification, development and selection phase, where the decision is defined as a commitment to a course of action. The model also highlights decision control implications but lacks the procedural guidance on how to used it.</td>
</tr>
<tr>
<td>Cynefin Framework</td>
<td>Kurtz and Snowden (2003); Snowden and Boone (2007)</td>
<td>Evolutionary perspective of complex systems approach. Non-sequential model. The model combines research from adaptive systems theory and cognitive science, and seeks to understand how people perceive situations in order to make decisions. The four quadrants of the model have to do with the decision making categories: complex, complicated, chaotic, simple.</td>
</tr>
<tr>
<td>MCDA</td>
<td>Montibeller and Franco (2010)</td>
<td>The model deals with a decision problem under conflicting criteria with large uncertainty. It follows as set of procedures in analyzing complex decisions to identify the most preferred option.</td>
</tr>
</tbody>
</table>
(a) Classical decision making process

(b) Military decision making process

(c) Mintzberg’s general process

Fig. 3 Strategic decision making process models, sources: Table 1
(d) Cynefin framework

1. Define the decision problem and identify the decision maker to guide the MCDM approach.

2. Identify the criteria and how these will be evaluated.

4. Allocate importance weights to each of the criteria.

6. Apply the decision rules.

7. Rank, or identify the “best compromise” alternative or set of alternatives. Sensitivity

3. Identify the alternatives.

5. Score the criteria for each of the alternatives.

(e) MCDA process

Fig. 3 continued Strategic decision making process models, sources: Table 1
Decision Theory

The theories linked to SDM are similar to the decision making theories. The majority of decision making theories are multidisciplinary and strategic in nature (Grant, 2012). Throughout the years several authors have suggested several classifications of these theories, but there is no unanimous agreement on the classifications. Brown (2005) argues that the theories can be divided in single and group theories, based on the garbage-can theory (Cohen et al., 1998).

Many researchers argue that the theories can be divided between rational, non-rational and bounded rational (Edwards, 1954; Eisenhardt and Zbaracki, 1992; Oliveira, 2007; Stanovich and West, 2000). Rational theories assume a rational and completely informed decision making (Drummond, 2012), where as the bounded rational theories assume a process oriented view of satisfaction and decision making leading on optimal choice based on incomplete information (Turpin, 2004). This distinction can be further enhanced by the classification into normative and descriptive (behavioural) decision theories (Ahmed et al., 2014). The distinction is due to the fact that normative theories are concerned with how decision should be made and descriptive theories describe how decisions how are actually made (Williams, 2010). The main SDM theories in the literature are shown in Fig. 4 and the most important of them are described in Table 2.

Fig. 4 Strategic decision making theories in the literature
<table>
<thead>
<tr>
<th>Theory</th>
<th>Authors</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attribute theory</td>
<td>Heider Fritz et al. (1958); Weiner (1972)</td>
<td>This theory originates from psychology and attempts to understand the causal behaviour of others by attributing internal and external factors. Internal factors are character, attitude, personality, where as external factors are the situation, environment. The theory has three stages: the observation, the deliberate behaviour and the attribution of causes.</td>
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<tr>
<td>Bayesian theory</td>
<td>Williams (2010)</td>
<td>It is a statistical theory that looks at the problem of pattern classification and considers the ideal situation. This situation is based on known probabilistic structures of the categories, and trade-off costs, which allow to determine the Bayes classification (optimal), predicting errors and generalization of novel constructs.</td>
</tr>
<tr>
<td>Game theory</td>
<td>Neumann and Morgenstern (1947)</td>
<td>It is an economic theory concerned with intelligent rational decision making. It argues that there is an equilibrium, which maximizes the gain for two actors independent of the information they have about the market or each other.</td>
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<tr>
<td>Multiple attribute utility theory</td>
<td>Keeney and Raiffa (1993)</td>
<td>This structured theory handles the trade-off between multiple attributes or objectives, comparing strengths and weaknesses of alternatives relative to the person taking the decision. It is the aggregation of single attribute utilities and this represents the difference between best and worst alternatives. The higher the multi-attribute utility measure, the more desirable is the alternative, which when ranked in order, shows the order of preference.</td>
</tr>
<tr>
<td>Prospect theory</td>
<td>Kahneman and Tversky (1979)</td>
<td>It is behavioural economic theory that describes how people make decisions between risky alternatives, when everything is known. It argues that people makes decisions based on the potential value of loss and gain. This is a descriptive theory and tries to evaluate real-life decision problems rather than come up with the optimal solution.</td>
</tr>
<tr>
<td>Satisfying theory</td>
<td>Simon (1946)</td>
<td>A bounded rationality theory, where the person taking a decision has limited information, and he uses this limited information with simplified knowledge to make a compromise (satisfying) decision, and not the optimal decision. The theory also argues that it is better off when a compromise solution is made rather than searching indefinite for the optimal solution.</td>
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<tr>
<td>Subjective expected utility theory</td>
<td>Kim et al. (2008); Savage (1954)</td>
<td>The theory argues that a decision is taken in the presence of risk between alternative strategies. The decision maker always seeks the best alternative and thus has a subjective weight of utility and estimation of likelihood. The theory makes the assumption that the person taking the decision is always rational.</td>
</tr>
</tbody>
</table>
Strategic Decision Making Methods

Depending on the problem, there are different types of SDM methods, arising from the theories. These are divided in two types: single criterion and multi-criteria, as shown on Fig. 5a. Different authors have considered different classifications for these, based on characteristics and method logic (Verbano and Nosella, 2010), or criteria interaction (Golcuk and Baykasoglu, 2016) or information on criteria (Zavadskas and Turskis, 2011). With the rise of artificial intelligence recently, Chai et al. (2013) divides the SDM methods in three categories: multi-attribute decision making methods, mathematical programming methods and AI methods (Fig. 5b). Table 3 summarizes the most commonly used SDM methods in the literature.

Fig. 5 Strategic decision making methods in the literature
<table>
<thead>
<tr>
<th>Method</th>
<th>Summary</th>
<th>Strength/ Weakness</th>
<th>Studies</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANP, AHP</td>
<td>This method is based in the hierarchic identification of weights of importance for selection criteria and alternatives. Each element is assumed to be independent and known. In its simplest form, it can act as a balanced scorecard.</td>
<td>Loss of information can occur due to potential compensation between good scores on some criteria and bad scores on other criteria. Complex and time-consuming computation is required.</td>
<td>Azis (1990); Dehe and Bamford (2015); Dodgson et al. (2009); Gade and Osuri (2014); Goffin and Mitchell (2016); Kabir et al. (2014); Kolios et al. (2016); Korhonen and Wallenius (1990); Mardani et al. (2015); Millet and Harker (1990); Saaty (1990a,b); Triantaphyllou and Shu (1998); Ullman (2002); Xu and Yang (2001); Zahedi (1990); Zavadskas et al. (2014)</td>
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<tr>
<td>DEMATEL</td>
<td>This method identifies interdependencies between criteria through causal relationships, identifying the influential strength of these.</td>
<td>Simple to compute. Does not require the criteria to be independent. Identification of causal relationships. Many hybrid variations.</td>
<td>Bian and Deng (2017); Büyüközkan and Ifi (2012); Chai et al. (2013); Chang et al. (2011); Chao and Chen (2009); Golcuk and Baykasoglu (2016); Kahraman et al. (2015); Lin and Wu (2008); Liu et al. (2017); Mardani et al. (2015); Marttunen et al. (2017); Shieh et al. (2010); Tseng et al. (2007); Wu (2008); Wu and Lee (2007a,b); Zavadskas et al. (2014)</td>
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<tr>
<td>ELECTRE</td>
<td>This method is concerned with outranking pair wise relations between alternatives, establishing a partial ranking by a process of elimination.</td>
<td>Applicable even when there is missing information, and when there are incomparable alternatives and uncertainty. Time consuming.</td>
<td>Andriosopoulos et al. (2012); Behzadian et al. (2010); Dehe and Bamford (2015); Figueira et al. (2010, 2016); Fülöp (2001); Gade and Osuri (2014); Greco et al. (2001); Kabir et al. (2014); Kahraman et al. (2015); Kolios et al. (2016); Majumder (2015); Mardani et al. (2015); Roy (1991); Songa et al. (2010); Triantaphyllou and Shu (1998); Zavadskas and Turskis (2011); Zavadskas et al. (2014); Zopounidis and Doumpos (2002)</td>
</tr>
<tr>
<td>Method</td>
<td>Description</td>
<td>Relevant References</td>
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<tr>
<td>MACBETH</td>
<td>This interactive method allows the evaluation of alternatives by making qualitative comparisons based on differences and attractiveness. Applicable even when there is missing information. Simple and easy to use. Problems arise when the group cannot agree on alternatives and weights.</td>
<td>Dodgson et al. (2009); Ferreira (2013); Kahraman et al. (2015); Zavadskas and Turskis (2011); Zavadskas et al. (2014)</td>
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<td>PROMETHEE</td>
<td>This is an outranking method for a finite set of alternatives based on conflicting criteria. It compares alternatives and identifies the deviations of each alternative to the selection criterion. Simple and efficient. No normalization is required. There are different versions, which can cause confusions. Time consuming. Complicated when the number of selection criteria is large.</td>
<td>Behzadian et al. (2010); Brans and Vincke (1985); Brans et al. (1984, 1986); Deshmukh (2013); Fülöp (2001); Gade and Osuri (2014); Kahraman et al. (2015); Macharis et al. (2015); Mardani et al. (2015); Mareschal (1988); Songa et al. (2010); Zavadskas and Turskis (2011); Zavadskas et al. (2014)</td>
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<tr>
<td>TOPSIS</td>
<td>This is a value-based compensatory method, which attempts to choose alternative solutions based on the shortest distance from the ideal solution. The ideal solution maximizes benefit and minimizes cost. Does not require attributes to be independent. Cardinal ranking of alternatives. Easy to implement. Only applicable when exact and total information is collected. Vector normalization is required.</td>
<td>Behzadian et al. (2012); Dehe and Bamford (2015); Hwang et al. (1993); Kabir et al. (2014); Kalbande and Thampi (2009); Kolios et al. (2016); Lai et al. (1994); Mardani et al. (2015); Triantaphyllou and Shu (1998); Xu and Yang (2001); Yeh (2002); Zavadskas and Turskis (2011); Zavadskas et al. (2014)</td>
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<tr>
<td>VIKOR</td>
<td>This method maximizes group utility and minimizes regret, by identifying a solution closest to the ideal in the presence of conflicting criteria. Non-preference model. No interactive participation of decision makers necessary. Linear normalisation needed.</td>
<td>Kabir et al. (2014); Kahraman et al. (2015); Mardani et al. (2015); Opricovic and Tzeng (2002, 2004, 2007); Zavadskas and Turskis (2011)</td>
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</table>
Conclusion

Technology Strategic Decision Making (SDM) requires a fair amount of information regarding the field in which the technology is to be selected for (Kalbande and Thampi, 2009) due to the nature of technological uncertainty (Grant, 2012). One such technology strategic decision is a commitment to mobilise resources (Cooper, 2006; Edwards, 1954; Ullman, 2002). SDM is the process of steps of identifying and choosing strategic alternatives to reduce uncertainty, and arrive at rational decision (Ahmed et al., 2014; Dewey, 1911; Mintzberg et al., 1976; Simon, 1961, 1993). In this short paper, we contribute to the growing literature on technology strategic decision making by producing a narrative literature review on strategic decision making processes, decision theory and strategic decision making methods. We hope researchers and practitioners will find this paper a useful overview of strategic decision making.

Acknowledgement

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