# DECISION DESIGN AND RE-ORDERING PREFERENCES: THE CASE OF AN EXPLORATION PROJECT IN A LARGE FIRM

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## Abstract

Decision theory has been long applied to project management for risk and uncertainty reduction. Among the foundations, the manager is considered following axioms describing his rationality; the most prominent ones being transitivity and independence. The order in preferences is not supposed be reversed yet unknown events of nature may perturb our understanding and may require designing new decisions going against decision theories, hence increasing uncertainty. In this paper we propose a model of decision making in the unknown whose hypotheses are tested on an industrial case in order to show that traditional decision making is not able to grasp the natural phenomenon of expansion and generativity as a manager senses the unknown in an innovation project. Bayesian Nets with Abraham Wald's foundations are used to sense the re-ordering preferences and the benefits of designing one's playground and being intransitive. The purpose is also to contribute to the idea that design theories, theories studying generative processes, by opposition to optimisation (decision theory) and ideation (creativity theory) can help extend the underlying logic of innovation management.

**Keywords**: Design theory, Decision making, Project management, Design management

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# 1 INTRODUCTION

In the field of innovation, firms launch projects involving uncertainties and the discovery of new parameters that need to be incorporated for decision-making. During the second half of the 20th century, several key contributions rooted in game theory and probabilities - based on a set of axioms defining rationality preferences - aimed at understanding the choices made by an agent at the light of events and consequences. Those works have been largely diffused into practice and to some extent for strategic decisions. Yet, controversies around the transitivity axiom (Tversky, 1969) with insight from experimental psychology and independence axiom (Allais, 1990) have shaken the understanding of rational behaviour thus requiring the elaboration of enhanced theoretical models to explain several paradoxes rooted in the foundations of decision theories. In real-life situations, and in innovation project management, some consequences of choices may appear different from original forecast and expected utility due to unobservable events: the unknown plays an important role when one is facing high uncertainty and partially known playground (Hatchuel et al., 2013). Breaking away from traditional problem-solving with decision paradigm, and its bounded rationality may be required (Dorst, 2006; Hatchuel, 2001) to expand one's playground to what remains to be known (Hey, 1983).
We would like to show a model of decision making in the unknown and illustrate it with a case of irrationality from the perspective of Wald's classic decision theory stream with two snapshots taken of a case study in a large aeronautical equipment manufacturer who managed the development of new technology whilst entering a monopolistic market involving the gradual design of their own decision playground to maximise their chances of success. We propose to demonstrate that design theories help explain what could be dubbed as irrational from the decision theory perspective; that from a probable gut feeling, luck and hope for success innovation project management leap into the unknown are forced to increase uncertainty, endogenising what is to be found, to seek potentially richer space to project one's utility, thus requiring the extension of the decision theories by a generative process to untangle the tipping point between exploration/exploitation in project management.

# 2 DECISION PARADIGM: A CERTAIN VIEW OF THE WORLD

Decision theory from its beginning and throughout its evolution has evolved with a set of axioms which hold a certain view of rationality: transitivity, independence and completeness; hence leaving little room to expansive behaviours that imply reconsidering the order of preferences at the light of different states of nature in addition to taking poor gambles whilst hoping for the playground to change favourably. In Figure 1, we show the genealogy of decision theory with its rationality and higher level branches, including the expandable one linking with theories of generativity considering knowledge creation and inclusion of independent knowledge, and higher theories relating to irrationality.

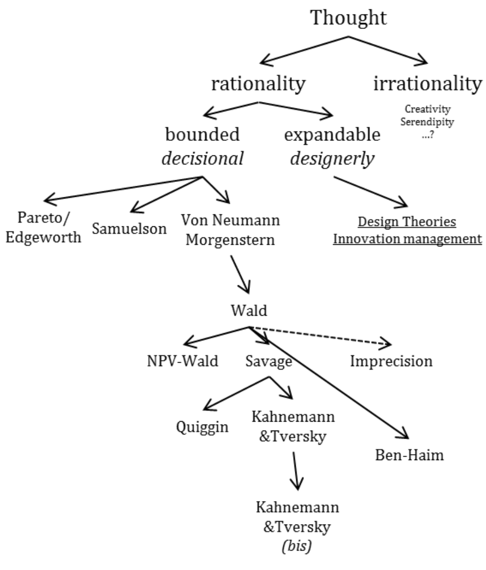



*Figure 1. Literature genealogy and positioning*

## 2.1 Decision theories: a restriction to what is certain and known

Decision theory, as a theory of instrumental rationality, has since philosophical considerations of Hume outlining reason as an instrument for our passions, to systems 1&2 described by the extensive studies on heuristics and biases (Tversky and Kahneman, 1974) have a had a great impact on the way we study choices: observe them and explain them. More specifically in the field of economics, understanding the choices made by economic agents became the centre of attention as their behaviour would explain demand by opposition to previous marginalist approaches focusing on utility and indifference curves (Pareto, 1909). Utility on its own is hard to measure, thus requiring a shift towards the study of relations, as maximisation of self-interest could not be generalised enough (Giocoli, 2005): the formalisation by (Wald, 1949) from the earlier works of (Von Neumann and Morgenstern, 1944) on game theory was then considered too hard for an operationalization and (Savage, 1954) proposed to infer utility functions and subjective probabilities from the sum of expected utilities. The latter became a source of intensive research to explicit economic behaviours without introspecting the agent as proposed by the seminal works of (Samuelson, 1938). Despite the tentative approach of psychologists to contribute to the introspection, and the presentation of paradoxes of Allais and Ellsberg revealing that rationality's definition is beyond axiomatic view of decision theories and behavioural economics; works of (Kahneman and Tversky, 1979) on prospect theory or its cumulative version, or rank-dependent (Quiggin, 1982) or even imprecise probabilities (Joyce, 2010) tried to encompass some of the inconsistencies whilst avoiding to violate the normative view of the transitivity axiom (Fishburn, 1992) and reconsiderations in recent works reinforcing transitive models (Baillon et al., 2014) thus always in the sense of observing how decisions are made, and theorising a fictitious *homo economicus* whose model is far from the real world as explained by (Hey, 1983). This whole field has been focusing on the approach that rationality, by opposition with irrationality (inconsistent with reason; with loss of clarity; incoherent) commonly associated with creativity, or odd phenomena such as serendipity. In other words, rationality has been seen in close association with uncertainty and risk reduction, meaning gradually projecting one's utility vector on allegedly known and certain states.

Nevertheless, despite stimulating research in this field challenging axioms, a whole field is also at stake when considering other spaces to be discovered: irrationality at a higher level appear promising as it can be guessed from axioms (Becker, 1962; Hey, 1983) and with insight from management literature (Brunsson, 1982). We understand here that the use of probabilities in economics and decision-making has a certain limited range that is framed by the hypothesis outlined by their mathematical foundations: omitting the unknown dimension. Consequently, in the case of new venture (Loch et al., 2008) those unmeasurable and unidentified events, expected utility theories are bare handed and can only be used for an ex-post assessment.

## 2.2 Design theories and innovation management: a guide to structure the unknown

The main issue here is to reach the unknown or model what could happen when trying to reach for it. Expanding the knowledge space appear as a standard feature of innovation projects, and help reconsider one's set of alternatives, consequences and perception of events' states, allowing to build value and redefine performance and assessment criteria, beyond net present value for instance. As shown above in Figure 1, we propose to start off with a broader understanding of rationality and reconsider decision-making with the insight of design theories, i.e. theories relying on the generative processes (Hatchuel et al., 2013). We must also highlight the other research stream that also looks at what could be seen as irrational, including phenomena such as serendipity and emergence of need-solution pairs (von Hippel and von Krogh, 2015). Following the theoretical tools of decision theories, trial & learn approaches appear as clever way to gradually discover our environment and unknowns. Recent research in management and design studies have proposed to explore the unknown with a portfolio management approach in order to minimise uncertainty across the board (Kokshagina et al., 2012). Multi-criteria methods (Keeney and Raiffa, 1979) can also be used to design a robust plan that could be as insensitive as possible to unknowns yet to be observed. Design theories going beyond Simon's bounded rationality (Hatchuel, 2001) help structuring the unknown: creating undecidable proposals, and several theories including parametric analysis (Kroll et al., 2013), infused design (Le Masson et al., 2013) , and C-K theory (Hatchuel and Weil, 2002) have largely contributed to this research stream.

## 2.3 Propositions and hypotheses

Consequently, facing real-world complexity and the issue of observing the unknown when seeking economic and financial success, project management appears to be requiring other devices and models to think through the decision-making process:

H1: Decision theories are insufficient to describe expansive behaviours;

H2: An extended decision model gambling on the unknown and accepting intransitivity can help explain the pattern of expansive behaviours;

H3: Expected utility and its derivatives such as Net Present Value in project management is a limiting performance indicator for exploration.

# 3 METHODOLOGY

Our methodology consists in testing the models we propose in the following section with an experimental approach based on Bayesian nets/Influence Diagrams, using Netica™ software. Decision models were elaborated on the base of the history of project management and interviews with several stakeholders, hence feeding the methodology as per mathematical theory as per (Koller and Friedman, 2009). We conducted a case study of the Icing Detection project carried over 15 years at Zodiac Aerospace business unit dedicated to sensing and system management, from 2000 until now and making its strategy to enter a monopolistic market: 8 interviewees were solicited with semi-structured interviews to trace the history of the project, the different initiatives, beliefs, strategy and decisions taken at different stages, in addition to full access to the field. The decision models were realised with the input of stakeholders and validation by managers. Probabilities and costs/utilities were evaluated from the interviews, and secondary material, in order to match Wald's approach of decision making.

We propose to look at the real-life project, their decision making process and the chosen device (regulation/specification working group) used as diffraction grating to observe the unknown and guide the project along.

# 4 TWO DECISIONAL MODELS

The input from traditional decision theory and insight from new stream of research challenging its paradigm in economics, psychology and management, encourages to see two different models that could explain decision making in exploratory project management, without falling into the blur of irrationality and complete uncontrolled processes. The unknown factor could be categorised into two domains, the first is associated with perturbative unknowns and those that are insignificant. It is of course the first domain that interests us and requires special treatment when using decision theories.

## 4.1 Model 1: optimisation behaviour

A first model would be the case of an agent acting in a world where the rationale is dictated by optimisation; consequently, we will conform to the axiomatic view of decision theories with finite sets of events, choices and consequences. The ultimate goal will be maximising here expected utility with the available information whilst taking account associated beliefs and expected net present values. The knowledge produced for the occasion is related to the uncertainty reduction as decisions are made, or in other words to reduce the variance in the likelihood of the found optimum.

In this case, the preferences order is never revised as gambles and utilities are computed once and never updated.

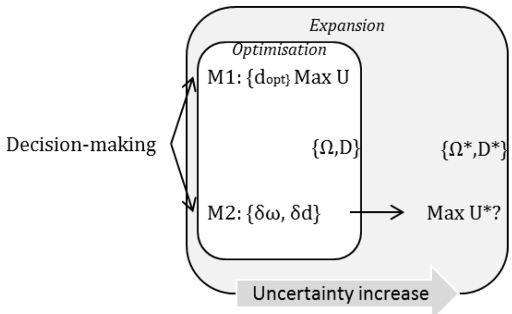
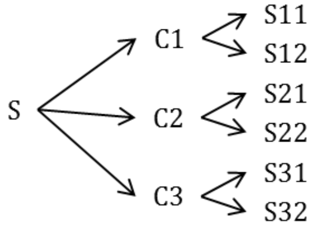
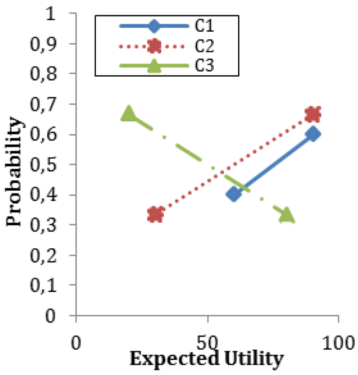
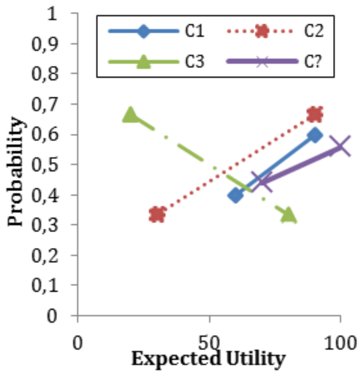
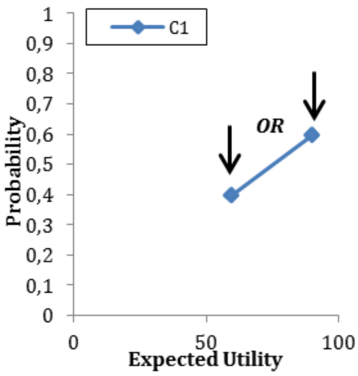
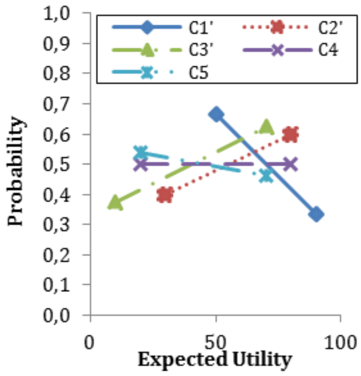



*Figure 2. Optimisation vs. Expansion*

### 4.2 Model 2: expansive behaviour

A second model would be the case of an agent looking at discovering the states of nature hoping for different outcomes. The starting point is not being "satisfied" with the preferences: it may sound irrational but also may be due to a certain "gut feeling" considering there is still more to learn from in order to compute a satisfactory expected utility. This update could be seen as intransitive a posteriori as the knowledge expansion, the re-incorporation of new beliefs and outcomes may re-order the preferences when comparing to the previous snapshot. This leap into the unknown is a generative process looking at gradually structuring the unknown (Epstein, 1990). In the diagram above (Figure 2), we can see the expansion we are aiming at when following model 2: the set of events Ω, the set of decisions D, can be extended by taking an odd decision δd which will give access to a δω of events thus allowing the reconsideration of the expected utility for a - potential - greater good.

*Table 1. Models*

| | Model 1 | Model 2 |
|---|---|---|
| Decision tree *(alternating nodes of choices and states of nature; the leaves are the consequences)* |   | Same decision tree as on the left, yet considering the possibility of designing new decisions or a new playground, thus reshuffling the tree. |
| Uncertainty and expected utility At t0 |   We choose here the best averaged expected utility (C1). |   We consider instead designing a new choice (C?) opening a new set of states or designing a different playground (different branches in decision tree). |
| Uncertainty and expected utility At t1 |   |   |
| Phenomenon | Choice C1 is made and nature plays and one ends up with one of the outcomes (one single point with a probability of 100%). | E.g. Choice C2 is made whilst hoping to change the playground: previous preferences change order and nature states have changed. Other choices appear (C4 and C5). |

The leap into the unknown, as described by Model 2, can also be seen in Figure 3 by considering that designing an optimal decision insensitive to the states of nature or designing a different playground for a better net present value implies projecting one's decision into an expanded unknown space with a potentially better economic outcome.

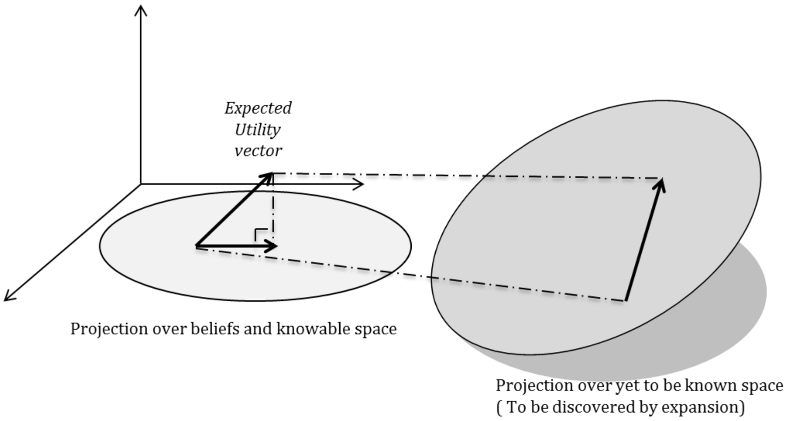



*Figure 3. Projection vs. Expansion*

## 5 HYPOTHESIS TESTING

For the project at Zodiac Aerospace (Z, group), the original situation consisted in tackling the safety issues related to the icing phenomena, which implied the removal by any means or its detection. Regulations had then evolve to enhance safety, the major aircraft manufacturers were then considering a potential upgrade of their anti-ice and ice detectors as the latter, thus reconsidering the monopole. At the group level, Z could provide anti-ice systems with another business unit (Za), or internally (Zi) could work on sensing systems in line with their own core business. In addition, Z has a long history of mergers and acquisitions especially when it comes to specific technologies, consequently the acquisition of business already in the marketplace of ice detectors was considered.
When computing the different probabilities of the states of nature considered at the start of the project, we find that it would have made for sense to target the anti-ice strategy (see Figure 4). The associated utility reflects the understanding of the situation, despite some hints that detecting icing conditions would also have been interesting. It is interesting to highlight the first technology development by the competition was the external intervention at the airport, before take-off, to spray a chemical impeding ice formation on wings. Yet, history shows Zi chose to bet on the detection strategy with a lower utility and riskier path.

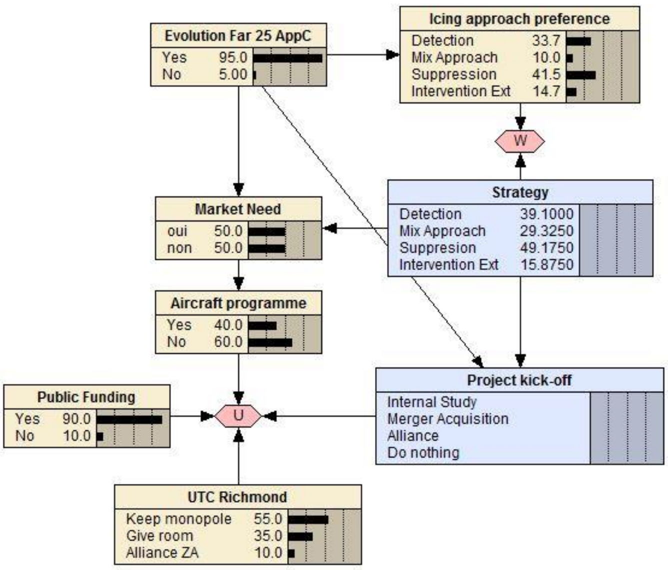



*Figure 4. Influence diagram - Phase 1 decision situation*

When using taking the snapshot at a later stage (see Figure 5), we find that Zi has completely dived into the field of icing conditions detection as the likelihood of detection appears higher than the removal. There is a certain parametric learning dimension, in addition to a structural one as the mapping changes as described in (Koller and Friedman, 2009). They managed to lead a EUROCAE working group, a consortium tasked to "update the In-Flight Ice Detection System (FIDS) Minimum Operational Specification ED-103 - 2016, and provide recommendations on the feasibility to standardize In-Flight Ice Crystals Weather Radar Long Range Awareness Function - 2016" (EUROCAE website). The group gathers all main players of the aviation industry concerned by icing conditions, competitors meet, share and discuss their work on the topics and aim at defining new specifications for aircraft safety. In parallel, several public funding campaigns complement the effort to foster research and applications in the field. At this point, the playground having evolved, the detection strategy appears as the most preferable choice according to the model, being more valued by different players. The anti-ice strategy is no longer considered and another signal is the absence of any working group to have the technology and related specification evolve. Zi had made the right choice given the new playground discovered whilst taking the initially riskier decision. We must highlight at this point, some project team members tried to build coherence in their decision, as highlighted by (Tversky and Kahneman, 1974) despite the beliefs and costs, net present values exposed during interviews feeding phase 1 (Figure 4).
As described in the model 2 (section 4.2), Zi created an expansion of its knowable space to project its expected utility vector; this variation from phase 1 to 2 has a generative feature: creation of new business and ecosystem with the support of collective agreement around a specification. The expected utility is higher than it was in the first phase, and the former optimal choice is now poorer considering the new playground.
Finally, we must stress the end situation where Zi finds itself: the specification having evolved with the understanding of the icing phenomena, three different situations were identified where icing must be detected and consequently removed with different criteria thus concerning in different ways commercial aviation, business jets and private aviation. However, most of the specification and concurrent technological development were lured by commercial aviation for a specific technological range therefore partially hiding the space of other applications, as explained by interviewees. Perhaps another use of the model 2 to further expand the projection space could have better opened other paths.

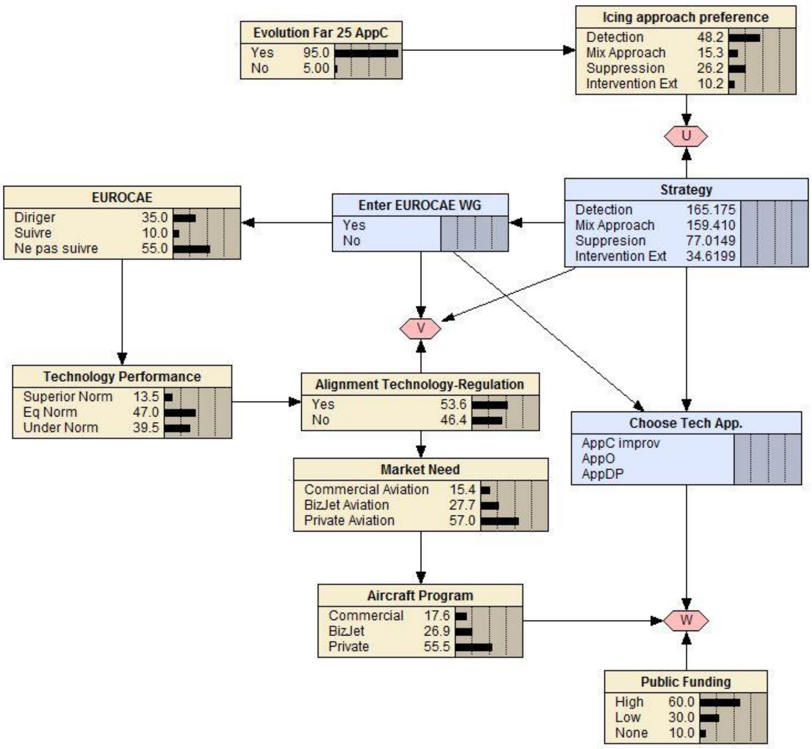



*Figure 5. Influence diagram - Phase 2 decision situation (DRAFT)*

## 6 RESULTS AND DISCUSSIONS

Drawing from our hypothesis testing, our first hypothesis H1 is confirmed: we can see that as in our Model 2 (section 4.2) that knowable space expansion appear as phenomena that decision-theory *à la Wald* is not able to grasp, due to its mathematical foundations based on finite sets and axioms not allowing "reversing" preferences order. Model 1 (section 4.1) is then poorer than Model 2. In other words, following Model 1, classical uncertainty reduction can lead us into thinking the agent is irrational, whereas our industrial case stages sound agents with an economic sense.

Yet, real-life situations violate axioms such as transitivity as discussed earlier and may reconsider preference order due to expansive learning. Here, we must precise this second order of learning that differs from Bayesian learning which may only condition an event to be most probable (posterior=1) or improbable (posterior=0). Expansive learning can imply re-ordering as shown in our results: the initial risky gamble became the best bet when discovering a new space. Our second hypothesis H2 is also confirmed: our model 2 considering expansive behaviours, allowing re-ordering of preferences helps accounting for other so-called 'irrational' valuable decisions.

As explained for Figure 3, when we decide to violate the normative behaviour dictated by decision theory, uncertainty increases as we have a larger projective space. And simultaneously, design theories can contribute to design a better economic outcome with the gradual discovery of the unknown space. Discovering one's surroundings appear, and what remains to be discovered, i.e. the search for novelty with potential reconsideration of one's preferences and understanding of contingencies may result in a better outcome. We can relate to promising works in robotics and mathematics such as (Mouret and Clune, 2015; Stanley and Lehman, 2015) aiming at avoiding fixation over a set of objectives but instead aim for what is novel: this artificial intelligence has managed to solve complex problems with gradual understanding of its world and possible behaviours realisable with the given features and according to the performance criteria.

Finally, our last hypothesis, H3 is also confirmed, as we see the expected values computed in our influence diagrams - with the net present values derived from case data - are misleading: following those would have encouraged following model 1, whereas model 2 was the most valuable, as history shows through a design effort.

These results overall lead us into thinking that design extends the scope of decision, thus considering designing decisions to have an optimal structuration of the unknown and be as profitable as possible. Naturally, we can ask what the performance criteria would be to guide this process.

### 6.1 Organisational considerations

The exploration effort led by the project team was partially sustained by public funding and the value creation happening with the consortium, hence opening the project to the unknown and mitigating it (Sydow et al., 2012, 2013). Absorptive capacity as introduced by (Cohen and Levinthal, 1990) and refined in (Lane et al., 2006) is a critical feature for a firm to reinforce its knowledge base, namely its projection space in decision-making. The opening enabled repurposing the teams who had previously worked in similar technological fields and transpose their expertise. It is interesting to see the core project team was rather autonomous over the 15 years and very few spill-overs happened with the rest of engineering teams or programme and marketing/sales teams. Consequently, transferring the project for further development brings up difficulties to translate the absorbed and re-ordered knowledge, the decision-making gate becomes again an issue across the firm requiring internal absorptive and expansion capacity to homogenise knowledge. It raises strong management issues as the expansive behaviours break away from traditional project management and increases misunderstanding across teams and their managers, with different visions and value networks.

### 6.2 Exploration: an infinite process?

One could argue the initial snapshot compared to the second one is the regulation of asymmetric information over time, as one could read through the theories developed by George Akerlof, Michael Spence and Joseph Stiglitz. However, the decision-maker had to make a move towards the unknown to uncover the potential true value of the a priori risky, undervalued choice. The agent is looking at changing his order of preference by seeking structuring knowledge.

The unknown lack of information which may explain a poor gamble is something a project manager should consider at all times: "are we missing something? Is the playground larger than expected? Is it different? It is sliding?" Should all poor gambles be deeply studied and tested in an exploratory project? Perhaps, but it is known that a portfolio approach is wiser in terms of risks (Kokshagina et al., 2016), and otherwise consortia are probably a good device to go for and mitigate the unknown and constitute a new path (Sydow et al., 2012, 2013). It is not exactly an infinite process as the ecosystem will stabilise: beliefs, expected values and variances will stabilise as well.

The inability of decision theory to cope with exogenous information and the 'variations on a theme' (Hey, 1983) are all fixated by the basic assumptions that the sets of choices, states and consequences are finite, certain and known. However, real-life situation is rather infinite and those sets evolve over time. It would be more realistic to consider infinite sets and the possibility to avoid the transitivity axiom to explain the generative process of exploration and design as a way of structuring the unknown. Several design and creativity theories/practices such as Design Thinking toolbox (Martin, 2009), TRIZ (Altshuller and Shulyak, 1996), or general designerly ways of knowing (Cross, 2001) are probably part of the cognitive/social level set of theories/practices that can generate novel paths for decision-making. Furthermore, the mathematical foundations of design theories, such as C-K Theory (Hatchuel et al., 2016; Hatchuel and Weil, 2002) or complementary approaches such as (Salustri, 2005), with set theory open promising research to extend the mathematical foundations of decision theories to exploratory and intransitivity behaviours explaining innovation project management and providing tools for it to untangle the knot between exploration/exploitation phases in project management.

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