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Original Paper

The Use and Value of Scenario Planning

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Abstract

Strategies are often approached with the assumption that uncertainty can be partially understood and minimized to some extent by exploring plausible future events. Scenario planning addresses this question by using scenarios to describe more than one evolution and future state of the business environment. Throughout the years, strategists and academics have worked hard to resolve the methodological chaos (Martelli, 2001) created by the increasing number of scenario development methods. Aiming to contribute towards this goal, the history of scenario planning is covered in this paper, as well as its use and value in a range of industry sectors including energy (oil and gas), defense and space. With the insight and understanding gathered by both our research and interviews with strategists in different organizations, we propose a framework that suggests how to select different methods depending on different domain characteristics. We also use our findings to suggest how scenario planning, despite having its roots in strategic decision-making, can be a valuable input to risk management and systems design.

Keywords

scenarios, scenario planning, decision-making, systems design, risk management

1. Introduction

The purpose of strategic planning is to develop a plan of actions - or a strategy - for an organization to meet its goals or vision within a given time frame. Due to the timescales associated with strategic planning (time horizons greater than 10 years are common), there is considerable uncertainty associated with the evolution and end-state (relative to the chosen time horizon) of the organization's business environment. As strategy development requires some degree of knowledge about the future, one of the most important challenges in strategic planning is how to evaluate a strategy, or, equivalently, how to develop one that is robust. Robustness here means that the strategy is likely to be successful - i.e., the organization is able to adequately respond - even if the business environment's actual evolution differs significantly from that which was predicted. This also imposes a significant challenge for decision makers who need to be able to make decisions under considerable uncertainty, and to recognize and successfully adapt their decisions to shifts in the business environment.

Scenario planning is a technique that addresses these questions by considering more than one future for the business environment. These alternative futures - or scenarios - are narratives of hypothetical, but plausible, future states, which describe the sequences of events leading to a particular state while highlighting the causal relationships behind key forces that affect those events (see figure 1).

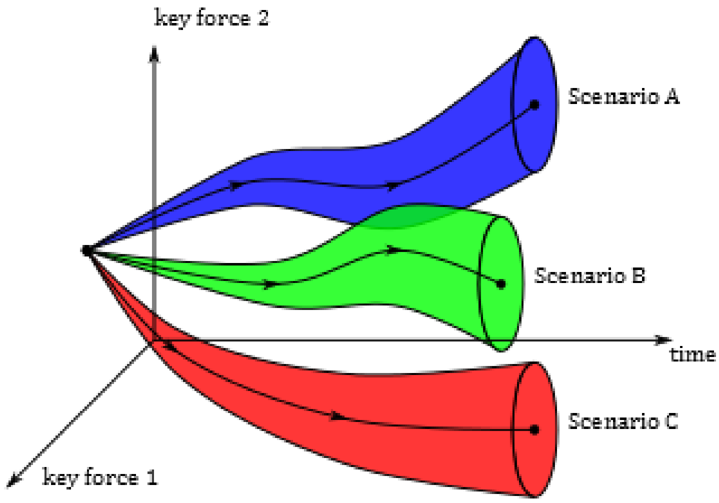

Figure 1. Evolution of Different Scenarios – the Volume around a Sequence of Events Represents the Associated Uncertainty (Growing in Time)

This paper addresses the history and use of scenario planning in several domains, namely, oil and gas, defense and space. It analyzes the processes used in each domain to better understand and describe the differences in methodologies, their maturity, and the value brought on by its use, and how these processes may be related to the nature of each domain. These findings are first used to address the so-called *methodological chaos* (Martelli, 2001) by describing, in general terms, the methodology that closely resembles those used in the domains that we have analyzed. Then, we propose a framework for the selection of the most appropriate scenario planning method given a set of domain characteristics. Finally, we use the insights obtained from our research and interviews with domain experts to propose applications of scenario planning to existing systems engineering processes as a way to deal with the uncertainty that is inherent to those processes.

1.1 Origins of Scenario Planning

Scenario planning has its origins in World War II, where it was used by military strategists to develop and evaluate war theatre strategies against what they considered possible enemy actions. After WWII, the importance of strategic planning did not decrease — with the world entering the Cold War, the political and technological environments became highly uncertain, and the effectiveness of any military strategy became even more dependent on those of other nations. The United States Department of Defense realized this fact, as well the urgency of investing in military planning, so that the right decisions on strategies and capabilities could be made (Bradfield, Wright, Burt, Cairns, & van der Heijden, 2005). Thus, in 1948, the RAND Corporation, a non-profit think tank, was founded and tasked to provide guidance and definition to the US military strategy.

It was at the RAND Corporation that war planning scenarios started to be developed as adaptations of theatrical scenarios through the work of a military strategist named Herman Kahn (Millett, 2003). In Kahn's view, scenarios represented a way to explore different futures through plausible combinations of sequences of events. The purpose of Kahn's scenarios was not to be used as a prediction tool, but rather as a way to improve people's theories and hypotheses (and, ultimately, their understanding of the environment) by forcing them to "*think about the unthinkable*" (Kahn, 1985).

Even though most of the early work on scenario planning was performed in the United States, scenarios were also being used in France, but with a different set of purposes: public policy and planning. In the late 1950s, Gaston Berger developed a scenario approach for long-term planning, named Prospective thinking, or *La Prospective*. Berger was also the founder of the *Centre d' Études Prospectives*, whose aim was to develop a scenario-based approach to develop positive images of the future for use in the political environment, providing the nation's policy makers with possible strategies for the future (Bradfield, Wright, Burt, Cairns, & van der Heijden, 2005).

1.2 Evolution of Scenario Planning

Herman Kahn continued to work on scenarios after he left the RAND Corporation to found the Hudson Institute, whose aim was to think about the future in unconventional ways. The Hudson Institute also marked the first uses of scenarios outside the military domain, since as funding for military projects decreased, the Institute started to shift focus towards domestic, social and economic problems. Soon after Kahn's departure, two former RAND strategists, Helmer and Gordon, in collaboration with Dalkey and other researchers at the California Institute of Technology and at the Stanford Research Institute's Futures Group, began experimenting with and developing scenarios as a planning tool (Bradfield, Wright, Burt, Cairns, & van der Heijden, 2005).

Scenario planning saw its first use in a business environment when Ian Wilson (General Electric) and Pierre Wack (Royal Dutch/Shell), based on Kahn's work on war game scenarios, redefined the use of scenarios as alternative and plausible descriptions of future outcomes for a given time horizon (Millett, 2003). This transition made possible the application of scenario planning to a broader context, which has benefited many organizations by allowing them to improve the robustness of their strategies and their knowledge of the uncertainty associated with possible future events.

The use of scenarios at the Royal Dutch/Shell as a strategic tool, together with the work developed at the Stanford Research Institute, resulted in a scenario planning methodology called Intuitive Logics. The name Intuitive Logics refers to a group of techniques of which the one used by Royal Dutch/Shell stands out as the best known example. One of the most defining characteristics of this group of techniques is their subjective and qualitative nature: they rely on tools such as disciplined intuition (i.e., based on logics, facts and examples), brainstorming, stakeholder and STEEP (Social, Technology, Economic, Environment and Political) analyses to understand the forces behind the focal issue and their possible evolutions. The scenarios developed using these techniques are often organized as a theme-oriented set of equally likely, plausible futures. Each scenario is usually in the form of a narrative, supported by graphics and some limited quantification of its main parameters, describing both the evolution and final (for the specified time-horizon) state of the environment and, in some cases, early warning signals (indicators that a given scenario is materializing), which are of particular interest to decision-makers. Despite the considerable number of Intuitive Logics models, the approach followed can be simplified and summarized to what follows (Bradfield, Wright, Burt, Cairns, & van der Heijden, 2005; Garvin & Levesque, 2006; Huss & Honton, 1987; Schwartz, 1996):

- Identify the focal issue or decision to be analyzed
- List all the driving forces (i.e., all the forces that affect the focal issue)
    - Separate the driving forces into predetermined (the ones whose evolution can be reasonably predicted) and uncertain (the remaining)
    - Rank the uncertain driving forces with respect to their impact on the focal issue, and identify their value range (i.e., extreme values)
- Create the scenario space by selecting the two most important uncertain driving forces - the critical uncertainties - using their value range as the axes of a two-dimensional graph
- Develop the scenarios based on the critical uncertainties and plot them on the scenario space (scenarios are usually characterized by a pair of extreme values of the critical uncertainties)
- Develop narratives describing the evolution of the world from its present state into that described by each of the scenarios, while considering the evolution of all the driving forces
- Assess the implications of each scenario for the focal issue
- Identify, for each scenario, early warning signals

Alongside the development of the Intuitive Logics methodology, another school emerged from the work of Gordon, Helmer and others researchers at RAND — the Probabilistic Modified Trends methodology — which includes two groups of techniques sharing the same mathematical principle of determining the probability (and impact) associated with the occurrence of possible future events: Trend Impact Analysis and Cross Impact Analysis.

The Trend Impact Analysis technique was developed by Theodore Gordon at The Futures Group in the 1970s as the evolution of a probabilistic forecasting tool. The technique takes as input time series data relevant to the focal issue and a list of possible future events, which may impact it in some way. For each of these events, its probability of occurrence (as a function of time) and its expected impacts are defined based on expert opinion. Scenarios are then constructed by extrapolating the time series data into the future (forecasting), obtaining the trends, and then considering the impact on those trends caused by the occurrence of the different events at different points in time (Bishop, Hines, & Collins, 2007; Bradfield, Wright, Burt, Cairns, & van der Heijden, 2005; Huss & Honton, 1987). Additionally, narratives can be added to relevant forecasts to provide for a more natural description of the scenario and its evolution.

Like the Trend Impact Analysis, the Cross Impact Analysis, developed by Theodore Gordon and Olaf Helmer at the RAND Corporation in the 1960s, also considers a list of possible future events and their probabilities of occurrence as defined by expert judgment. However, it differs from it by the fact that this list is then further refined by computing the conditional probabilities associated with sets of events. Together with a set of drivers affecting the focal issue, these probabilities can then be used as input to a Monte Carlo simulation, which generates combinations of events and the associated probabilities of occurrence (Bishop, Hines, & Collins, 2007; Bradfield, Wright, Burt, Cairns, & van der Heijden, 2005; Huss & Honton, 1987).

In the mid-1970s, Michel Godet, who had previously worked with the Prospective approach, began using a more mathematical and computer-based probabilistic approach to develop scenarios for several French institutions. Similarly to the Probabilistic Modified Trends School, *La Prospective* is mainly quantitative, analytical and probabilistic in nature, relying on complex computer-based analysis and mathematical modeling. The tools used, which include system, actors and morphological[1] analyses as well as key variable and probability identification, are often proprietary and highly integrated. The scenarios developed are both qualitative and quantitative, and are organized as a set of probabilistic scenarios (i.e., each scenario has a probability associated with its occurrence) describing alternative futures, and supported by a mathematical model and a defining set of assumptions (Bishop, Hines, & Collins, 2007; Bradfield, Wright, Burt, Cairns, & van der Heijden, 2005; Godet, 2000; Godet & Roubelat, 1996). The approach followed by this methodology can be summarized as:

- Analyze the problem posed and define the system under examination
- Diagnose of the organization, from know-how to product lines
- Identify the key internal and external variables using a structural analysis
- Understand the dynamics of the organization in its environment, its past development, its strengths and weaknesses with respect to the principal actors in its strategic environment: this will point to the key questions for the future
- Reduce uncertainty surrounding the key questions for the future by consulting experts able to highlight mega trends, wild cards, and the most likely environmental scenarios
- Highlight strategic options compatible with both the organization vision and the most likely scenarios

[1] Morphological analysis is a tool used for multidimensional problem solving, where the ranges for each dimension (or parameter) are specified, defining the state space for the problem. The analysis then lies in selecting the problem states (combinations of values) which are of interest for the problem at hand.

- Assess strategic options – this step marks the end of the reflection part of the exercise and the beginning of the decision-making
- Emphasize strategic choices and move from thinking to making a decision
- Implement the plan of action

Although scenario planning techniques have developed throughout the years and many different approaches can be found in the literature, some common steps are shared between the majority of scenario approaches (Mietzner & Reger, 2005):

- Identification of key decisions or focal issues
- Identification of driving forces, pre-determined elements and critical uncertainties
- Development of scenario plots, each representing a different and plausible future
- Identification of key indicators for each of the scenarios

1.3 Scenario Planning at Royal Dutch/Shell

For much of its early history, Royal Dutch/Shell relied on forecasts about its business environment to develop its strategies. During the 1960s, an increasing number of failures of its forecast-based planning approach triggered Shell's interest in scenarios, and led some of its planners to work on a set of scenarios that had the price of oil as its focal issue (van der Heijden, 2005).

Using Kahn's philosophy for scenario development, Royal Dutch/Shell's planners knew they had to first identify what was predictable (the predetermined elements) and what was uncertain about the oil prices in the coming years. Prices are driven mainly by the relationship between supply and demand, both of which planners assumed to be predictable - demand had been growing at a constant rate since World War II, and there were plenty of oil sources to keep up with demand. Pierre Wack, a planner at Shell, not satisfied with this analysis, decided to look into supply and those in control of it - at the time, oil companies and the governments of the producing countries. By doing this, he realized that supply was, in fact, uncertain, as it may not always be the best option for producing governments to continue to increase production at the same rate as the demand (if, for example, the production rate surpasses their economic needs). This, in turn, led the planners to create a scenario where governments would keep production levels below those needed to meet demand, resulting in a shortage - the *Crisis* scenario (van der Heijden, 2005; Wack, 1985).

Soon after, Shell executives found in the Yom Kippur war signs that the *Crisis* scenario was unfolding, and started to make their decisions in preparation for the eventuality that the crisis would indeed materialize, namely, changing investments on their refining capacity, and stockpiling oil. By the time the Organization of Arab Petroleum Exporting Countries (OAPEC) started an oil embargo as a response to the United States' decision to provide supplies and replacement weapons to the Israeli military during the Yom Kippur war, triggering an oil shortage that would result in a major oil crisis, Shell was able to take advantage of its previous decisions and adapt immediately, maintaining profitability and outperforming its competitors. In fact, its use of scenario planning provided Shell a competitive advantage, as other oil industries not only failed to rapidly adapt to the crisis but, more importantly, took years to understand that a fundamental change in the oil business had just happened — a switch from a buyer's market to a sellers' one (van der Heijden, 2005).

The success of the application of scenario planning led to its entry into Shell's processes for corporate strategy definition: in the beginning of the 1980s, the evaluation of projects against the set of scenarios being used at the time (instead of a single-line forecast, which had been used until then) became mandatory. This decade also saw the expansion of the scope of the scenarios, which started to move beyond business-related concerns (such as oil prices) to include economic and political issues (Cornelius, van de Putte, & Romani, 2005). By the late 1980s, the use of scenario planning had spread throughout the company and people in different sectors and at different levels were using the concept of equally likely alternative futures to help them in their decision-making processes.

With the beginning of the 1990s, Shell started to make publicly available a summary of the output of their triennial scenario planning process. It was also at this time that it started to consider external stakeholders and their perspectives, and to include geo-political and economic analyses in their scenarios (Cornelius, van de Putte, & Romani, 2005).

In 1992, with the fall of the Berlin Wall and the Soviet Union as a setting, Shell's scenarios addressed the question of how countries would respond to the increasingly movements towards globalization, and political and economic liberalization. While in *New Frontiers* these movements were embraced, sparking growth and improving standards of living in developing countries, *Barricades* described a world where national interest dominated, accentuating the gap between rich and poor countries (Royal Dutch Shell, 1992).

By 1995, when Shell's next set of scenarios was issued (Royal Dutch Shell, 1995), it was obvious that globalization, liberalization and technology advances were unstoppable, leading Shell's scenario planners to coin the acronym TINA - *There Is No Alternative* - which would be a recurring theme for years to come. For this reason, the two scenarios developed were built on 1992's *New Frontiers*. The main question for Shell was now how the world was going to adopt the forces of technology, globalization and liberalization: *Just Do It!* described a world driven by individualism and libertarianism, as opposed to *Da Wo* ('Big Me') where a more communitarian approach was considered.

Similarly to what happened in 1995, the 1998 scenarios built on *Just Do It!*, as this appeared to be the favored approach to the forces behind TINA (Royal Dutch Shell, 1998). Shell's focus was now on the effects of these forces (TINA above: increasing globalization, liberalization and technological growth) at the level of corporations, institutions and governments, and at the level of the individual (TINA below: increasing choices, education and wealth), questioning which of the two - *The New Game* and *People Power*, respectively - would dominate in the future.

The 2002 issue of Shell's scenarios looked at the recent reaction forces to TINA (such as the growing number of protests against globalization), and which group would be the most influential in defining the “three 'R's”: regulations for liberalization, restraints on technology and rules for globalization (Royal Dutch Shell, 2002). *Business Class*, as the name suggests, describes a world ruled by the global elite towards greater economic integration, whereas *Prism* looks at a more regional world, defined by multiple cultures.

With the September 11 terrorist attacks and the Enron scandal as background, the 2005 global energy scenarios focused on the effects of these crises on the relationships between the markets, civil society, and the states (Royal Dutch Shell, 2005). Shell presented this issue on what it called the *Trilemma Triangle*, where three forces - market incentives, communities, and state regulation - competed against each other for three (conflicting) objectives: market efficiency, social cohesion, and national security, respectively. Three "two wins, one loss" scenarios were developed — *Low Trust Globalization* (Security and Efficiency), *Open Doors* (Cohesion and Efficiency) and *Flags* (Security and Cohesion).

While TINA had been a driving theme throughout the 1990s and part of the 2000s, 2008 saw the introduction of its successor: TANIA (Royal Dutch Shell, 2008).TANIA came about as Shell recognized that the global energy system was facing serious challenges, driven by the three dilemmas identified in the previous iteration of their scenarios, and that there was no quick and easy solution to them; thus TANIA — *There Are No Ideal Answers*. Still, the scenarios developed described two alternative approaches: *Scramble* saw states rushing to secure their energy supplies; in *Blueprints*, coalitions at many different levels formed to address the challenges to supply, demand and even climate change.

Almost 40 years after its first scenarios, Shell's latest issue of its global energy scenarios concentrates on globally growing energy needs and the widening gap between supply and demand (Royal Dutch Shell, 2011). While it recognizes that the 2008 *Scramble* and *Blueprints* scenarios remain valid visions of the future, it updates them to reflect, among other things, the ongoing financial crisis (which started in 2008), the results of several summits and discussions on the subject of climate change and, the insights gained with the use of three Shell-internal scenarios, in use since 2008: *Severe-yet-Sharp, Deeper-and-Longer and Depression 2.0*.

1.4 The Role of Scenario Planning in Strategic Planning and Decision-Making

The use of scenario planning enables the understanding of the uncertainties affecting the business environment, improving the understanding about the problem at hand and promoting a critical examination of existing assumptions and mental models. Other techniques, such as forecasting, assume that a most likely future can be anticipated by looking at past and present trends of events in the business environment. This may work well in short-term planning situations but will most likely fail in long-term planning activities, as the degree of uncertainty may prevent any meaningful analysis. Furthermore, due to their reliance on trends, forecasts are usually unable to predict any significant discontinuities or disruptive events, which have considerable value to planners due to the significant change in strategy usually associated with them. Scenarios, on the other hand, recognize these uncertainties as unavoidable, and address them through the exploration and understanding of the associated events and underlying causes. Through detailed analysis of an organization’s business environment, scenario planners are able to develop scenarios against which strategies and decisions can be evaluated.

In order to be integrated in strategic planning activities, scenarios need to go through a set of processes: although scenarios allow for a significant reduction of some of the uncertainties associated with the business environment, these need to be reduced further so that a robust strategy can be defined. To narrow down the uncertainty it is necessary to analyze, for each scenario, market demand trends – this will indicate what the customer might be looking for under that particular scenario. From here, competitor intelligence can be used to infer possible strategies that competitors can employ and so highlight what can be done differently and uniquely. A comprehensive risk analysis of the business environment projection allows further reduction of the uncertainty associated with each scenario and, in turn, a better definition of the company's products or services. Even though strategy definition can accompany this progressive reduction in uncertainty, it is only at this point that a strategy can become fully defined. As scenarios provide a description of not only the business environment but also of the macro-economic environment, market demand can be modeled. The process of developing strategies from a set of scenarios is illustrated in figure 2 (Cornelius, van de Putte, & Romani, 2005).

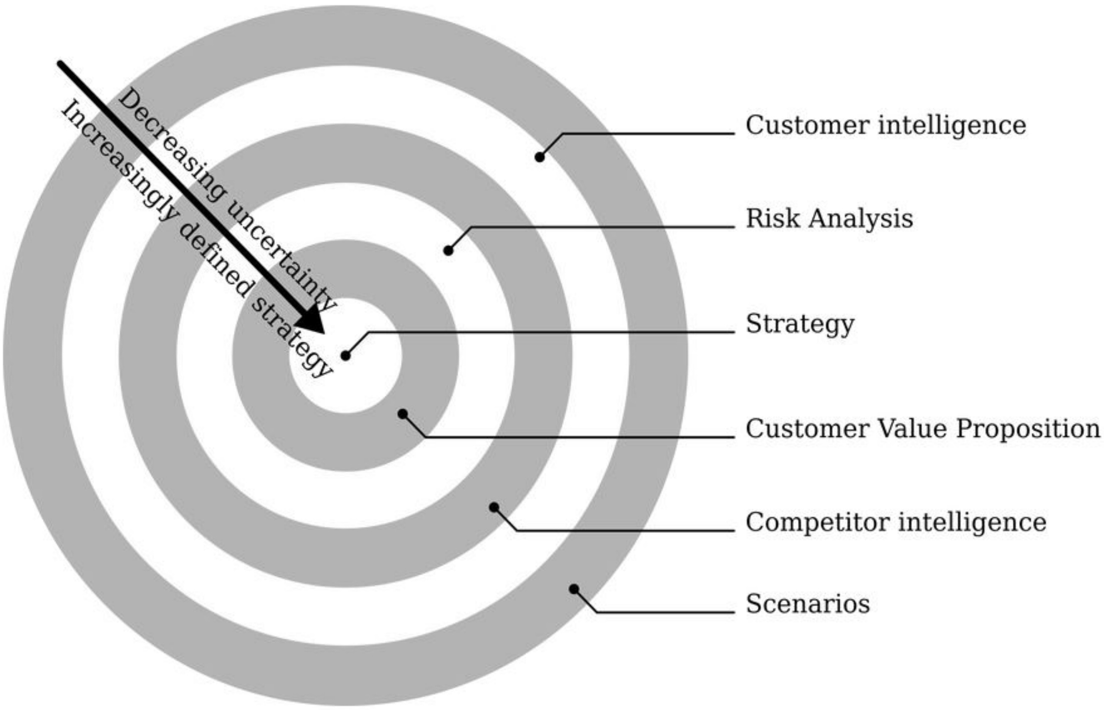

Figure 2. Strategies are Developed by Building upon the Information Contained in the Scenarios

In order to clarify the available options and think about their implications, scenario thinking should be addressed as a continuous activity, at various levels of strategy definition and decision-making. Understanding the scenario dynamics (i.e., its driving forces and cause-and-effect relationships) is a key aspect of this continuous ability to understand and assess the environment — only this way it is possible to recognize unfolding events and act accordingly. By forcing strategists and decision makers to continuously challenge their mental models by considering multiple plausible futures, scenario planning stimulates and encourages what is called organizational learning — a process that makes people change their assumptions and perceptions about the organization, markets and competitors (Schoemaker & van der Heijden, 1992).

2. Methodology

The first step of our work consisted of a thorough research and analysis of available literature on scenario planning, which allowed us to explore its history and the main methodologies used to support its practical implementation. This step also allowed the identification of relevant domain-specific literature and resources for the selected domains (oil and gas, defense and space). At this point, a quick assessment was performed in order to identify domains where there was a potential lack of information. This revealed some gaps for the defense and space domains, which were addressed by conducting additional research and by contacting domain experts in order to request additional information and resources. For each of the domains, examples of the application of scenario planning in a relevant organization were investigated, with a clear focus on the methodologies employed to develop scenarios, and on how these are integrated into the organization's activities.

Some remarks on the choice of organizations with respect to the selected domains should be made. For the oil and gas domain, Royal Dutch/Shell was chosen, due to its pioneering use of scenario planning and due to the wealth of information available on both the application of scenario planning and on the scenarios themselves. For the defense domain the North Atlantic Treaty Organization (NATO) was chosen, as it is a very important multinational organization. Similarly, for the space domain, the European Space Agency (ESA) and the United States' National Aeronautics and Space Administration (NASA) were chosen.

With the insight and understanding gathered thus far, we analyzed the differences on the use of scenario planning between domains and proposed a framework of scenario planning process selection based on two relevant domain characteristics. Finally, the relationship between scenario planning and systems engineering is addressed.

3. Results

3.1 Global Scenario Development Approach at Shell

The scenarios in use at Shell can be described as stories about different possible futures, covering the trends and events that lead up to them. These scenarios form the basis for strategic conversations - discussions about the implications of those futures on businesses and current strategies, and on how to best prepare for them. Shell's scenario development approach comprises five main phases: Preparation, Pioneering, Map-making, Navigation and Reconnaissance (Royal Dutch Shell, 2008). This process, while explorative and creative in nature, relies on analytical thinking, based on both clear facts and informed intuition, to prepare the company for the future, and is performed every three years.

3.1.1 Preparation

The preparation phase starts with the definition of the scenario project objectives, and the nomination of the core team of the scenario building exercise. Next, it is necessary to define and prioritize the focal issues that the team should analyze. Interviews with Shell's decision-makers follow, in order to explore possible factors or issues that they think are or should be a matter of concern, the clusters into which they would group them, and finally the possible cause-and-effect links between the events. The results of this step can be placed into two sets: a first set that relates to future trends or events in the external environment and will have a significant impact on the organization, and a second set where concerns, aspirations and barriers within the organization are pointed by the interviewee based on an individual perspective.

3.1.2 Pioneering

The second phase refers to the scenario building process and starts with the research material being brought together and cross-checked in order to highlight gaps and to broaden perspectives. Team members then discuss a wide range of subjects, such as science and technology, social change, economics, politics, globalization and governance, energy markets, connectivity, sustainable development and business design, etc., presenting their findings in their particular field of research. The intended result is to find new and critical questions about the future that can be grouped into smaller and more focused set of themes, setting the direction of further research.

The team needs now to understand how each theme might unfold in the future and what are the critical uncertainties associated with them. More specifically, the team has to identify the driving forces behind each theme and how they relate, the most certain and uncertain aspects of the driving forces, and what are the most likely certainties and the most challenging and extreme uncertainties.

The next step defines the scenario structure, which is composed by one or more focal questions (broad definition of the major challenge(s) that the primary users are likely to face in the future), a branching point with two or more branches for each critical uncertainty (different directions that critical uncertainties may follow) and the scenario outlines (stories that result from the selection of a certain path among the different branches). When outlining the scenarios, fundamental differences within and between scenarios, that result in major implications for the primary users, should be set. This is an iterative process that challenges and confronts the assumptions, perceptions and mental models of those involved, and can follow different approaches:

- Deductive — Two uncertainties are selected, and their ranges are drawn as the axes of a 2D graph. Then, storylines are developed, describing how the world would evolve from its present state to that described by each of the four quadrants. Finally, "transition" storylines are also developed describing how each quadrant could transform into one of the others (see figure 3).

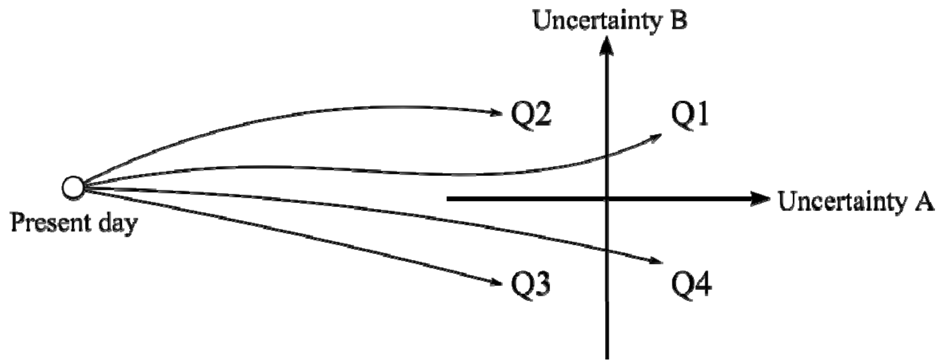

Figure 3. Deductive Approach to Scenario Development (the Transition Paths Are Not Pictured)

- Inductive — Several different chains of events (i.e., sequences with at least three events) are created, and a storyline is developed for each chain, describing how the world would evolve from the present day, through the chain's events, up to the defined time horizon, the point at which the (end) scenarios are described (see figure 4).

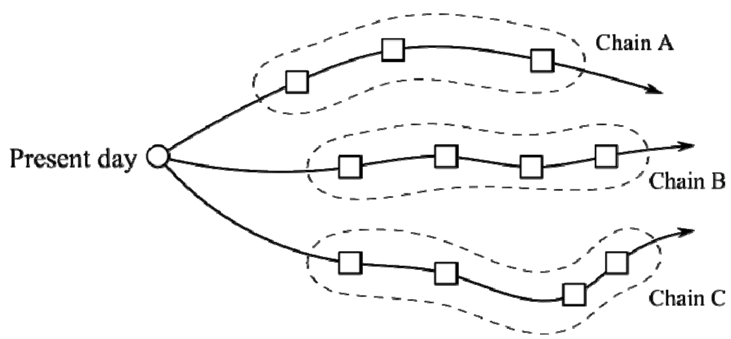

Figure 4. Inductive Approach to Scenario Development

- Normative — Unlike the two previous approaches, in the normative approach, planners already have an idea or description of the scenario at the desired time horizon. Starting from this description, a storyline of how the scenario could come into existence is developed by working backwards in time. This way, any necessary major events can be identified, and the plausibility of the scenario can be assessed (see figure 5).
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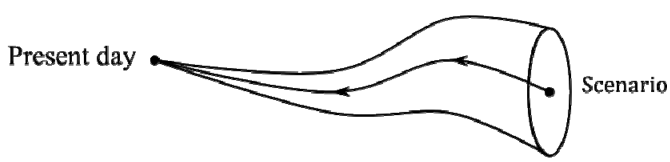

Figure 5. Normative approach to scenario development

After outlining the scenarios, these have to be tested for consistency and relevance - if they fail to meet both aspects, scenarios are reworked or disregarded. The internal consistency of scenarios ensures that the scenario structure and the respective storyline - i.e., the key issues, their driving forces and respective certainties or uncertainties and outcomes - are compatible. The objective is to look for contradictions using, for instance, a consistency matrix. The relevance of the scenario set should also be addressed considering the users or the target audience of the scenarios. Shell's approach to scenario development does not include the assignment of probabilities to the different scenarios nor to their constituent elements, as scenarios are intended to recognize and describe different perspectives and not to combine the differences into quantifiable values.

3.1.3 Map-Making

Once scenarios are ready, they can be presented to the scenario builders and tested for plausibility and challenge. The outcome of all the scenarios must be capable of happening — plausibility — and a morphological analysis is often used for the purpose. Ideally, scenarios should also represent a clear break with the present mental models, challenging the underlying assumptions — this is fundamental for the scenarios to be of value. The resulting scenario set will address the same key issues and include the same certainties - what will differ in all scenarios is the way uncertainties may unfold.

3.1.4 Navigation

Shell does not use scenarios as a one-off exercise that addresses particular situations. Instead, scenarios are used in a systematic way over a period of time, supporting the development of the organizational strategy, challenging assumptions and mental models, and testing plans and strategies. Therefore, it is important that individuals connect their own perspectives with the scenarios, as an attempt to challenge their assumptions and confront these with those of others, shaping the way they think and perceive the future.

3.1.5 Reconnaissance

A proper reflection of scenarios' implications on future strategies follows the full understanding of those scenarios. Shell suggests that if implications seem to be the same, regardless of the scenario, then this may indicate that a particular set of actions can or should be implemented immediately and securely. Still, the pursuit of other strategic options will depend on how well they will play in all the scenarios and, obviously, on how the business environment actually evolves. At this stage, planners also look for signals that indicate whether the dynamics explored within each scenario, and on which potential decisions and strategies are based, are actually happening. This will help organizations respond faster and more effectively to a changing environment.

3.2 NATO's Long Term Defense Planning Process

With the end of the Cold War, there was a considerable shift in long term planning at NATO, as it moved from planning against a single, dominant threat (with regular updates driven by technology advancements and conflict developments) to a world of diverse, fast-moving threats. This led NATO to develop its current Long Term Defense Planning Process (LTDPP), which usually looks from ten to thirty years ahead to identify the capabilities needed to deal with future threats (RTO Studies, Analysis and Simulation Panel, 2003). In its LTDP handbook, NATO describes some of what it considers the best practices of conducting long term defense planning, which includes the use of scenario planning. One of the scenario development processes used by NATO in the scope of Long Term Defense Planning considers three phases: Framing, Mechanics and Appraisal.

3.2.1 Framing

The process begins with the definition of the key issue or problem, which, depending on the level, will address political, military, operational or tactical challenges (in growing level of detail). Together with the level, a detailed problem definition will help in the identification of the dimensions of the problem space. The following are presented as typical dimensions (from (RTO Studies, Analysis and Simulation Panel, 2003)):

- General:
    - Time frame
    - Conflict scale
- Security environment:
    - Area of interest (Gulf of Aden, Middle East, etc.)
    - Type of situation (crisis, peace, war fighting, etc.)
    - International relations (alliances, partnership, confrontation, etc.)
    - Alliances (NATO, etc.)
- Parties:
    - Parties involved (groups, nations, etc.)
    - Political objectives
    - Strategic military objectives
- Conflict:
    - Military capacities
    - Technological level
    - Geography
    - Duration
- Facts:
    - Concept of Operations
    - Doctrine
    - Technology
    - Time dynamics
    - Trends
    - Threat Evolution

It is worth to note that, unlike other domains, the problem space can include several dimensions (i.e., more than just two or three); since each scenario represents a point in the problem space, the resulting set of scenarios can be (very) large.

3.2.2 Mechanics

This phase covers the systematic identification of the driving forces behind the key issue and the construction of the scenarios. While the handbook (RTO Studies, Analysis and Simulation Panel, 2003) does not describe the process used for the identification of the driving factors, it does describe the use of the morphological analysis to define the ranges for these, for the problem space dimensions and, additionally, for the identification of relevant sets of values from these, from which to build scenarios.

3.2.3 Appraisal

The final phase of the process focuses on the use of two main criteria to review scenarios: credibility and relevance. For a scenario to be credible, it needs to be plausible. This is, however, unrelated with the scenario's probability: a scenario needs to be possible, not probable (in fact, it may even be unlikely, as long as it is plausible). The other criterion, relevance, means that the scenario should be useful with respect to the focal issue and the purpose of the scenario planning exercise, while also containing enough information to be of use to its end-users, such as military analysts and decision makers. At the end of the scenario building process it is often necessary to perform a trade-off between the number of scenarios for analysis (a large set is often desirable so that it spans the entire uncertainty space) and the required analytic resources (often limited). The problem of scenario selection is addressed in several ways, by ensuring that the scenario set is:

- Consistent with the issue under consideration
- Appropriate to the processes for which it serves as input (e.g. mission analysis, training and education, systems procurement, .etc.)
- Covers only key dimensions (i.e., external factors, capabilities of actors and environmental factors)

3.3 European Space Agency's Long-Term Plan

Scenario planning has been used regularly at the European Space Agency (ESA) with the objective of defining its Long-Term Plan (LTP) by re-evaluating ESA's programs against different political and economic scenarios. Even though ESA's LTP is updated yearly, scenario planning is performed every three years, in preparation for ESA's Ministerial Council (triennial), where its long term strategy (and funding) is discussed and agreed. Within the scope of the LTP preparation, ESA develops what are called programmatic scenarios.

The programmatic scenarios take as key uncertainties the member states' contributions and preferences with respect to particular programs, and funding from the European Union (EU) for different programs. The scenarios focus on assessing the high-level financial impact that possible variations on this funding may have in the on-going and future programs of the Agency. For each scenario, the consequences on all programs are assessed and, if applicable, some alternatives are suggested (e.g. collaborations with other agencies in response to a decrease in funding).

These scenarios, developed by looking at the worldwide political environment and at different

European institutions, are based on regular analyses of the political and economic situation and relevant trends provided by ESA offices located in Washington (where NASA Headquarters are located), Moscow (location of Roscosmos headquarters) and Brussels (seat of the European Commission and location of the European Parliament). For ESA headquarters, scenarios mainly describe different evolutions for the EU and member-states' contributions towards both mandatory and optional programs. These scenarios are then used to define alternative proposals — comprising funding levels, plans and roadmaps — for each program, while trying to fulfill its short (1-2 years), medium (2-4 years) and long-term (5-10 years) objectives. The goal is to develop a set of proposals that fits with the developed scenarios, the evolution of Europe's space policy, and is compatible with member-state's funding levels, as well as their expertise and industrial base.

More recently, scenario planning has also been used at the European Space Agency in the Forecast of the European Space Sector study (4ESS). This study aims to better understand and gain insight on the European Space sector by, as the name implies, forecasting its evolution under different scenarios so that recommendations and suggestions for improvement can be made (European Space Agency, 2012). Due to the fact that 4ESS is a recent study, and that there is limited information publicly available, it is unclear how the scenarios, findings and recommendations from the study are being developed and integrated into ESA's activities.

3.4 Scenario-Based Strategic Planning for NASA's Aeronautics Enterprise

In 1997, the United States' National Research Council (NRC), in cooperation with NASA, The Futures Group (TFG) and the Systems Technology Group of the Science Applications International Corporation (SAIC), conducted a scenario-based study with the goal of helping NASA define its strategy by achieving a better understanding of how possible long-term (15 to 25 years) developments of the global aeronautics domain would impact the US position and competitiveness, and of how to plan appropriately (National Research Council, 1997). The study was divided into three main phases: a pre-workshop phase, a scenario development phase and a planning phase.

The scenario building process started with the identification of the main issues and trends - past, present and future - driving the aeronautics domain and its several branches, such as military and civil aviation and space, air traffic management, information and communication systems, and global and national transportation systems. This was achieved through a series of interviews with domain experts within those branches, as well as leaders in the aeronautics field, who were asked to think about possible issues impacting the future of the global aeronautic sector, and to identify the driving forces behind them. These drivers were then condensed into a smaller set of drivers, which became the dimensions of the scenario space. Considering two possible variations for each driver, several combinations of scenarios were determined and five scenarios were selected for further analysis at the workshop due to their challenging nature or opportunities they presented for the future of aeronautics.

After the scenarios were outline and selected, these were then taken to the workshop, where each scenario was assigned to a group of participants that included experts from academia, government and industry. Each group was tasked with further development and refinement of the scenario to which they were assigned, by creating a storyline, describing how the driving forces would evolve over time up to the defined time horizon while, at the same time, considering the effects of potential incremental and disruptive technology developments. Once development was complete, each group looked at its scenario to identify opportunities and needs for the aeronautics sector, their technology implications, and to discuss if and how NASA could play a role in addressing those needs and opportunities.

Once all groups finished the development and analysis of their scenarios, a cross-checking phase ensued, where the needs and opportunities identified for each scenario were assessed and grouped with respect to their applicability to each of the remaining scenarios. This enabled planners to prioritize sets of needs and opportunities to later discuss their implications in terms of science and technology. The ultimate goal was to identify a set of areas of technological development required to maintain US competitiveness in the aeronautics field, which would then be used by a government-industry-academia partnership (with NASA as lead) to define a formal national R&D strategy.

4. Discussion

4.1 Use of Scenario Planning in the Selected Domains

One of the most immediate and relevant findings of our research was the difference between the consistency and maturity associated with the use of scenario planning in the different domains. While both Royal Dutch/Shell and NATO appear as very consistent and mature users, employing established techniques covering different levels of the business environment, users in the space domain appeared to be at the other end of the spectrum: other than ESA's regular use of programmatic scenarios, scenario planning exercises seem to be sporadic and limited to large-scale, strategic applications, focusing on the evolution of an entire sector - ESA's 4ESS and NASA's NRC studies. It is interesting to note that, in both cases, the agencies resorted to external institutions to help them with the exercise - in line with the maturity of in-house scenario planning expertise at that level. Also relating to maturity is the finding that Shell's application of scenario planning has been so successful that it has been able to construct scenarios based on those from a previous iteration, indicating that the latter have, to some extent, materialized and, more importantly, validating Shell's process.

Another interesting finding is the fact that the programmatic scenarios in use at ESA are close to what Wack termed “first-generation scenarios”, that is, scenarios based on the quantification of straightforward uncertainties (Wack, 1985). Still, given that the purpose is to define proposals to be presented to member-states, the use of first - rather than second - generation scenarios might be sufficient.

Finally, it is worth to note that other than a mention of the potential use of the Prospective methodology in one of the NATO's documents, most, if not all, applications seem to rely on the Intuitive Logics group of techniques. This may be due to, on the one hand, it being a very well-known technique as evidence by its wide use, and, on the other hand, the fact that most of the issues (and respective key drivers) covered do not lend them to the mathematical modeling required by other techniques.

4.2 A Framework for Process Selection

The selection and application of different strategic planning processes (and of different scenario planning processes in particular) depends on the main characteristics of an organization's business environment, and, of course, on the available expertise on strategic planning and on the history and maturity of those processes at the organization. Based on our results, a framework that tries to capture this selection process and that addresses the *methodological chaos* (Martelli, 2001) resulting from the many scenario planning processes available, is proposed in figure 6.

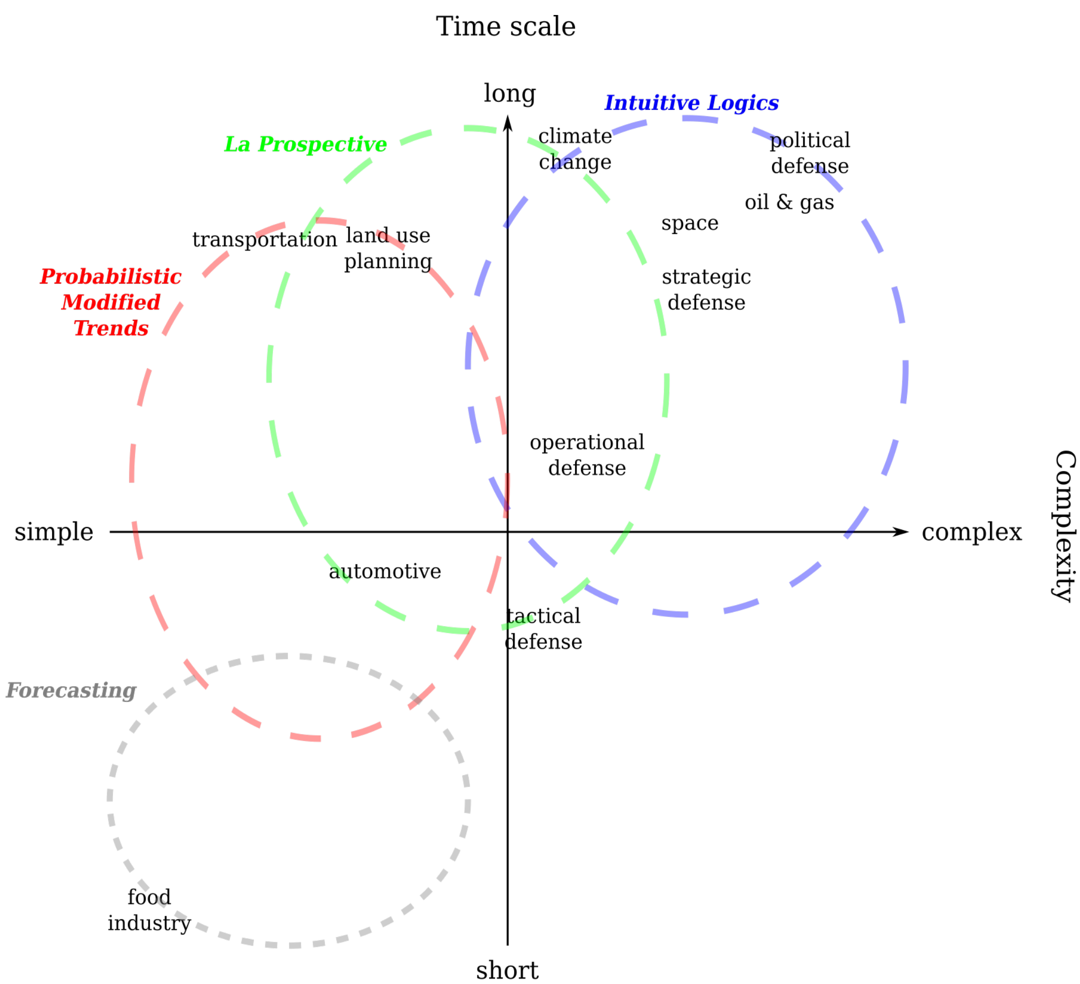

Figure 6. An Example of a Framework for Scenario Planning Process Selection

This framework relies on two domain characteristics that reflect, to some extent, important criteria organizations use for strategic process selection: time and complexity. These dimensions are not part of the scenario method itself and do not need to be validated as such. Instead, they are a lens we have chosen to look through to better understand the application of the process and to distinguish between domains and the suitable scenario planning method.

Here, time refers to the driving (or characteristic) timescales of a domain's most important processes and the life cycle of its products. Domains concerned with short timescales may employ strategic tools such as forecasts, as the immediate future may not have a sufficiently high level of uncertainty to require in-depth considerations to be made about the more distant future, unlike organizations working mostly with long-duration projects and systems.

Whereas for the commercial aircraft industry, for instance, this could be in the order of 40 years (the duration of the life cycle for a given aircraft model, from concept to disposal/end of support operations), for the space industry it could be half that value (e.g., a typical earth-observation satellite project may last for 20 years). On the other end of the spectrum is the consumer electronics sector - a very agile industry working with extremely short life cycles (when compared with the previous examples). For this reason, the planning horizon should also be much shorter — the case could then be made that forecasting techniques may still be of use since, as forecasts will not be made too far into the future, there is not considerable associated uncertainty.

Complexity, in turn, could be thought of as referring to how easy (or difficult) it is to formally describe or model the relationships between a domain's driving forces and uncertainties. Simple or low complexity domains or sectors are those for which there is a clear, visible cause-and-effect relationship between driving forces and uncertainties, and where there is also a low degree of coupling between drivers. In contrast, complex or high complexity domains would be those in which the cause-and-effect between driving forces and uncertainties are not fully visible and/or well understood. At the same time, there may also be hidden couplings between key drivers, making the application of scenario development processes harder.

In domains for which mathematical models can be obtained for some or most of the associated driving forces and uncertainties, analytic techniques such as *La Prospective* or Probabilistic Modified Trends can be used. An example of a low complexity domain would be the food industry, where key drivers are simple, and the connections between these and the uncertainties are (arguably) straightforward. Contrarily, in domains with high complexity, such as defense, characterized by political and diplomatic, not always visible uncertainties, analytic techniques are less of an option, rendering applications of strategic planning heavily reliant on expert judgment and qualitative (rather than quantitative) analysis.

It is important to say that all the domains represented were placed in the framework considering the positioning of the other domains. For instance, climate change and defense are both high-complex domains but the latter appears as more complex as the former. This results from the fact that even though the driving forces behind climate change are considerably complex, these relationships tend to be more visible than those in defense, which results, based on our description, in a more complex environment.

Finally, it should be noted that this framework is provided as a high-level example of what a framework for scenario planning method selection could look like and that we do not intend to look at it as a unique picture of the industries represented. Further refinement of this framework requires both depth and breadth in domain-specific research, that is, the use of scenario planning needs to be researched in other domains and, for each domain, more than one organization should be considered.

4.3 Potential Use and Value of Scenario Planning for Systems Engineering

Despite being used almost exclusively as a strategic planning tool, scenario planning can also be used to aid and add value to other activities. For instance, it can help project managers and system development teams to manage risk, by ensuring that a more robust assessment is performed through the consideration of multiple plausible environments. The use of scenario planning also allows for greater confidence on the operational flexibility of a given system, as the risks of operating it in a set of different environments are better understood. Scenario planning may also encourage a creative and forward-looking approach to design, as it embraces uncertainty and frees the designer to contemplate otherwise impossible trade-offs.

A successful system is one that delivers value to its stakeholders by meeting (or exceeding) their needs. These, however, may change over time and, as a result, the same system will be delivering less value (i.e., moving target problem). If, instead of looking at stakeholders' current needs, system designers try to understand what are the factors driving those needs and how they may evolve over the system's life cycle, a more meaningful and robust set of needs (and corresponding definitions of value) can be obtained.

At the same time, as it is seldom the case - particularly for systems with long development cycles - that the operating environment is the same as the one which was envisioned in the early stages of system design (or, even if it is, that it stays the same over the system's lifetime), it also makes sense to use scenarios to address the uncertainty associated with a system's future operating environment.

Applying a scenario planning approach to stakeholder needs identification and usage modeling would help address one of the biggest challenges in systems design - requirements definition. Changes in requirements are commonplace during system development, as stakeholder needs may change in response to changes in the systems environment and, of course, due to the progressive maturity of the system's design. As the design matures, however, changes in requirements become increasingly costly, due to the amount of effort required to comply with a new requirement in an otherwise well-defined system. The use of a scenario-based approach to the previous design phases would help designers define a more robust set of system requirements, that is, a set of requirements that are applicable to all the scenarios that were considered.

5. Conclusion

Current scenario planning methodologies differ considerably in their nature. While techniques such as Trend Impact Analysis, Cross Impact Analysis and *La Prospective* follow a more mathematical approach, their applicability is somewhat limited, as they often require the use of quantitative data such as time series, which, depending on the focal issue and driving factors being considered, may not be available. At the same time, these techniques often require the assignment of probability distributions to the occurrence of possible future events, which may rely on the use of unjustifiable assumptions. Intuitive Logics techniques, on the other side, have a greater range of applications, but are less scientific in nature, relying heavily on qualitative and subjective judgment, thus making their process less transparent and traceable.

Another important aspect in the use of scenario planning has to do with the value associated with the scenario set, which, of course, depends on the technique used. The Intuitive Logics approach, for instance, may use the extreme values of the two most critical uncertainties to span the so-called problem space, which in turn defines the set of possible outcomes. Moreover, there is additional value in the fact that this technique promotes understanding and insight about the key issue by challenging existing mental models about the problem. Other techniques use different approaches to come up with the scenario set, which may or may not fully represent the scenario space or improve understanding of the problem.

The framework proposed reflects the fact that, depending on the specific characteristics of a certain domain or application, different scenario planning processes may be better suited. The development of an improved framework based on different criteria (including the value a technique creates), could not only help planners choose the technique that best fits their needs, but it could possibly help address the current issue of *methodological chaos* (Martelli, 2001).

Finally, a more detailed understanding of how scenario planning could contribute to other processes is fundamental to increase the scope of its applicability and take advantage of its benefits at different levels of organizations. This will require detailed review of existing scenario development techniques to determine how these could be tailored to other processes.

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