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A review of scenario planning

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ABSTRACT

This paper reviews the scenario planning literature looking for answers for the following questions: How do qualitative and quantitative scenario methods differ and what are the advantages and disadvantages? What methods exist for quantitative scenario planning? Particularly quantitative scenario methods often lead to a large number of so-called "raw" scenarios that need to be further refined, discussed, and verbally described. How do scenario planners select raw scenarios for further exploration and how many should they choose? How is the problem of validation addressed in scenario studies?

1. Introduction

In the present era characterized by uncertainty, innovation and change, increasing emphasis is being placed on the use of scenario planning techniques because of its usefulness in times of uncertainty and complexity [1]. Scenario planning stimulates strategic thinking and helps to overcome thinking limitations by creating multiple futures. This paper provides a detailed review of scenario planning literature, highlights various prominent scenario building techniques and discusses the scenario selection and validation issues. Section 2 provides an overview of the field of scenario planning. In Section 3, the principal scenario development approaches are discussed. Section 4 describes the quantitative techniques for scenario planning and makes comparison among various quantitative scenario planning approaches. Section 5 discusses the appropriate number of scenarios and how to select raw scenarios in a scenario building project. Various tools and techniques presented in the literature are used for identification of the most critical scenario drivers and selection of the scenarios. In Section 6, scenario validation criteria presented in scenario planning literature is summarized. In the end, conclusion of the paper is presented.

2. Scenario planning

Scenarios are considered a valuable tool that helps organizations to prepare for possible eventualities, and makes them more flexible and more innovative [2]. Scenarios are outline of some aspects of future and generally scenario refers to an outline of the plot of a dramatic work, script of a motion picture or a television program [3]. Herman Kahn is considered one of the founders of futures studies and father of scenario planning, defines scenario in his book as "a set of hypothetical events set in the future constructed to clarify a possible chain of causal events as well as their decision points" [4]. Scenarios are description of a future situation and the course of events which allows one to move forward from the actual to the future situation [5]. Scenarios are also defined as alternative futures resulting from a combination of trends and policies [6]. Scenario planning techniques are frequently used by managers to articulate their mental models about the future in order to

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make better decisions [7]. In technology planning, forecasting, strategic analysis, and foresight studies, scenarios are used to incorporate and emphasize those aspects of the world that are important to the forecast.

Systematic use of scenarios for clarifying thinking about the future started after the World War II and US Department of Defense used it as a method for military planning in 1950s at RAND Corporation [3,4,8–13]. After that scenario methodology was extensively used for social forecasting, public policy analysis and decision making in 1960s. Scenario building process exerts a strong influence on human thinking, decision-making process and initiate a public debate [14]. Schoemaker describes that scenario planning must outline the possible futures, capture a wide range of options, stimulate thinking about the future and challenge the prevailing mindset and status quo [1,15]. Futures studies help to see the present differently and these are a devise for 'disturbing the present' [16]. Therefore, it is important that while developing and analyzing scenarios, it should be encouraged to consider options beyond the traditional operational and conceptual comfort zone of the organization [17–19]. This encouragement will help to explore new possibilities and unique insights.

Consideration of multiple possible future alternatives helps to conduct future planning in a holistic manner [20,21] and significantly enhance the ability to deal with uncertainty and the usefulness of overall decision making process [9,22]. Scenario planning helps us to be prepared for futures and innovate the futures [2]. Scenario planning is a good way to question the future [23]. Scenarios provide an overall picture of the environment and highlight the interactions among several trends and events in the future [24]. Moreover, scenario planning presents all complex elements together into a coherent, systematic, comprehensive and plausible manner [3]. Scenarios are also very useful for highlighting implications of possible future system discontinues, identifying nature and timings of these implications, and projecting consequences of a particular choice or policy decision [17]. Scenario provides the description of future situation and the development or portrayal of the path that leads us out of today and into the future [25]. Schwab et al. also state that scenario approach involves developing future situations (scenarios) and describing the path from any given present to these future situations [26]. Thus scenario planning process helps to make the desirable future real [27].

Use of scenario planning has increased significantly during the last decade [28]. Research indicates that there is correlation between adoption of scenario planning techniques and uncertainty, unpredictability and instability of the overall business environment [29]. Increasing uncertainty has increased the importance of identifying future trends and expected business landscape. Therefore, utilization of scenario has increased due to greater complexity and uncertainty in the business environment. Researchers have also reported a direct link between scenario planning activities and innovation [30].

In general scenarios can be developed for any time frame but generally they provide greater usefulness if developed for long term [7]. Usage of scenario planning for long range planning and strategic foresight facilitates to adapt quickly to major changes [22]. Future uncertainty increases as we move away from the present and look further into the future. Fig. 1 highlights the widening of scenario cone and broadening of the realm of future possibilities [25]. Various factors which can influence the direction of future development of an enterprise are also shown in Fig. 1.

Scenario planning has been extensively used at corporate level and in many cases it has been applied successful at national level [10,31,32]. Scenarios are applicable to the planning needs of all large public and private institutions especially at times when a critical decision has to be made in uncertain environment. Scenario planning helps organizations to test their strategy [2]. At corporate level Shell is considered the most celebrated and best known user of scenarios in the world for business context and usage of scenarios has helped the company to cope with the oil shock and other uncertain events in 1970s [3,10,33]. Empirical research conducted by Linneman and Klein indicates that after the first oil crisis in early 1970s, number of U.S. companies using scenario planning techniques doubled [34,35]. It was observed that at corporate level scenario planning approach was more popular among large size companies, scenarios were generally used for long range planning for 10 years or more, and majority of scenario users belong to capital intensive industries like aerospace, petroleum

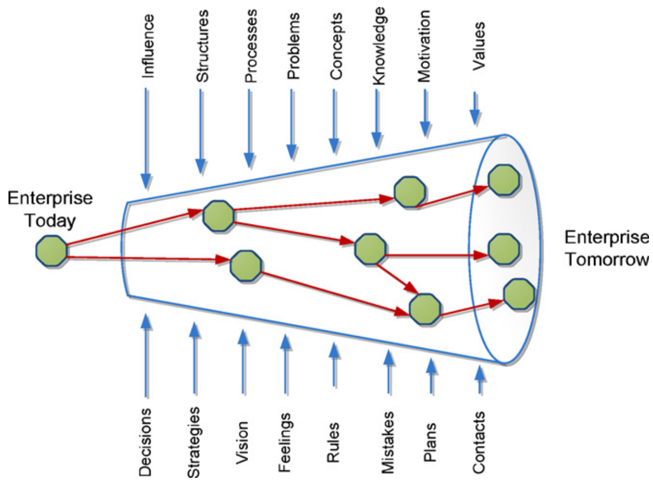

Fig. 1. Scenario cone showing multiple possibilities [25].

etc. They further reveal that almost fifty percent (50%) of all US Fortune 1000 companies were actively using scenarios in the early 1980s [34,35].

Pierre Wack published two papers in Harvard Business Review, which are considered the most frequently quoted papers in scenario planning literature [36,37]. Based upon his vast experience in scenario planning at Royal Dutch Shell, he presented scenario building criteria based on three main principles including, identification of the predetermined elements in the environment, the ability to change mindset in order to re-perceive reality and developing macroscopic view of the business environment [37–39]. Predetermined elements are historical actions, events that have already occurred or likely to occur. It is critical to unfold consequences of these events because they act as the driving forces pushing for outcomes [38,39]. Macroscope is used as a metaphor, means to encourage people to explore their environment over a wider area than they would normally undertake and bring out the idea of the wider, complex inter-connected system in which an organization exists [37]. Moreover, new understanding of the business environment will change managerial mindsets and it will help them to acquire the ability to re-perceive reality [38,39]. Mintzberg also highlights the importance of changing the managerial worldview and state that it is a much more demanding task than building the scenarios [40].

The scenario building process also contributes toward organizational learning [41,42]. A recent study on review of scenario planning literature reveals that main benefits of using scenarios are improvement of decision making process and identification of new issues and problems which may arise in the future [22]. In the scenario planning literature, scenarios mean different thing for different users and often developed for various purposes [43]. Scenarios are developed for different audiences depending upon the scope of the scenario project. According to a research by European Foresight Monitoring Network, the potential audiences of scenario planning studies may be from government agencies, industry, non-governmental organizations, private companies, decision makers and general audience [44]. However, scenarios must be matched appropriately to the needs of the client and their expected outcomes [23].

Scenario does not predict the future, but it explores multiple plausible future situations with the purpose of extending the sphere of thinking of the participants in the scenario development process [45,46]. Scenarios are different from forecasts because in scenarios a range of possible outcomes resulting from uncertainty are explored whereas, purpose of forecasts is to identify the most likely pathway and estimate uncertainties [25]. Therefore, scenario planning is not forecasting of the most probable future but it creates a set of the plausible futures [47].

3. Classification of scenario planning methods

There is no single approach to scenario planning and literature review reveals that there are several methodologies for generating scenarios with many common characteristics [3,10,13,22]. In general scenario planning is a fairly practitioner driven approach. Bradfield et al., Keough et al. and Chermack et al. review various methodological approaches and guidelines presented in the literature for scenario building [10,13,48]. Bishop et al. also study more than dozen techniques for scenario planning and comment on utility, strengths and weaknesses of these methodologies [49]. Scenario building models presented by Schwartz and Schoemaker are considered very popular and often cited in the scenario planning literature [10,22,48]. Schwartz describes in detail each step of his scenario building model consisting of eight steps and suggested plotting scenario drivers to develop various scenarios [50]. Schoemaker presents a very comprehensive and detailed scenario building model consisting of ten steps and recommends to initially develop two extreme scenarios (optimistic and pessimistic scenarios) [15,51]. After reviewing several prominent scenario planning models Keough and Shanahan also present a generic scenario building model [48]. In general these scenario building techniques emphasize on defining the issues, identifying key drivers, stakeholders, trends, constraints and other important issues in a systematic way and ranking of these items by importance and uncertainty.

The scenario development approaches presented by Dator, Inayatullah, Galtung and Wilber are depth based, rather than bread based and instead of dealing with uncertainty, these scenarios expose power relations. Eminent futurist Dator states that, "What futurists can and often do study, are 'images of the future' in people's minds" [52]. He further elaborates that future studies often serve as the basis of actions in the present. Dator's work on his alternative futures approach articulates four scenario archetypes [53]. Taking these four scenarios, one can envisage how future would look in each of these scenarios [54]. Dator proposes the following archetypes [53]:

Continued growth: In this future, it is assumed that current conditions and trends are enhanced.
Collapse: This future results as continued growth fails and there are great contradictions.
Steady state: This future seeks to arrest growth and find a balance in the economy and with nature. It highlights a balanced, softer and fairer society.
Transformation: This future tries to change the basic assumptions of the other three. It comes out either through dramatic technological change or spiritual change.

Inayatullah develops an integrated approach to scenario planning consisting of the preferred future, the disowned future, the integrated and the outlier [54]. He develops causal layered analysis and demonstrates the role for causal layered analysis for transformative futures thinking [54,55]. Inayatullah's method is a sophisticated way to categorize and organize different views of and concerns about the futures. Therefore, it helps to think effectively about the futures. Inayatullah states that in an increasingly complex world, futures studies can help people to create the world in which they wish to live [54]. He also proposes connections between six foundational futures concepts, six questions, and six pillars of practice [55]. He outlines ways to integrate several eminent futures techniques: including macro-history, scenarios, futures wheels, integral futures, and emerging issues analysis [55].

Dator's approach provides the scenarios of continuation, collapse, disciplinary society and transformational society through high technology or high spiritual change. It facilitates futurist's abilities to name and frame their own ideas and concerns, and their potential for change within such debates. Whereas, Inayatullah argues that alternative future scenarios are conjured and derived, based on how the notion of the future is being perceived, preferred or even feared. Inayatullah emphasizes that futurists should attempt to "deepen the future" by applying causal layered analysis to seek possible social, economic and political perspectives on the issues anticipated.

Bezold from the Institute for Alternative Futures (IAF) develops *aspirational futures*: an approach to learn about future and its uncertainty from the understanding what might happen and commitment for creating the preferred future [56]. This approach is based on Dator's work on his alternative futures approach and Alvin Toffler's work [56]. Similarly, Robertson uses similar categories: business as usual, disaster, authoritarian control, hyper-expansionist and humane ecological [57]. Other futurists also propose similar scenarios entitled 'more of the same', technological fix, edge of disaster and sustainable development [58].

Wilber presents a way of integrating the central ideas using a multiple disciplinary approach consisting of scientists, engineers, psychologists and even mystics [59–61]. This synthesis resulted in a framework that views the world through a four quadrant framework created by a simple division between inner and outer on a vertical axis; and between individual and social on the horizontal axis. According to Wilber, the upper half of the diagram represents individual realities, whereas the lower half indicates social or communal realities. Similarly, the right half represents exterior forms (i.e. what things look like from the outside) and the left hand highlights interior forms (i.e. what things look like from within) [59–61]. It is also arguably the most comprehensive macro-history theory available to date [62].

Slaughter, Hayward and Voros present integral framework for scenario development [61,63–66]. Slaughter argues that scenarios development approaches focus almost exclusively on external and empirically based observations of reality that take the worldview of the observer, and actors within them are for granted [61]. Slaughter further emphasizes that futurists and foresight practitioners should look more deeply into their social contexts to find the levers of change. Integral futures approach provides deeper insight into the nature and dynamics of individual organization, and help to address the missing elements. Integral scenario methods are generally better methods because they can achieve higher quality outcomes than previous methods, provide richer options and helps to engage in depth with the multiple scenarios and crises situations [56,59,61,62].

Dennis List proposed a new, comprehensive, and flexible approach to anticipate the future, based on scenario planning and named it Scenario Network Mapping (SNM) [67,68]. In this approach a wide range of stakeholders participate in creating a roadmap-like scenario network rather than the several discrete scenarios developed using any traditional scenario planning approach. These networks begin in the past and may have multiple entry points into the present. Each node in the network is regarded as a scenario and can be explored in detail if required.

On the basis of perspective, scenarios are classified into descriptive and normative scenarios [31]. Descriptive scenarios are extrapolative in nature and present a range of future likely alternative events. Normative scenarios are goal directed and respond to policy planning concerns in order to achieve desired targets. Scenarios are also classified on the basis of scenario topic (problem specific verses global scenarios), breadth of the scenario scope (i.e. one sector verses multi-sector scenarios), focus of action (i.e. environmental verses policy scenarios), and level of aggregation (i.e. micro verses macro scenarios) [69].

Numerous scenario building methods have been developed, ranging from simplistic to complex, qualitative to quantitative. Some scenario building techniques essentially rely on qualitative approaches and inputs, while others make extensive use of statistical and computational tools (quantitative techniques) [70] and on this basis we can characterize scenarios based on qualitative data and quantitative data [71]. Due to large number of scenario development techniques and models presented in the literature some authors describe it as 'methodological chaos' [7,13]. Schnaars cites that some scenario development models presented in the literature are impractical and never been adequately tested [46]. Some researchers argue that preference for scenario planning approach has slightly declined because scenario methods are evolved into set of very complex sub-techniques which are difficult to implement easily and often help of an expert and/or a sophisticated software tool is required [72].

There are three schools of techniques or major approaches for the development of scenarios having some sub-techniques [8,13,73–75]. Two out of these three principal approaches for scenario development are initiated from Anglophone countries USA and UK, and one emerged from France. These approaches are: (1) intuitive logics, (2) probabilistic modified trends (PMT) methodology and (3) the French approach of La prospective.

3.1. Intuitive logics school

Intuitive logics methodology has received most of the attention in the scenario planning literature [13]. This approach was earlier proposed by Herman Kahn at the Rand Corporation in the 1960s. Intuitive logic approach was used by Pierre Wack and his colleagues at Royal Dutch Shell [38,39], therefore, sometimes this technique is also referred as the 'Shell approach' to scenarios. This method now dominates the scenario development in the USA and many other countries [13]. Intuitive logic approach assumes that business decisions are based on a complex set of relationships among the economic, political, technological, social, resource, and environmental factors [74]. These scenarios are hypothetical sequences of events constructed for the purpose of focusing attention on causal processes and decision-points [76]. It is important to clearly understand these factors in order to provide insights and improve decision making process.

Intuitive logics approach does not use any mathematical algorithm and scenario development models proposed by Schwartz and van der Heijden belong to intuitive logics approach [25]. There are many variations of the intuitive logics models published in the literature ranging from five steps to fifteen steps or more [13,77]. However, the methodology proposed by Stanford Research Institute International (SRI) is the most popular and frequently used [73–75].

Intuitive logical approach can be used to develop flexible and internally consistent scenarios. However, this technique strongly relies on the knowledge, commitment, credibility and communication skills of the scenario team members [74]. Some of these key environmental forces are precise, quantitative and predictable, like demographics etc., while many other factors are imprecise, qualitative and difficult to predict like customers' attitudes, politics, financial condition, product demand etc. [75].

3.2. Probabilistic modified trends (PMT) school

This second approach known as the 'probabilistic modified trends' methodology evolved out of the work of Olaf Helmer and Ted Gordon and others at the RAND Corporation in the USA [13,49]. This school of scenario planning incorporates two quite different matrix based methodologies, trend impact analysis (TIA) and cross impact analysis [13]. These techniques involve the probabilistic modification of extrapolated trends.

The underlying principal for the development of TIA at the Futures Group is the fact that traditional forecasting methods just rely on historic data extrapolation without considering the effects of unprecedented future events [10,13,74]. So this approach combines traditional forecasting techniques like time series analysis with the qualitative factors to strengthen the scenario analysis [73].

Cross impact analysis (CIA) technique has been used in many different contexts. CIA model was developed by Gordon and Helmer in 1966 at the RAND Corporation [13,74]. In this approach a range of causal and correlation cross impact variants are developed in a cross impact matrix. The underlying principal for the development of this approach was that it is unrealistic to forecast an event in isolation without considering occurrence of other key impacting events. Therefore, cross impact analysis is used to capture the interrelationship between key influencing factors [78].

A number of proprietary methodologies are developed to conduct cross impact analysis. The most popular techniques include IFS (Interactive Future Simulations), previously known as BASICS (BATTELLE Scenario Inputs to Corporate Strategies) developed by the Battelle Memorial Institute, INTERAX (Interactive Cross Impact Simulation) developed by Enzer at the Center for Future Research (CFR), University of Southern California, and SMIC (French acronym for Cross Impact Systems and Matrices) developed by Duperrin and Gabus [13,73–75,78]. Detailed description, comparison and analysis of these quantitative scenario building techniques is performed in the subsequent sections.

3.3. French school – La prospective

French philosopher Gaston Berger presented the concepts of scenario planning approach for long term planning and he named it La prospective or prospective thinking [10,36]. Underlying principal of this approach is that the future is not part of a predetermined temporal continuity, and it can be deliberately created and modeled [13,79–81]. A French governmental organization known as DATAR (the Office for Regional Planning and Development) played a critical role in the late 1960s and 1970s for the development of this approach [8,36,82,83]. de Jouvenel states that primary purpose of La prospective method is to better understand the contemporary world, and the hidden potentialities and dangers [81]. This approach develops normative scenarios of the future and articulate idealistic future images so that scenarios can serve as a guiding vision to policy makers and provide a basis for future action [84]. French approach gives greater flexibility and more general meaning to the scenarios [83]. In France scenarios are more often used for public sector planning than corporate level planning [13] and usually scope of scenario work is narrowly focused [84].

According to Durand the French method of scenario construction is based upon four essential concepts: the base, the external context, the progression and the images [83]. In depth analysis and scanning of the present situation is called the base. Studying the general environment of the system surrounded by social, economic, political, diplomatic, national or international context is called the external context. The progression is historical simulation derived from the dynamic base and constraints of the external context. Finally in the progression toward the future, there is a need for establishing a kind of cross section that represents reality at that time, called images of the future in a scenario [83]. Barel presents concept of social forecasting to assess the elements of change in a contemporary society [85].

Michel Godet from the Department of Future Studies at SEMA group conducted scenario projects for many French national institutions and developed mathematical and computer based probabilistic approach for generating scenarios [5] and tools developed by Godet are known as the French school of La Prospective [13,69]. MORPHOL and SMIC PROB-EXPERT are his popular tools for scenario development. MORPHOL is a computer version of morphological analysis and SMIC PROB-EXPERT is a form of cross-impact with some variation [49]. Godet states that La prospective is a blend of analysis tools [5] and some tools such as structural analysis and the MICMAC method are very popular [86]. Bradfield et al. describe La prospective as a combination of the intuitive logics and probabilistic modified trend methodologies [13]. This methodology has been applied to a wide range of public issues including the education, environment, urbanization and regional planning.

Table 1
Comparison of the principal scenario development techniques [13].

Scenario characteristics	Intuitive logics methodology	La prospective methodology	Probabilistic modified trends (PMT) methodology
Purpose	Multiple, from a one-time activity to make sense of situations and developing strategy, to an ongoing learning activity	Usually a onetime activity associated with developing more effective policy and strategic decisions	A onetime activity to make extrapolative prediction and policy evaluation
Scenario type/perspective	Descriptive or normative	Generally descriptive	Descriptive
Scope	Can be either broad or narrow, ranging from global, regional, country, industry to a specific issue	Generally a narrow scope but examines a broad range of factors within that scope	Scope is narrowly focused on the probability and impact of specific events
Time frame	Varies: 3–20 years	Varies: 3–20 years	Varies: 3–20 years
Methodology type	Process oriented approach, essentially subjective and qualitative	Outcome oriented approach, which is directed, objective, quantitative and analytical relying on complex computer based analysis and modeling	Outcome oriented approach, very directed, objective, quantitative and analytical using computer based extrapolative simulation models
Nature of scenario team	Usually an internal team from the organization for developing scenarios	Combination of some members from client organization led by an expert (external consultant)	External teams, scenario developed by experts (external consultants)
Role of external experts	Experienced scenario practitioner to design and facilitate the process. External experts are used to obtain their views for new ideas	Leading role of external expert using an array of proprietary tools for comprehensive analysis	Leading role of external expert using proprietary tools and expert judgments to identify high impact unprecedented events
Tools	Generic tools like brainstorming, STEEP analysis, and stakeholder analysis	Proprietary and structural tools like Micmac, SMIC and Mactor analysis etc.	Proprietary tools like trends impact and cross impact analysis etc.
Starting point	A particular management decision, issue or general concern	A specific important phenomenon of concern	Decisions/issues for which detailed and reliable time series data exists
Identifying key driving forces	Intuition, STEEP analysis, research, brainstorming techniques, and expert opinion	Interviews with stakeholders and comprehensive structural analysis using sophisticated computer tools	Curve fitting to past time series data to identify trends and use expert judgment to create database of unprecedented events
Developing scenario set	Defining the scenario logics as organizing themes or principles	Matrices of sets of possible assumptions based on the key variables for future	Monte Carlo simulations to create an envelope of uncertainty around base forecasts
Output of scenario exercise	Qualitative set of equally plausible scenarios in narrative form with strategic options, implications, and early warning signals	Multiple quantitative and qualitative scenarios supported by comprehensive analysis, implications and possible actions	Quantitative baseline case plus upper and lower quartiles of adjusted time series forecasts
Use of probabilities	No, all scenarios are equally probable	Yes, probability of the evolution of variables under assumption sets of actors' behavior	Yes, conditional probability of occurrence of unprecedented and disruptive events
No. of scenarios	Generally 2–4	Multiple	Usually 3–6 depends on the no. of simulations
Evaluation criteria	Coherence, comprehensiveness, internal consistency, novelty, supported by rigorous structural analysis and logics	Coherence, comprehensiveness, internal consistency tested by rigorous analysis; plausible and verifiable in retrospect	Plausible and verifiable in retrospect

3.4. Comparison of the major scenario development approaches

van Notten and his colleagues from the International Centre for Integrative Studies (ICIS), Netherlands, identify 14 specific characteristics to characterize scenarios from three major categories based upon scenario project goals, process design and scenario content [71]. It is a valuable contribution and provides a very detailed and useful mechanism for analyzing and comparing various scenario development techniques.

Comparison of the various characteristics of three major scenario development techniques i.e. intuitive logics, probabilistic modified trends and French approach of La prospective is presented in Table 1 [13]. The probabilistic modified trends technique (PMT) is quantitative in nature whereas intuitive logics approach is a qualitative technique [49]. The French approach of La prospective is a formalized approach which uses a combination of qualitative of and quantitative tools, and researchers describe it as a blend of both intuitive logics and PMT methodologies [13].

4. Quantitative scenario planning methods

There are several quantitative methodologies for development of scenarios. Based on scenario planning literature, the following methods are considered most popular quantitative techniques for constructing scenarios [13,69,73–75,78]. In this section, these scenario planning methods are explained and compared.

- Interactive Cross Impact Simulation (INTERAX)/SMIC (French acronym for Cross Impact Systems and Matrices)
- Interactive Future Simulations (IFS)
- Trend impact analysis (TIC)
- Fuzzy Cognitive Map (FCM) based scenario planning approach

4.1. Interactive Cross Impact Simulation (INTERAX)

The INTERAX (Interactive Cross-Impact Simulation) methodology was developed by Enzer at the Center for Futures Research (CFR), Graduate School of Business Administration, University of Southern California [13,73,75,87]. This technique uses both analytical models and expert judgment to develop a better understanding of alternative future environments. A detailed multidisciplinary database containing important information of broad range of long-range strategic issues and future trends and events is developed through a Delphi study of 500 experts to support the scenario building activities [73,74,88]. Initial database has information of 100 events and 50 trend forecasts and it is updated periodically. This database is developed based on the assumption that the macro societal conditions are common to most strategic issues; therefore, one environmental scan can be used to support several issues [87].

This approach explores alternative futures as part of an iterative procedure which begins with a broad overview of possible future changes [87,88]. According to Enzer, INTERAX process develops better understanding of how conditions can branch from one evolutionary path to another, and how policy actions can be used to manage these conditions [87]. CFR highlights that scenarios developed using INTERAX approach can help companies with major decisions for a large range of issues, including new product and market opportunities, capital investments, plant and equipment acquisition, mergers and acquisitions, and R&D planning [75].

4.2. Interactive Future Simulations (IFS)

Interactive Future Simulations (IFS) technique was previously known as BASICS (BATTELLE Scenario Inputs to Corporate Strategies) and it was developed by the Battelle Memorial Institute in 1970s [13,49,73,74]. The main difference between IFS and INTERAX techniques is that IFS does not use Monte Carlo simulation, and it does not require an independent forecast of the key indicators or variables [73,74].

IFS methodology emphasizes market and customer orientation, promotes a long range perspective and provides insights into business dynamics using cause and effect relationships [13,73,74]. Moreover, this process identifies novel and diverse ideas, encourages contingency planning and provides an early warning system of major changes in the business environment [74].

4.3. Trend impact analysis (TIA)

Trend impact analysis is another quantitative approach for developing scenarios and it has been used since 1970s. TIA is a combination of statistical extrapolations with probabilities and provides a systematic approach to combine extrapolation based upon historical trends with judgment about the probabilities and impacts of selected future events [10,13,74,78]. Thus TIA considers the effects of unprecedented events which may occur in the future. An unprecedented event with higher impact is likely to swing the trend relatively far in any direction from its un-impacted course based on historical trends. Gordon describes that the following two principal steps are necessary to conduct trend impact analysis [78]:

i. A curve is fitted to historical data in order to calculate future trend.

ii. Expert judgments are used to identify set of future events that could cause deviations from the extrapolation of historical data. Expert judge probability of occurrence as a function of time and its expected impact.

According to Gordon, TIA method has been used frequently and it has been applied to determine health care futures, pharmaceutical market futures, and forecast petroleum consumption in transportation to assess effectiveness of several policies [78]. This approach has been used by many US federal agencies including Federal Aviation Administration, Federal Bureau of Investigation, National Science Foundation, Department of Energy, Department of Transportation and State of California [78].

Both TIA and CIA methodologies have some similarities, however CIA incorporates an additional layer of complexity by considering priori probability of occurrence of events through expert judgments which may affect future [13]. In CIA approach conditional probabilities are determined in pairs of future events through cross impact calculations. So it is not a standalone probabilistic forecasting tool and does not generate naive extrapolations based only on historical data [73,74,78]. Therefore we can conclude that CIA methodologies provide a better approach to generate a range of alternative future scenarios.

4.4. Fuzzy Cognitive Maps (FCM) based scenarios

Causal cognitive maps are also used for developing scenarios [89]. Robert Axelrod introduced cognitive maps in the 1970s to represent social scientific knowledge as an interconnected, directed graphs consisting of nodes and edges/arrows [90,91]. Nodes represent various concepts and arrows highlight causal relationship between various concepts. Each concept is influenced by the interconnected concepts based on the value of corresponding causal weights. The visual nature of these maps facilitates understanding of existing dependencies and contingencies between various concepts. In this approach diverse mental models of the multiple experts are captured in form of simple causal maps and this process help experts to identify key issues and explore alternative futures [92]. The mapping process fosters system thinking and allows experts to better assess their own mental models and indicate their subjective knowledge [92].

Kosko invented Fuzzy Cognitive Maps (FCM) which are extension and enhancement of a cognitive map with the additional capability to model complex chains of causal relationships through weighted causal links [93]. FCMs are mainly used to analyze and aid the decision making process by investigating causal links among relevant concepts [90]. FCMs can overcome the indeterminacy problems of the causal cognitive maps which occurs when one concept is influenced by an equal number of negative and positive ingoing arrows [94]. Moreover, applying casual cognitive map can lead to large and complex models, in which the indirect effects, feedback loops and time lags are difficult to analyze [92].

FCM analyze interrelations between phenomena that are graphically represented in causal cognitive maps or influence diagrams [20]. In general each concept (node) in a FCM model may reflects a state, variable, event, action, goal, objective, value or other system component. These concepts are non-linear functions that transform the path weighted activation toward their causes. Finite number of FCMs can be combined together to produce the joint effect and capture opinion of multiple experts together in one collective map [91] and provides a more holistic overview of the pertinent issues surrounding the subject area [95]. Moreover, causal maps allow systematic integration of multiple perspectives when considering longer term planning [95]. Taber and Siegel propose estimation of expert credibility weights in order to combine multiple FCMs [96].

FCM has gained considerable research interest and this approach has been applied in numerous applications in different domains [97]. FCMs have been used to study and analyze foreign policy, stock-investment, software adoption, modeling IT project management, designing and improving information system evaluation, product planning, manufacturing problems, fault detection and troubleshooting for electronic circuits, supervisory system control analysis, web data mining, socio-economic modeling, ecosystem and water quality issues, emigration issues, drug control, child labor issues, and community mobilization against the AIDS epidemic [20,91,98–107].

FCM based scenario development is a very new approach and recently Jetter et al. and van Vliet et al. propose the viability of FCM as a method for scenario development [92,108]. FCM is a powerful modeling technique and an attractive tool to improve quality of scenario planning. This approach has been used recently to develop scenarios for wind energy sector [109,110]. Kok and van Delden identify that the weak link between qualitative and quantitative scenarios is a major obstacle toward development of integrated scenarios [111]. Literature also highlights the importance using imagination followed by causal analysis for scenario building process [47]. FCM uses fuzzy logic and it can integrate qualitative analysis. Therefore, FCM based scenario development approach has potential to combine qualitative storylines and quantitative models [108]. Research also indicates that integration of multiple approaches in scenario building process guarantees more robust scenarios [25,76].

FCM based scenario planning process is conducted through an expert panel. Knowledge of the experts is captured in a weighted causal map/FCM model. Participation of stakeholders in this process increases their input in the model and facilitates to develop consensus among them. Map building process facilitates and encourages debate and discussion amongst key stakeholders regarding scenario theme [95]. Experts also help to identify various combinations of input vectors for performing FCM simulation. Literature highlights the importance of capturing multiple mental models in future foresight projects [19,112]. Thus FCM based scenarios provide the benefits of intuitive scenario approach coupled with quantitative

Table 2
Comparison of the quantitative scenario development technique.

Generic steps for scenario development	Fuzzy Cognitive Map (FCM) based scenarios	Trend impact analysis	INTERAX	Interactive Future Simulations (IFS)
The topic	1. Scenario preparation	1. Identify key scenario drivers 2. Create scenario space	1. Define the issue and time period of analysis	1. Define and structure the topic
Key decisions	2a. Knowledge capture		2. Identify the key indicators	
Trend extrapolation		3. Collect time series data 4. Prepare naive extrapolation	3. Project the key indicators	
Influencing factors	2b. Knowledge capture (identify key concepts and drivers)	5. Establish list of impacting events	4. Identify the impacting event	2. Identify areas of influence
Analysis of factors	3a. Scenario modeling	6. Establish probs. of events occurring over time	5. Develop event prob. distribution	3. Define descriptors write essays; assign initial probabilities
Cross-impact	3b. Scenario modeling (develop causal map, with weighted causal links)		6. Estimate cross impacts 7. Complete cross impact analysis	4a. Complete cross impact matrix
Initial scenarios	4a. Scenario development	7. Modify extrapolation	8. Run the model	4b. Run the program 5. Select scenarios for further study
Sensitivity analysis	4b. Scenario development (using different set of inputs vectors to see behavior of FCM model)			6. Introduce uncertain events; conduct sensitivity analysis
Detailed scenarios	5. Scenario selection and refinement	8. Write narratives		7a. Prepare forecasts
Implications	6. Strategic decisions			7b. Study implications

analysis. Utility of FCM based scenarios significantly depends on the quality of underlying causal map, therefore it is critical to select knowledgeable experts, and carefully examine the causal relationships, uncertainties and assumptions.

4.5. Comparison of quantitative scenario planning approaches

Comparison of the quantitative methods for developing scenarios is presented in the following table. INTERAX, Interactive Future Simulations (IFS) and trend impact analysis are the popular quantitative techniques for developing scenarios and often used in uncertain business environments. The steps identified for each technique are compared with a generic set of steps for scenario planning. In two widely cited papers, Huss and Honton made a comparison of the prominent quantitative techniques for scenario building [73,74]. The comparison made by Huss and Honton has been modified in Table 2, and Fuzzy Cognitive Map (FCM) based scenario development approach is also compared against other well-known quantitative techniques for scenario development.

Based upon literature review the strengths and the weaknesses of these quantitative methods is summarized in Table 3 [10,13,73–75,78].

Scenario building techniques have evolved due to the change in the futures research paradigm from a more quantitative approach (in the 1970s) toward a more qualitative and process-oriented one [69]. Martino cites that despite utilization of various tools to aid the scenario development, it is still a highly subjective art and scenarios remain qualitative in nature [24]. While discussing the future of scenario planning, Love argue that it will further change and become part of the ‘‘collective intelligence’’ of the future [113]. Strictly quantitative methods are often criticized because these methods rely solely on historical data and assume that same trends will prevail in future [78]. Generally quantitative methods are considered useful for narrowly focused projects having short time horizon, while qualitative methods are considered appropriate for projects having large scope and long time horizon. It is highlighted in Fig. 2, that usefulness of quantitative methods declines steadily as we look further into the future, whereas usefulness of qualitative approaches increases in this case [25]. Therefore, both qualitative and quantitative approaches are complementary and strengthen each other when used together.

5. Selection of raw scenarios and appropriate number of scenarios

There is no precise response to the question as how many future scenarios are optimal in the scenario planning literature. Various futurists and researchers have recommended different number of alternative scenarios usually ranging from three to six scenarios. It is critical to develop a manageable number of scenarios, in a logical manner, that best captures the dynamics of the situation and communicates the core issues effectively [69]. Durance and Godet recommend to develop scenarios around four or six fundamental hypotheses, because otherwise the sheer magnitude of possible combinations will be overwhelming [8]. Global Business Network (GBN) and Sanford Research Institute (SRI) in their methods recommend to limit

Table 3
Strengths and weaknesses of quantitative scenarios planning techniques.

Method	Strengths	Weaknesses
Trend impact analysis	This approach combines more traditional forecasting techniques such as time series and econometrics with the qualitative factors	The method does not evaluate possible impacts which the events may have on each other
	User identifies the impacting factors and evaluates their probability of occurrence and the strength of their impact	Designed primarily for the evaluation of one key decision or forecast variable which is quantitative and on which historical information exists
	Trend extrapolation is modified to take into account perceptions about how future events may change due to unprecedented events	Process is sometimes constrained due to unavailability of reliable historic time series data
Interactive Future Simulations (IFS)	It generates a distribution of scenarios based on their level of consistency and relative likelihood of occurrence	It is a probabilistic forecasting tool and computer algorithm generates scenarios, i.e. descriptions of a business environment likely to occur at the end of the forecast horizon
	It uses both ranges of influencing variables (descriptor states) and uncertain events. This allows user to look at a wide set of outcomes and provides additional flexibility	The user must use some creativity in incorporating the time dynamics
INTERAX	It combines the strengths of trend impact analysis with the strengths of cross impact analysis	INTERAX has a high start-up cost, and difficult to use
	Provides an excellent statistical distribution of outcomes around the average	The selection of events which occur in the first interval is based solely on a random selection using the initial user entered probabilities

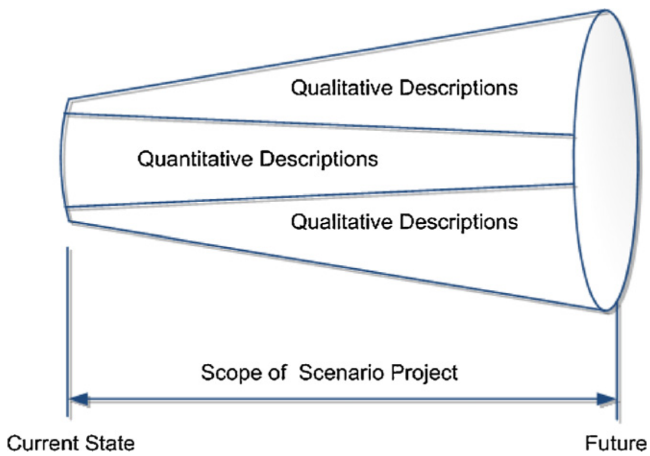

Fig. 2. Qualitative versus quantitative scenario analysis [25].

the number of scenarios to four by combining two hypotheses [8]. However, this is an oversimplifying approach which may lead to ignore some subtleties or important details.

Bezold suggests that scenarios should be developed by considering the most likely (expectable), challenging (what could go wrong) and visionary (surprisingly successful) possibilities [11]. Wilson states that the number of scenarios should not be fewer than two, and more than four [114]. Schwab et al. recommend to develop three scenarios in the scenario building process: trend extrapolation, best-case and worst-case scenario [26]. Schnaars reviewed the scenario planning literature and state that most researchers conclude that developing three scenarios is the best approach [46].

Table 4 provides a comparison of recommended number of scenarios and scenario selection approach highlighted by different researchers and futurists in the scenario planning literature.

Pillkahn discusses the number of scenarios developed and their implication highlighted in Table 5 [25]. It is evident from Tables 4 and 5, that 3–5 scenarios are considered appropriate by most of the researchers. Mietzner and Reger state that only a limited number of scenarios can be developed in detail, otherwise the process dissipates [69]. So it is difficult to manage large number of scenarios. Moreover, in case of generating more than five scenarios, the cost of drafting and evaluating these large number of scenarios will be very high and not justifiable.

Number of scenarios developed for a project significantly depends upon how many uncertainties of the future environment are considered and their plausible combinations create scenarios. There are three approaches to draft scenarios: minimal approach, standard approach and maximum approach [25]. There are various tools that can be used in

Table 4
Summary of recommended number of scenarios and approaches for scenario selection.

Source	Recommended number of scenarios	How do scenario planners select scenarios?
Becker [115]	3	Selects plausible combinations of key factors
Bezold [11]	3	Develop scenarios for most likely, challenging and visionary possibilities
Durance and Godet [8]	4–6	Develop fundamental hypotheses
de Kluyver [116]	3	Judgmental translation into optimistic & pessimistic and most likely possibilities
Linneman and Klein [34]	3–4	Select plausible combinations of key factors
MacNulty [117]	3–4	Judgmental integration of trends and intuition
Vanston et al. [118]	3–6	To conform the scenario themes
Van der Heijden [9]	At-least 2 or more	Identify the driving forces, mega trends and critical uncertainties
Schoemaker [15]	More than 2	Identify key decision variables, trends, predetermined elements, and major uncertainties
Schwartz [50,119]	4	Rank the focal issues and key factors on the basis of importance and uncertainty in a 2×2 matrix
Wilson [120,121]	3–4	Scenario writing and cross impact analysis
Bradfield et al. (intuitive logics methodology) [13]	2–4	Intuition, expert opinion, STEEP analysis, brainstorming techniques
Bradfield et al. (PMT methodology) [13]	3–6	Quantitative trend analysis and use of expert judgment
Hicks and Holden [58]	4	Create scenarios entitled ‘more of the same’, ‘technological fix’, ‘edge of disaster’ and ‘sustainable development’
Miles and Keenan [122]	3–5	Through scenario workshops and focusing on key driving forces, likely developments and desired outcomes
Dator [53]	4	Developed alternative futures based on four scenario archetypes: continued growth, collapse, steady state and transformation
Inayatullah [42,54]	3–5	Develop scenarios through causal layered analysis
Galtung [123]	4	Identify two major uncertainties and develops scenarios based on these
Robertson [57]	5	Develop business as usual, disaster, authoritarian control, hyper-expansionist and humane ecological

Table 5
Evaluation of number of scenarios in a project [25].

Number of scenarios	Implications
1	It will be the most likely scenario, though it is convenient for strategy formulation but one scenario will not yield any alternate future or future options
2	Two scenarios are usually based on two extreme situations (optimistic and pessimistic scenarios) which are difficult to handle in the context of evaluation
3	Recommended by many researchers but there is a risk of focusing on the middle (most likely) scenario
4	Possible, good cost-benefit ratio
5	Possible
More than 5	Possible, but cost of drafting and evaluating large number of scenarios will be very high and not justifiable

each approach for scenario selection. Pillkahn suggests that combination of multiple methods and basic principles ensure generation of more robust scenarios [25].

Minimal approach uses two key drivers or trend to create scenarios. This approach is often criticized because overall situation/environment is over simplified. Generally it is difficult to evaluate the future against only two uncertainties or hypotheses. Therefore, it is quite possible that the futurist/scenario planner may miss some critical elements if the minimal approach is applied. Curry and Schultz indicate challenges and state that reducing the focus on two drivers simplify the effort but requires great care to choose appropriate factors that are sufficiently different from one another to generate a strategic conversation [124].

Standard approach is considered appropriate when it is not possible to reduce number of uncertain factors to two. Usually in standard approach 3–8 number of uncertain factors are considered and number of scenarios generated usually range from 3 to 6. The maximum approach is appropriate if there are many uncertain elements in the environment. In this approach various tools like Wilson matrix, morphological analysis, cross impact analysis and consistency analysis are used to evaluate all elements. Scenario planners and futurist recommend based upon their experience that scenarios with fewer but carefully examined and elaborated factors are likely to give better results than scenarios with many factors generated through a software tool [25]. Van Der Heijden recommends to consider around 6 or 7 key variables for scenario development [9]. Table 6 highlights the scenario drafting approaches and commonly used tools and methods.

Table 6
Three approaches for drafting scenarios [25].

	Minimal approach	Standard approach	Maximum approach
Number of uncertainties	2	3–8	Greater than 8
Tools and method used	Four quadrant matrix or 2 × 2 matrix approach	Wilson matrix, morphological analysis, consistency analysis	Wilson matrix, morphological analysis, cross impact analysis, consistency analysis
Scenario project cost	Minimal	Appropriate	Very high

Analysis of scenario planning literature highlights that only few researchers propose to create two scenarios, whereas most of them propose to create three or more than three scenarios. Because less than three scenarios are considered inappropriate and cannot highlight all possible alternatives. However, it has been discussed that development of large number of scenarios is also not desirable. Therefore, based on literature review and analysis it can be concluded that creation of 3–5 future scenarios are appropriate for a scenario project.

5.1. Four quadrants matrix – minimal approach

The minimal approach is appropriate when overview of all elements in the environment reveals that only two criteria or factors are enough and can be used to determine future developments [25,50,125]. This is also called the double uncertainty, or 2 × 2 matrix approach. Scenarios are developed in each of the four quadrants of a grid representing the most important and the most uncertain factors, so this approach helps to target two key uncertainties and organize scenarios around them [50]. Galtung also proposed the double variable method, that identifies the two major uncertainties and develops scenarios based on these uncertainties [123].

5.2. Wilson matrix

Literature highlights the importance of identifying, and prioritizing the most interesting, uncertain and important scenario elements [50]. In scenario planning Wilson matrix can be used to evaluate and prioritize the influence/impact and uncertainty of each scenario driver, concept or factor. Wilson matrix ranks all factors against two dimensions: potential impact and probability that the trend/factor will develop in to a significant issue [25]. So it determines degree of uncertainty and their potential impact on the future of all scenario elements. It has been recommended that "high", "medium" and "low" categories are sufficient to evaluate both dimensions [25]. Wilson matrix used in a scenario case study is shown in Fig. 3. Scenario driver are prioritized and those having high priority are shown in the upper right side of the matrix.

Van der Heijden also presents a similar concept in his impact-predictability matrix that resembles the Wilson matrix [9]. He recommends to select scenario elements that are expected to have significant impact on business/organization and also exhibit a higher degree of uncertainty [9]. In the impact-predictability matrix both dimensions are evaluated against two scales: "low", and "high". Hence, the Wilson matrix is considered better than the impact-predictability matrix.

5.3. Morphological analysis

Fritz Zwicky proposed morphological analysis in the 1960s for exploring all the possible solutions to a multi-dimensional and non-quantifiable problem [126]. Morphological analysis has been used by a number of researchers in the field of futures

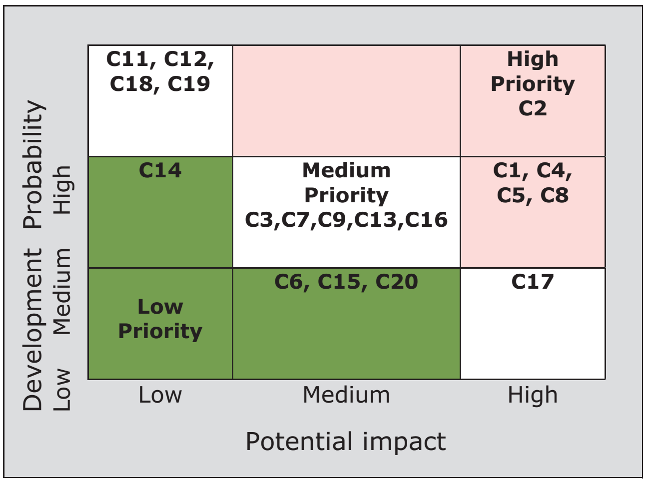

Fig. 3. Use of Wilson matrix to prioritize scenario drivers [110].

Variations	C 1 Economic growth	C 2 Growing energy demand	C 4 Increasing cost of energy	C 5 Design innovations	C 8 Favoring government policies
Variation A	1A: economic growth in country	2A: Increased energy demand	4A: Increase in energy cost	5A: Design innovations in wind turbine	8A: Favoring policies for wind by the government
Variation B	1B: No economic growth	2B: No increase in energy demand	4B: energy cost remains stable	5B: No design innovations takes place	8B: Favoring policies are not adopted

Input Vector 2
1B-2B-4B-5B-8A
Input Vector3
1B-2A-4A-5A-8B
InputVector 1
1A-2A-4B-5B-8B

Fig. 4. Morphological analysis to generate raw scenarios [110].

studies, technological forecasting and development of scenarios [8,43,127,128]. This process is considered as an improvement to the scenario selection and refinement activities [36]. Jenkins recommends using morphological analysis to eliminate incompatible combinations of factors [129] and create plausible combinations. With the help of morphological analysis, we can see various elements and dimensions in the system and develop raw scenarios for the future.

Fig. 4 highlights an example from a case study, where three raw scenarios have been generated using morphological analysis. This process helps to ensure that there is no contradiction in these combinations. Morphological analysis is a useful tool and it helps to visually analyze combination of various conceivable development variations for all scenario drivers and ensure plausibility.

5.4. Cross impact analysis

Cross impact method was originally developed by Gordon and Helmer in 1966 and since then it has been widely used as future research method [130]. The cross impact analysis techniques are used to identify the important chains of possible occurrences and the degree to which the occurrence of each possible event changes the likelihood of occurrence of the others [131,132]. Thus it seeks probability of an event given that various other events have or have not occurred [132]. This technique requires development of a model in which the causal linkages among many important trends/events are described [131]. In this approach a cross impact matrix is developed. In cross impact analysis matrix, impact and effect of each factor or trend on rest of the factors/trends is identified [25].

A simple example of cross impact analysis is shown in the following figure involving 10 trends ranging from T1 to T10. A score is assigned on a scale of 0–3 as mentioned in Fig. 5. The trend which has the strongest impact on the other trends is identified by taking sum of their score. In this example T1, T4, T7, and T10 have the strongest impact (highest score) and can be considered as the powerful drivers for scenario development. So like Wilson matrix, cross impact analysis is also used for evaluating the scenario drivers and identifying the critical drivers.

	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	Score
T1		3	3	3	2	3	3	2	1	2	**22**
T2	0		3	0	3	0	2	0	1	2	11
T3	1	1		0	0	0	2	1	0	0	5
T4	2	2	3		3	2	3	1	1	2	**19**
T5	0	2	3	0		0	2	1	1	3	12
T6	2	1	3	1	1		1	0	1	2	12
T7	1	2	2	2	2	1		3	2	3	**18**
T8	2	3	3	1	1	0	3		1	2	16
T9	2	1	0	2	1	2	2	2		1	13
T10	3	3	3	3	3	0	2	2	1		**20**

Highest Score:	T1, T4, T7, and T10	0 Independent	1 Dependent
		2 Slight Impact	3 Strong Driver

Fig. 5. Hypothetical example of cross impact analysis [25].

Table 7
Summary of scenario validation criteria.

Source	Scenario validation criteria						
	Plausibility	Consistency/ coherence	Creativity/ novelty	Relevance/ pertinence	Importance	Transparency	Completeness/ correctness
Alcamo and Henrichs [133]	X	X	X	X			
Van der Heijden [9]	X	X	X	X			
Durance and Godet [8]		X	X	X	X	X	
Bradfield et al. [13]	X	X		X			
Porter et al. [31]	X	X					X
Intuitive logics methodology [13]	X	X	X	X			X
La prospective methodology [13]	X	X					X
Burt [76]	X	X					
de Brabandere and Iny [19]	X	X	X	X		X	
Paul Schoemaker [15,51]	X	X					
Peter Schwartz [10,50]	X	X					X
Peterson et al. [135]	X	X					
Wilson [114]	X	X	X	X			
Vanston et al. [118]	X	X		X			
Kosow and Gaßner [136]	X	X				X	X

6. Scenario validation

In scenario planning literature many researchers have identified scenario validation criteria. Chermack et al. highlight its importance and state that scenarios must be checked for validity to ensure that scenarios form adequate basis for making important decisions [10]. Wilson suggests five criteria for selecting scenarios [114]:

- *Plausibility*: The selected scenarios have to be capable of happening,
- *Consistency*: The combination of logics in a scenario has to ensure that there is no built-in internal inconsistency and contradiction,
- *Utility/relevance*: Each scenario should contribute specific insights into the future that help to make the decision,
- *Challenge/novelty*: the scenarios should challenge the organization's conventional wisdom about the future,
- *Differentiation*: they should be structurally different and not simple variations on the same theme.

In his widely cited publication on scenario planning van der Heijden presents the following five basic criteria for scenarios [9]:

- At least two scenarios are needed to reflect uncertainity
- Each scenario must be plausible
- Scenarios must be internally consistent
- Each scenario must be relevant to the client's concern
- Scenarios must produce a new and original perspective on the issues

Durance and Godet argue that scenarios should meet five conditions including; pertinence, coherency, likelihood, importance, and transparency in order to be credible and useful [8]. They further state that transparency is an important condition and without it the intended audience will not consider the scenarios [8]. Alcamo and Henrichs also propose that each scenario should adequately meet the following basic criteria [133]:

- Plausibility
- Consistency
- Creativity
- Relevance

Bradfield et al. emphasize that regardless of the scenario developmental methodology; coherence, plausibility, internal consistency and logical underpinning are the common baseline criteria by which all scenarios should be validated [13]. Burt describes that scenarios should have description of a plausible future and an internally consistent account of how a future world unfolds [76]. de Brabandere and Iny argue that good scenarios must be relevant to the decisions to be taken, coherent, plausible, convincing, transparent, easy to recount and illustrate [19]. Foster state that ensuring consistency is the cardinal rule for scenario planning [134]. Schoemaker emphasizes the importance of internally consistency and plausibility in scenario building activities [15] and recommends to check consistency of each scenario related to the trends and the

Table 8
Methods used to select and validate the raw scenarios.

Method	Purpose
Minimal approach (2 × 2 matrix approach)	Define scenarios by two, the most important and the most uncertain factors facing the organization
Wilson matrix	Evaluate and prioritize the scenario drivers against their potential impact and uncertainty (probability to develop into a significant issue in the future)
Morphological analysis	Develop raw scenarios/input vectors and access plausibility
Cross impact analysis	Identify the strongest scenario drivers that have the highest shaping potential
Consistency analysis	To verify the internal consistency of raw scenarios

	C1	C2	C3	C4	C10	C11	C14	
C1								
C2	4							
C3	3	4						
C4	3	5	4					
C10	3	4	4	4				
C11	3	4	4	4	5			
C14	3	4	4	5	4	5		

1= Totally Inconsistent, 3= Neutral, 5= Supporting

2= Partially Inconsistent, 4= Slight Positive Impact,

Fig. 6. Consistency matrix for raw scenario 1 [110].

outcome combinations of raw scenarios [51]. He further explains that scenario developer should ensure that the trends are compatible and outcome of scenario is plausible [51].

Table 7 summarizes the scenarios validation criteria proposed by various researchers and futurists in the scenario planning literature.

Summary of the scenario validation criteria highlights that the internal consistency is the most important criterion followed by plausibility. Creativity and relevance are also quite important. Consistency analysis can be performed to assess internal consistency of the scenarios. Plausibility of the scenario can be ensured by using the morphological analysis. Therefore, we can conclude that consistency and plausibility are the decisive conditions for assessing scenarios as credible.

Some methods used to select and validate the raw scenarios are highlighted in Table 8. Both Wilson matrix and cross impact analysis can be used to identify the most critical scenario drivers. Morphological analysis can be perfomed to ennsure plausibility and consistency analysis can be used to assess internal consistency of scenarios.

6.1. Scenario consistency analysis

It is evident from Table 7 that scenario planning literature emphasizes a lot on the importance of the internal consistency of the developed scenarios. Consistency analysis is conducted to verify the internal consistency of raw scenarios. Many software tools are also available to support the consistency analysis. It is usually performed after conducting the morphological analysis and creating raw scenarios. Consistency analysis is used to check the compatibility of combined variations of various scenario drivers (concepts, trends etc.) in these raw scenarios [25]. Consistency is also used for conveniently reducing the number of scenarios to a manageable amount [137].

Pillkahn suggested to assign a score on a scale of 1–5 in the consistency matrix in order to evaluate the consistency of the developed scenarios [25]. A score of 1 is assigned in the consistency matrix, if there is total inconsistency (impossible combination) and a score of 5 is assigned, if both factors are highly linked and positively impact each other or have mutual dependency as shown in Fig. 6.

Usually experts are asked to evaluate the internal consistency of raw scenarios and assign scores in the consistency matrix based on their judgment. They are asked to review the compatibility among various scenario drivers and ensure that there is no contradiction. Fig. 6 depicts consistency analysis performed in a case study where internal consistency of a scenario is verified through the consistency matrix.

7. Conclusion

In this paper an overview of the scenario planning literature has been presented. Major approaches for scenario planning are reviewed and their strengths and weaknesses are analyzed. It can be concluded that scenario planning approaches comprising of a combination of qualitative and quantitative techniques are better and can result in generating robust scenarios. A detailed review of scenario selection issues and scenario validation criteria is also presented in this paper. Tools like Wilson matrix and cross impact analysis can be used to evaluate the scenario drivers/trends. Subsequently, the most critical drivers/trends are used to generate raw scenarios. Also it is critical to develop appropriate number of scenarios. Based on detailed analysis it can be concluded that 3–5 future scenarios are appropriate for a scenario project. Internal consistency and plausibility are the most important aspects regarding scenario validation. It has been shown that consistency matrix is used to ensure internal consistency of raw scenarios, and morphological analysis is used to assess plausibility. Consistency and plausibility are the decisive conditions for assessing credibility of scenarios. We have witnessed a significant increase in the use of scenario planning during the last decade. This paper is the first attempt to review and summarize the scenario validation criteria presented in literature. Therefore, this is paper has not only provides an overview of scenario planning literature and discussed various approaches, but also attempted to answers some questions from the practical aspects of scenario planning like scenario selection, appropriate number of scenarios and scenario validation issues.

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