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A scenario-based roadmapping method for strategic planning and forecasting: A case study in a testing, inspection and certification company

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Highlights

- A scenario-based roadmapping method builds for strategic planning and forecasting.
- The method embeds scenarios of future change into roadmap for strategic planning.
- Possible scenarios are generated and tested to reflect situations in practice.
- Roadmaps and action plans are generated according to the possible scenarios.

Abstract

Nowadays, flexibility is one of key factors when dealing with future changes in the complex and rapidly changing business environment. Various researchers and practitioners are paying attention to the concept of scenario planning in regard to the roadmapping in their market and technology activities. However, the process of the existing scenario-based roadmapping methods is conceptual and relatively little attention has been paid to embedding scenarios with future changes into roadmaps for strategic planning and decision-making at organizational level. In this paper, a scenario-based roadmapping (SBRM) method for strategic planning and decision-making is presented which incorporates scenario planning (macro level) and roadmapping (micro level) perspectives. The proposed method was designed and developed for companies to build possible scenarios reflecting future situations in practice, to assess the impact of each scenario, and to develop roadmaps that incorporate the external and internal issues as well as the actions according to the scenarios. To realize the capability of the proposed method, a case study was conducted in a Global Testing, Inspection and Certification (TIC) company in Hong Kong.

Keywords: Scenario planning, Technology roadmapping, Scenario-based roadmapping, Strategic planning and forecasting

1. Introduction

Nowadays, adaptation is one of the critical factors for success in the complex and

rapidly changing business environment. Two aspects of adaptation include speed (Lindgren and Bandhold, 2003) and the ability to handle complexity (Ashby, 1956), which are often emphasized as critical factors. Ashby (1956) mentioned that the only way to destroy variety (i.e. complexity) is through variety (i.e. flexibility, adaptation, resilience). Chakravarthy (1997) observed that market leaders must "repeat innovations, establish customer networks, sense the flow of new products, and share responsibility for new strategy throughout the firm". Lengnick-Hall and Wolf (1999) also noted that the combination of speed and adaptiveness is critical, which is called "strategic flexibility". Flexibility is one of the key issues when dealing with the changes in uncertain business environments (Geum et al., 2014). Many management techniques and tools are well-known and useful for managing the future in various industries and businesses. They include creativity techniques, patent and publication analyses, market analyses, benchmarking and competition analyses, portfolio management, scenario planning, technology roadmaps, internal or external workshops, Internet search agents/ machines, and so on (Firat et al., 2008; Mortara et al., 2014). They are also adopted for innovation and technology management across the world (e.g. in Japan, Korea, Singapore, the Netherlands, Turkey, the United Kingdom (UK), the United States (US) and so on). Various researchers and practitioners are increasingly paying attention to the concept of scenario planning in the roadmapping in their market and technology activities.

1.1 Scenario Planning

Scenario planning is one of the most common tools cited in the management literature (Mortara et al., 2014). Lindgren and Bandhold (2003) stated the definition of scenario planning as "an effective strategic planning tool for medium- to long-term planning under uncertain condition. It helps us to sharpen up strategies, draw up plans for the unexpected and keep a lookout in the right direction and the right issues". Scenario building is used to describe various expected or supposed situations of the future. A scenario represents an imaged picture of a possible future with alternative characteristics based on certain assumptions and conditions (Firat et al., 2008). For flexible strategic planning, the scenario plays an important role to provide different descriptive stories of the business environment and scenario planning can be applied as an effective approach to deal with a complex and rapidly changing business environment (Chermack, 2005; Geum et al., 2014). The scenario planning method is widely adopted by government, academia, researchers, and many different sectors, particularly in the public domain (Bañuls et al., 2013; Dong et al., 2013; Schoemaker et al., 2013; Weigand et al., 2014; Raford, 2015), energy (Fortes et al., 2015), healthcare (MacKay and Tambeau, 2013; Phadnis et al., 2014), telecommunications (Chang, 2015),

and urban planning (Viguié et al., 2014; von Wirth et al., 2014), and is spreading to many other areas (von der Gracht and Darkow, 2010; Palo and Tähtinen, 2011; Yuan et al., 2012; O'Brien and Meadows, 2013; Tapinos, 2013; Dorrestijn et al., 2014). Moreover, some researchers have provided insight into generating future scenarios (von der Gracht and Darkow, 2010; Dong et al., 2013; Phadnis et al., 2014; Viguié et al., 2014; von Wirth et al., 2014; Fortes et al., 2015; Raford, 2015), sensing and interacting with the environment (e.g. emerging trends) (Palo and Tähtinen, 2011; Cairns et al., 2013; Ramírez et al., 2013; Schoemaker et al., 2013; Raford, 2015), conducting forecasting and foresight (Yuan et al., 2012; Bañuls et al., 2013; Dorrestijn et al., 2014; Weigand et al., 2014; Chang, 2015) as well as facilitating decision support and making (Cairns et al., 2013; Ram and Montibeller, 2013; Wright et al., 2013; Fortes et al., 2015; Parker et al., 2015).

1.2 Technology Roadmapping

Technology roadmapping is one of the popular management tools for managing emerging and potential technologies in fields of technology planning and development. By leveraging the graphical visualization of a plan with a multiple layer and timeline, a technology roadmap is used to identify alternative technology development paths for achieving desired objectives. The roadmap is also used to make connections among all the factors (e.g. technology, product, services, resources) to better understand the relationship between market objectives and technology development based on its flexible layout which aligns with the timeline (Cheng et al., 2014). In other words, a technology roadmap is used to serve as a combination of maps to anticipate future needs and shape the future. In the 1970s, Motorola applied the technology roadmapping approach for product improvement according to the evolution of technology (Willard and McClees, 1987). Four significant types of roadmap were proposed by Kappel (2001), such as science/technology roadmaps, industry roadmaps, product/technology roadmaps and product roadmaps. In a few decades, the technology roadmapping approaches have become widely used by government, researchers, and industrialists in many different business and technology areas, particularly for large technology-intensive firms in the aerospace and defence sector (Farrukh et al., 2009; Vishnevskiy et al., 2015), consumer electronics sector (Lischka and Gemunden, 2008; Huang et al., 2014; Li et al., 2015), and energy sector (Daim and Oliver, 2008; Shibata et al., 2010; Hooshangi et al., 2013; Dixon et al., 2014; Vishnevskiy et al., 2015), and is spreading to many other areas (Gerdsri et al., 2009; Phaal et al., 2010; Saritas and Aylen, 2010; Amadi-Echendu et al., 2011; Kerr et al., 2012; Carvalho et al., 2013; Cheng et al., 2014; Geum et al., 2015; Lee et al., 2015b). Moreover, some researchers have provided insight into roadmapping disruptive technologies (Kostoff et al., 2004; Daim and Oliver, 2008;

Amer and Daim, 2010; Carvalho et al., 2013; Dixon et al., 2014; Furukawa et al., 2015) and assessing emerging technologies (Linton, 2004; Daim and Oliver, 2008; Yasunaga et al., 2009; Amer and Daim, 2010; Phaal et al., 2011; Huang et al., 2014; Furukawa et al., 2015; Li et al., 2015).

1.3 Scenario-based Roadmapping

Many studies of scenario planning and technology roadmapping are found in the literature. However, there is little relevance of studying strategic planning and forecasting which attempt to integrate scenario planning into technology roadmapping for the preparation for change in complex future conditions, proposing the concept of "scenario-based roadmapping". Jovane et al. (2003) conducted a foresight study on manufacturing so as to define new production paradigms of Flexible Automation using foresight scenario building and roadmapping approaches. Strauss and Radnor (2004) proposed a methodology of multi-scenario roadmapping with the integration of two independent management tools (i.e. scenario planning and roadmapping) for dynamic and uncertain market and corporate environments. By leveraging the principles of Strategic Thinking and Scenario Planning, an operative planning tool was proposed to generate both quantitative and qualitative scenarios for the development of corporate and business strategies, and the tool was demonstrated through a case study of 3G mobile TV services in the 3G wireless industry (Pagani, 2009). Saritas and Aylen (2010) proposed a method which jointly uses two techniques (i.e. roadmapping and scenarios) to conduct Foresight exercises for the assessment of clean production development at national level. Applying the concepts of risk analysis and scenario planning, Kajikawa et al. (2011) proposed a new technology roadmapping process to identify embedded risk (i.e. technical, commercial, organizational, and social risks and uncertainties) to implement a variety of feasible energy technology options based on plausible and expected reduction scenarios in Japan. According to the two roadmaps for renewable energy strategies conducted by the European Commission (i.e. a roadmap for moving to a competitive low-carbon economy in 2050 and Energy Roadmap 2050), five different low-carbon scenarios were assessed which not only take into consideration electricity generation technologies, but also grid and storage issues (Hey, 2012). A five-step methodology was developed by using various qualitative techniques (i.e. scenario, roadmap and surveys) to identify existing challenges for emergency management and forecasting the future development of loosely coupled logistic systems in the logistics industry (Thorleuchter et al., 2012). A system roadmap of the future of logistics over 20 years containing a timetable and recommendations for government and companies was developed by human experts.

To take advantage of technology roadmapping and system dynamics, Geum et al. (2014) provided a combined approach to support scenario planning which consists of three steps including scenario building, technology roadmapping, and system dynamics simulation. Three scenarios (i.e. optimistic, pessimistic and neutral scenarios) for a case study of car-sharing services in Korea were considered to demonstrate the applicability of the proposed approach. Cagnin and Könnölä (2014) developed four principles for the design and management of global foresight exercises on Intelligent Manufacturing Systems, including (a) understanding interconnected innovation systems, (b) responsiveness towards diverse languages and cultures, (c) capacity to reconfigure international networks, and (d) 'glocal' impact orientation. A quantitative model was developed to analyze future scenarios of energy systems in Japan which incorporated roadmapping as technical scenarios for the implementation of the feasibility study of technology options (Kikuchi et al., 2014). Lee et al. (2015a) proposed a scenario-based roadmapping approach for decision makers to assess the impacts of changes on organizational plans. Amer et al. (2016) proposed a new scenario-based roadmapping approach to build multiple future scenarios using a fuzzy cognitive map (FCM) in order to implement the roadmapping based on FCM-based scenarios. The approach was applied to develop a wind energy roadmap in Pakistan successfully, and this case study was used to demonstrate the capability of the proposed approach for strategic planning at national level.

1.4 Summary

In the literature, scenario planning and technology roadmapping are two widely used future techniques which help management executives set priorities for research and technology development (Saritas and Aylen, 2010). The characteristics of scenario planning and technology roadmapping approaches are summarized in Table 1.

Table 1 Characteristics of scenario planning and technology roadmapping approaches (adapted from Lindgren and Bandhold, 2003; Strauss and Radnor, 2004; Saritas and Aylen, 2010; Rohrbeck et al., 2013; Lee et al., 2015a)

Scenario Planning	Technology Roadmapping
Foresight method	Forecasting method
Macro view (i.e. macro thinking)	Micro view (i.e. micro planning)
Backcasting (i.e. future to present)	Forecasting (i.e. past to future)
Strong in medium- to long-term planning	Strong in short-term planning
A part of corporate strategic planning	A domain of business operation planning
Addresses the full context of decisions and the anticipation of a broad range of	Addresses the strategies, directions and detailed tasks explicitly

possible changes	
Image of the future	Detailed frame of the future
Focus on multiple futures	Focus on a single future
Possible, plausible futures	Probable futures
Future is uncertain	Future is predictable
Uncertainty-based (i.e. medium to high uncertainties)	Based on certain relations (i.e. low degree of uncertainty)
Illustrates risks	Hides risks
Strengths in • Enhancing vision • Facilitating strategic discussions • Creating an image of future developments	Strengths in • Detailed planning • Enforcing decisions • Identifying interdependencies between market and technology

By leveraging the characteristics of both approaches, scenario-based roadmapping offers a strong capability for decision-making in strategic planning and forecasting to respond to complex and rapidly changing business environments in terms of flexibility (Strauss and Radnor, 2004; Saritas and Aylen, 2010; Cagnin and Könnölä, 2014; Geum et al., 2014; Lee et al., 2015a; Amer et al., 2016). However, there are two major limitations found in the literature of scenario-based roadmapping which include:

(a) Macro-level scenario-based roadmapping approach

In the literature, the existing scenario-based roadmapping approaches are used widely for Foresight and Future Studies at macro level (i.e. national and industrial levels) and they mainly focus on monitoring and analyzing alternative future changes (Jovane et al., 2003; Pagani, 2009; Saritas and Aylen, 2010; Kajikawa et al., 2011; Hey, 2012; Thorleuchter et al., 2012; Cagnin and Könnölä, 2014; Geum et al., 2014; Kikuchi et al., 2014; Amer et al., 2016), as shown in Table 2. Moreover, scenario planning is strong in regard to building scenarios with a macro view of future changes, while technology roadmapping is strong for the development of roadmaps with a micro view for action planning (Geum et al., 2014; Lee et al., 2015a). As shown in Table 3, most of the existing approaches were proposed to implement strategic-level roadmaps with macro-level scenarios, but only a few researchers are paying attention to support roadmapping by scenario planning at micro level (i.e. organizational and operational levels) for corporate planning (Strauss and Radnor, 2004; Lee et al., 2015a).

Table 2 Literature summary of scenario-based roadmapping

Authors	Research Area	Level	Study on

Jovane et al. (2003)	Foresight	Industrial	Flexible automation in the manufacturing industry
Strauss and Radnor (2004)	Strategic Planning	Organizational	Corporate planning
Pagani (2009)	Forecasting and planning	Industrial	3G mobile TV
Saritas and Aylen (2010)	Foresight	Industrial	Clean production in metal manufacturing in Europe
Kajikawa et al. (2011)	Foresight	National	Energy technologies focusing on risk analysis and assessment of the CO_2 reduction potential in Japan
Hey (2012)	Foresight	National	Low-carbon and energy strategies in Europe
Thorleuchter et al. (2012)	Emergency Management	National	Loosely logistic system for emergency management in Germany
Geum et al. (2014)	Scenario Planning	National	Car-sharing business in Korea
Cagnin and Könnölä (2014)	Foresight	National	Intelligent manufacturing systems (IMS) in Europe
Kikuchi et al. (2014)	Foresight	National	Future energy systems in Japan
Lee et al. (2015a)	Strategic Planning	Organizational	Assessment of the impacts of future changes for organizational plans
Amer et al. (2016)	Future Studies	National	National-level wind energy sector in Pakistan

(b) Conceptual scenario-based roadmapping process

As shown in Table 3, the previous studies only suggest the conceptual structures of scenario-based planning, but do not evaluate the outcomes of the scenario(s) and how the outcomes of the scenario(s) are reflected in the scenario-based roadmap. Most of the existing approaches mainly focus on building simple scenarios to support technology roadmapping or simply suggest the concept of multi-path roadmapping. Strauss and Radnor (2004) found that only a single scenario is usually taken as a straight-line projection of the future so as to facilitate the decision-making process for

strategic planning and forecasting in a simple way. Lee et al. (2015a) also mentioned that these studies may only provide a conceptual way to make decisions for strategic planning and forecasting under the simple future conditions using graphical mapping tools. Moreover, Saritas and Aylen (2010) proposed that scenarios are used as visions to support the roadmapping process for future choices, implying that the scenarios may not be embedded in the roadmapping process practically. There is a missing link in the literature regarding how to embed scenarios with future changes into roadmaps for strategic planning and decision-making at the organizational level.

Table 3 Comparison of the existing scenario-based roadmapping approaches

Method	Strauss and Radnor (2004)	Saritas and Aylen (2010)	Amer et al. (2016)	Proposed SBRM approach
Domain	Strategic Planning	Foresight	Strategic Planning	Strategic Planning
Purpose	Corporate planning	Policy and strategy making	Future studies	Corporate planning
Focus on	Alternative future	Alternative future	Alternative future	Alternative future
Level	Organizational level	National level	National level	Organizational level
View of thinking	Micro view (i.e. micro planning)	Macro view (i.e. macro thinking)	Macro view (i.e. macro thinking)	Micro view (i.e. micro planning)
Process				
Scenario building	○	○	○	○
Scenario assessment	×	×	○	○
Scenario selection	×	×	○	○
Integration of scenarios in a roadmap	○	N/A	○	○
Outcome				
Scenario	• Micro level • Multiple • Qualitative	• Macro level • Multiple • Quantitative	• Macro level • Multiple • Qualitative	• Micro level • Multiple • Qualitative
Scenario-based roadmap	• Strategic and operational level • Multiple	N/A	• Strategic level • Multiple	• Strategic and operational level • Multiple

○ = Provided; × = Not provided; N/A = Not applicable

In order to address the key issues found in the existing methods, this paper attempts to design and develop a scenario-based roadmapping (SBRM) method by incorporating environment-oriented (i.e. scenario planning) and company-oriented (i.e. roadmapping) approaches for strategic planning and decision-making. By a combination of both scenario planning and technology roadmapping approaches, the proposed method is a management tool for organizations to conduct scenario building, assessment, and selection of possible scenarios, as well as embed possible future scenarios with positive

and negative impacts into operational roadmaps with an action plan. It also provides companies with insights into how they can get ready to understand possible future scenarios with positive and negative impacts and implement action plans for future changes.

2. Scenario-based Roadmapping (SBRM) Method

The scenario-based roadmapping (SBRM) method for strategic planning and decision-making is proposed to build possible scenarios reflecting future situations in practice, to assess the impact of each scenario, and to develop roadmaps with external and internal issues as well as the actions according to the scenarios. As shown in Figure 1, the proposed method consists of five main phases including prerequisite preparation (Phase 1), scenario team formation (Phase 2), scenario building (Phase 3), scenario assessment and selection (Phase 4), and scenario-based roadmapping (Phase 5). Figure 1 illustrates a framework for the proposed SBRM method.

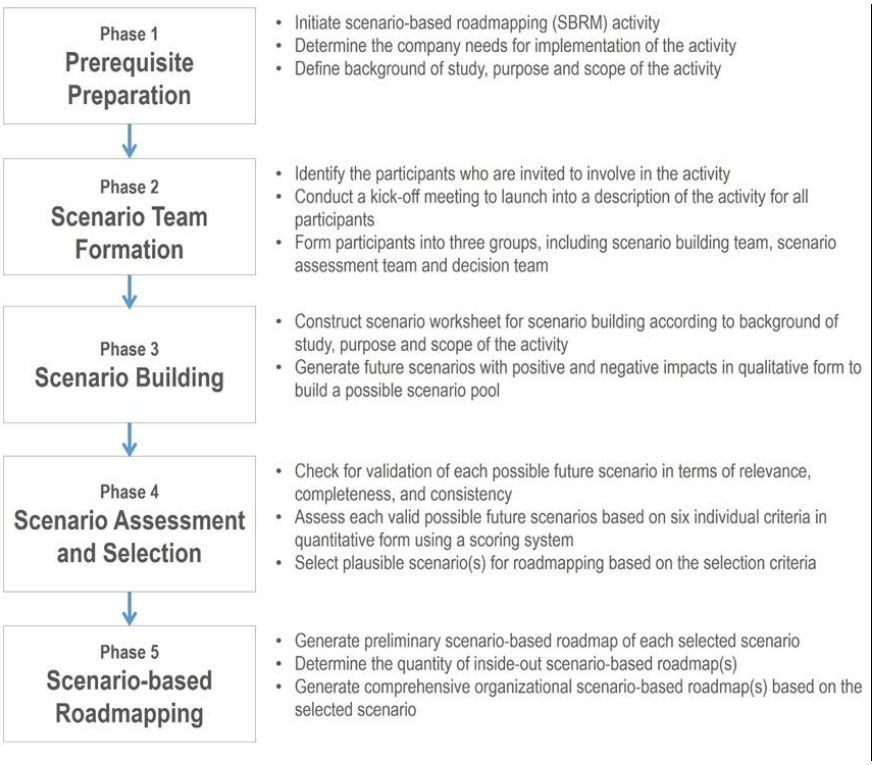


Figure 1 Framework for the proposed scenario-based roadmapping (SBRM) method

2.1 Phase 1 – Prerequisite Preparation

Prerequisite preparation is the first step of the proposed SBRM method (i.e. Phase 1) and aims to provide a preliminary discussion to determine the company need for the implementation of SBRM activity. Staff from top management are highly encouraged to be involved in this phase, since they act as initiators of the SBRM activity and are

also responsible for determining the company needs, the background of study, purpose and scope, and other staff for the arrangement of the activity.

2.2 Phase 2 – Scenario Team Formation

Scenario team formation is Phase 2 of the proposed method that aims to identify participants who are invited to be involved in the SBRM activity. The participants are grouped into three teams in order to play three different roles including scenario building team, scenario assessment team and decision team. The scenario building team is responsible for generating possible scenarios using a qualitative approach to build a possible scenario pool. To ensure the quality of the scenarios, experienced staff who are familiar with the industry/market/technology should be invited to be the members of the scenario building team. The scenario assessment team is responsible for evaluating the possible scenarios generated by the scenario building team using a quantitative approach. Managerial staff who possess relevant experience are invited to assess the future scenarios from technical, financial and marketing perspectives. They are required to be members of the scenario assessment team. They include technical manager, sales manager and financial manager. According to the assessment results, the decision team is responsible for selecting the plausible scenario(s) from the possible scenario pool for the implementation of the technology roadmap and the top management staff in the organization are highly recommended to participate in this team.

2.3 Phase 3 – Scenario Building

In the phase of scenario building (Phase 3), various possible scenarios are generated by the scenario building team. A guideline for scenario building was designed for the participants to construct the possible scenarios in a consistent and qualitative format by adapting the principles of the six thinking hats method (de Bono, 2010), as follows:

- Organization of the thinking process (blue hat thinking)
  Since blue hat thinking focuses on managing the thinking process and the use of the other hats, the thinking process of the scenario building activity is designed and developed systematically to provide a clear picture of how to generate a future scenario during the activity.
- Information (white hat thinking)
  White hat thinking focuses on data, facts, information known and information needed. The information (i.e. hard facts) available to support a future scenario is required to provide the justifications that are needed.
- Emotions (red hat thinking)
  Red hat thinking focuses on feelings, hunches, gut instincts and intuition. It is used to interpret the intuitive information (i.e. future forecast) to support the future

scenarios, but no justifications are required.

- Optimism (yellow hat thinking)
  Yellow hat thinking focuses on values and benefits, such as why something may work. It is used to think about positive impacts of a future scenario (i.e. enablers or benefits).
- Discernment (black hat thinking)
  Black hat thinking focuses on difficulties and potential problems, such as why something may not work. It is used to think about the negative impacts of a future scenario (i.e. barriers or risks).
- Creativity (green hat thinking)
  Green hat thinking focuses on creativity, such as possibilities, alternatives, solutions and new ideas. It is used to generate new ideas or suggestions or possible solutions regarding how to deal with future scenarios.

According to the proposed thinking method of scenario building, a framework for scenario building worksheet is purposely designed to elicit information for building consistent and qualitative scenarios, which consists of three sections, including introduction, instruction and questions for scenario building (see Figure 2).

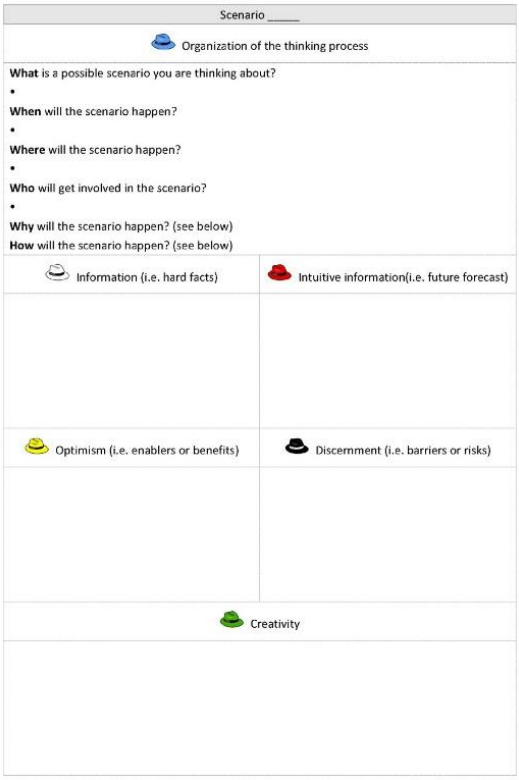


Figure 2 Framework for the scenario building worksheet

The background of study, purpose and scope of the SBRM activity are described in the Introduction section so as to make sure that the participants have a better understanding of the activity. Instructions are provided in the form of a clear guideline to help the participants to build scenarios using the worksheet. Two series of questions for building positive and negative future scenarios are designed in terms of what, when, where, who, why and how using the Kipling method (five Ws and one H or 5W1H).

- **What** is the possible scenario you are thinking about?
- **When** will the scenario happen?
- **Where** will the scenario happen?
- **Who** will get involved in the scenario?
- **Why** will the scenario happen?
- **How** will the scenario happen?

In this phase, each member of the scenario building team should provide at least a pair of scenarios (i.e. positive and negative future scenarios) as an expected deliverable after the completion of the scenario building worksheet.

2.4 Phase 4 – Scenario Assessment and Selection

The scenario generated in Phase 3 is a construct in qualitative form, which is not measurable quantitatively. In the scenario planning study conducted by Amer et al. (2013), many researchers identified that plausibility, consistency, relevance, creativity, and completeness as significant criteria for the assessment and selection of a scenario. In this phase, a framework for scenario assessment was designed and developed to check the validity of each possible scenario in order to ensure its credibility, which takes (a) relevance, (b) completeness, (c) consistency, (d) plausibility and (e) creativity into account.

(a) Relevance: each scenario must be relevant to the company's need, purpose and scope of the scenario-based roadmapping (SBRM) activity.
(b) Completeness: each scenario should be generated completely in terms of 5W1H.
(c) Consistency: each scenario is generated based on the proposed framework for the scenario building worksheet.
(d) Plausibility: each scenario must be plausible and capable of happening.
(e) Creativity: each scenario must be new in relation to the issues concerned in the SBRM activity.

All scenarios (i.e. positive and negative future scenarios) generated in Phase 3 are required to be validated in terms of relevance, completeness and consistency. If the scenario is able to fulfil these three criteria, the scenario is considered to be a valid

scenario for scenario assessment in terms of plausibility and creativity.

2.4.1 Scenario Assessment

Each valid scenario (i.e. positive and negative future scenarios) is assessed in terms of plausibility and creativity. Since the proposed SBRM method is a pragmatic management tool for the organization to implement an action plan according to the plausible future scenario, impact, estimated market share, estimated investment and government support are also taken into account in the scenario assessment. In the proposed SBRM method, a series of assessment criteria is designed and developed to determine whether the scenario is plausible in terms of feasibility (c_1), degree of innovativeness (c_2), impact (c_3), estimated market share (c_4), estimated investment (c_5), and government support (c_6). For the quantitative assessment of scenarios, the team is offered a 5-point scale scoring system (i.e. scores of 1, 2, 3, 4 and 5) to evaluate the scenario based on six individual criteria, as shown in Table 4.

Table 4 5-Point scale scoring system for scenario assessment

Scores	**1**	**2**	**3**	**4**	**5**
Feasibility	Very low	Low	Moderate	High	Very high
Degree of Innovativeness	Very low	Low	Moderate	High	Very high
Impact	Very low	Low	Moderate	High	Very high
Estimated Market Share	Very low	Low	Moderate	High	Very high
Estimated Investment	Very high	High	Medium	Low	Very low
Government Support	No	Less	Moderate	More	Fully

Feasibility (c_1) is assessed for the future scenario based on its practicality. If the scenario feasibility is high or very high (i.e. score of 4 or 5), it means that the scenario may be a plausible or probable future scenario. If the scenario feasibility is very low or low (i.e. score of 1 or 2), this indicates that the scenario may be impossible or less possible to happen in the future. If the scenario feasibility is moderate (i.e. score of 3), the scenario may be a possible one. Degree of innovativeness (c_2) is used to determine whether the future scenario is new to the market, business or service. If the degree of innovativeness is high or very high (i.e. score of 4 or 5), the scenario may be a new or fairly new idea to the market, business, or service in the future. Otherwise, a very low or low degree of innovativeness (i.e. score of 1 or 2) represents that the scenario is existing or nothing

new to the market, business, or service in the future. If the degree of innovativeness is moderate (i.e. scores of 3), the scenario may be a fair one. Impact (c_3) is used to determine whether the future scenario has an effect or influence on the market, business, or service. If the scenario has a marked or remarkable effect in the future, it may be rated a score of 4 or 5, and otherwise it may be rated a score of 1, 2, or 3.

Estimated market share (c_4) is an indicator of market competitiveness, which is used to measure the business performance of a company compared to its competitors. Different industries have different definitions of the market share percentage, so the range of the percentage of a market share for scenario assessment is determined by the expert or senior managerial staff in specific industries. Estimated investment (c_5) is time, money and human resources expected to be spent in the future scenario within a specific time frame. If the investment is high or very high, the scenario may be rated a score of 4 or 5, and otherwise it may be rated a score of 1, 2, or 3. Government support (c_6) is used to determine how the government provides support to the industry, market or business such as policy support, technology and innovation support as well as financial support. If the government provides full support to the industry, market or business, the scenario may be rated a score of 5; otherwise, it may be rated a score of 1.

Each member of the scenario assessment team gives their marks in terms of the scores (s_{ij}) to each criterion taking into consideration the strengths and weaknesses of the future scenario using a scenario assessment form, as shown in Table 5.

Table 5 Scenario assessment form

Criteria	**Scores (1-5)**	**Justifications**
Feasibility		
Degree of Innovativeness		
Impact		
Estimated Market Share		
Estimated Investment		
Government Support		

After collecting all the assessment results from the scenario assessment team, average scores of individual criteria for each scenario ($\bar{s}_i$) are calculated by using Equation (1), as illustrated in Table 6. The average score of each individual criterion ($\bar{s}_i$) is defined as:

$$\bar{s}_i = \sum_{j=1}^{n} s_{ij} \,/\mathrm{n} \qquad (1)$$

where $\bar{s}_i$ is an average score of each individual criterion, s_{ij} is an individual score of criterion assessed by each member, m is the total number of the individual criteria ($i = 1,2,\dots,m$) and n is the total number of members ($j = 1,2,\dots,n$) in the scenario assessment team.

Table 6 Average scores of individual criteria for scenario assessment

Criteria, c_i	**Individual Scores, s_{ij}**			**Average Scores of Individual Criteria, $\bar{s}_i$**
	s_{i1}	s_{i2}	s_{i3}	
Feasibility (c_1)	s_{11}	s_{12}	s_{13}	$\bar{s}_1$
Degree of Innovativeness (c_2)	s_{21}	s_{22}	s_{23}	$\bar{s}_2$
Impact (c_3)	s_{31}	s_{32}	s_{33}	$\bar{s}_3$
Estimated Market Share (c_4)	s_{41}	s_{42}	s_{43}	$\bar{s}_4$
Estimated Investment (c_5)	s_{51}	s_{52}	s_{53}	$\bar{s}_5$
Government Support (c_6)	s_{61}	s_{62}	s_{63}	$\bar{s}_6$

Feasibility (c_1) is the most significant criterion for scenario assessment which is used to determine the practicality of a future scenario. To ensure the quality of the scenario, if the average scores of the feasibility ($\bar{s}_1$) of the scenario are lower than 3, the scenario may not be treated as a possible scenario and it may not be submitted for scenario selection. If $\bar{s}_1$ is equal to or higher than 3, the scenario is considered to be a plausible scenario which is retained in the possible scenario pool for further consideration. Based on this condition, a decision variable f is used to determine whether the scenario is plausible or possible, which is defined as:

$$f = \begin{cases} 0, & otherwise \\ 1, & if\ \bar{s}_1 \geq 3 \end{cases} \qquad (2)$$

As shown in Table 7, the weighted scores and the ranking of the scenario are used to identify which scenario is a plausible scenario as well as which scenario is the most important for consideration, respectively. Each criterion has a relative weighting (w_i) ranging from 0 to 1 to reflect its importance to the scenario. The sum of weighting of all the criteria should be equal to 1. The weighting of each criterion may be determined by experts in the industry or senior managerial staff in the company. The higher the weighting of the criterion, the more importance to the scenario that is inferred. Based

on Equation (1), the weighted average scores of individual criteria ($\overline{s_{w_i}}$) are defined as:

$$\overline{s_{w_i}} = \bar{s}_i \cdot w_i \qquad (3)$$

Based on Equation (2) and Equation (3), an overall score of the future scenario ($\overline{S_w}$) is defined as:

$$\overline{S_w} = f \cdot \sum_{i=1}^{n} \overline{s_{w_i}} \qquad (4)$$

After the completion of scenario assessment, the ranking of the positive and negative future scenarios is determined according to the overall score of the scenario as shown in Table 8.

Table 7 Weighted average scores of individual criteria and overall scores for scenario assessment

Criteria, c_i	**Average Scores of Individual criteria, $\bar{s}_i$**	**Relative weighting, w_i**	**Weighted Average Scores, $\overline{s_{w_i}}$**
Feasibility (c_1)	$\bar{s}_1$	w_1	$\overline{s_{w_1}}$
Degree of Innovativeness (c_2)	$\bar{s}_2$	w_2	$\overline{s_{w_2}}$
Impact (c_3)	$\bar{s}_3$	w_3	$\overline{s_{w_3}}$
Estimated Market Share (c_4)	$\bar{s}_4$	w_4	$\overline{s_{w_4}}$
Estimated Investment (c_5)	$\bar{s}_5$	w_5	$\overline{s_{w_5}}$
Government Support (c_6)	$\bar{s}_6$	w_6	$\overline{s_{w_6}}$
Overall scores of the scenario			**$\overline{S_w}$**

Table 8 Score table of overall assessment results

	Overall Scores					
	Positive Future Scenario			**Negative Future Scenario**		
Criteria	**A_P**	**B_P**	**C_P**	**A_N**	**B_N**	**C_N**
Feasibility						
Degree of Innovativeness						
Impact						
Estimated Market Share						
Estimated Investment						

Government Support						
Weighted Scores:						
Ranking:						

2.4.2 Scenario Selection

Scenario selection aims to select plausible future scenario(s) from the valid scenarios for implementation of scenario-based roadmapping. Members of the decision team should read all scenario building worksheets of the valid possible scenarios in detail. A summary of the valid scenarios is also generated in terms of "when", "where" and "who" for the decision team's consideration. Except for the summary and assessment results of the scenarios in Phase 4, the decision team should take the company needs, purposes and scopes of the SBRM activity into consideration to select the plausible scenario(s) from the valid scenarios. Criteria for selection of a plausible future scenario are given as follows:

(a) The scenario must have high relevance to the company's needs;
(b) The scenario should match the purpose and scope of the SBRM activity;
(c) The scenario should be generated by the completeness of information in terms of 5W1H;
(d) An action plan for the future changes should be provided at organizational level; and
(e) Individual scores of criterion "feasibility" must be equal to 4 or above.

If the valid scenario can fulfil the above mentioned criteria, it can be considered a plausible scenario for implementation of scenario-based roadmapping in Phase 5.

2.5 Phase 5 – Scenario-based Roadmapping

Scenario-based roadmapping aims to implement the organizational future action plan(s) with a timeline according to what plausible future scenarios they can serve. The scenario-based roadmapping process comprises two main steps including preliminary scenario-based roadmapping, and inside-out scenario-based roadmapping.

2.5.1 Preliminary scenario-based roadmapping

Preliminary scenario-based roadmapping is proposed to generate a preliminary scenario-based roadmap with the aim of visualizing the action plan for each selected scenario from an outside-in perspective. A framework for the preliminary scenario-based roadmap is designed and shown in Figure 3 and consists of six components: suggested action plan, timeline, milestones, drivers (i.e. internal and external),

provider(s) (person or party who is involved in and takes actions in the plan) and consumer(s) (person or party who is involved in and serves in the plan).

By adapting the Hybrid Roadmapping Method (HRMM) (Cheng et al., 2014), the preliminary roadmap is generated by the scenario building team based on information elicited in the worksheets of the selected scenario(s) completed in Phase 3. Content in the roadmap expresses their ideas and opinions in regard to the future action plan with a timeline according to the selected plausible scenario. The preliminary roadmaps are checked for validation by the scenario assessment team for inside-out scenario-based roadmapping use.

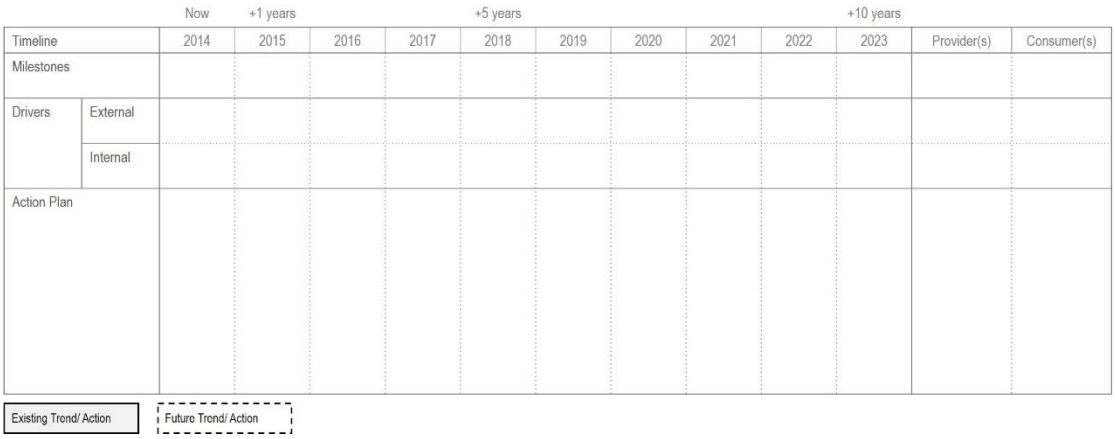


Figure 3 A framework for the preliminary scenario-based roadmap

2.5.2 Inside-out scenario-based roadmapping

On the basis of the preliminary scenario-based roadmap, inside-out scenario-based roadmapping is used to generate comprehensive organizational scenario-based roadmap(s) with the aim of implementing the future action plan(s) from an inside-out perspective. A framework for the organizational scenario-based roadmap is designed and shown in Figure 4 and consists of seven components: future action plan, timeline, milestones, drivers (i.e. internal and external), expected outcome, provider(s) and consumer(s).

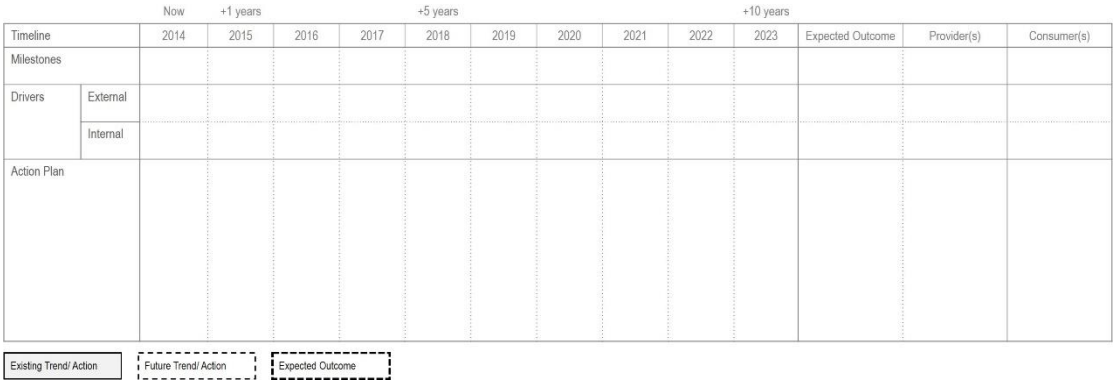


Figure 4 A framework for the organizational scenario-based roadmap

Before the implementation of the inside-out scenario-based roadmapping, the decision team should make a decision to determine the quantity of inside-out scenario-based roadmaps. All the participants of the SBRM activity are invited to conduct the scenario-based roadmapping from an organizational viewpoint via a face-to-face discussion approach. Content of the organizational roadmap(s) visualizes their future action plan for the organization within a time frame according to what plausible future scenarios they can serve (i.e. the selected plausible scenario).

3. Case Study and Trial Implementation

To realize the capability of the proposed SBRM method, a case study was conducted in a Global Testing, Inspection and Certification (TIC) company in Hong Kong. The target company named "Company T" currently has more than 30,000 employees around the world located in 50 countries and established its Hong Kong office in 1996 which provides various testing, product certification, and management system certification services for electrical and electronic products.

3.1 Prerequisite Preparation and Scenario Team Formation of the SBRM Activity

Nowadays, the establishment of manufacturers' testing laboratories appears to be a future trend in mainland China. Many TIC companies realize that this trend provides great opportunities for expanding their business into the China market. The target company also has full intention of providing various services to assist product manufacturers establish their own testing laboratories following the procedures developed by the International Electrotechnical Commission (IEC). This is particularly true for these three procedures of the programme, i.e. Testing at Manufacturer's Premises (TMP), Witnessed Manufacturer's Testing (WMT) and Supervised Manufacturer's Testing (SMT). In the process of prerequisite preparation (i.e. Phase 1), Company T determined the company needs for implementation of the proposed scenario-based roadmapping activity. The target company wanted to explore the future

scenarios for establishment of manufacturers' testing laboratories in mainland China. With regard to the company needs, the proposed SBRM method was applied for strategic planning and forecasting of the manufacturers' testing laboratories programme in the TIC industry based on a 10-year horizon (i.e. 2014 - 2023). Top management of the target company conducted a kick-off meeting to initiate the SBRM activity. They also invited participants in the company who would be involved in the activity to attend the meeting. The proposed SBRM method was introduced to all the participants.

3.2 Background of the Study

Traditionally, TIC companies provide services to their clients (e.g. manufacturers) for product testing, inspection and certification as a Certification Bodies Testing Laboratory (CBTL). Starting from 2007, the International Electrotechnical Commission (IEC) established a programme named "Manufacturers' Testing Laboratories" in the IEC System for Conformity Testing and an Electrotechnical Equipment and Components Certification Body (IECEECB) Scheme. By using the IECEECB scheme, manufacturers who are responsible for the design, development and production of their products are required to have the capability to establish testing laboratories in consideration of personnel, facilities, and equipment for testing their products (IEC, 2007). To understand the market needs, four different procedures were developed by the IEC for obtaining CB Test Certificates under controlled conditions:

- Testing at Manufacturer's Premises (TMP) Procedure
- Witnessed Manufacturer's Testing (WMT) Procedure
- Supervised Manufacturer's Testing (SMT) Procedure
- Recognized Manufacturer's Testing (RMT) Procedure

Descriptions of TMP, WMT, SMT, and RMT programmes are summarized and illustrated in Table 9 (adapted from IEC, 2007).

Table 9 Descriptions of TMP, WMT, SMT and RMT programmes

Programme	Laboratory	Equipment	Personnel	NCB's responsibility		
				Supervise	Witness	Assess
TMP	●	●	○	-	-	-
WMT	●	●	●	-	○	-
SMT	●	●	●	○	○	-
RMT	●	●	●	-	-	○

● = conducted/provided by Manufacturer; ○ = conducted/provided by 3rd Party Laboratory

3.3 Development of the Scenario Building Worksheet

In this case, the target company wanted to focus on services for the programme "establishment of manufacturers' testing laboratories in Mainland China". According to the proposed methodology (i.e. Phase 3) as mentioned in Section 2.3, a guideline for scenario building was designed and developed for generating future scenarios and consisted of three main sections including introduction, instruction, and questions for scenario building. The guideline for scenario building is illustrated in Appendix A. In the introduction, the background of the study, purpose, and scope of the SBRM activity were described, and information about the industry and a market overview were also included. Instructions provided a clear guideline to the participants on how to construct positive and negative future scenarios during the activity. There was a total of 16 questions for building the future scenario: the first eight questions (i.e. P1 – P8) attempted to construct positive future scenarios while the other eight questions (i.e. N1 – N8) aimed at constructing negative future scenarios.

P1. What is the possible future scenario that may happen and bring opportunities or positive impacts to Hong Kong's TIC industry in the coming 10 years?

P2. Why do you think that this future scenario is possible to happen in the future? Is there any evidence to support the scenario? *(The information (i.e. hard facts) available to support the future scenario is required to be provided and the justifications are needed.)*

P3. When will the scenario be expected to happen in the future according to your estimation?

P4. Where will the scenario happen?

P5. Who will get involved in the scenario? Within or outside the company?

P6. How will the scenario happen?

P7. Do you have any ideas or suggestions or solutions regarding how to deal with the future change in this scenario?

P8. What resources may be allocated to support this scenario? *(Please also provide the justifications for how the resources will be utilized in this scenario.)*

N1. What is possible future scenario that may happen and bring challenges or negative impacts to Hong Kong's TIC industry in the coming 10 years?

N2. Why do you think that this future scenario is possible to happen in the future? Is there any evidence to support the scenario? *(The information (i.e. hard facts) available to support the future scenario is required to be provided and the justifications are needed.)*

N3. When will the scenario be expected to happen in the future according to your

estimation?

N4. Where will the scenario happen?

N5. Who will get involved in the scenario? Within or outside the company?

N6 How will the scenario happen?

N7. Do you have any ideas or suggestions or solutions regarding how to deal with the future change in this scenario?

N8. What resources may be allocated to support this scenario? *(Please also provide the justifications for how the resources will be utilized in this scenario.)*

3.4 Development of a Scoring System and Assessment Form

According to Phase 4 of the proposed SBRM method as mentioned in Section 2.4, the scoring system and assessment form for the case study were developed, as shown in Tables 10 and 11. Ranges of the estimated market share and relative weightings of individual criteria were determined by managerial staff of the target company.

Table 10 Scoring system for the case study

Scores	**1**	**2**	**3**	**4**	**5**
Feasibility	Very low	Low	Moderate	High	Very high
Degree of Innovativeness	Very low	Low	Moderate	High	Very high
Impact	Very low	Low	Moderate	High	Very high
Estimated Market Share	<5%	6% - 9%	10 %	10% - 13%	>13%
Estimated Investment	Very high	High	Medium	Low	Very low
Government Support	No	Less	Fair	More	Fully

Table 11 Assessment form for the case study

Criteria	**Relative weighting**	**Scores (1-5)**	**Justifications**
Feasibility	0.3		
Degree of Innovativeness	0.2		
Impact	0.2		
Estimated Market Share	0.1		
Estimated Investment	0.1		
Government Support	0.1		
Total sum of weighting	1		

4. Results and Discussion

This section summarizes and discusses the results of the case study. In the process of scenario building (Phase 3), members of the scenario building team were invited to construct possible scenarios in a consistent and qualitative format using the scenario building worksheets developed in Section 3.2. On the completion of the scenario building in Phase 3, three completed worksheets (i.e. worksheets A, B and C) were collected and six future scenarios were obtained to build a possible scenario pool, consisting of three positive (i.e. **A_P**, **B_P** and **C_P**) future scenarios and three negative (i.e. **A_N**, **B_N** and **C_N**) future scenarios, as shown in Appendix B. All these worksheets were passed to the scenario assessment team for assessment and selection.

In the process of scenario assessment and selection (i.e. Phase 4), six scenarios (i.e. **A_P**, **A_N**, **B_P**, **B_N**, **C_P**, **C_N**) were checked for validity in terms of consistency, relevance, and completeness. Validation results of the scenarios are shown in Figure 5(a), (b) and (c), respectively. According to the validation results, all the scenario building in Phase 3 fulfilled the three criteria, so they were considered to be valid scenarios for conducting assessment in terms of plausibility and creativity in the case study.

Scenario	Consistency	White	Red	Yellow	Black	Green
A_P	✓	●	●	●	●	●
A_N	✓	●	●	●	●	●
B_P	✓	●	●	●	-	●
B_N	✓	●	-	-	●	●
C_P	✓	●	●	●	●	●
C_N	✓	●	●	-	●	●

(a)

Scenario	Relevance	Company Need	Purpose	Scope	TMP	WMT	SMT	RMT
A_P	✓	●	●	●	★	★	★	★
A_N	✓	●	●	●	★	★	★	★
B_P	✓	●	●	●	-	-	★	★
B_N	✓	●	●	●	-	-	-	-
C_P	✓	●	●	●	-	-	-	-
C_N	✓	●	●	●	-	★	★	-

(b)

Scenario	Completeness	What	When	Where	Who	Why	How
A_P	✓	●	●	●	●	●	●
A_N	✓	●	●	●	●	●	●
B_P	✓	●	●	●	●	●	●
B_N	✓	●	●	●	●	●	●
C_P	✓	●	●	●	●	●	●
C_N	✓	●	●	●	●	●	●

(c)

Figure 5 Validation results of each scenario in terms of (a) consistency, (b) relevance and (c) completeness

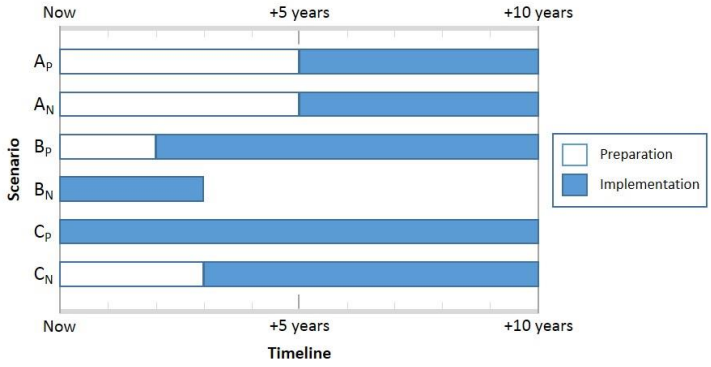
According to the scoring system as illustrated in Table 10, these six valid scenarios were assessed based on the six criteria by the scenario assessment team using the assessment form as shown in Table 11, and the assessment results of possible future scenarios were calculated in terms of the weighted scores and ranking, as shown in Table 12. In this case study, the scores of feasibility for all scenarios were 3 or 4, so all the scenarios were submitted to the decision team for further consideration.

Table 12 Assessment results of the six possible future scenarios

	Scores					
	Positive Future Scenario			**Negative Future Scenario**		
Criteria (Relative Weighting)	**A_P**	**B_P**	**C_P**	**A_N**	**B_N**	**C_N**
Feasibility (0.3)	4	4	4	3	3	4
Degree of Innovativeness (0.2)	3	2	1	2	1	3
Impact (0.2)	4	3	3	5	3	4
Estimated Market Share (0.1)	3	3	3	3	3	3
Estimated Investment (0.1)	3	4	2	3	3	3
Government Support (0.1)	4	4	2	5	2	4
Weighted Scores	**3.6**	**3.3**	**2.9**	**3.4**	**2.5**	**3.6**
Ranking	**1**	**2**	**3**	**2**	**3**	**1**

In the process of scenario selection, the decision team of the target company conducted a summary of all the valid scenarios in terms of "when", "where", and "who" for further consideration, as shown in Figures 6(a), (b), and (c), according to the completed scenario building worksheets. In terms of "when", three out of the six possible future scenarios (i.e. **B_P**, **B_N**, **C_P**) were for short-term targets, and the others (i.e. **A_P**, **A_N**, **C_N**)

were for medium- to long-term targets, as shown in Figure 6(a). In terms of "where", the scenarios will happen mainly in mainland China and Hong Kong. In terms of "who", the stakeholders involved in the scenarios are manufacturer, Company T (i.e. target company), personnel of the target company, investor, auditor, competitor, TIC Industry, Hong Kong Accreditation Service (HKAS), IEC, and Hong Kong Council for Testing and Certification (HKCTC).



(a)

	Where will the scenario happen? (Location)		
Scenario	1	2	3
A_P	China	-	-
A_N	Hong Kong	China	-
B_P	Hong Kong	China	-
B_N	Hong Kong	China	-
C_P	Hong Kong	-	-
C_N	China	-	-

(b)

	Stakeholder													
Scenario	Manufacturer	Company T	Managerial Staff	Technical Staff	Financial Staff	Sales Staff	HR Staff	Investor	Auditor	Competitor	TIC	HKAS	IEC	HKCTC
A_P	●	●	-	★	★	-	-	●	-	-	-	-	●	-
A_N	●	●	-	★	-	-	-	-	-	●	●	-	●	-
B_P	●	●	-	★	-	-	-	-	●	-	●	●	●	-
B_N	●	●	★	★	★	★	★	●	-	●	●	-	-	●
C_P	●	●	★	★	★	★	★	●	-	-	●	-	-	●
C_N	●	●	-	★	-	-	-	-	-	-	-	-	●	-

(c)

Figure 6 Summary of all the valid scenarios in terms of (a) "when", (b) "where" and (c) "who"

Scenarios **A_P** and **C_N** were chosen as plausible scenarios for implementation of scenario-based roadmapping, since they fulfilled the following selection criteria:

(a) Both scenarios were highly related to the company needs in terms of "what" (i.e.

WMT and SMT in the manufacturers' testing laboratories programme);

(b) Both scenarios matched the purpose and scope of the SBRM activity in terms of "when" (i.e. medium- to long-term target, 2014 – 2023), "where" (i.e. mainland China, Hong Kong) and "who" (i.e. manufacturers in mainland China and personnel in TIC Company);

(c) Both scenarios provided a clear picture to describe "why" and "how" the scenario would happen, from various perspectives of the information (i.e. hard facts), intuitive information (i.e. future forecast), optimism (i.e. enablers or benefits) and discernment (i.e. barriers or risks);

(d) Both scenarios provided practical action plans on how to deal with future changes in organizational and operational aspects; and

(e) Both scenarios had individual scores for the criterion "feasibility" of 4.

In the process of preliminary scenario-based roadmapping, two preliminary scenario-based roadmaps were generated to visualize the suggested action plans according to each selected plausible scenario (i.e. scenarios **A_P** and **C_N**), as shown in Figures 7 and 8. The preliminary roadmaps demonstrated the action plans individually regarding how to deal with future change within the time frame based on each selected scenario.

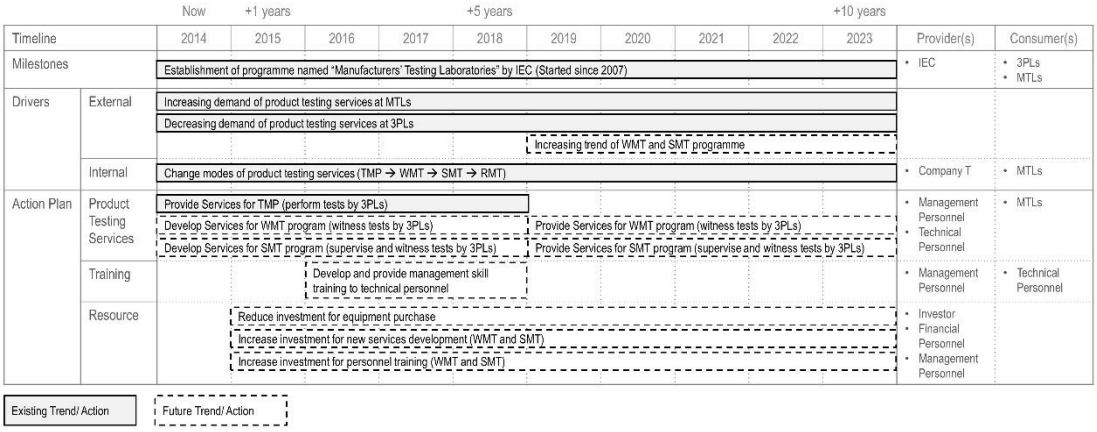


Figure 7 Preliminary scenario-based roadmap of scenario **A_P**

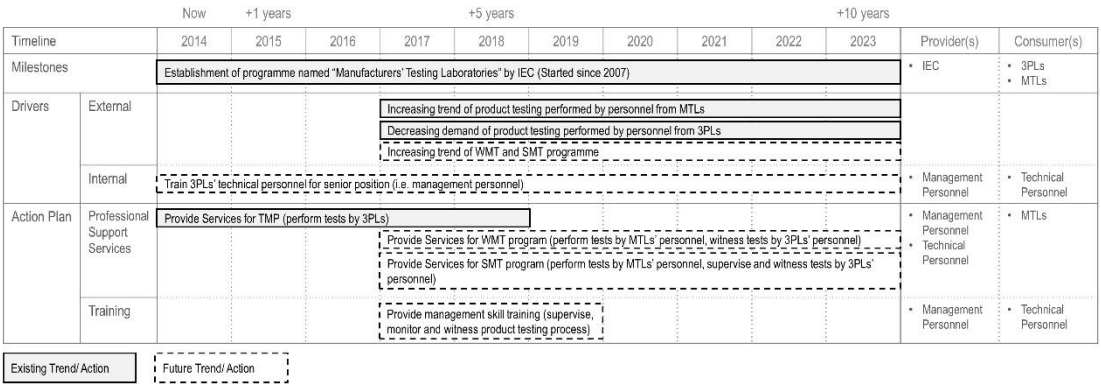


Figure 8 Preliminary scenario-based roadmap of scenario **C**N

After the completion of the preliminary roadmapping, all members of the three teams (i.e. scenario building, scenario assessment and decision teams) were invited as participants to conduct a one-day workshop for the implementation of inside-in scenario-based roadmapping. At the beginning of the workshop, the decision team determined that two selected scenarios were incorporated into one inside-out scenario-based roadmap, since the external drivers of two selected scenarios (i.e. **A**P and **C**N) were quite similar that concerned the increasing trend of SMT and WMT programmes in the future, and they provided a long-term plan with similar solutions (i.e. providing new services for the programmes and new management skill training for technical personnel) for dealing with the future changes in organizational view. A comprehensive scenario-based roadmap of business development for Manufacturers' testing laboratories in the TIC industry in the period between 2014 and 2023 was generated in regard to organizational view according to the experience and opinions of the participants, as well as the information obtained from the two selected future scenarios (i.e. preliminary roadmaps and scenario building worksheets) and their preliminary roadmaps, as shown in Figure 9.

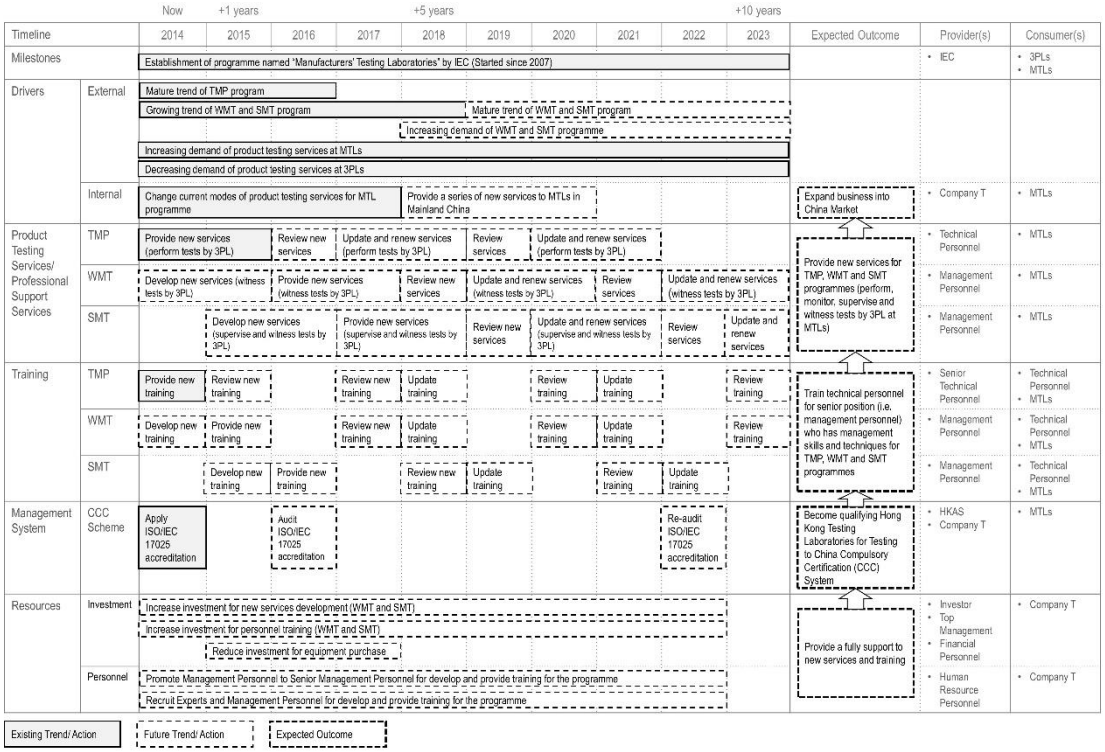


Figure 9 A comprehensive scenario-based roadmap for business development of the Manufacturers' testing laboratories programme in the TIC industry based on a 10-year horizon

As shown in Figure 9, the comprehensive organizational scenario-based roadmap can be used to visualize an operational action plan for the future ten years with the aim of answering company needs (i.e. expanding business into the mainland China market), as well as achieving the purpose and scope of the SBRM activity according to what plausible future scenarios they can serve (i.e. scenario $\mathbf{A_P}$ and $\mathbf{C_N}$).

To evaluate the performance of the proposed SBRM method, a feedback form was designed for the collection of feedback from the company, containing a total of 10 statements. On a Likert-type scale, the respondents were offered a choice of five responses (i.e. strongly agree, agree, neutral, disagree, strongly disagree) so as to express how they agree or disagree with a particular statement. After completion of all the phases of the proposed SBRM method, the target company was invited to evaluate the performance of the proposed method by using the feedback form.

According to the feedback collected from the target company as shown in Table 13, they strongly agreed that the proposed SBRM method stimulated the participants to formulate some ideas that they had not thought of before the implementation of the SBRM activity. With regard to the deliverables of the proposed method, they expressed

that the possible scenarios can be built as shown by the results to describe what may happen in the future in terms of 5W1H and various thinking perspectives using the scenario building worksheet. They also agreed that the proposed method is able to visualize the plausible scenario(s) that may happen in the future which provided a better understanding of positive (i.e. opportunities, enablers) and negative impacts (i.e. challenges, barriers) in future scenarios. They also agreed that the proposed method is helpful for strategic planning, forecasting and decision-making, since the possible future scenarios are constructed in a consistent and qualitative format and they are assessed based on six individual criteria in a quantitative format.

Table 13 Feedback form collected from the target company

1. The outputs are able to generate possible scenarios that may happen in the future.	Agree
2. The outputs provide a better understanding of the positive impacts of future scenarios.	Agree
3. The outputs provide a better understanding of the negative impacts of future scenarios.	Agree
4. The outputs are shown by the results to identify plausible scenarios that may happen in the future.	Agree
5. The outputs provide various solutions for the future changes.	Agree
6. The proposed method can help us to implement the roadmapping easily.	Strongly agree
7. The proposed method stimulated the participants to formulate some ideas that they hadn't thought of before.	Strongly agree
8. The proposed method is helpful for decision-making.	Agree
9. The proposed method is helpful for strategic planning and forecasting.	Agree
10. You will encourage others to apply the proposed method for strategic planning and forecasting.	Agree

Moreover, they pinpointed that the scenario-based roadmap was constructed successfully according to the selected scenarios, since the proposed SBRM method assisted them to implement the roadmapping process easily and provided them various solutions for dealing with future changes. Last but not least, the target company will continue to apply the proposed SBRM method as an effective management tool for strategic planning, decision-making and forecasting in the future, since the proposed method provides possible long-term benefits to the organization.

5. Conclusions

Nowadays, various companies are paying much attention to flexible future techniques for strategic planning and forecasting in complex and rapidly changing environments. The exploration of scenario planning and roadmapping is the evolution of a few decades of research. By leveraging the characteristics of both approaches, awareness of the concept of "scenario-based roadmapping" has increased for the preparation for change in complex future conditions in a decade. The literature provides evidence that the existing scenario-based roadmapping approaches are used widely to monitor and analyze future changes for Foresight and Future Studies at macro level (i.e. at national and industrial levels). However, there is a gap regarding how to embed the scenarios into roadmaps to plan for future actions at a micro level (i.e. at organizational and operational levels). Moreover, most previous research may not be practical as it mainly focused on building simple scenarios to support technology roadmapping or simply suggested the concept of multi-path roadmapping, but not embedding scenarios into a roadmap or evaluating the outcomes of the scenario(s) nor how to reflect the outcomes on the scenario-based roadmap.

In order to address the key issues found in the literature, this paper presents a scenario-based roadmapping (SBRM) method as an effective tool for strategic planning and decision-making by combining scenario planning with roadmapping approaches. The proposed SBRM method provides companies a practical scenario-based roadmapping process to conduct scenario building, assesses and selects possible scenarios, and embeds possible future scenarios with positive and negative impacts into operational roadmaps with an action plan. In this study, the proposed method was designed and developed to consist of five main phases, namely prerequisite preparation (Phase 1), scenario team formation (Phase 2), scenario building (Phase 3), scenario assessment and selection (Phase 4), and scenario-based roadmapping (Phase 5). Prerequisite preparation aims to determine the company needs for implementation of the SBRM activity, and to define the background of the study, purpose and scope of the activity in order to imitate the activity by top management. Scenario team formation is used to identify the participants who are invited to be involved in the activity and delegated to various groups, such as scenario building team, scenario assessment team and decision team for implementing the scenario-based roadmapping process. Scenario building is a significant phase (i.e. Phase 3) to build various possible future scenarios with positive and negative impacts by the scenario building team to visualize the future change in a qualitative format. The guideline of scenario building was designed to construct the possible scenarios in a consistent and qualitative format, by the adaption of the Kipling

method (five Ws and one H or 5W1H) and principles of the six thinking hats method. In Phase 4, each possible future scenario is checked for validity in terms of relevance, completeness and consistency first. Each valid scenario is assessed based on six individual criteria by the scenario assessment team quantitatively. A 5-point scale scoring system was designed and developed to provide a quantitative method (i.e. scores of 1, 2, 3, 4 and 5) for scenario assessment. According to the results of scenario assessment, the ranking of all the valid scenarios was determined based on the overall score of the scenario. In the process of scenario selection, the plausible scenario(s) was/were selected from the valid scenarios based on a series of selection criteria by the decision team for implementing the scenario-based roadmapping process. The scenario-based roadmap is constructed in Phase 5 according to the scenario(s) selected in Phase 4 for companies to have a clear picture about where they are, what they need to further investigate and where they will go.

The proposed SBRM method was implemented in a Global Testing, Inspection and Certification (TIC) company to realize its capability. The target company attempted to expand their business into the China market due to the establishment of the manufacturers' testing laboratories programme. The proposed method is applied for strategic planning and forecasting the manufacturers' testing laboratories programme in the TIC industry based on a 10-year horizon (i.e. 2014 - 2023). By adaption of six thinking hats and Kipling methods, the guideline for scenario building and the scenario building worksheet were designed and developed to elicit information for the participants to construct the possible scenarios in a consistent and qualitative format in Phase 3. In the case study, a total of six scenarios were built using the worksheet according to the guideline, i.e. three positive future scenarios and three negative future scenarios. Each possible future scenario was assessed to determine whether the scenario was plausible quantitatively in terms of feasibility (c_1), degree of innovativeness (c_2), impact (c_3), estimated market share (c_4), estimated investment (c_5) and government support (c_6). According to the assessment results, two possible future scenarios were selected as plausible scenarios for implementing the scenario-based roadmapping. A scenario-based roadmap was developed for strategic planning and forecasting according to the two selected scenarios. The target company made positive comments on the proposed SBRM which is relatively effective and easy to use, even though they had good knowledge and technical realization of the mature market and technology in the TIC industry. They also expressed that the results of the study were useful and practical to provide fresh insights for strategic planning and forecasting. Moreover, it not only allowed the company to externalize their insight of plausible future scenarios with positive and negative impacts at micro level for strategic planning and forecasting,

but also helped the company to visualize the future action plan according to the plausible future scenarios in an effective way. This is particularly important when companies attempt to manage market and technology activities practically for strategic planning and technology management.

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Appendix A – Guideline for Scenario Building

Guideline for Scenario Building

Title: Strategic Planning and Forecasting on Manufacturers' Testing Laboratories Programme in the TIC industry out to 10-year horizon (i.e. 2014 - 2023)

(A) Introduction

Nowadays, establishment of manufacturers' testing laboratories appears to be a future trend in mainland China. Many Testing, Inspection and Certification (TIC) companies realize that this trend provides great opportunities for expanding their business into the China market. Our company also has fully intention of providing various services to assist product manufacturers establish their own testing laboratories following the procedures developed by the International Electrotechnical Commission (IEC). This is particularly true for these three procedures of the programme, i.e. Testing at Manufacturer's Premises (TMP), Witnessed Manufacturer's Testing (WMT) and Supervised Manufacturer's Testing (SMT). Currently, our company would explore what the future scenarios about the establishment of manufacturers' testing laboratories in mainland China. With regard to the company needs, a scenario-based roadmapping method is applied for strategic planning and forecasting on manufacturers' testing laboratories programme in the TIC industry based on a 10-year horizon (i.e. 2014 - 2023).

Industry Overview

Testing, Inspection and Certification (TIC) industry is a well developing industry in Hong Kong. In 2009-2010 Hong Kong Policy Address, the Chief executive mention that Testing and Certification industry is one out of six industries strategically (六大優勢產業) in Hong Kong. However, the industry is living in a turbulent environment, meaning that the environment and changing rapidly such as social, technological, economic, environmental, and political etc.

Traditionally, TIC companies provide services to their clients (e.g. manufacturers) for product testing, inspection and certification as a Certification Bodies Testing Laboratory (CBTL). Starting from 2007, the International Electrotechnical Commission (IEC) established a programme named "Manufacturers' Testing Laboratories" in the IEC System for Conformity Testing and of Electrotechnical Equipment and Components (IECEE) Certification Body (CB) Scheme. The purpose of the Scheme, is "to facilitate trade by promoting harmonization of the national standards with international Standards and cooperation among accepted National Certification Bodies (NCBs) worldwide in order to bring product manufacturers a step closer to the ideal concept of "one product, one test, one mark, where applicable"." (IEC, 2008). Using the Scheme, manufacturers who are responsible to design, development and production their products, they are required to have capability to establish testing laboratories in consideration of personnel, facilities, and equipment for testing their products (IEC, 2007). To gain the recognition of the market needs, four different procedures were developed by IEC for obtaining CB Test Certificates under controlled conditions.

- Testing at Manufacturer's Premises (TMP) Procedure
- Witnessed Manufacturer's Testing (WMT) Procedure
- Supervised Manufacturer's Testing (SMT) Procedure
- Recognized Manufacturer's Testing (RMT) Procedure

Descriptions of CBTL, TMP, WMT, SMT and RMT are illustrated in Table 1 (adapted from IEC, 2007).

Table 1 Descriptions of CBTL, TMP, WMT, SMT and RMT (Adapted from IEC, 2007)

Laboratory Type	Definitions
CBTL	"A laboratory independent of manufacturing interests that has been recognized within the CB Scheme to test specified categories of products and to issue CB Test Reports." "A laboratory successfully assessed within CB Scheme performs all necessary tests with own equipment in own facilities"
TMP	"A manufacturer's laboratory being used by CBTL staff." "A representative of an accepted CBTL, under the responsibility of its NCB performs the full test in a manufacturer's laboratory with its own or the manufacturer's equipment"
WMT	"A manufacturer's laboratory being used for 100% Witnessed Testing by the NCB or, at the request of the NCB, by a CBTL." "A representative of an accepted CBTL, on the request of an NCB, witnesses all tests done by a manufacturer's laboratory which uses its own equipment"
SMT	"A manufacturer's laboratory being used by an NCB to conduct agreed testing within categories of products for which the manufacturer has design and production responsibility, generally with supervision of tests and quality processes." "A representative of an accepted NCB or an accepted CBTL, on request of an NCB, supervises the quality management system and the laboratory testing processes and witnesses some part of each agreed testing program at a manufacturer's laboratory, which uses its own equipment."
RMT	"A manufacturer's laboratory being used by a NCB to conduct agreed testing within categories of products for which the manufacturer has design and production responsibility, generally with supervision of quality processes." "A representative of an accepted NCB or an accepted CBTL, on request of an NCB, assesses initially and on an on-going basis the capability and expertise of the manufacturer's laboratory according to ISO/IEC 17025 and any other relevant IECEE Operational Documents, including the laboratory's quality management system and the laboratory's testing processes. RMT may be supervised by a registered LTR under the responsibility of a NCB. An LTR may conduct initial assessment only if employed within the same corporate."

As shown in Table 1, TMP is a widely used procedure in the programme as compared with other three procedures (i.e. WMT, SMT and RMT), which, at the request of an National Certification Body (NCB), personnel from a third-party laboratory conduct tests at manufacturer's laboratory with its own or manufacturer's equipment. For WMT, the commonality is to conduct tests in manufacturer's laboratory while the tests is conducted by manufacturer's staff rather than third-party employee, which it is similar to TMP. The duty of the third-party employee is to bear witness to all tests done by manufacturer's laboratory to ensure that the testing procedure is matched with international Standard. SMT is not a common used procedure in the programme. For SMT, a presentative of an accepted NCB/ third-party laboratory supervises the quality management system and the laboratory testing processes as well as witnesses some part of each agreed testing program at a manufacturer's laboratory. For the role of third-party laboratory, the job nature will change from testing staff to supervisor/ expert. For the RMT, this procedure is similar to SMT, but NCB is required to assess the capability of expertise of the manufacturer's laboratories according to ISO/IEC 17025, not required to witness or supervise all the test programmes.

Market Overview (Source: Hong Kong Certification and Testing Council (HKCTC) report)

Political Dimension:

- In order to enhance the safety requirement, the government will revise the regulation/ requirement regularly. So TIC industry need to facilitate their compliance with revised regulatory requirement.
- Some inspections now taken by the government while it may transfer to the private sector.

Social Dimension:

- Regard to local demand, about half of the business receipts for testing is from medical testing due to the health consciousness.
- Regard to external demand, textiles, clothing & footwear, toys & games, and electrical product.
- On system certification, ISO 9001 certificates granted has been stable in recent years, there is increasing demand for new types of system certification.
- The development of product certification in Hong Kong is at early stage. Since product certification can help enhance the quality of the products concerned, it is able to create new business opportunities for the testing and certification industry.
-

Technological Dimension:

- On physical metrology, the Standards and Calibration Laboratory of ITC is tasked with maintaining the reference standards of physical measurement traceable to the International system of Units (SI) for Hong Kong, promoting the international acceptance of these standards, and providing traceable calibration service to serve the local economy.
- On chemical metrology, the Government Laboratory develops chemical metrology in Hong

Kong. It provides chemical metrology support by organizing proficiency test programs and developing standard testing method.

(B) Instructions

1. Please read the following guidelines for scenario building carefully before you start to complete this worksheet.

2. Two series of questions for building positive and negative future scenarios are listed in this worksheet in terms of what, when, where, who, why and how using the Kipling method (five Ws and one H or 5W1H). The directions of the questions are shown as follows: -
   - **What** is the possible scenario you are thinking about?
   - **When** will the scenario happen?
   - **Where** will the scenario happen?
   - **Who** will get involved in the scenario?
   - **Why** will the scenario happen?
   - **How** will the scenario happen?

3. A guideline for scenario building is proposed for you to construct the possible scenarios in consistent and qualitative format by adapted the principles of six thinking hats method (de Bono, 2010), as shown below: -
   (a) Organization of the thinking process (blue hat thinking)
   Since blue hat thinking focuses on managing the thinking process and the use of the other hats, the thinking process of the scenario building activity is designed and developed systematically to provide a clear picture of how to generate a future scenario during the activity.
   (b) Information (white hat thinking)
   White hat thinking focuses on data, facts, information known and information needed. The information (i.e. hard facts) available to support a future scenario is required to provide the justifications that are needed.
   (c) Emotions (red hat thinking)
   Red hat thinking focuses on feelings, hunches, gut instincts and intuition. It is used to interpret the intuitive information (i.e. future forecast) to support the future scenarios, but no justifications are required.
   (d) Optimism (yellow hat thinking)
   Yellow hat thinking focuses on values and benefits, such as why something may work. It is used to think about positive impacts of a future scenario (i.e. enablers or benefits).
   (e) Discernment (black hat thinking)
   Black hat thinking focuses on difficulties and potential problems, such as why something

may not work. It is used to think about the negative impacts of a future scenario (i.e. barriers or risks).

(f) Creativity (green hat thinking)
Green hat thinking focuses on creativity, such as possibilities, alternatives, solutions and new ideas. It is used to generate new ideas or suggestions or possible solutions regarding how to deal with future scenarios.

(C) Questions for Building Future Scenario

(C1) Questions for Scenario Building of Positive Future Scenario

P1. What is the possible future scenario that may happen and bring opportunities or positive impacts to Hong Kong's TIC industry in the coming 10 years?

P2. Why do you think that this future scenario is possible to happen in the future? Is there any evidence to support the scenario? *(The information (i.e. hard facts) available to support the future scenario is required to be provided and the justifications are needed.)*

P3. When will the scenario be expected to happen in the future according to your estimation?

P4. Where will the scenario happen?

P5. Who will get involved in the scenario? Within or outside the company?

P6. How will the scenario happen?

P7. Do you have any ideas or suggestions or solutions regarding how to deal with the future change in this scenario?

P8. What resources may be allocated to support this scenario? *(Please also provide the justifications for how the resources will be utilized in this scenario.)*

(C2) Questions for Scenario Building of Negative Future Scenario

N1. What is possible future scenario that may happen and bring challenges or negative impacts to Hong Kong's TIC industry in the coming 10 years?

N2. Why do you think that this future scenario is possible to happen in the future? Is there any evidence to support the scenario? *(The information (i.e. hard facts) available to support the*

future scenario is required to be provided and the justifications are needed.)

N3. When will the scenario be expected to happen in the future according to your estimation?

N4. Where will the scenario happen?

N5. Who will get involved in the scenario? Within or outside the company?

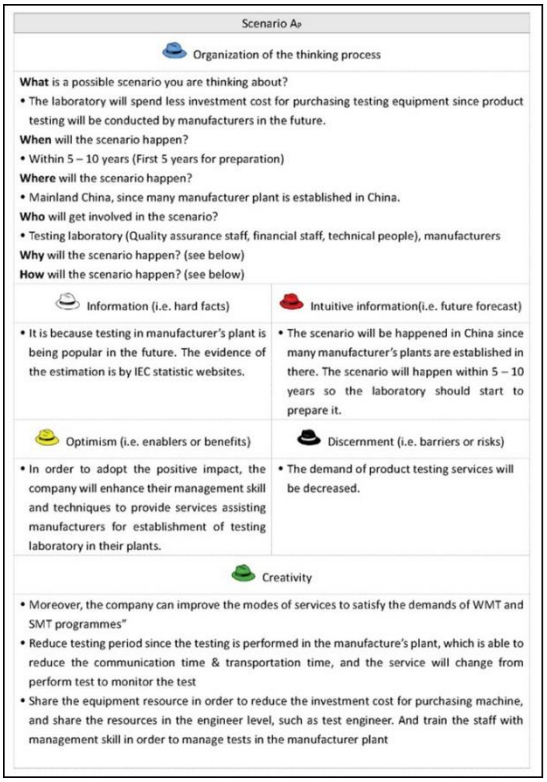
N6 How will the scenario happen?

N7. Do you have any ideas or suggestions or solutions regarding how to deal with the future change in this scenario?

N8. What resources may be allocated to support this scenario? *(Please also provide the justifications for how the resources will be utilized in this scenario.)*

*** You should answer **ALL** the questions. ***

Appendix B Six Future Scenarios Generated in Phase 3



Scenario A_P

Organization of the thinking process

What is a possible scenario you are thinking about?
- The laboratory will spend less investment cost for purchasing testing equipment since product testing will be conducted by manufacturers in the future.

When will the scenario happen?
- Within 5 – 10 years (First 5 years for preparation)

Where will the scenario happen?
- Mainland China, since many manufacturer plant is established in China.

Who will get involved in the scenario?
- Testing laboratory (Quality assurance staff, financial staff, technical people), manufacturers

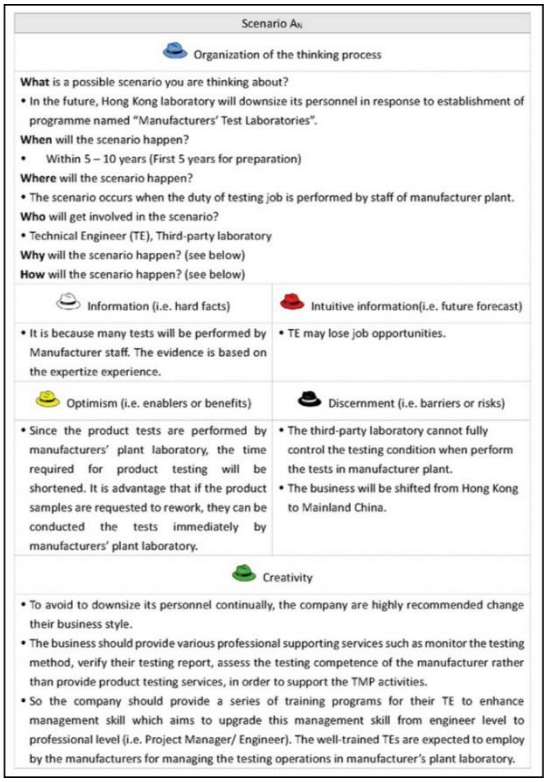
Why will the scenario happen? (see below)

How will the scenario happen? (see below)

Information (i.e. hard facts)	Intuitive information(i.e. future forecast)
• It is because testing in manufacturer's plant is being popular in the future. The evidence of the estimation is by IEC statistic websites.	• The scenario will be happened in China since many manufacturer's plants are established in there. The scenario will happen within 5 – 10 years so the laboratory should start to prepare it.
Optimism (i.e. enablers or benefits)	**Discernment (i.e. barriers or risks)**
• In order to adopt the positive impact, the company will enhance their management skill and techniques to provide services assisting manufacturers for establishment of testing laboratory in their plants.	• The demand of product testing services will be decreased.

Creativity

- Moreover, the company can improve the modes of services to satisfy the demands of WMT and SMT programmes"
- Reduce testing period since the testing is performed in the manufacture's plant, which is able to reduce the communication time & transportation time, and the service will change from perform test to monitor the test
- Share the equipment resource in order to reduce the investment cost for purchasing machine, and share the resources in the engineer level, such as test engineer. And train the staff with management skill in order to manage tests in the manufacturer plant



Scenario A_N

Organization of the thinking process

What is a possible scenario you are thinking about?
- In the future, Hong Kong laboratory will downsize its personnel in response to establishment of programme named "Manufacturers' Test Laboratories".

When will the scenario happen?
- Within 5 – 10 years (First 5 years for preparation)

Where will the scenario happen?
- The scenario occurs when the duty of testing job is performed by staff of manufacturer plant.

Who will get involved in the scenario?
- Technical Engineer (TE), Third-party laboratory

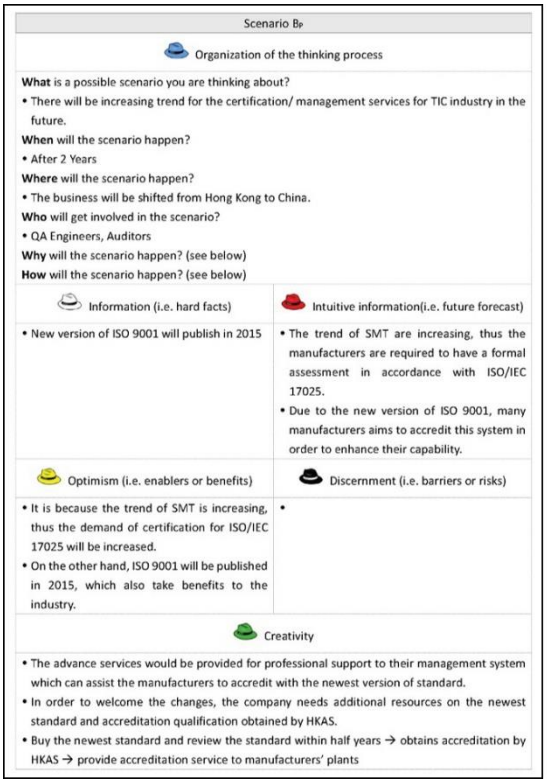
Why will the scenario happen? (see below)

How will the scenario happen? (see below)

Information (i.e. hard facts)	Intuitive information(i.e. future forecast)
• It is because many tests will be performed by Manufacturer staff. The evidence is based on the expertize experience.	• TE may lose job opportunities.
Optimism (i.e. enablers or benefits)	**Discernment (i.e. barriers or risks)**
• Since the product tests are performed by manufacturers' plant laboratory, the time required for product testing will be shortened. It is advantage that if the product samples are requested to rework, they can be conducted the tests immediately by manufacturers' plant laboratory.	• The third-party laboratory cannot fully control the testing condition when perform the tests in manufacturer plant. • The business will be shifted from Hong Kong to Mainland China.

Creativity

- To avoid to downsize its personnel continually, the company are highly recommended change their business style.
- The business should provide various professional supporting services such as monitor the testing method, verify their testing report, assess the testing competence of the manufacturer rather than provide product testing services, in order to support the TMP activities.
- So the company should provide a series of training programs for their TE to enhance management skill which aims to upgrade this management skill from engineer level to professional level (i.e. Project Manager/ Engineer). The well-trained TEs are expected to employ by the manufacturers for managing the testing operations in manufacturer's plant laboratory.



Scenario B_P

Organization of the thinking process

What is a possible scenario you are thinking about?
- There will be increasing trend for the certification/ management services for TIC industry in the future.

When will the scenario happen?
- After 2 Years

Where will the scenario happen?
- The business will be shifted from Hong Kong to China.

Who will get involved in the scenario?
- QA Engineers, Auditors

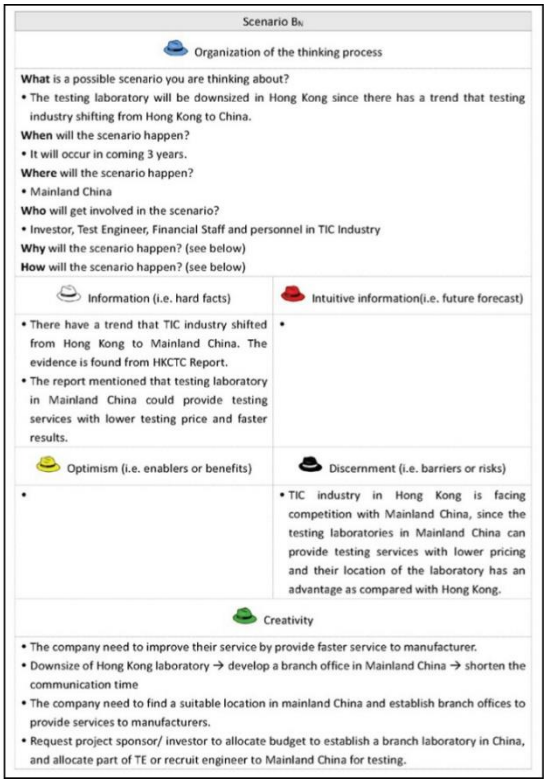
Why will the scenario happen? (see below)

How will the scenario happen? (see below)

Information (i.e. hard facts)	Intuitive information(i.e. future forecast)
• New version of ISO 9001 will publish in 2015	• The trend of SMT are increasing, thus the manufacturers are required to have a formal assessment in accordance with ISO/IEC 17025. • Due to the new version of ISO 9001, many manufacturers aims to accredit this system in order to enhance their capability.
Optimism (i.e. enablers or benefits)	**Discernment (i.e. barriers or risks)**
• It is because the trend of SMT is increasing, thus the demand of certification for ISO/IEC 17025 will be increased. • On the other hand, ISO 9001 will be published in 2015, which also take benefits to the industry.	•

Creativity

- The advance services would be provided for professional support to their management system which can assist the manufacturers to accredit with the newest version of standard.
- In order to welcome the changes, the company needs additional resources on the newest standard and accreditation qualification obtained by HKAS.
- Buy the newest standard and review the standard within half years → obtains accreditation by HKAS → provide accreditation service to manufacturers' plants



Scenario B_N

Organization of the thinking process

What is a possible scenario you are thinking about?
- The testing laboratory will be downsized in Hong Kong since there has a trend that testing industry shifting from Hong Kong to China.

When will the scenario happen?
- It will occur in coming 3 years.

Where will the scenario happen?
- Mainland China

Who will get involved in the scenario?
- Investor, Test Engineer, Financial Staff and personnel in TIC Industry

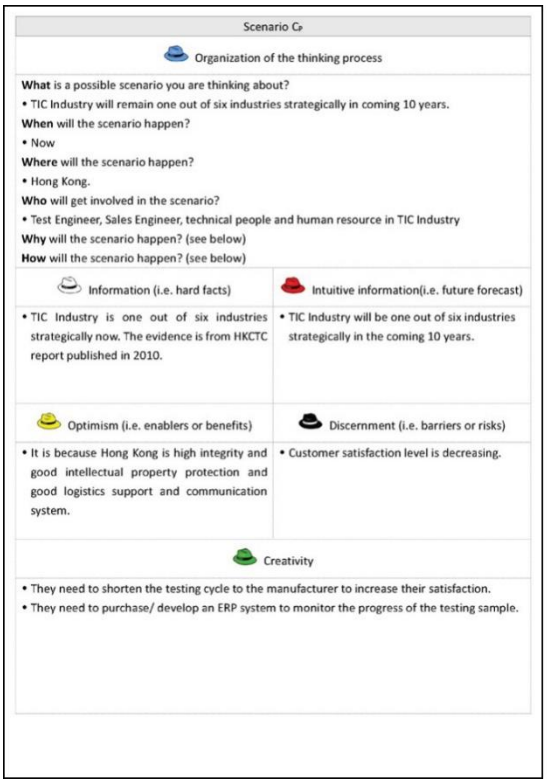
Why will the scenario happen? (see below)

How will the scenario happen? (see below)

Information (i.e. hard facts)	Intuitive information(i.e. future forecast)
• There have a trend that TIC industry shifted from Hong Kong to Mainland China. The evidence is found from HKCTC Report. • The report mentioned that testing laboratory in Mainland China could provide testing services with lower testing price and faster results.	•
Optimism (i.e. enablers or benefits)	**Discernment (i.e. barriers or risks)**
•	• TIC industry in Hong Kong is facing competition with Mainland China, since the testing laboratories in Mainland China can provide testing services with lower pricing and their location of the laboratory has an advantage as compared with Hong Kong.

Creativity

- The company need to improve their service by provide faster service to manufacturer.
- Downsize of Hong Kong laboratory → develop a branch office in Mainland China → shorten the communication time
- The company need to find a suitable location in mainland China and establish branch offices to provide services to manufacturers.
- Request project sponsor/ investor to allocate budget to establish a branch laboratory in China, and allocate part of TE or recruit engineer to Mainland China for testing.



Scenario C_P

Organization of the thinking process

What is a possible scenario you are thinking about?
- TIC Industry will remain one out of six industries strategically in coming 10 years.

When will the scenario happen?
- Now

Where will the scenario happen?
- Hong Kong.

Who will get involved in the scenario?
- Test Engineer, Sales Engineer, technical people and human resource in TIC Industry

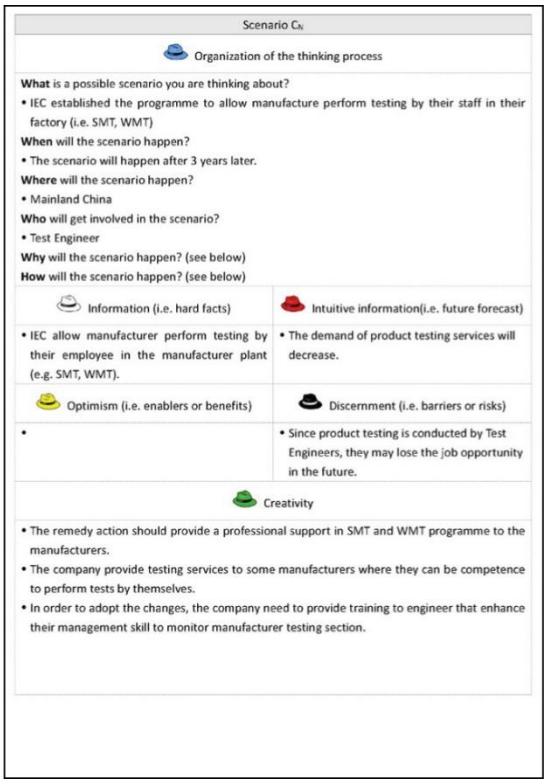
Why will the scenario happen? (see below)

How will the scenario happen? (see below)

Information (i.e. hard facts)	Intuitive information(i.e. future forecast)
• TIC Industry is one out of six industries strategically now. The evidence is from HKCTC report published in 2010.	• TIC Industry will be one out of six industries strategically in the coming 10 years.
Optimism (i.e. enablers or benefits)	**Discernment (i.e. barriers or risks)**
• It is because Hong Kong is high integrity and good intellectual property protection and good logistics support and communication system.	• Customer satisfaction level is decreasing.

Creativity

- They need to shorten the testing cycle to the manufacturer to increase their satisfaction.
- They need to purchase/ develop an ERP system to monitor the progress of the testing sample.



Scenario C_N

Organization of the thinking process

What is a possible scenario you are thinking about?
- IEC established the programme to allow manufacture perform testing by their staff in their factory (i.e. SMT, WMT)

When will the scenario happen?
- The scenario will happen after 3 years later.

Where will the scenario happen?
- Mainland China

Who will get involved in the scenario?
- Test Engineer

Why will the scenario happen? (see below)

How will the scenario happen? (see below)

Information (i.e. hard facts)	Intuitive information(i.e. future forecast)
• IEC allow manufacturer perform testing by their employee in the manufacturer plant (e.g. SMT, WMT).	• The demand of product testing services will decrease.
Optimism (i.e. enablers or benefits)	**Discernment (i.e. barriers or risks)**
•	• Since product testing is conducted by Test Engineers, they may lose the job opportunity in the future.

Creativity

- The remedy action should provide a professional support in SMT and WMT programme to the manufacturers.
- The company provide testing services to some manufacturers where they can be competence to perform tests by themselves.
- In order to adopt the changes, the company need to provide training to engineer that enhance their management skill to monitor manufacturer testing section.