A MULTI-PERSPECTIVE SCENARIO-BASED ROADMAPPING FOR STRATEGIC PLANNING AND TECHNOLOGY FORECASTING

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A Multi-perspective Scenario-based Roadmapping for Strategic Planning and Technology Forecasting

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CERTIFICATION OF ORIGINALITY

I hereby declare that this thesis is my own work and that, to the best of my knowledge and belief, it reproduces no material previously published or written, nor material that has been accepted for the award of any other degree or diploma, except where due acknowledgement has been made in the text.

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Abstract

Abstract of a thesis entitled *"A Multi-perspective Scenario-based Roadmapping for Strategic Planning and Technology Forecasting"* submitted by CHENG, Mei Na for the degree of Doctor of Philosophy at The Hong Kong Polytechnic University in August, 2016.

Nowadays, flexibility is one of key factors when dealing with future changes in the complex and rapidly changing business environment. Technology change driven forward by innovation, affects everybody's business. Smart organizations do not wait for change to happen but proactively monitor and take the advantage of the changing environment and new innovations. On the other hand, the existing methods for technology forecasting and assessment considerably help technology management professionals. However, there are a number of challenges and limitations for traditional technology forecasting and assessment based on roadmapping which include:

(a) Most of the existing roadmapping processes heavily rely on expert knowledge, experience and opinions. The roadmapping process can only be successful when participants have good technical realization and comprehensive knowledge in a mature market which provide rich information.

(b) Few researchers are paying attention to supporting roadmapping by scenario planning at organizational level. The existing scenario-based roadmapping approaches are used widely to monitor and analyze future changes for foresight in national and industrial levels. However, there is a gap in regard to how to embed the scenarios into roadmaps to plan for the future actions at organizational and operational levels.

(c) Most previous research may not be practical because the focus is on building simple scenarios to support technology roadmapping or simply suggesting the concept of multi-path roadmapping, but not evaluating the outcomes of the scenario(s) and how to reflect the outcomes on the scenario-based roadmap.

To address the challenges and limitations found in the literature on technology forecasting and assessment, a multi-perspective scenario-based roadmapping (MSBRM) methodology for strategic planning and technology forecasting 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. In the present study, the proposed MSBRM method consists 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). A guideline for scenario building was designed for the organizations to construct the possible scenarios in a consistent and qualitative format by adapting the principles of the Kipling method (5W1H, i.e. what, when, where, who, why and how) and the six thinking hats method. A series of validation and assessment criteria and a scoring system were designed and developed to validate and assess the possible future scenarios quantitatively, in order to generate the scenario pool for scenario selection. A total of five criteria were designed and developed to select the plausible future scenario(s) for implementing roadmapping. A hybrid roadmapping method was designed and developed to generate a preliminary and organizational roadmap with action plans according to the selected plausible scenario(s) from outside-in and inside-out perspectives.

An information-driven scenario building method (IDSBM) is presented to facilitate the development process of the proposed MSBRM method. The proposed method was designed and developed for companies to identify scenario elements and generate scenario narratives in order to implement scenario-based roadmapping by using scenario-oriented information. In the present study, the proposed IDSBM comprises five main phases, that are information acquisition (i.e.

Phase 1), metadata construction (i.e. Phase 2), keyword extraction (i.e. Phase 3), scenario elements identification (i.e. Phase 4), and scenario narrative generation (i.e. Phase 5). A series of definitions and identification rules was designed for organizations to identify and capture the components of the scenario elements (i.e. what, when, where, who, why and how) from the collected scenario-oriented information. A method of scenario narrative generation was designed and developed to construct narratives in a consistent and qualitative format for building information-driven scenarios and outside–in scenario-based roadmaps by using narrative tags.

To realize the capability of the proposed methods, two case studies were conducted in two companies in Hong Kong. Encouraging results have been obtained. Two target companies made positive comments on the proposed MSBRM and IDSB methods 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 testing, inspection and certification (TIC) and information and communication technology (ICT) industries.

On the whole, the study attempts to develop methodologies of the proposed MSBRM and IDSB approaches as flexible and practical tools for strategic planning and technology forecasting. The successful development of the MSBRM

and IDSB methods will not only address the limitations and challenges in traditional roadmapping-based technology forecasting and assessment methods but also open up a new way for strategic planning and technology forecasting.

Publications Arising from the Thesis

Refereed Journal Papers:

1. Cheng, M.N., Wong, Jane W.K., Cheung, C.F. and Leung, K.H. (2016), "A Scenario-based Roadmapping Method for Strategic Planning and Forecasting: A Case Study in a Testing, Inspection and Certification Company", Technological Forecasting and Social Change, vol. 111, no. 19, pp. 44-62, doi: 10.1016/j.techfore.2016.06.005.
2. Cheng, M.N., Cheung, C.F. and Wu, C.Y. (2016), "A Hybrid Roadmapping Method for Strategy Planning and Forecasting: A case study on e-Commerce in China", International Journal of Foresight and Innovation Policy, reviewed and revised.
3. Lee, C.K.M., Cheng, M.N., and Ng, C.K. (2015), "IoT-based Assets Management System for Healthcare-related Industries", International Journal of Engineering Business Management, vol. 7, no. 19, doi: 10.5772/61821.
4. Cheung, C.F., Rozhkov, M., Wang, Y., Cheng, M.N., and Tsui, E. (2015), "A study of workplace context and its relationship with team competences", International Journal of Information Technology & Business Management, vol. 33, no. 1, pp. 6-21.

Refereed Conference Papers:

1. Cheng, M.N., Cheung, C.F., Fung, S.H. and Tsang, K.K. (2014), "A Hybrid Roadmapping Method for Technology Forecasting and Assessment: A Case Study in an Information and Communication Technology Company", Proceedings of PICMET '14 Conference, Kanazawa, Japan, 27-31 July, 2014, pp. 2882-2890.

2. Wong, Jane W.K., Cheung, C.F., Chan, O.Y. and Cheng, M.N. (2015), "Knowledge-Based Standard Updates and Changes in a Testing and Certification Company: A Case Study", Proceedings of 12th European Conference on Intellectual Capital, Knowledge Management and Organisational Learning, Bangkok, Thailand, 5-6 November, 2015, pp. 418-425.

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Chapter 1

Introduction

Nowadays, many opportunities can be grasped by organizations in a complex and rapid changing business environments. For maximization of these opportunities, many organizations have prepared for how to deal with future change and whether they are ready to transform into opportunities in order to enhance their competitive advantages. Nowadays, organizations pay much attention to flexible future techniques for strategic planning and technology forecasting, since flexibility is one of the significant factors for the preparation for change in complex future conditions. Various researchers and practitioners are paying attention to the concept of scenario planning in regard to the roadmapping in their market and technology activities. On the whole, the existing methods help organizations and practitioners considerably. However, they have a number of limitations which include:

(i) Expert-driven scenario planning and roadmapping processes

Most of the existing scenario planning and roadmapping processes rely heavily on expert knowledge, experience and opinions. Both processes can only be implemented successfully by participants who have good technical

realization and comprehensive knowledge with a mature market which provide rich information.

(ii) Macro-level scenario-based roadmapping (SBRM) approach

Few researchers are paying attention to support roadmapping by scenario planning at organizational level. The existing scenario-based roadmapping approaches are used widely to monitor and analyze future changes for Foresight at National and Industrial levels. However, there is a gap in regard to how to embed the scenarios into roadmaps so as to plan for the future actions at organizational and operational levels.

(iii) Conceptual process of the SBRM approach

Most previous research may not be practical because the focus is on building simple scenarios to support technology roadmapping or simply suggesting the concepts of multi-path roadmapping, but not evaluating the outcomes of the scenario(s) and how to reflect the outcomes on the scenario-based roadmap.

1.1 Research Objectives and Scope

In this research, a multi-perspective scenario-based roadmapping (MSBRM) method was considered as an effective tool for strategic planning and forecasting by the combination of scenario planning with roadmapping approaches. As a whole, the objectives of this research work were:-

(i) To investigate the feasibility of scenario-based roadmapping in macro and micro levels of perspectives to deal with future change for organizations;

(ii) To develop an multi-perspective scenario-based roadmapping (MSBRM) method for incorporating scenarios from different organizational perspectives into roadmapping in order to facilitate strategic planning and technology forecasting;

(iii) To develop an information-driven scenario building (IDSB) method for the identification of potential scenario elements in order to enhance the scenario building process of the MSBRM method; and

(iv) To verify the performance of the methods through a series of experiments and trial implementation in selected reference sites.

1.2 Significance of the Research

The proposed MSBRM and IDSB methods attempt to address the limitations and challenges in traditional roadmapping-based technology forecasting and assessment methods. The successful development of the multi-perspective scenario-based roadmapping (MSBRM) method and the information-driven scenario building (IDSB) method will open up a new way for strategic planning and technology forecasting. They are expected to enhance the organizations' strategic planning and forecasting process in identifying new business

opportunities for exploiting new technology, and exploring, assessing and planning innovation opportunities which aim for further growth and development of technology-intensive and innovation enterprises.

1.3 Organization of the Thesis

The thesis consists of eight chapters. The first chapter introduces the background of the study, problem formulation, objectives and significance of the study. Chapter 2 provides a literature review which discusses the organizational challenges in complex and rapidly changing business environments, overview of technology management methods, especially scenario-based roadmapping, which forms the background of the study. Methodologies of the proposed multi-perspective scenario-based roadmapping (MSBRM) method and information-driven scenario building (IDSB) method are presented in Chapters 3 and 4 comprehensively. Chapter 5 focuses on the evaluation of the performance of the MSBRM and IDSB methods through a series of control experiments. In Chapter 6, the realization of the capabilities of the MSBRM and IDSB methodologies in real life applications is undertaken by trial implementation and case studies in two selected reference sites. The conclusion of the study and some suggestions for further work are discussed in Chapters 7 and 8, respectively.

Chapter 2

Literature Review

This chapter presents a literature review relevant to the present study. Challenges of complex and rapidly changing environments are discussed, which include barriers slowing responses to change and the inside-out organizational viewpoint. Key drivers for adapting to change are also presented, such as strategic flexibility, and outside-in organizational viewpoint. An overview of technology management (TM) and its processes in the organizations is provided. Existing methods that facilitate the process of strategic planning and technology forecasting are also reviewed, especially technology roadmapping and scenario planning. A comprehensive literature review of scenario-based roadmapping is conducted. A summary of research gaps in the literature is also presented.

2.1 Organization Challenges

Globally, the external environment is rapidly changing, such as changing market and technology that are driven forward by innovation, which is affecting everybody's business. Technologies in organizations may change nothing, but empower them to transform their business landscapes (Chan, 2013). Boss (2016)

mentioned that the pace of change globally and the rate of technology development are two of the top leadership challenges in organizations, which may also challenge any leader's judgment and decision making in order to maximize the landscape of complexity in the organization.

2.1.1 Pace of change in the external environment

In a complex and rapidly changing business environment, many organizations are facing the challenges of fast-changing trends in the market and technology and have to make a huge amount of decisions in order to increase their competitiveness. The Economist Intelligence Units conducted a research study named "how companies are responding to a fast-changing business environment" in 2011 that included a global online survey and in-depth interview (Mitchell, 2011). Three hundred and ninety respondents (i.e. business executives) in the world (30% from Asia, 30% from Europe, 30% from North America, and 10% from others in the world) were invited to complete an online survey, and a group of experts and senior executive were also invited to provide insights via in-depth interviews (Mitchell, 2011). A snapshot of the survey results is illustrated in Figure 2.1 that is adapted from research report of the Economist Intelligence Unit (Mitchell, 2011).

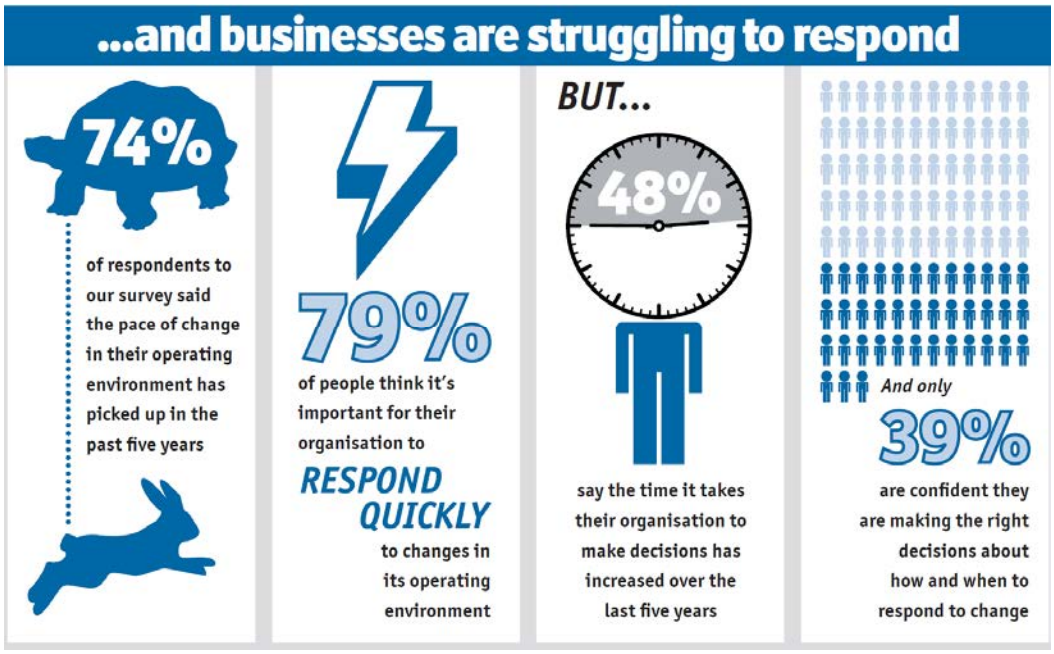


Figure 2.1 Snapshot of survey results (Adapted from Mitchell, 2011)

According to the survey results, majority of the respondents (74%) reported that the pace of change in their business environment has already picked up, and most respondents (79%) realized the importance for their organizations to respond quickly to change. On the other hand, nearly half of the respondents (48%) reported that they take much longer to make critical decisions for their organizations, with 40% and 8% of them taking months and years to make decisions respectively, and more than half of the respondents (61%) were not confident in making the right decisions about how/ when to respond to change. In summary, two major challenges of change in the external environment are required to be addressed by organizations, which include: -

(a) Taking longer to make critical business decisions; and

(b) Making the wrong decisions about how and when to respond to change.

Due to the accelerating pace of change and increasing complexity of the business environment, uncertainty about the future is growing. This may force decision makers in the organizations to increase the time (i.e. months or years) to make critical decisions. Moreover, the decision makers may not have confidence to make the right decisions to respond to change. Since the external environment keeps changing, the competition and complexity are relatively increasing, the decision makers may have pressure of decision-making as the costs and benefits of making right or wrong decisions are relatively higher.

To rise to the challenges of pace of change, organizations should find a flexible way of keeping a balance between making decisions efficiently as well as responding to change effectively and efficiently. And the leaders or decision makers should put much effort into thinking about multiple possible or plausible future scenarios for their organizations, in order to build awareness of future change and uncertainties.

2.1.2 Inside-out organizational viewpoint

The normal perspective for most organizations is from inside to out. According to the research report from the Economist Intelligence Unit (Mitchell, 2011), the

respondents mentioned that the most valuable source of information for identifying the change in the external environment are customers (61%), and the others include, partners (33%), regulators (30%), suppliers (29%), the media (25%), government (17%), investors (15%), business advisers (e.g. accountancy firms), trade associations (9%), and non-governmental organizations (8%), as shown in Figure 2.2.

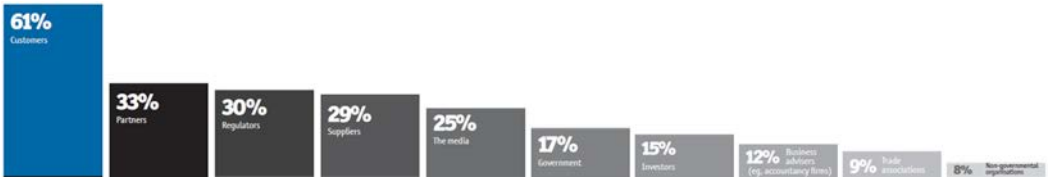


Figure 2.2 Source used for identification of change in the external environment (Adapted from Mitchell, 2011)

As shown in Figure 2.3, they start by looking at their own organization and then focusing on their own customers, partners, competitors, technologies and resources within their own business arena. In the inside-out perspective, it may be barely satisfactory to plan market activities for the next few years in a less competitive and stable environment. If the focus is on long-term business development (i.e. product or technology development) in a more competitive, complex and rapidly changing environment, the inside-out perspective may be inadequate for this environment to make it easy for the organization to deal with

future changes in the external environment that have not already become obvious or mature.

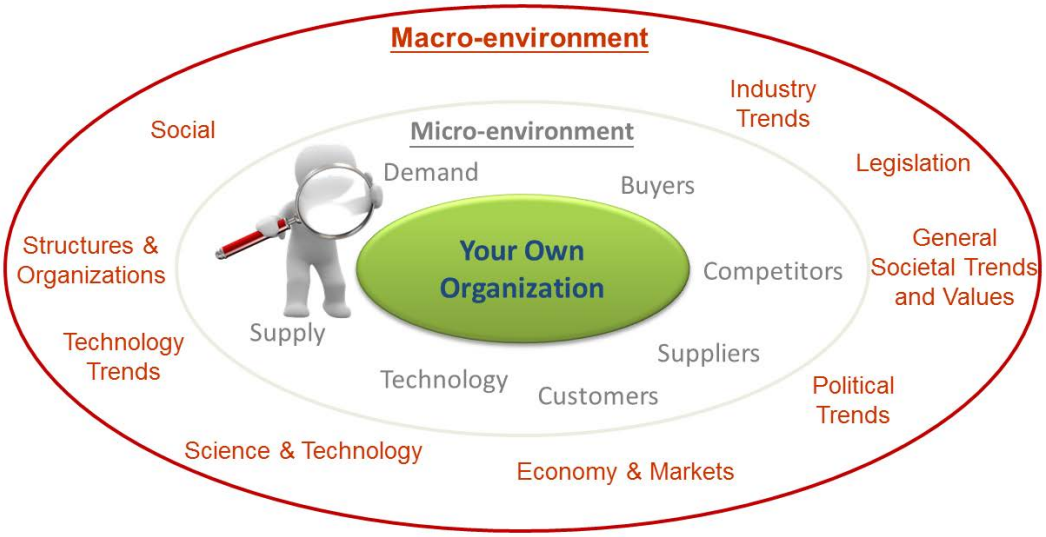


Figure 2.3 Inside-out perspective

To anticipate the changes in the external environment, it is necessary to start by looking at the driving forces that may affect the business development of the organization. Moreover, Chermack (2005) mentioned that organizations should have an understanding of the external environments in which they operate as long-term monitoring. Long-term development in the business arena greatly depends on driving forces in the surrounding world. The outside-in perspective is highly recommended for these organizations to look into the driving forces behind the changes deeply, as well as to track and analyze trends regularly in the surrounding world (Savioz, 2004; Lindgren and Bandhold, 2009; Cheng et al., 2014), as shown

in Figure 2.4. In other words, organizations should make sure to seek views and information from external and internal stakeholders, not only their customers.

Figure 2.4 Outside-in perspective

2.1.3 Key drivers for adapting to change

Adaptation is one of the critical factors for success in complex and rapidly changing business environments. Two aspects of adaptation include speed (Lindgren and Bandhold, 2009) 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). Strategic flexibility is the combination of robustness and responsiveness (Bettis and Hitt, 1995). Chakravarty (1997) observed that the

market leaders must “repeat innovations, establish customer networks, sense the flow of new products, and share responsibility for new strategy throughout the firm”. Lenglick-Hall and Wolf (1999) also highlighted that strategic flexibility is the combination of speed and adaptiveness that is the critical driver to deal with future change. Flexibility is one of the key issues when dealing with the changes in uncertain business environments (Geum et al., 2014). Organizations are paying much attention to flexible future techniques for strategic planning and forecasting (Lindgren and Bandhold, 2009; Geum et al., 2014).

Smart organizations do not wait for change to happen but proactively monitor and take advantages of complex and rapidly changing environments, new or potential technologies, and new innovations. To express inside-out and outside-in perspectives in terms of proactiveness, most organizations mainly focus on the present status (i.e. inside-out perspective) to solve their existing problems and treat present problems, but fails focus on future so as to anticipate the future needs and to shape the future (i.e. outside-in perspective). Effective organizations may proactively take a big step in managing for the future constantly. Managing for the future will encourage new ideas, develop flexible processes, and invest in the management of knowledge and technology that will allow the organizations not only to adapt and survive, but also shape the future change. To well-equip the

organizations for the future, there may be an opportunity to drive the organizations from cleaner positions (i.e. clean acute problems and treat present problems) to a shaper role (i.e. anticipate future needs and shape the future). There are four levels of proactiveness which are illustrated in Figure 2.5 that is adapted from Lindgren and Bandhold (2009).

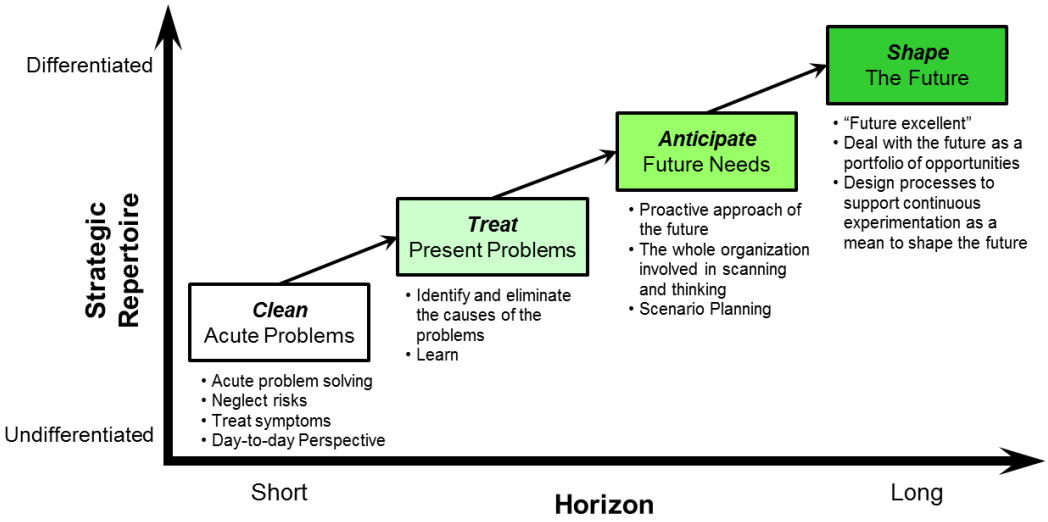


Figure 2.5 Four levels of proactiveness: from cleaner to shaper (adapted from Lindgren and Bandhold, 2009)

To maximize opportunities in complex and rapidly changing business environments, all organizations not only need to respond to uncertain market and technological change quickly, but also deal with future change proactively and develop corresponding action plan efficiently, in order to take competitive advantage of the fast changing environment.

2.2 Overview of Technology Management

2.2.1 Technology management in organizations

In the past, the development of the economy mainly relied on labour and capital in the world, so called "resource-based economy". Nowadays, the development of the economy has shifted to "knowledge-based economy" as a global trend. In the knowledge-based economy, Cortright (2001) defined a view of the economy called "New Growth Theory" that resuscitate an old tradition of return-oriented thinking, as well as internalize technology into an economic system of how to push the market. This theory comprises two main points that are "it views technological progress as a product of economic activity" and "unlike physical objects, knowledge and technology are characterized by increasing returns, and these increasing returns drive the process of growth" (Cortright, 2001).

Technology is defined by various researchers (Wright and Smith, 1989; Probert et al., 1999; Wyk, 2002). Basically, technology can be defined basically as "the integration of people, knowledge, tools and systems with the objective to improve people's lives" (Wright and Smith, 1989). Probert et al. (1999) describe technology as "the technical knowhow of the business, with a key role in wealth generation". According to Wright and Smiths' definition, Pretorius (2001) describes technology in terms of particular relationships among elements that is

"these relationships are the skills that people need to operate the tools and systems, procedures that contain the knowledge needed to operate the tools and systems and new knowledge generation that includes training". A schematic diagram of definition of technology is shown in Figure 2.6 that is adapted from Pretorius (2001).

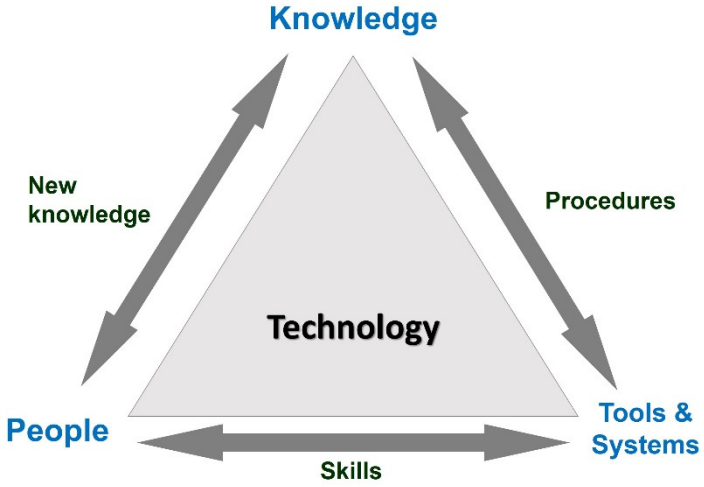


Figure 2.6 Schematic diagram of definition of technology (Adapted from Pretorius, 2001)

Starting from the late 1980s, research on technological change has received considerable and growing interest (Coombs et al., 1987). Understanding different dimensions of the technological change is complex and uncertain. Technology is a primary cause of change and the key to productivity and change as well as change being a fact of life (Porter et al., 2011). Some elements of the challenge imposed by technology, such as shortening of product lifecycle (Qualls et al., 1981; Kessler and Chakrabarti, 1996; González et al., 2008; Gerdsri et al., 2009; Routley et al., 2011; Wong et al., 2015), increasing technological change (Sood and Tellis, 2005;

Rycroft, 2006; González et al., 2008; Arman and Foden, 2010; Amadi-Echendu et al., 2011; Gibson and Matthews, 2013), increasing pace of technology development (Phaal et al., 2001a; Farrukh et al., 2009; Amadi-Echendu et al., 2011; Behkami and Daim, 2012), increasing complexity of product and technology (Phaal et al., 2001a; Gerdsri et al., 2009), increasing complexity of technological innovation (Lee et al., 2011; Wang and Cheung, 2011; Meng et al., 2013), increasing innovation speed (Kessler and Chakrabarti, 1996; Kessler and Bierly, 2002; Langerak and Hultink, 2005; Parry et al., 2009), and increasing speed of the diffusion of innovations (Lee et al., 2003).

In the concept of Knowledge Management (KM), technology is a types of knowledge in organizations that requires to be managed effectively (Phaal et al., 2004). Technology management (TM) is a multidisciplinary subject, which encompasses decisions related to TM strategy, process and product, people and organization. Definitions of TM are found in the literature, as shown in Table 2.1. Badawy (1993) defines TM as a tool that is "crucial in offsetting the risks of new technology while acquiring the operational benefits it provides". The National Research Council (1987) describes TM as a strategy to "link engineering, science, and management disciplines to address the planning, development, and implementation of technological capabilities, in order to shape and accomplish the

strategic and operational objectives of an organization". Thamhain (2005) also states that TM is "art & science in creating value by using technology together with other resources of an organization". The European Institute of Technology and Innovation Management (EITIM) also propose management of technology as a process that "addresses the effective identification, selection, acquisition, development, exploitation and protection of technologies (product, process and infrastructural) needed to maintain a market position and business performance in accordance with the company's objectives" (Phaal et al., 2004).

Table 2.1 Definitions of Technology Management (TM)

Author (Year)	Definition of Technology Management (TM)
Badawy (1993)	"Technology management is crucial in offsetting the risks of new technology while acquiring the operational benefits it provides."
National Research Council (1987)	"Management of technology links engineering, science, and management disciplines to plan, develop, and implement technological capabilities to shape and accomplish the strategic and operational objectives of an organization."
European Institute of Technology and Innovation Management (EITIM) (N.A.)	"Technology management addresses the effective identification, selection, acquisition, development, exploitation and protection of technologies (product, process and infrastructural) needed to maintain a market position and business performance in accordance with the company's objectives." (Phaal et al., 2004)
Thamhain (2005)	"Management of Technology is the art & science in creating value by using technology together with other resources of an organization."

2.2.2 Technology management processes in organizations

As shown in Figure 2.7, a framework of technology management (TM) process is proposed by Gregory (1995) to enable creation and utilization of technology in an organization that consists of five basic processes, such as identification, selection, acquisition, exploitation and protection.

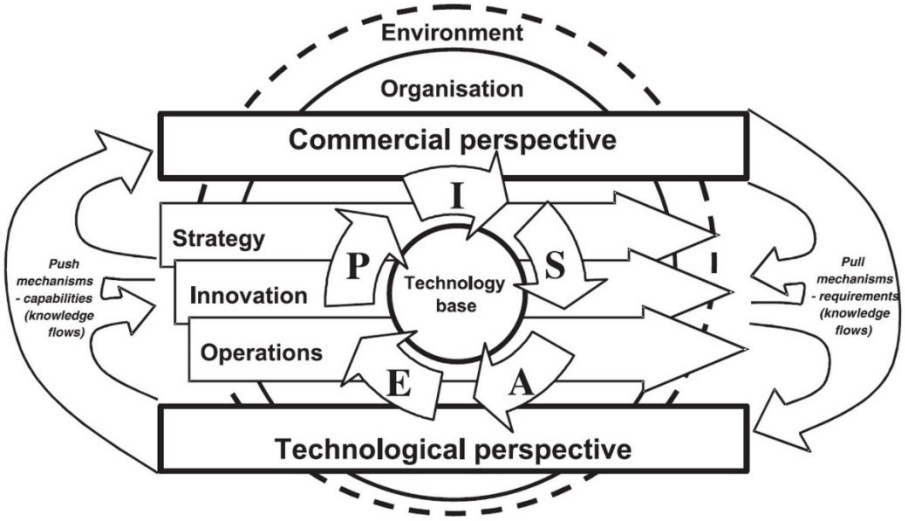


Figure 2.7 A framework of technology management (TM) process (Adapted from Gregory, 1995)

(i) Identification

Identification is the first step of the TM process, as well as aims to identify the technologies in the internal and external environments that are not part of the technology base currently, but may have potential impact on the existing and future business activities and may be important to the business in the organization. Methods and techniques for identification of technologies

include scanning and monitoring of technology and market, technology assessment, technology benchmarking, information management, and so on.

(ii) Selection

On completion of the technology identification process, the next step is selection, and aims to evaluate and select the potential technologies that should be supported in the organization based on different criteria. Methods and techniques for selection of technologies include technology forecasting, technology auditing and benchmarking, decision-making process, and so on.

(iii) Acquisition

Following selection of technologies, acquisition is the third step of the TM process and aims to conduct acquisition and assimilation of selected technologies in organizations. Methods and techniques for acquisition include internal research and development (R&D), licensing and joint venture, project management, and so on.

(iv) Exploitation

After conducting acquisition, the selected technologies are treated as parts of the technology base in the organization. Exploitation is the forth step of the TM process for taking advantages of these technologies, such as making

profits. Methods and techniques for exploitation include incremental development, new process or product development, and so on.

(v) Protection

Protection is the fifth step of the TM process and aims to protect the technological knowledge and expertise in order to maximize the values and minimize the risk for technology transfer outside organizations. Methods and techniques for protection include knowledge management, intellectual property management, and so on.

2.2.3 Strategic technology analysis

Strategic Technology Analysis (STA) has gone a long way in simplifying the process of TM that can be applied at different levels of the organization, such as corporate governance, overall strategy, functional, and operational procedures. Based on theory of STA, Wyk (2002) suggested the definition of technology that "Technology is created competence. It is expressed in technological entities consisting of devices, procedures, and acquired human skills". Khalil (2000) also defines technology as "all the knowledge, products, processes, tools, methods, and systems employed in the creation of goods or in providing services". Unit of analysis of "technology" in the STA theory is technological entity. In the literature,

three researchers define the components of technological unity and the descriptions of components are summarized and illustrated in Tables 2.2, 2.3 and 2.4, respectively. Zeleny (1986) proposed that the technological unity is "a unique combination of hardware, software, brainware and support net", as shown in Table 2.2. The Technology ATLAS Team (1987) and Arasti (2004) also suggested 4 basic components of technology, such as technoware, humanware, infoware and orgaware, as shown in Tables 2.3 and 2.4.

Table 2.2 Components of technological unity defined by Zeleny (1986)

Component	Description
Hardware	Physical structure and logical layout of the equipment or machinery that is to be used to carry out the required tasks *(refers not only to a particular physical structure of components, but also to their logical layout as well)*
Software	Knowledge of how to use the hardware in order to carry out the required tasks *(refers to the "know-how" of tasks to achieve goals and objectives)*
Brainware	Reasons for using the technology in a particular way, i.e. know-why *(means the application and justification of hardware/ software deployment, the "know-what" and "know-why" of technology; that is, what to employ, how, when, and why)*
Support Net	The unity of hardware, software, and brainware – toward stated goals *(suggest the complex network that support the proper use and functioning of a given technology)*

Table 2.3 Components of technological unity defined by the Technology ATLAS Team (1987)

Component	Description	Example
Technoware	Object-embodied technology	Tools, machines, equipment, machines, vehicles, physical facilities
Humanware	Person-embodied technology	Experiences, skills, knowledge, wisdom, creativity
Infoware	Document-embodied technology	All kinds of documentation pertaining to process specifications, procedures, theories, observations
Orgaware	Institution-embodied technology	Facilitates the effective integration of Technoware, Humanware and Infoware, and consists of management practices, linkages

Table 2.4 Components of technological unity defined by Arasti (2004)

Component	Description	Example
Technoware	Physical assets such as equipment, machinery, tool that is used to carry out a specific activity/ task	Hardware, Tools, Machines, Equipment
Infoware	Knowledge and information of how to use hardware in order to carry out the required activity/ task	Software, know-how
Humanware	Human skills needed for using hardware and infoware in order to carry out the required activity/ task	Operating/ R&D/ innovation capability, skill
Orgaware	Organizational and managerial structure to coordinate three above components in order to carry out the required activity/ task	Routines

2.3 Overview of Technology Management Approaches

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, etc. (Reger, 2001; Firat et al., 2008; Mortara et al., 2014). They are also adopted for innovation and technology management across the world (e.g. Japan, Korea, Singapore, Netherlands, Turkey, United Kingdom (UK), the United States (US), etc.. In the literature, scenario planning and technology roadmapping are two widely used future techniques which help management executives set priorities for strategic planning and technology development (Saritas and Aylen, 2010).

2.3.1 Scenario planning

Scenario planning is one of the most common tools as an effective method for organizations to study future uncertainties and investigate assumptions and has obtained increased attention in the last 30 years and is cited in the management literature (Chermack, 2005; Mortara et al., 2014). Lindgren and Bandhold (2009) stated the definition of scenario planning as "an effective strategic planning tool for medium-term 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).

2.3.2 Technology roadmapping

Technology roadmapping is one of the popular management tools for managing emerging and potential technologies in the fields of technology planning and development. The use of technology roadmapping has become more widespread

in recent decades. 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. Garcia and Bray (1998) stated that "A single path may be selected and a plan is developed. If there is high uncertainty or risk, then multiple paths may be selected and pursued concurrently. The roadmap identifies precise objectives and helps to focus resources on the critical technologies that are needed to meet those 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 and radar charts to anticipate future needs and shape the future. In many situations, company's ideas are always bounded by what they know but ignore what they do not know.

Initially, the value of the technology roadmaps for innovation lies in the recommendation of new technologies and products based on the evolution of existing technologies and products. Motorola was the forefront of application into technology roadmapping in the late 1970s for the improvement of the alignment between product and 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., 2015a).

Moreover, some researchers have provided insights 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).

2.3.3 Integration of scenario planning into technology roadmapping

Many studies of scenario planning and technology roadmapping are found in the literature. 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., 2015b; Amer et al., 2016). The characteristics of scenario planning and technology roadmapping approaches are summarized in Table 2.5 (adapted from Lindgren and Bandhold, 2003; Strauss and Radnor, 2004; Saritas and Aylen, 2010; Rohrbeck et al., 2013; Lee et al., 2015b).

Scenario planning is one of the well-known backcasting methods (i.e. future to present) to enable medium-term to long-term corporate strategic planning from a macro view (i.e. macro thinking), but it is less suitable for detailed planning. Roadmapping is one of the famous forecasting methods (i.e. past to future) to enable short-term business operational planning from a micro view (i.e. micro planning). Moreover, scenario planning addresses the whole picture of decisions and the foresight of a number of possible conditions, but roadmapping addresses the strategies, directions and detailed tasks explicitly. In view of the “future”,

scenario planning mainly focuses on the image of the future as well as multiple possible and plausible futures, while on the contrary roadmapping focuses on detailed frame of the future as well as a single probable future.

Table 2.5 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., 2015b)

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 possible changes	Addresses the strategies, directions and detailed tasks explicitly
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 • Conducting detailed planning • Enforcing decisions • Identifying interdependencies between market and technology

In terms of uncertainty and risk, scenario planning is able to cope with uncertainty-based future (i.e. medium to high uncertainties) and illustrate risks, but roadmapping is able to deal with the future based on certain relations (i.e. low

degree of uncertainty) and hidden risks. Last but not least, scenario planning has its strengths in enhancing vision, facilitating strategic discussions and creating an image of future developments, whereas roadmapping has its strengths in conducting detailed planning, enforcing decisions and identifying interdependencies between market and technology.

However, there is little relevance of studying strategic planning and forecasting which attempts to integrate scenario planning into technology roadmapping for the preparation of change in complex future conditions, proposing the concept of "scenario-based roadmapping".

2.4 Scenario-based Roadmapping

Few researchers and practitioners are increasingly paying attention to the concept of scenario planning in the roadmapping in their market and technology activities. A literature summary of scenario-based roadmapping is given in Table 2.6.

In the literature 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.

Table 2.6 Literature summary of scenario-based roadmapping

Authors	Research Area	Level	Study on
Jovane et al. (2003)	Foresight	National	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. (2015b)	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
Hansen et al. (2016)	Strategic Decision Making	Organizational	Future development and evaluation of the rail automation market for passenger transport systems in Germany
Siebelink et al. (2016)	Strategic Innovation	Organizational	Innovation activities of construction industry in the Netherlands

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. (2015b) 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. Hansen et al. (2016) presented a four-step scenario-based technology roadmapping approach to assess the relevance of market drivers and products and technologies for strategic decision-making and the approach was demonstrated in the future development and evaluation of the rail automation market for passenger transport systems in Germany. Siebelink et al. (2016) introduced a scenario-driven business roadmapping approach to deal with uncertainty in the environment in order to provide insights for the organizations during their strategic innovation activities. An application of the approach was conducted in a construction company in the Netherlands. Table 2.7 provides a summary of the comparison of the existing scenario-based roadmapping approaches. A comprehensive table for comparison of the existing scenario-based roadmapping approaches found in the literature is shown in Appendix A.

Table 2.7 Comparison of the existing scenario-based roadmapping approaches

Method	Strauss and Radnor (2004)	Saritas and Aylen (2010)	Amer et al. (2016)	Proposed MSBRM 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

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 2.6. 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., 2015b). As shown in Table 2.7, 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 supporting roadmapping by scenario planning at micro level (i.e. organizational and operational levels) for corporate planning (Strauss and Radnor, 2004; Lee et al., 2015b).

(b) Conceptual scenario-based roadmapping process

As shown in Table 2.7, 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. (2015b) 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.

In order to address the key issues found in the existing methods, this research attempted to design and develop a multi-perspective scenario-based roadmapping (MSBRM) method by incorporating environment-oriented (i.e. scenario planning) and company-oriented (i.e. roadmapping) approaches for strategic planning, technology forecasting 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.

Chapter 3

Multi-perspective Scenario-based Roadmapping Method

An overview of research methodology is proposed for this present study, which is presented at the beginning of this chapter. Following the research methodology, a newly developed multi-perspective scenario-based roadmapping method is also described in this chapter.

3.1 Research Methodology

The research methodology of the present study is shown in Figure 3.1. It is design and development of scenario-based roadmapping (MSBRM) method and information-driven scenario building (IDSB) method, experimental performance evaluation of the proposed methods, and implementation. Firstly, a literature review is conducted which focuses on organization challenges, technology management and its process, scenario planning and technology roadmapping, and scenario-based roadmapping. To address the research gaps found in the literature, a multi-perspective scenario-based roadmapping (MSBRM) is designed and developed for generating, assessing and selecting the possible future scenario, as

well as embedding the scenario into roadmap with action plan. To facilitating the scenario building process of the MSBRM method, an information-driven scenario building (IDSB) method is designed and developed for identifying scenario elements and generating scenario narrative from scenario-oriented information. The performance of two proposed methods are evaluated through a series of experimental validation. Last but not least, the MSBRM and IDSB methods are applied in two reference sites for demonstrating their capabilities.

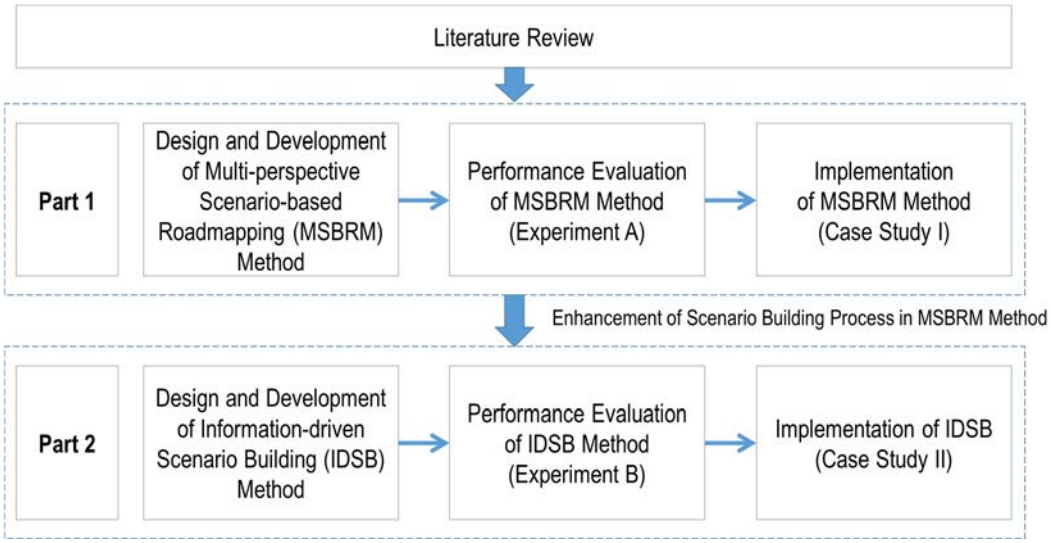


Figure 3.1 Framework of research methodology

3.2 Framework of the Multi-perspective Scenario-based Roadmapping Method

The multi-perspective scenario-based roadmapping (MSBRM) method for strategic planning and technology forecasting, by incorporating environment-oriented (i.e. scenario planning) and company-oriented (i.e. roadmapping)

approaches is presented in this chapter. By a combination of both scenario planning and roadmapping approaches, the proposed MSBRM method was designed and developed as a pragmatic scenario-based roadmapping process for organizations 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.

The overall process of the proposed MSBRM 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 3.2 shows a framework for the proposed MSBRM method.

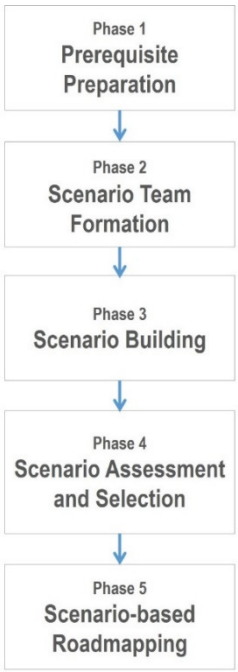


Figure 3.2 Framework for the proposed multi-perspective scenario-based roadmapping (MSBRM) method

In Phase 1, prerequisite preparation aims to determine the company needs for implementation of the MSBRM activity, and to define the background of the study, purpose and scope of the activity in order to imitate the activity by top management. In Phase 2, 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 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. A series of scenario-based roadmaps is constructed in Phase 5 according to the scenario(s) selected in Phase 4, such as preliminary roadmap and organizational roadmap. The roadmap provides the companies a clear picture about where they are, what they need to further investigate and where they will go. A comprehensive description of the proposed MSBRM method is presented in the following sections.

3.3 Phase 1 – Prerequisite Preparation

Prerequisite preparation is the first step of the proposed MSBRM method (i.e. Phase 1) and aims to provide a preliminary discussion to have an understanding various perspectives of the company need for the implementation of the MSBRM activity, such as "what future issues is the company exploring?" or "what is the future scenario you are thinking about?". As shown in Figure 3.3, the key procedures conducted in the phase "prerequisite preparation" are summarized as follow: -

(a) Initiate scenario-based roadmapping (MSBRM) activity;

(b) Determine the company needs for the implementation of the activity; and

(c) Define the background of study, purpose and scope of the activity.

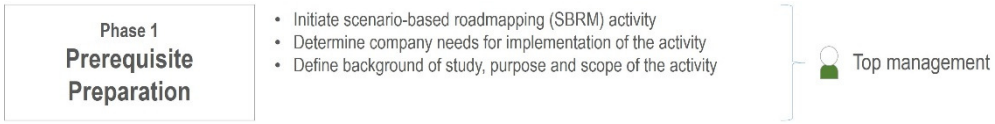


Figure 3.3 Key procedures and participants involved in the phase of prerequisite preparation

Staff from top management are highly encouraged to be involved in this phase, since they act as initiators of the MSBRM activity. They are also responsible for determining the company needs, and defining the background of study, and purpose and scope of the activity. A list of questions about the future issues are suggested to be discussed so as to determine the company needs, such as

- potential future issues about the industry/market/business/technology of the company is concerned about;
- understanding future issue;
- understanding the stakeholders (e.g. market leader, competitor, government, association, supplier, consumers) involved in or engaged in future issues;
- future trends of industry/market/business/technology;
- future landscape of industry/market/business/technology;
- evolution of the industry/market/ business/technology;
- maturity and availability of the future industry/market/business/technology;
- key opportunity and critical success factors;
- enablers and barriers relating to future issues;

- business driver about the future;
- business strategy to deal with future issues;
- position and roles of company in future issues; and so on.

3.4 Phase 2 – Scenario Team Formation

Scenario team formation is the second step of the proposed method (i.e. Phase 2) that aims at identifying appropriate participants who are invited to be involved in the MSBRM activity. As shown in Figure 3.4, the key procedures conducted in the phase "scenario team formation" are summarized below: -

(a) Identify appropriate participants who are invited to join in the activity;

(b) Group participants into different team, including scenario building team, scenario assessment team and decision team; and

(c) Conduct a kick-off meeting to launch into a description of the activity for all participants.

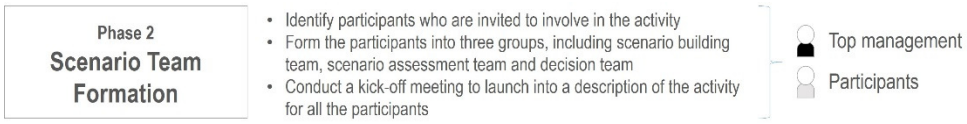


Figure 3.4 Key procedures and participants involved in the phase of scenario team formation

Before conducting a kick-off meeting for the activity, the appropriate participants are required to be identified by top management of the company. Basic

requirements for selecting the appropriate participants who implementing scenario-based roadmapping activity are shown in the following: -

(a) He/she should be one of stakeholders who involve in the market and technology activities in the company.

(b) He/she should have basic knowledge and technical realization in the investigated field of the SBRM activity.

(c) Expertise and knowledge of scenario planning and technology roadmapping are not a must.

The selected participants are grouped into different teams in order to play roles including scenario building team, scenario assessment team and decision team.

(i) Scenario building team

The scenario building team is responsible for generating possible scenarios using a qualitative approach to build a possible scenario pool in the process of scenario building (i.e. Phase 3). The members of the scenario building team are also responsible for generating the preliminary scenario-based roadmap of each selected scenario in the process of scenario-based roadmapping (i.e. Phase 5). To ensure the quality of the scenarios, experienced staff who are familiar with the industry/market/business/technology should be invited to be the members of the scenario building team.

(ii) Scenario assessment team

The scenario assessment team is responsible for evaluating the possible scenarios generated by the scenario building team using a quantitative approach in the process of scenario assessment and selection (i.e. Phase 4). 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, marketing manager and financial manager.

(iii) Decision team

According to the assessment results, the decision team is responsible for selecting the plausible scenario(s) from the possible scenarios generated in Phase 3 for the implementation of the scenario-based roadmapping. The top management staff in the organization are highly recommended to participate in this team.

Besides, all the participants are invited to attend the kick-off meeting conducted in Phase 2, and to generate comprehensive organizational scenario-based roadmap(s) in Phase 5. On the completion of the scenario team formation, top management conducts a kick-off meeting to initiate the MSBRM activity formally to all

participants. During the meeting, description and arrangement of the activity are presented to all participants.

3.5 Phase 3 – Scenario Building

Scenario building is the third step of the proposed method (i.e. Phase 3) that aims to generate possible future scenarios with positive and negative impacts qualitatively by the scenario building team, which are highly related to the issues concerned in the MSBRM activity (i.e. company's needs, purpose and scope). As shown in Figure 3.5, the key procedures conducted in this phase of "scenario building" are summarized below: -

(a) Construct a guideline for scenario building according to the background of the study, purpose and scope of the activity; and

(b) Generate possible future scenarios with positive and negative impacts in qualitative form using the scenario building worksheet.

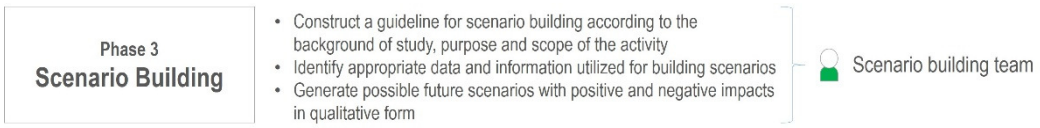


Figure 3.5 Key procedures and participants involved in the phase of scenario building

In this Phase, each participant is requested to provide at least a pair of possible future scenarios (i.e. one scenario with positive impacts and one scenario with

negative impacts) as expected deliverables. By adapting the Kipling method (five Ws and one H or 5W1H), each possible future scenario is generated in terms of what, when, where, who, why and how, through the following six questions about the future scenario.

- **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 addition to the Kipling method, the principles of the six thinking hats method (de Bono, 2010) is also adapted to construct the scenarios in a consistent and qualitative format. Functions and roles of each thinking hats are described clearly, as shown below: -

(i) Organization of the thinking process (blue hat thinking)

Blue hat thinking focuses on managing the thinking process of the scenario building activity. By making use of the other hats, the thinking process is designed and developed systematically to generate a possible future scenario which provides a clear picture of the future change during the activity. This

hat is used to answer the question "what is a possible scenario you are thinking about?".

(ii) Information (white hat thinking)

White hat thinking focuses on data, facts, information known and information needed about the scenario. The information (i.e. hard facts) available to support a future scenario is required to provide the justifications that are needed. This hat is used to answer the question "Why will the scenario happen?" with justifications.

(iii) Emotions (red hat thinking)

Red hat thinking focuses on participants' emotions, intuition and feelings about the scenario that is used to collect opinions and reactions to the possible future scenario. When using this hat, people can express the intuitive information (i.e. future forecast, hunches, gut instincts, likes, dislikes, loves or hates) to support or not support the future scenarios. Since this hat is not used to understand the reason behind these feelings, justifications are not required. This hat is used to answer the question "Why will the scenario happen?" without justifications.

(iv) Optimism (yellow hat thinking)

Yellow hat thinking focuses on the positive side of a possible future scenario which is used to identify reasons why the scenario may work and to probe for positive impacts, enablers, benefits, values, or opportunities. This hat is used to answer the question "Why will the scenario happen?".

(v) Discernment (black hat thinking)

Black hat thinking focuses on the negative side of a possible future scenario which is used to identify reasons why the scenario may not work and to spot negative impacts, barriers, difficulties, dangers, potential problems or risks. This hat is used to answer the question "Why will the scenario happen?".

(vi) Creativity (green hat thinking)

Green hat thinking focuses on creativity that is used to express possibilities, alternatives, suggestions, possible solutions or new ideas regarding how to deal with future scenarios. This hat is used to answer the question "How will the scenario happen?".

Before starting to implement the scenario building process, a guideline for scenario building is required to be constructed that aims at providing guidance to guide the participants how to generate possible future scenario(s) in relation to the issues concerned in the MSBRM activity insistently and qualitatively.

The guideline is composed of three sections, including introduction, instruction and questions for scenario building. The introduction is the first section of the guideline that is used to describe the company needs, background of the study, purpose and scope of the MSBRM activity so as to make sure that the participants have a better understanding of the activity. Instructions are the second section of the guideline that provides the participants a clear explanation how to build scenarios in terms of why and how, based on the principles of the six thinking hats method. In the third section of questions for scenario building, two series of questions about the future scenario which is related to the issue concerned in the MSBRM activity are provided for building positive and negative future scenarios respectively, in terms of what, when, where, who, why and how.

According to the proposed thinking methods of scenario building, a scenario building worksheet is purposely designed as an effective tool to elicit information for building possible future scenarios in a consistent and qualitative format. The framework for the scenario building worksheet is shown in Figure 3.6.

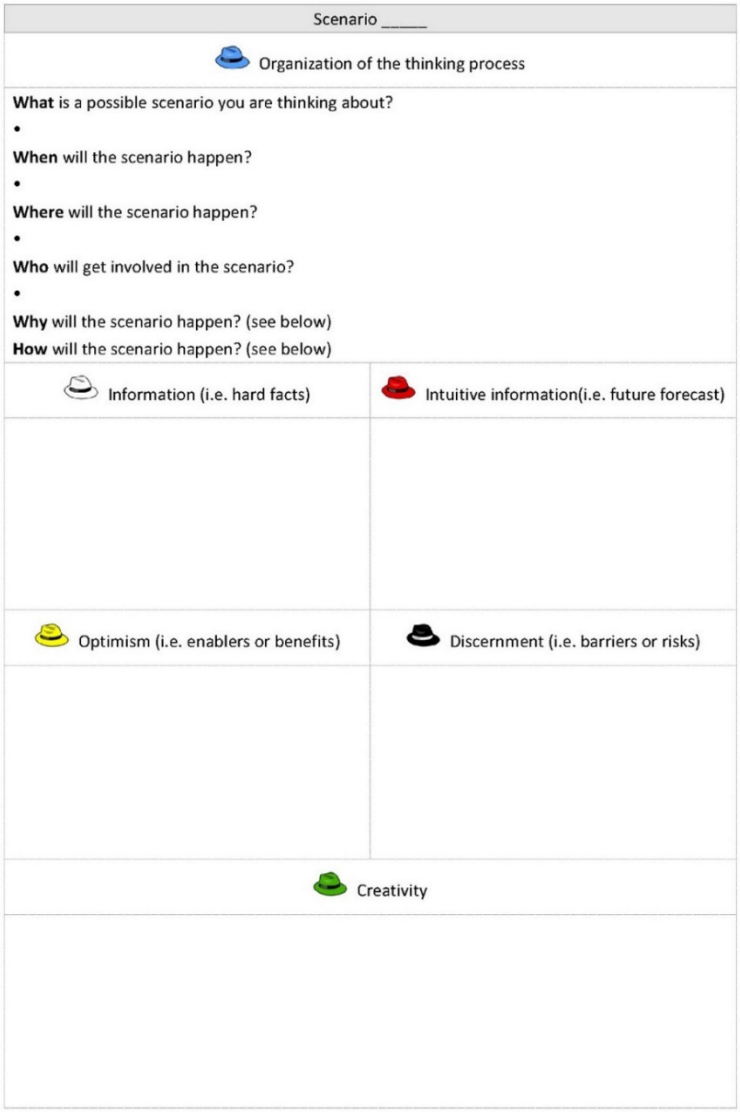


Figure 3.6 Framework for the scenario building worksheet

3.6 Phase 4 – Scenario Assessment and Selection

Since the scenario generated in Phase 3 is a construct in qualitative form, which is not measurable quantitatively, scenario assessment and selection is the fourth step of the proposed method (i.e. Phase 4) that aims to assess possible future scenarios quantitatively, and select the plausible future scenario(s) for the implementation of scenario-based roadmapping.

In the scenario planning study conducted by Amer et al. (2013), many researchers identified 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 is designed and developed to check the validity of each possible scenario in order to ensure its credibility, which takes relevance, completeness, consistency, plausibility and creativity into account.

As shown in Figure 3.7, the key procedures of the phase "scenario assessment and selection" are summarized as below: -

(a) Check for validation of each possible future scenario in terms of relevance, completeness, and consistency;

(b) Assess each valid possible future scenario based on six individual criteria in quantitative form using a scoring system; and

(c) Select plausible scenario(s) for roadmapping based on the selection criteria.

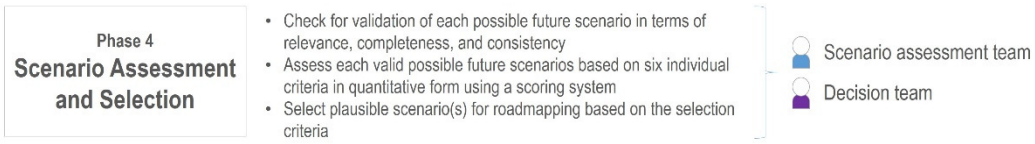


Figure 3.7 Key procedures and participants involved in the phase of scenario assessment and selection

3.6.1 Scenario validation

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. Requirements of the three scenario validation criteria are shown below: -

(a) Relevance: each scenario must be relevant to the company's needs, purposes and scope of the scenario-based roadmapping (MSBRM) 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.

If the scenario is able to fulfil these three criteria, the scenario is treated as a valid scenario for scenario assessment in terms of plausibility and creativity. Three validation tables are designed for checking the relevance, completeness and consistency of the scenario, as shown in Figures 3.8.

Scenario	Relevance	Company Need	Purpose	Scope
A_P				
A_N				
B_P				
B_N				
C_P				
C_N				
⋮				

(a)

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

(b)

Scenario	Consistency	White	Red	Yellow	Black	Green
A_P						
A_N						
B_P						
B_N						
C_P						
C_N						
⋮						

(c)

Figure 3.8 Validation tables for checking the (a) relevance, (b) completeness and (c) consistency of the scenario

3.6.2 Scenario assessment

On the completion of the scenario validation, each valid scenario (i.e. positive and negative future scenarios) is assessed in terms of plausibility and creativity.

(a) Plausibility: each scenario must be plausible and capable of happening.

(b) Creativity: each scenario must be new in relation to the issues concerned in the MSBRM activity.

Since the proposed MSBRM method is a pragmatic management tool for an 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 MSBRM 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 3.1.

Table 3.1 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

According to the 5-point scale scoring system for scenario assessment, the scoring scheme of each assessment criterion is described as follows: -

(i) Feasibility

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 feasibility of scenario 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.

(ii) Degree of innovativeness

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.

(iii) Impact

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.

(iv) Estimated market share

Estimated market share (c_4) is an indicator of market competitiveness, which is used to measure the business performance of a company as 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.

(v) Estimated investment

Estimated investment (c_5) is the 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.

(vi) Government support

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 3.2.

Table 3.2 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 (3.1), as illustrated in Table 3.3. The average score of each individual criterion ($\bar{s}_i$) is defined as:

$$\bar{s}_i = \sum_{j=1}^{n} s_{ij} \,/\mathrm{n} \tag{3.1}$$

where $\bar{s}_i$ is an average score of each individual criterion, s_{ij} is an individual score of the criterion assessed by each member, m is the total number of 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 3.3 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:

$$f = \begin{cases} 0, & otherwise \\ 1, & if\ \bar{s}_1 \geq 3 \end{cases} \tag{3.2}$$

As shown in Table 3.4, 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 (3.1), the weighted average scores of individual criteria ($\overline{s_{w_i}}$) are defined as:

$$\overline{s_{w_i}} = \bar{s}_i \cdot w_i \tag{3.3}$$

Based on Equation (3.2) and Equation (3.3), an overall score of the future scenario ($\overline{S_w}$) is defined as:

$$\overline{S_w} = f \cdot \sum_{i=1}^{n} \overline{s_{w_i}} \tag{3.4}$$

Table 3.4 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			$\overline{S_w}$

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 3.5.

Table 3.5 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:						

3.6.3 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 MSBRM 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 MSBRM 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.

3.7 Phase 5 – Scenario-based Roadmapping

Scenario-based roadmapping is the fifth step of the proposed method (i.e. Phase 5) and aims to implement the organizational future action plan(s) with a timeline

according to what plausible future scenarios they can serve. For this purpose, a hybrid roadmapping method (HRMM) is designed and developed by incorporating environment-oriented (i.e. outside-in) and company-oriented (i.e. inside-out) perspectives which provides a scenario-based roadmapping process to embed the selected scenario(s) into roadmaps. The HRMM comprises two main processes including preliminary scenario-based roadmapping and organizational scenario-based roadmapping. By an integration of outside-in and inside-out approaches, the preliminary scenario-based roadmapping aims at addressing the individual action plan(s) according to selected scenario(s) in the outside-in view whereas inside-out scenario-based roadmapping is concerned with the implementation of comprehensive action plan(s) according to the plausible scenario (s) for strategic planning and forecasting in organizational view.

As shown in Figure 3.9, the key procedures conducted in this phase "scenario-based roadmapping" are summarized below: -

(a) Generate a preliminary scenario-based roadmap of each selected scenario;

(b) Determine the quantity of inside-out scenario-based roadmap(s); and

(c) Generate comprehensive organizational scenario-based roadmap(s) based on the selected scenario(s).

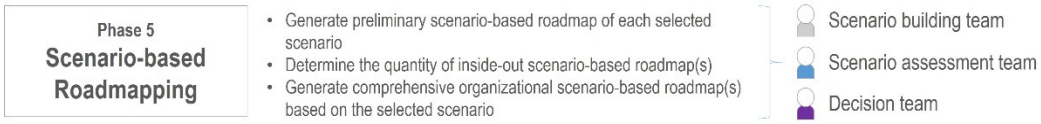


Figure 3.9 Key procedures and participants involved in the phase of scenario-based roadmapping

3.7.1 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. Since the proposed MSBRM method is a scenario-driven approach, a framework for the preliminary scenario-based roadmap is designed in terms of 5W1H and is shown in Figure 3.10. The framework consists of six components: timeline, milestones, drivers (i.e. internal and external), suggested action plan, provider(s) and consumer(s). For the proposed method, the preliminary scenario-based roadmap is prepared as the action plan of plausible future scenarios. Functions of components in the roadmap framework are described as follows: -

(i) Timeline

Timeline is placed in the top layer of the roadmap that is used to indicate the expected/estimated time for happening scenarios/events and taking actions, such as "**when** will the scenario happen?", "**when** the events will happen" and "**when** the actions will be expected to be taken".

(ii) Milestone

Following the timeline, milestone is placed as the second layer that is used to indicate the main issue concerned in the MSBRM activity, such as "**what** possible future scenario will happen" or "**what** important events that precipitate the scenario will happen".

(iii) Driver

Driver is placed at the third layer of the roadmap, which consists of two sub-layers: (a) external drivers and (b) internal drivers. External driver layer is used to identify the environment-oriented drivers of the scenario (e.g. market driver, technological driver, economical driver, policy driver, etc.). Internal driver layer is used to indicate the organization-oriented drivers of the scenario (e.g. corporate strategy, business driver, etc.). Both drivers of the scenario can help to provide an answer to the question "**why** will the scenario happen?".

(iv) Action plan

Action plan is placed at the bottom layer of the roadmap, which is used to express a feasible action plan regarding **how** to deal with future change of the selected plausible scenario.

(v) Provider

Provider represents the person or party **who** is involved in the scenario and takes actions in the plan.

(vi) Consumer

Consumer represents the person or party **who** is involved in the scenario and served in the plan.

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.

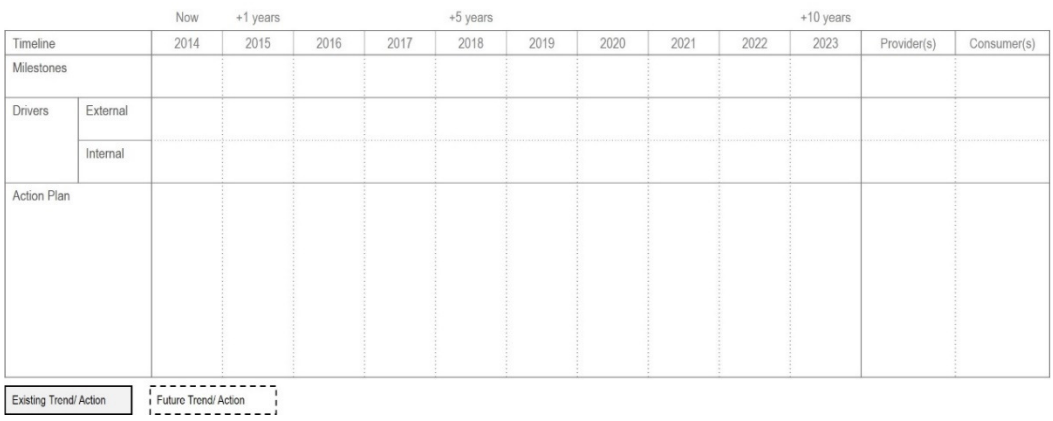


Figure 3.10 A framework for the preliminary scenario-based roadmap

3.7.2 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 in terms of 5W1H and shown in Figure 3.11, which is similar to the framework of the preliminary roadmap, except the component "expected outcome".

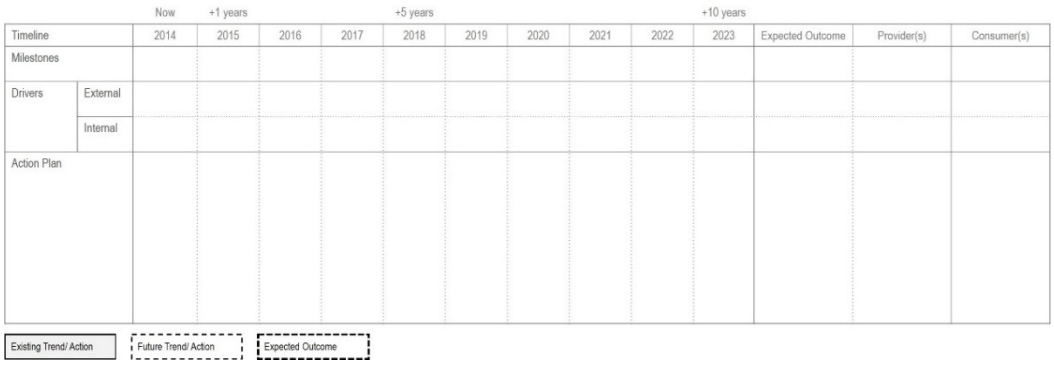


Figure 3.11 A framework for the organizational scenario-based roadmap

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 MSBRM 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 timeframe

according to what plausible future scenarios they can serve (i.e. the selected plausible scenario).

3.7.3 Outside-in roadmapping

On the basis of the organizational scenario-based roadmap, outside-in roadmapping is a monitoring process and a validation stage for organizations to evaluating the credibility of the organizational roadmap in secondary data analysis from an outside-in perspective. To be precise, the context of roadmap (i.e. each tag on the roadmap) is validated by external technology intelligence through search engine, patent and publication databases to see whether the similar ideas of solutions/applications/services/technologies were advanced by someone (i.e. competitor). If similar idea is found, the detail of the similar idea is collected for monitoring and validation purpose. On the completion of the outside-in roadmapping, the results of external technology intelligence are generated for the monitoring and validation of the organizational roadmap.

3.8 Summary

This chapter presents a multi-perspective scenario-based roadmapping (MSBRM) method as a useful tool for strategic planning and decision-making by combining scenario planning with roadmapping approaches. Comprehensive procedures of

the proposed MSBRM method are presented for implementing the organizational scenario-based roadmap(s). An overall framework of the proposed MSBRM method is summarized in terms of procedures and resources (i.e. participants, and tools) involved in the MSBRM activity, as shown in Figure 3.12.

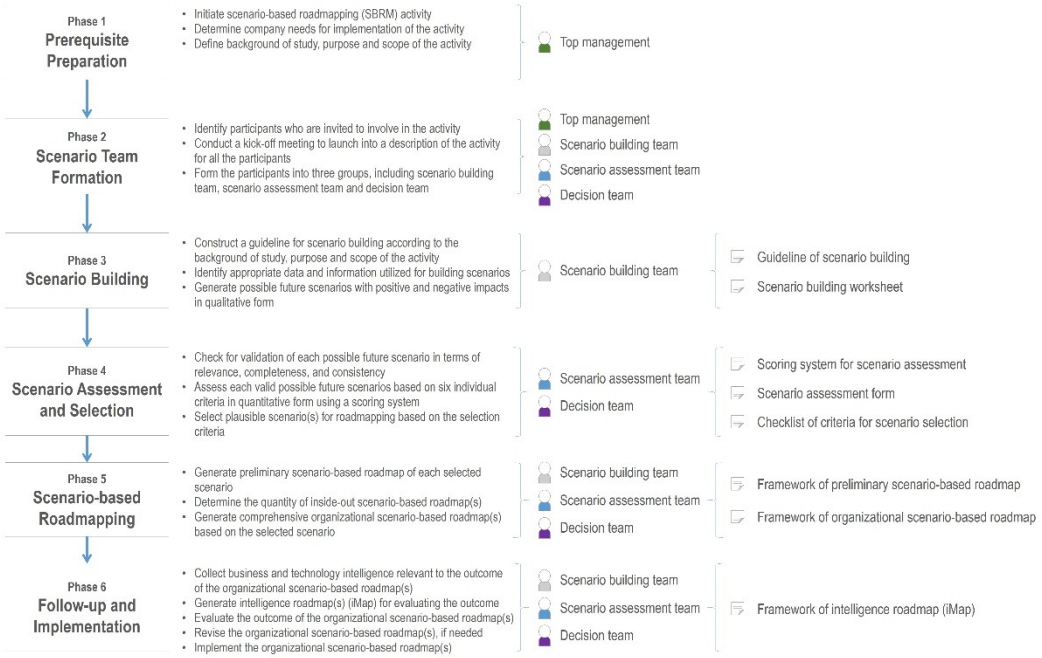


Figure 3.12 Detailed framework for of the proposed MSBRM method

The proposed MSBRM method was designed and developed which 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).

The methodology of the MSBRM approach is presented in this chapter, which attempts to address the limitations of the existing MSBRM approaches in the

literature (Chapter 2). Following this chapter, an information-driven scenario building (IDSB) method is proposed to support multi-perspective scenario-based roadmapping, and the methodology of the IDSB method will be presented in Chapter 4.

Chapter 4

Information-driven Scenario Building Method to Support Scenario-based Roadmapping

According to the proposed multi-perspective scenario-based roadmapping (MSBRM) method mentioned in Chapter 3, the possible future scenarios are generated in terms of what, when, where, who, why and how using the Kipling method. Also, the principles of the six thinking hats method (de Bono, 2010) is also adapted to construct the scenarios in a consistent and qualitative format. By incorporating business information into the strategic planning and forecasting process, an information-driven scenario building (IDSB) method is designed and developed as an information-driven scenario building tool for organizations to facilitate the development process of the scenario-based roadmapping. Figure 4.1 illustrates an architecture of the proposed IDSB method.

As shown in Figure 4.1, the overall process of the proposed IDSB method consists of five main phases including information acquisition (Phase 1), metadata construction (Phase 2), keyword extraction (Phase 3), scenario element identification (Phase 4), and scenario narrative generation (Phase 5), respectively. Before implementing the proposed IDSB method, an information collection team

is required to be formed by the top management of the company, which is responsible for collecting the scenario-oriented information, constructing metadata of the collected information, extracting keywords, identifying scenario elements, as well as generating scenario narratives. Moreover, the scenario assessment team also plays a key role in defining the keywords and identifying scenario elements for building possible future scenarios based on their professional judgment.

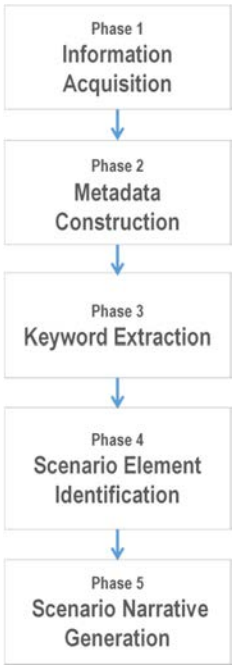


Figure 4.1 Architecture for the proposed IDSB method

4.1 Information Acquisition Phase

Development of an information-driven scenario starts with information collection. Information acquisition is the first step of the proposed scenario building method (i.e. Phase 1) which aims to collect scenario-oriented information from the

collection of documents so as to identify scenario elements in order to build possible future scenarios.

In the process of information collection, scenario-oriented information is defined as a collection of information (e.g. hard facts, opinions) extracted from offline and online documents that are relevant to the issue concerned in the MSBRM activity. Document collection is a group of documents of large participation and collaboration of various experts and the general public, which is used for extracting scenario-oriented information. In general, a document is composed of various components, such as sentences, table of contents, pages, chapters, sections, figures, tables, and references. Moreover, three types of scenario-based information are found in a document, which are structured information, unstructured text, and semi-structured information. Examples of structured information, unstructured text, and semi-structured information in the documents, papers, and patents are shown in Table 4.1, respectively.

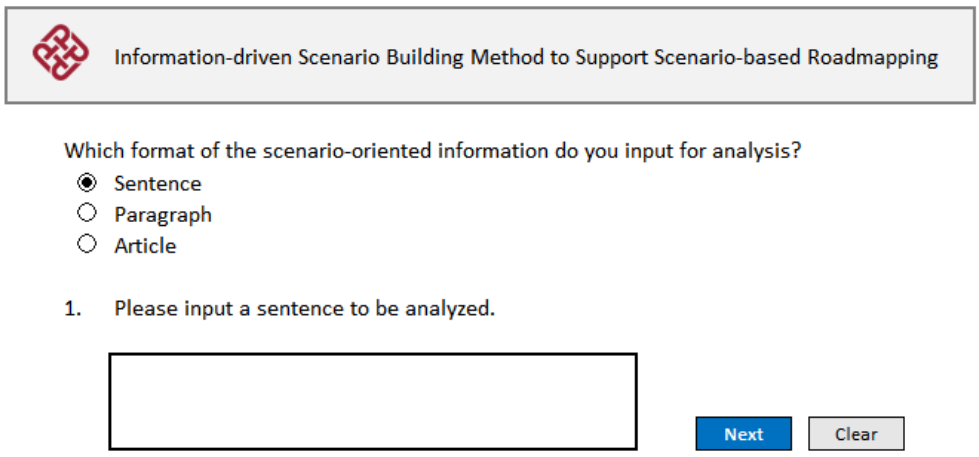
In this study, the structured information is defined as any information that contains formal structures (i.e. data tables, database) in the document, such as document metadata. The unstructured text is defined as free text in the document that does not contain formal structures. The semi-structured information is a combination of structured information and unstructured text, such as patents, and papers.

Table 4.1 Examples of structured information and unstructured text in a document, paper and patent

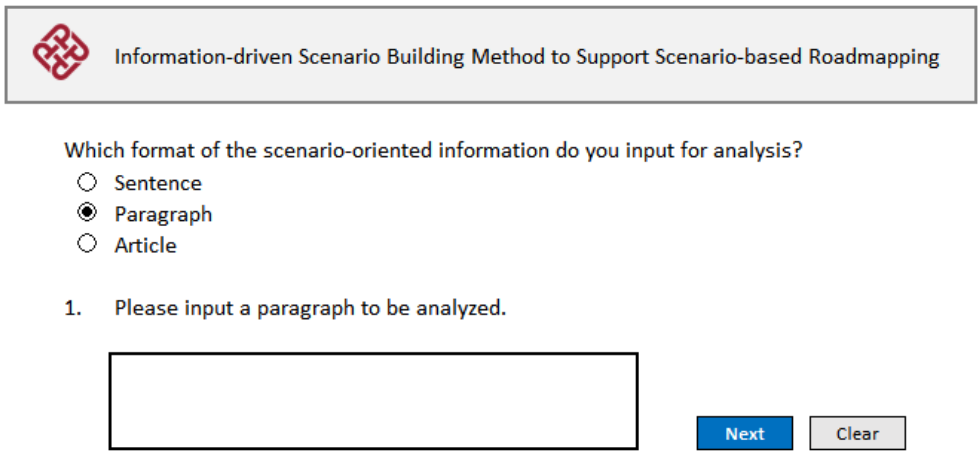
Types	Examples
Structured information	• Document: author names, data in tables, document metadata, etc. • Paper: author names, data in tables, article history, keywords, etc. • Patent: patent number, filing date, assignees, IPC codes, etc.
Unstructured text	• Document: full-text content, figures, photos and graphic images, etc. • Paper: title, abstract, full-text content, etc. • Patent: title, abstract, claims, and description of the invention, etc.

In the process of the information selection, the scenario building team should identify scenario-oriented information regarding the company's needs, purposes and scope of the MSBRM activity. Various types of scenario-oriented information are allowed to be collected for building possible future scenarios, such as trends (i.e. current and future), forecast and foresight (i.e. short-term or long-term), published scenarios, published roadmaps about industry/market/business/ technology, and so on. Moreover, forms of information are different, such as news, reports, articles, papers, patents, books, short notes, web pages, blogs and so on, from various online and offline sources. And the providers of the information can be stakeholders who are involved in the scenario, such as experts, practitioners, company, government, industrial associations, academic and research institutions.

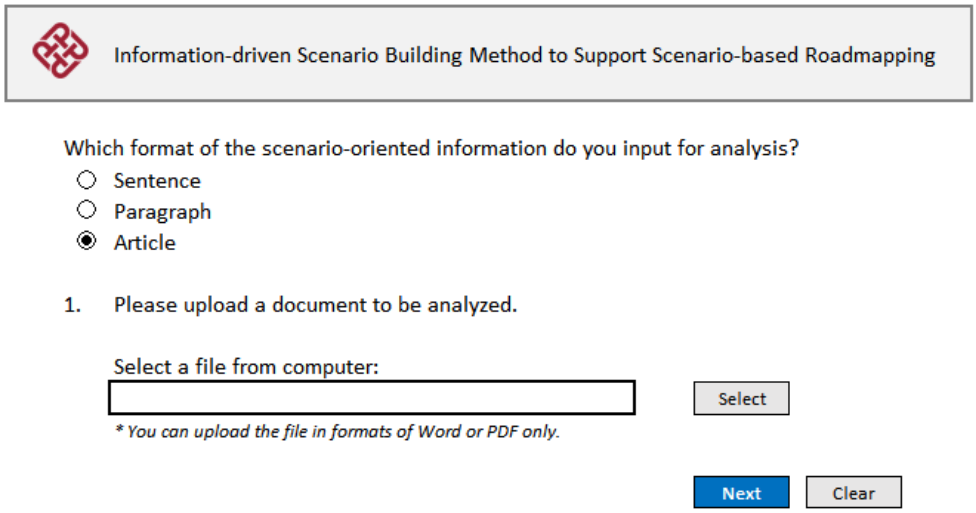
In the information acquisition process, the format of the scenario-oriented information can be in the form of a sentence, a paragraph or a full article. Snapshots of user interfaces for information acquisition for formatting sentences, paragraphs and articles are shown in Figure 4.2 (a), (b) and (c), respectively.



(a)



(b)



(c)

Figure 4.2 Snapshots of user interfaces for information acquisition in formats of (a) sentence, (b) paragraph and (c) article

On completion of the information acquisition, all the collected information set is treated as scenario-oriented documents in this study. Structured information in the documents are pre-processed by metadata construction, and unstructured text in the documents will be extracted for identifying scenario elements (i.e. Phase 3).

4.2 Metadata Construction Phase

Metadata construction is the second phase of the proposed scenario building method (i.e. Phase 2) which aims to pre-process the structured data from the collected documents systematically using information retrieval techniques in order to construct document metadata and build a hierarchical tree of the document. A procedure for metadata construction is designed and developed, which consists of two steps, including: -

(a) Collection of document metadata from structured data; and

(b) Building of a hierarchical tree of the document.

4.2.1 Gathering document metadata from structured information

Collection of document metadata aims at gathering document metadata from the structured data in the documents. In general, metadata are defined as "data about data" or "information about information" (National Information Standards Organization, 2004). Three types of metadata are commonly used, such as descriptive metadata, structural metadata, and administrative metadata.

In this study, the document metadata are defined as structured data providing various types of information about the document to machine understandable information. As shown in Figure 4.3, a metadata schema was designed and developed for structuring metadata of the documents acquired in Phase 1. Three types of metadata are required to be collected in the phase of metadata construction for organizing scenario-oriented information and identifying the source of scenario-oriented information in structured and digital format. Each type of metadata has different components to provide information of the document in different dimensions, as shown in Table 4.2.

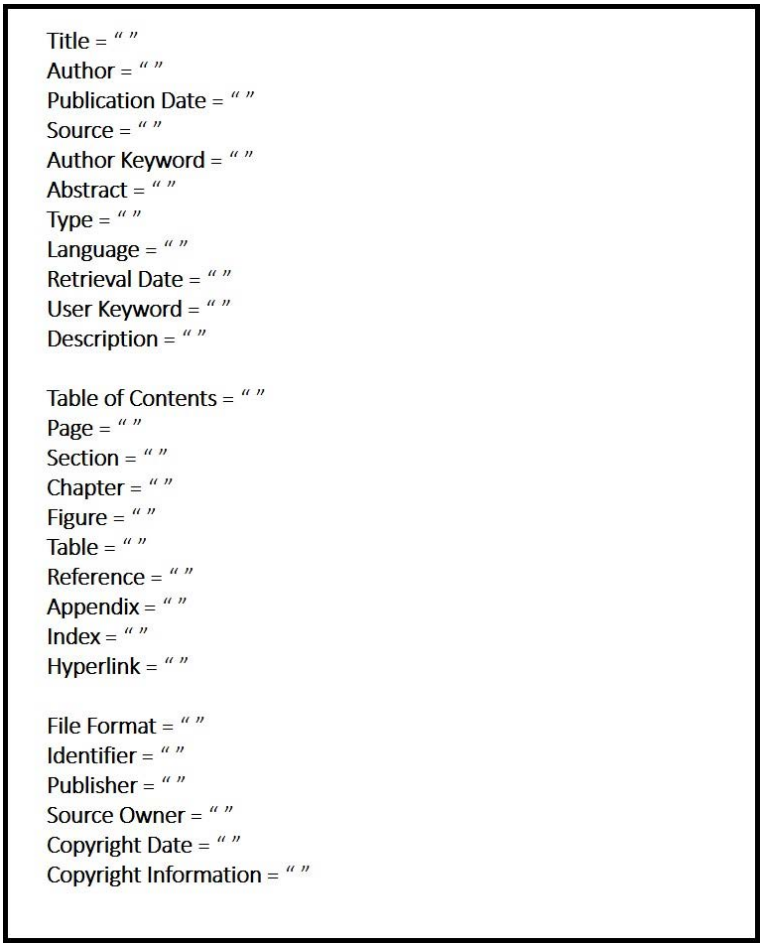


Figure 4.3 Metadata schema of the document

Table 4.2 Components of descriptive, structural and administrative metadata

Descriptive Metadata	Structural Metadata	Administrative Metadata
• Title • Author/Creator • Publication Date • Source • Author Keyword • Abstract • Type • Language • Retrieval Date • User Keyword • Description	• Table of Contents • Page • Chapter • Section • Figure • Table • References	*Technical Metadata* • File Format • Identifier • Publisher *IPRs Metadata* • Source owner • Copyright date • Copyright information • Access right

4.2.1.1 Descriptive metadata

Descriptive metadata describe the document for purpose, which is used to identify basic information of the document and enable users to find the appropriate document effectively. As shown in Table 4.3, eight components of the descriptive metadata can be collected from the document, such as title, author/ creator, publication date, source, author keywords, abstract, document type, and language.

Table 4.3 Definitions of components in descriptive metadata collected from the document

Component	**Definition**	**Collected from**
Title	Title of the document	Document
Author/ Creator	Author/creator of the document	Document
Publication Date	Publication date/issue date of the document (e.g. 2016, 2016-01 or 2016-01-01) • Format: YYYY, YYYY-MM or YYYY-MM-DD	Document
Source Path	Source path of the document • Type: URL or Path of file	Document
Author Keyword	Keywords of the document defined by the author	Document
Abstract	Statements summarizing the important points of the document	Document
Type	Type of the document (e.g. article, report, book, webpage, blog, text, figure, table, etc.)	Document
Language	Language of the document (e.g. English, Chinese, etc.)	Document

Three specific components are defined by users, such as retrieval date, user keywords, and description of the document. Definition of components in the descriptive metadata are described and illustrated in Table 4.4.

Table 4.4 Definitions of components in descriptive metadata provided by the user

Component	**Definition**	**Provided by**
Retrieval Date	Date of accessing the document (e.g. 2016, 2016-01 or 2016-01-01) • Format: YYYY, YYYY-MM or YYYY-MM-DD	User
User Keyword	Keywords of the document defined by the user	User
Description	A short statement describing the document	User

In the process of structuring descriptive metadata, sources of the scenario-oriented information can be the user, electronic source or print source. Major components of the descriptive metadata are entered by users which can be found in the document, such as title (i.e. document name or article title), author/creator (i.e. in the company or outside the company), publication date, source path (i.e. URL, or file path), author keyword, abstract, type (i.e. article, blog, book, figure, report, table, text, website, or other), and language (i.e. English, Chinese, or Other). In addition, some components of the descriptive metadata can be defined by the user to machine customized information of the document, including retrieval date, user

keyword and description. A snapshot of the user interface for descriptive metadata construction is shown in Figure 4.4.

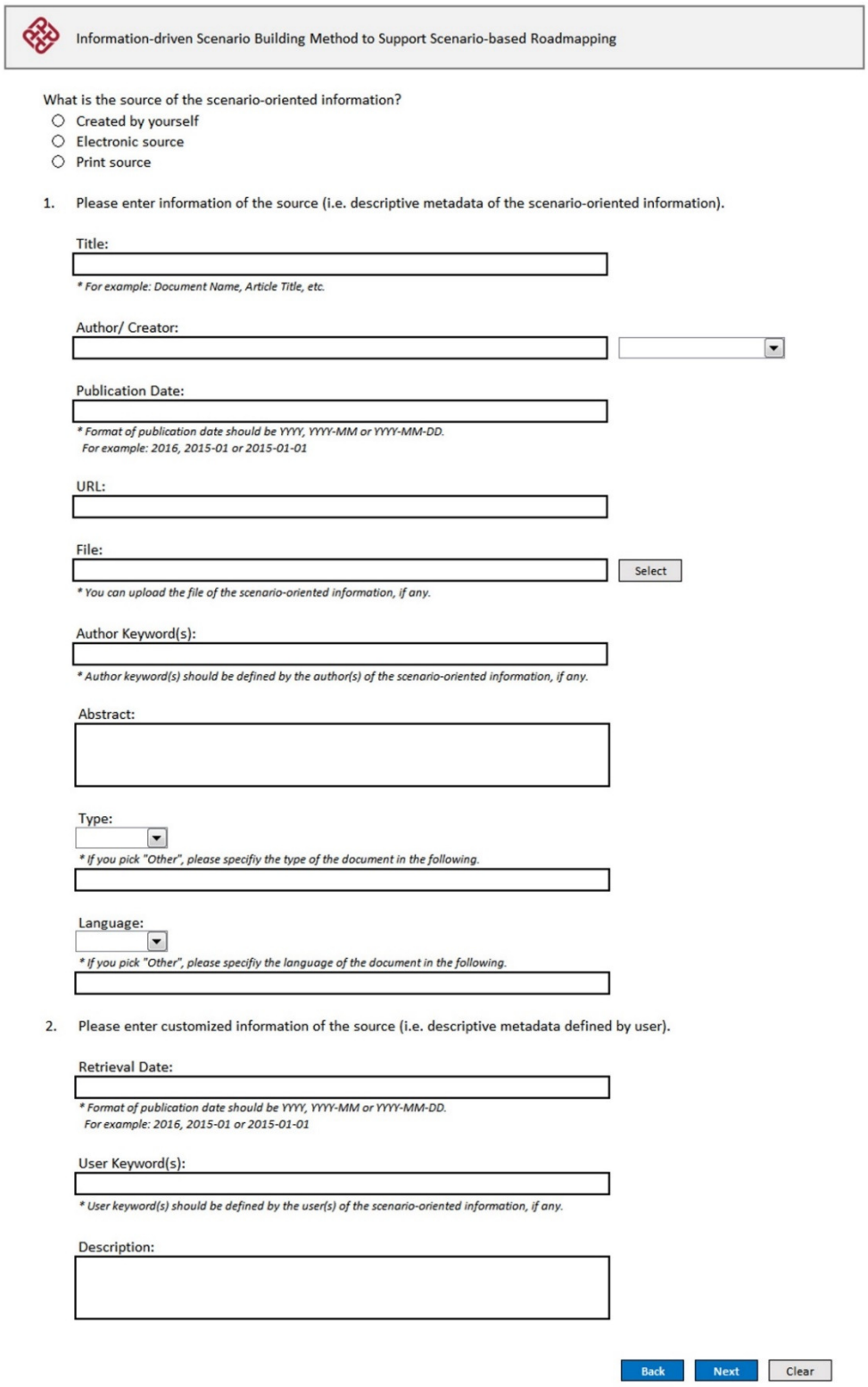


Figure 4.4 A snapshot of user interface for descriptive metadata construction

On completion of the descriptive metadata construction, all the collected information sets are treated as descriptive metadata of the scenario-oriented documents in this study. Structural metadata of the scenario-oriented information are constructed in the next step.

4.2.1.2 Structural metadata

Structural metadata represent a physical or logical structure of the document to facilitate navigation of the document, which is used to provide information about the structure of the document, as well as show the relationship of sub-objects (e.g. Figure 1 in Section A) in the document. As shown in Table 4.2, components of the structural metadata are table of contents, pages, chapters, sections, figures, tables, and references which are described in Table 4.5. In the case of the document having structured information (i.e. table of contents, list of figures or list of tables), this structured information can be used directly to construct a hierarchical tree of the document. Otherwise, the structural metadata of the document in quantitative form are collected, and structural metadata of the document in qualitative form are collected to construct a hierarchical tree of the document later that is presented in Section 4.2.2.

Table 4.5 Descriptions of components of structural metadata

Component	Semantics	Provided by
Table of contents	Existence of table of contents in the document (i.e. Yes or No) • If the document contains a table of contents/ list , the value of the component = "Y"; otherwise "N".	Document
Chapters	Total number of chapters in the document	Document
Sections	Total number of sections in the document	Document
Section Levels	Total number of section levels in the document	Document
Figures	Total number of figures in the document	Document
Tables	Total number of tables in the document	Document
References	Total number of references in the document	Document
Pages	Total number of pages in the document	Document

In the process of constructing structural metadata, the quantity of each component is required to be provided by the users which can be determined in the document, such as numbers of chapters, sections, section levels, figures, tables, references and pages. Snapshots of user interfaces for structural metadata construction are shown in Figure 4.5. Upon completion of the structural metadata construction, all the collected information sets are treated as structural metadata of the scenario-oriented documents in this study. Structural metadata of the scenario-oriented

information are used to construct a hierarchical tree of the document in the next step.

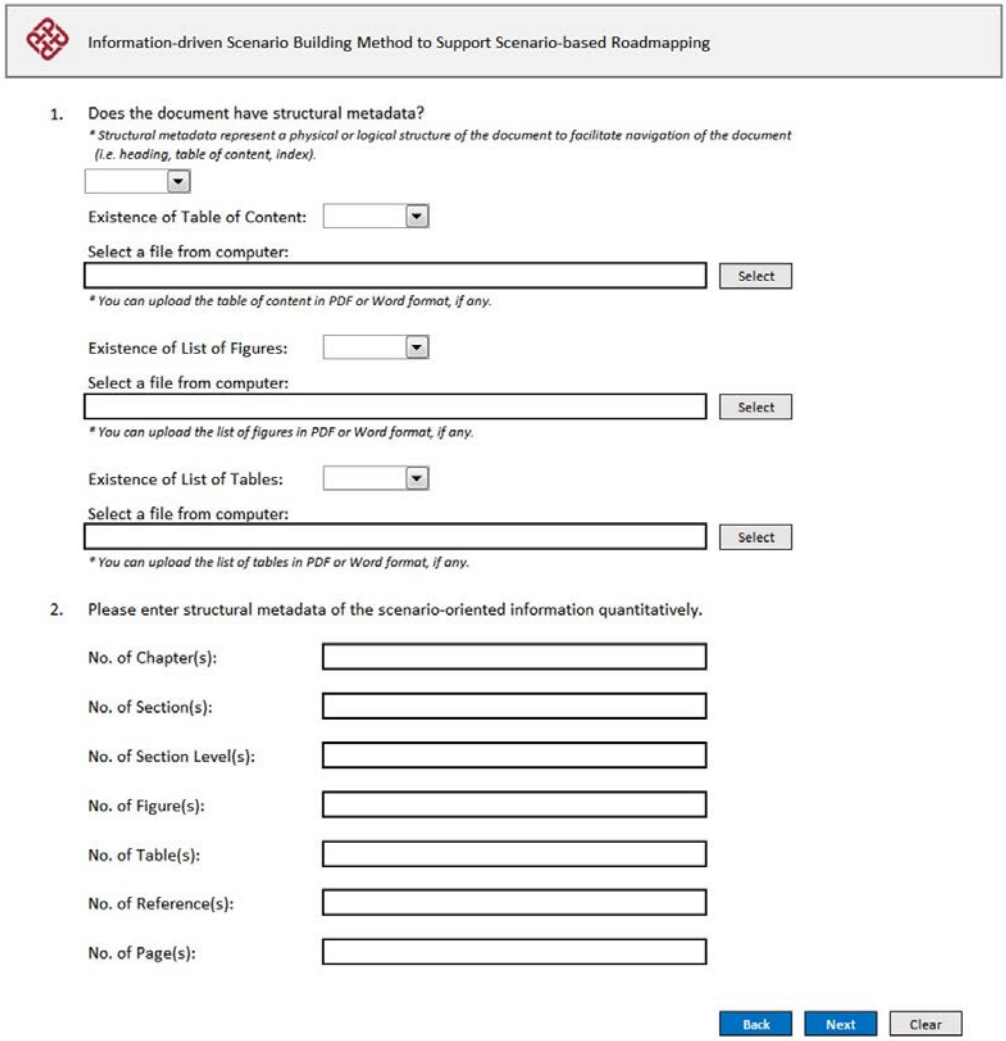


Figure 4.5 A snapshot of user interface for structural metadata construction

4.2.1.3 Administrative metadata

Administrative metadata provide information necessary to manage the document from technical and intellectual property rights (IPRs) perspectives, which is used to facilitate the access right of the documents in the future. As shown in Table 4.2,

two types of administrative metadata are technical metadata and intellectual property rights (IPRs) metadata. The semantics of each components of administrative metadata are described in Table 4.6.

Table 4.6 Descriptions of components of administrative metadata

Component	**Semantics**	**Collected from**
Technical Metadata		
File format	File format of the document that are stored in database (e.g. pdf, word, access, hard copy, etc.)	Document
Identifier	Identifier of the document (e.g. International Standard Book Number (ISBN), Digital Object Identifier (DOI), Persistent Uniform Resource Locator (PURL), etc.)	Document
Publisher	Publisher of the document	Document
Intellectual Property Rights (IPRs) Metadata		
Source owner	Source owner of the document	Document
Copyright date	Copyright date of the document • Format: YYYY, YYYY-MM or YYYY-MM-DD (e.g. 2016, 2016-01 or 2016-01-01)	Document
Copyright information	Copyright information of the document	Document
Access rights	Description of IPRs and use conditions	Document

Technical metadata are preservation information of the document that contains information needed to archive and preserve the document, and its components are file format, identifier, and publisher. IPRs metadata are information about rights management of the document, and its components are source owner, copyright date, copyright information, and access rights.

In the process of structuring administrative metadata, all components of the administrative metadata are inputted by users which can be found in the document or source of the document. A snapshot of user interface for administrative metadata construction is shown in Figures 4.6.

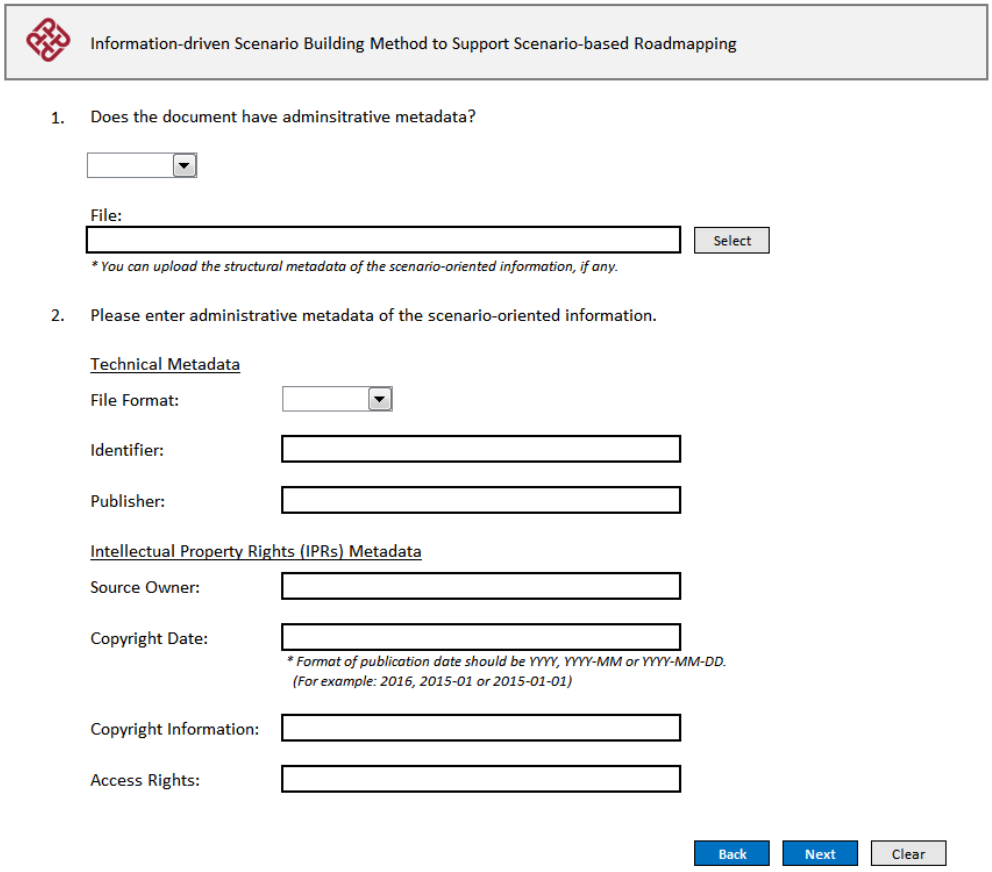


Figure 4.6 A snapshot of user interface for administrative metadata construction

Upon completion of the administrative metadata construction, all the collected information sets are treated as administrative metadata of the scenario-oriented documents in this study.

4.2.2 Building a hierarchical tree of the document

The building of a hierarchical tree aims at indicating the structure of each document collected in Phase 1. In this study, the hierarchical tree presents a physical or logical structure of the document (i.e. table of contents), and also shows the relationship of different components (e.g. Figure 1 in Section A) in the document. The structural metadata can be used to build the hierarchical tree of the document. To structure the components systematically, two types of numbering systems have been designed for coding the components of the document at single and multiple levels. A single-level numbering system is designed for structuring the figures, tables, and references of the document by code and number, as shown in Table 4.7. The codes of the document, figures, tables, and references are **D**, **F**, **T**, and **R**, the numbering of the components is **1**, **2**, **3**, …, ***n***, and the coding numbers of the components are **D1**, **D2**, **D3**, …, and **D*n***, **F1**, **F2**, **F3**, …, and **F*n***, **T1**, **T2**, **T3**, …,and **T*n***, and **R1**, **R2**, **R3**, …, and **R*n***, where ***n*** is total number of each components in a document.

Table 4.7 Single-level numbering system of components in the document

Component	Coding Number	Description
Document	**D1**, **D2**, **D3**, …, **D*n***	Documents 1, 2, 3, …, and ***n***
Figures	**F1**, **F2**, **F3**, …, **F*n***	Figures 1, 2, 3, …, and ***n*** in a document
Tables	**T1**, **T2**, **T3**, …, **T*n***	Tables 1, 2, 3, …, and ***n*** in a document
References	**R1**, **R2**, **R3**, …, **R*n***	References 1, 2, 3, …, and ***n*** in a document

A multiple-level numbering system has been designed for structuring the chapters and sections of the document by level and number, as shown in Table 4.8. According to the level of the numbering system, level 1 represents the chapters in the document, and level 2 represents the section of the document. For sub-sections of the section, the numbering of the level is 3, 4, 5, …, ***m***, where ***m*** is the total level of sub-sections. Number of levels depends on the level of the subsections of the section. The numbering of the chapters, sections and sub-sections are **0**, **1**, **2**, **3**, …, ***c***, **1**, **2**, **3**, …, ***s***, and **1**, **2**, **3**, …, ***ss***, where ***c*** is the total number of chapters, ***s*** is the total number of sections in the chapter, and ***ss*** is the total number of subsections in the section. If the document contains sections only, the numbering of the chapters is 0. For instances, the total number of the sections in Chapter 1 are 3, the numbering of the sections is 1.1, 1.2 and 1.3. If the number of subsections in section 1.1.2 is 4, the numbering of the subsections is 1.1.2.1, 1.1.2.2, 1.1.2.3 and 1.1.2.4.

Table 4.8 Multi-level numbering system for chapters and sections

Component	Level	Numbering	Description
Chapters	1	0, 1, 2, 3, …, ***c***	• Chapter 1 2, 3, …, ***c*** of the document • If the document contains sections only, the numbering of the chapter is 0.
Sections	2	1, 2, 3, …, ***s***	Sections 1.1, 1.2, 1.3, …, 1.***s*** of Chapter 1 in the document (Section 1, 2, 3, …, ***s*** of Chapter 1)
Sub-sections	3	1, 2, 3, …, ***ss***	Section 1.1.1, 1.1.2, 1.1.3, …, 1.1.***ss*** of Chapter 1 in the document (Subsection 1, 2, 3, …, ***ss*** of Section 1.1)
	4		Section 1.1.1.1, 1.1.1.2, 1.1.1.3, …, 1.1.1.***ss*** of Chapter 1 in the document (Subsection 1, 2, 3, …, ***ss*** of Section 1.1.1)
	5, …, ***m***		Section 1.1.1.1.1, 1.1.1.1.2, 1.1.1.1.3, …, 1.1.1.1.***ss*** of Chapter 1 in the document (Subsection 1, 2, 3, …, ***ss*** of Section 1.1.1.1)

On completion of coding the components in the document, the hierarchical tree is built to show the relationship between different components by indentation and number. An example of the hierarchical tree for a document is shown in Figure 4.7. In this example, a document named “Testing and Certification Industry in Hong Kong” contains 5 sections, 3 sub-sections, 1 figure, 3 tables, and 1 reference (Hong Kong Trade Development Council (HKTDC), 2015). Since there are no chapters in the document, the numbering of the chapters is 0. The tree clearly

shows the relationship among sections (i.e. 0.1, 0.2, 0.3, 0.4, 0.5), subsections (i.e. 0.4.1, 0.4.2, 0.4.3), figure (i.e. F1), tables (i.e. T1, T2, T3) and reference (i.e. R1) in the document.

D1 Testing and Certification Industry in Hong Kong
0.1 Industry Data
T1 (in 2013)
T2 Data for private independent establishments
T3 Share of business receipts of the private independent establishment by type of service
R1 Source: HKTDC from HKSAR Census and Statistics Department, Hong Kong Council for Testing and Certification
0.2 Range of Services
F1 Type of Services
0.3 Services Providers
0.4 Industry Development and Market Outlook
0.4.1 Hong Kong as a Testing and Certification Centre
0.4.2 Support and Facilitation from the Government
0.4.3 Market Opportunities and Recent Developments
0.5 Closer Economic Partnership Arrangement between Hong Kong and the Mainland (CEPA)

Figure 4.7 Example of a hierarchical tree

The hierarchical tree also provides a snapshot of the document indicating scenario element "what", for example, "what issues the document is concerned about" or "what information the document is providing". The tree also provides the linkage of the relationship between the extracted sentence and the heading in the document. For instance, the sentence D20 is extracted as scenario-oriented information in the document which is located in Section 0.4.1 of the document. According to the hierarchical tree (see Figure 4.7) of the document, this scenario-oriented information is highly related to the scenario elements "what" in the same document, such as "Testing and Certification Industry in Hong Kong", "Industry Development and Market Outlook" and "Hong Kong as a Testing and Certification

Centre". Moreover, the tree is also used to facilitate navigation of the document for information retrieval.

4.3 Keyword Extraction Phase

Keyword extraction is the third phase of the proposed scenario building method (i.e. Phase 3). This process aims to extract and define the keywords from the unstructured text in the documents collected in Phase 1 in order to generate a preliminary set of keywords (i.e. noun, verb and adjective phrases) for identification of scenario elements. The process for keyword extraction has been designed and developed, which consists of two main steps.

(a) Extract keywords from unstructured texts; and

(b) Define the extracted keywords.

4.3.1 Extract keywords from unstructured text

This step aims to extract the keywords from unstructured text in the documents. In general, a document can be represented as a batch of words appearing in it, but some words are representative and some are not. In this study, there is an assumption that all the documents collected in Phase 1 can be expressed by a set of keywords that is relevant to the scenario. Based on the assumption, each sentences in the document represents scenario-oriented information, and the

keywords in the sentence are defined as representative words (i.e. “industry”) or phrases (e.g. Hong Kong), which semantics facilitates in identifying the scenario elements in the documents. Only nouns, verbs and adjectival phrases in the document are selected to be keywords.

By applying the text mining technique, a keyword extraction algorithm is purposely proposed to convert the unstructured text in a document into keywords. Moreover, a natural language parser named “Stanford Parser” (i.e. Stanford Parser version 3.6.0) is used for words and sentence analysis based on grammatical structure, which is developed by the Stanford Natural Language Processing (NLP) Group (2015). First of all, the unstructured text is extracted by sentence using punctuation characters (i.e. full stops and question marks) and newline characters (i.e. line break and paragraph breaks).

Hence, each word in the extracted sentences are tagged with part-of-speech (POS) tagger code using a POS tagger. The POS tag codes for noun, verb and adjective are summarized in Table 4.9, and a full list of the POS tagger codes is shown in Appendix B (Santorini, 1990). Afterwards, the extracted sentences are analyzed based on their grammatical structure, and the tagged tokens in the extracted sentences are also grouped with their nearby token as noun phrase, verb phrases and adjective phrases based on their POS tag codes, respectively. Finally, noun

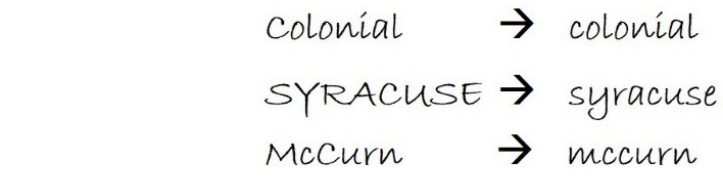
phrases, verb phrases and adjective phrases are identified from the extracted keywords.

Table 4.9 Part-of-Speech (POS) tag codes of noun, verb and adjective (adapted from Santorini, 1990)

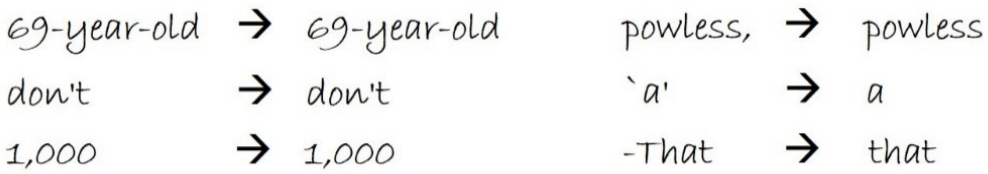
Part-of-speech (POS)	**POS Tag Code**	**Description**
Noun	• NN • NNS • NNP • NNPS	• Noun, singular or mass • Noun, plural • Proper noun, singular • Proper noun, plural
Verb	• VB • VBD • VBG • VBN • VBP • VBZ	• Verb, base form • Verb, past tense • Verb, gerund or present participle • Verb, past participle • Verb, non-3rd person singular present • Verb, 3rd person singular present
Adjective	• JJ • JJR • JJS	• Adjective • Adjective, comparative • Adjective, superlative

In the process of keyword extraction, a consideration is taken into account, which is tokenization. By using the tokenization approach, all the extracted keywords (i.e. noun, verb and adjective phrases) are converted into lower case, and only non-alphanumeric characters (i.e. punctuation characters) located at the front and the

end of the keyword are removed, not for removing all the non-alphanumeric characters in the document. Two examples of tokenization are illustrated in Figure 4.8 (a) and (b). A non-alphanumeric characters list is illustrated in Appendix C which is adapted from Lawrence Livermore National Laboratory (LLNL) (2007). On completion of tokenization, a preliminary set of keywords for a document is generated for further use.



(a)



(b)

Figure 4.8 Examples of tokenization (a) lower case and (b) non-alphanumeric characters

A sentence is used as an example to demonstrate the keyword extraction algorithm, as shown in Figure 4.9. A sentence "The Hong Kong Council for Testing and Certification has been established to enhance the professional standards and recognition of Hong Kong's testing and certification services in the international arena." is extracted in the document (HKTDC, 2015).

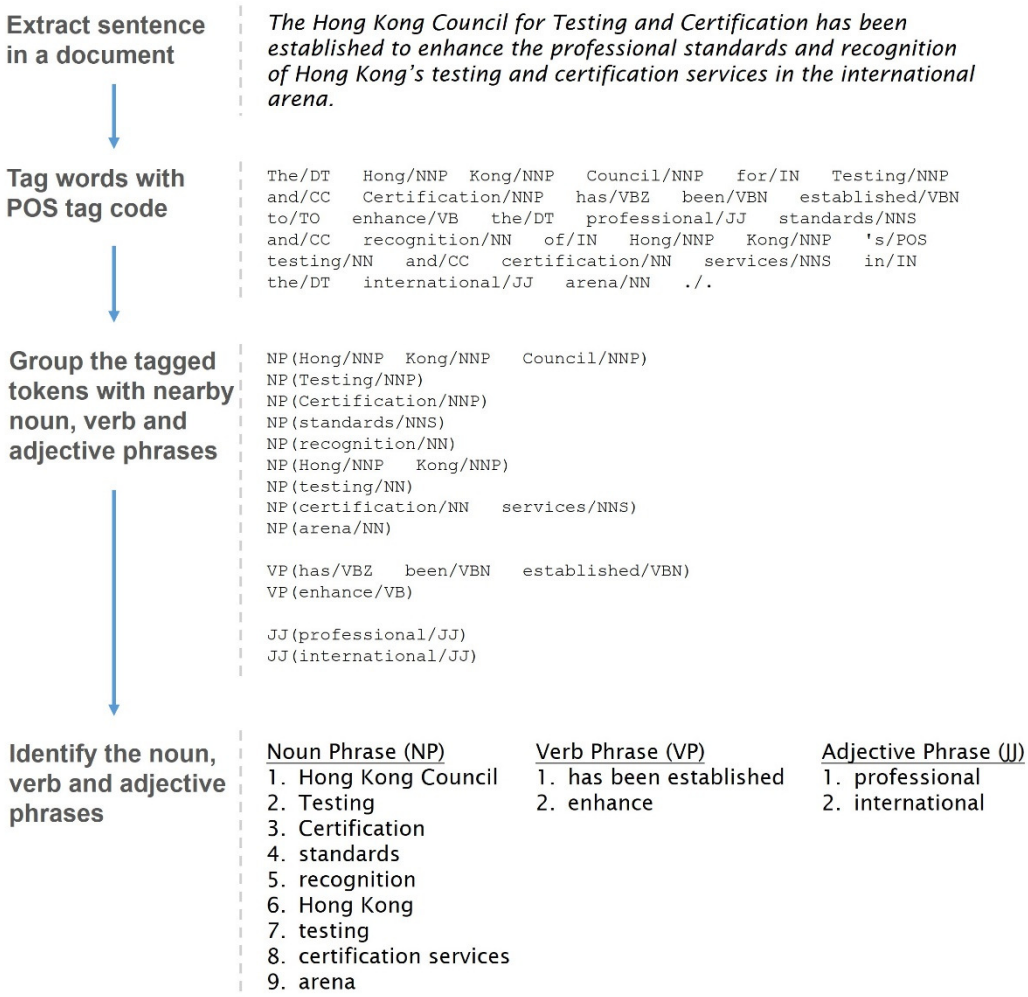


Figure 4.9 Demonstration of the keyword extraction algorithm

After tagging the words in the sentence, the sentence is analyzed based on grammatical structure. The noun phrases (NP), verb phrases (VP) and adjective phrases (JJ) in the sentence are identified. Noun phrases of the keywords that are found in the extracted sentence include "Hong Kong Council", "Testing", "Certification", "standards", "recognition", "Hong Kong", "testing", "certification services" and "arena". Verb phrases of the keywords include "has been established" and "enhance". Adjective phrases of the keywords include "professional" and "international".

4.3.2 Defining the extracted keywords

On completion of keyword extraction, a preliminary set of keywords is generated. However, these keywords are inadequate to describe the scenario elements of the possible future scenarios. For this purpose, keyword definition is a qualitative screening process conducted by human judgment that aims at defining the extracted keywords by consolidation and alignment processes based on their judgment, in order to develop keywords as controlled vocabulary and thesaurus in a document. There are two processes for conducting keyword definition; one is keyword consolidation and another is keyword alignment. Only noun phrases in the document are selected for keyword definition, and keywords that are too general and unnecessary are eliminated during the process.

4.3.2.1 Keyword consolidation

Keyword consolidation aims to combine the extracted keywords (i.e. noun phrases) with meaning in the document. An example of keyword consolidation is shown in Table 4.10. In this example, a sentence found in the document is “The Hong Kong Council for Testing and Certification has been established to enhance the professional standards and recognition of Hong Kong’s testing and certification services in the international arena.” (HKTDC, 2015). Noun phrases of the

keywords extracted in the sentence include “Hong Kong Council”, “Testing”, “Certification”, “standards”, “recognition”, “Hong Kong”, “testing”, “certification services” and “arena”.

Table 4.10 Example of keyword consolidation

Sentence in a document (HKTDC, 2015)	The Hong Kong Council for Testing and Certification has been established to enhance the professional standards and recognition of Hong Kong’s testing and certification services in the international arena.
Extract keywords (i.e. noun phrases)	The **Hong Kong Council** for **Testing** and **Certification** has been established to enhance the professional **standards** and **recognition** of **Hong Kong**’s **testing** and **certification services** in the international **arena**.
Eliminate unnecessary keywords	~~***The***~~ **Hong Kong Council** for **Testing** and **Certification** has been established to enhance ~~***the***~~ **professional standards** and **recognition** of **Hong Kong~~’s~~ testing** and **certification services** in ~~***the***~~ **international arena**.
Consolidated keywords	**Hong Kong Council + Testing + Certification** **→ “Hong Kong Council for Testing and Certification”** **testing + certification services** **→ “testing and certification services”**

After conducting keyword extraction, the keywords extracted from the sentence include “Hong Kong Council”, “Testing”, “Certification”, “established”, “enhance”, “professional standards”, “recognition”, “Hong Kong’s testing”, “certification services”, and “international arena”. After the expert completes the screening process, some extracted keywords are found based on the expert’s

judgement, which are required to be consolidates, such as “Hong Kong Council”, “Testing”, “Certification”, “Hong Kong’s testing” and “certification services”. On completion of keyword consolidation, two new keywords are defined, including “Hong Kong Council for Testing and Certification” and “Hong Kong’s testing and certification services”.

4.3.2.2 Keyword alignment

Keyword alignment aims to conduct alignment of the extracted keywords in a document to develop a list of controlled vocabulary. This process is required to be conducted after the keyword consolidation, since consolidated keywords can also be proceeded with for keyword alignment. Two examples of keyword alignment are shown in Table 4.11 and Figure 4.10, respectively.

Table 4.11 Example 1 of keyword alignment

Keyword 1	Keyword 2	Reason for alignment
industry	= Hong Kong's testing and certification industry	Same meaning
HKAS	= Hong Kong Accreditation Service	Abbreviation

For example 1, the keywords are found from the same document, such as “HKAS”, “Hong Kong Accreditation Service”, “Hong Kong's testing and certification industry”, and “industry”. After completing the screening process, these keywords

are required to be aligned based on the expert's judgment, since they have the same meaning as each other. As a result, "industry" has the same meaning as "Hong Kong's testing and certification industry", as well as "HKAS" being an abbreviation of the "Hong Kong Accreditation Service".

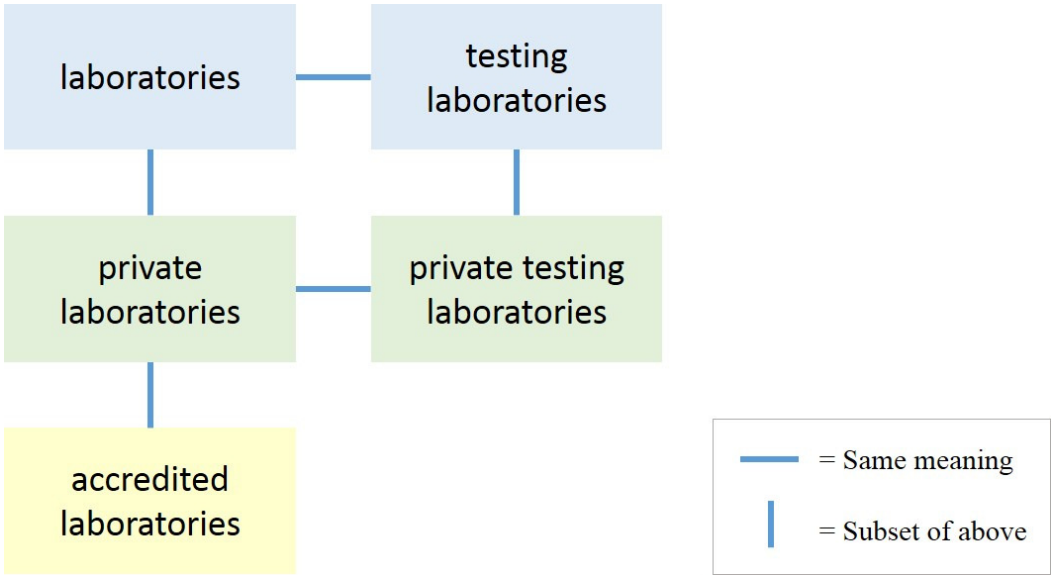


Figure 4.10 Example 2 of keyword alignment

For example 2, some keywords found in the same document are required to be aligned with the same meaning and subset based on the expert's judgment, such as "laboratories", "private laboratories", "testing laboratories", "accredited laboratories" and "private testing laboratories", as shown in Figure 4.10. In terms of the same meaning, the keyword "laboratories" is aligned with the keyword "testing laboratories", whereas, keyword "private laboratories" is aligned with the keyword "private testing laboratories". In terms of subset, the keyword "accredited

laboratories" is a subset of the keyword "private laboratories", and the keyword "private laboratories" is a subset of the keyword "laboratories".

Following keyword consolidation and alignment, all the extracted keywords are defined as controlled vocabulary and thesaurus based on their judgment. A keyword pool contains the defined keywords for each document, which is the expected outcome in this Phase and is prepared for identification of scenario elements.

4.4 Scenario Elements Identification

Identification of scenario elements is the fourth phase of the proposed scenario building method (i.e. Phase 4) which aims to identify the scenario elements by using the extracted keywords for building the possible future scenarios. In the proposed IDSB method, six scenario elements are required to be identified from the scenario-oriented information for building the possible future scenarios, which include "what", "when", "where", "who", "why" and "how". The semantic for identification of these scenario elements in this study is summarized in Table 4.12. Methods of identifying each scenario element are described in Sections 4.1, 4.2, 4.3 and 4.4, respectively. In the process of identifying scenario elements, an extracted sentence is the unit of analysis. Each scenario element is required to be identified in terms of "what", "when", "where", "who", "why" and "how" by users

which can be found in the extracted sentence. A snapshot of the user interface for scenario element identification is shown in Figure 4.11.

Table 4.12 Characteristics of six scenario elements

Scenario elements	**Description**	**Identification rules**
What	• Scenario, events, actions, or a combination of them	• Headings of documents • Extracted sentences • Noun phrases
When	• Past, Present, or Future • Specific date	• Verb phrases • Noun phrases
Where	• City, or Country • Specific Place	• List of Countries and Cities • Noun phrases
Who	• Person, party, organization or a combination of them • In the company/ outside the company	• Noun phrases
Why	• Information with justifications (i.e. White) • Emotions without justifications (i.e. Red) • Optimism (i.e. Yellow), • Discernment (i.e. Black) • Creativity (i.e. Green)	• Whole sentence (i.e. Whole) or phrase in the sentence (i.e. Part) • Noun phrases • Adjective phrases
How	• Possibilities, alternatives, suggestions, possible solutions, action plans or new ideas • Provider, Consumer	• SAO structure (i.e. noun phrase + verb phrase + noun phrase)

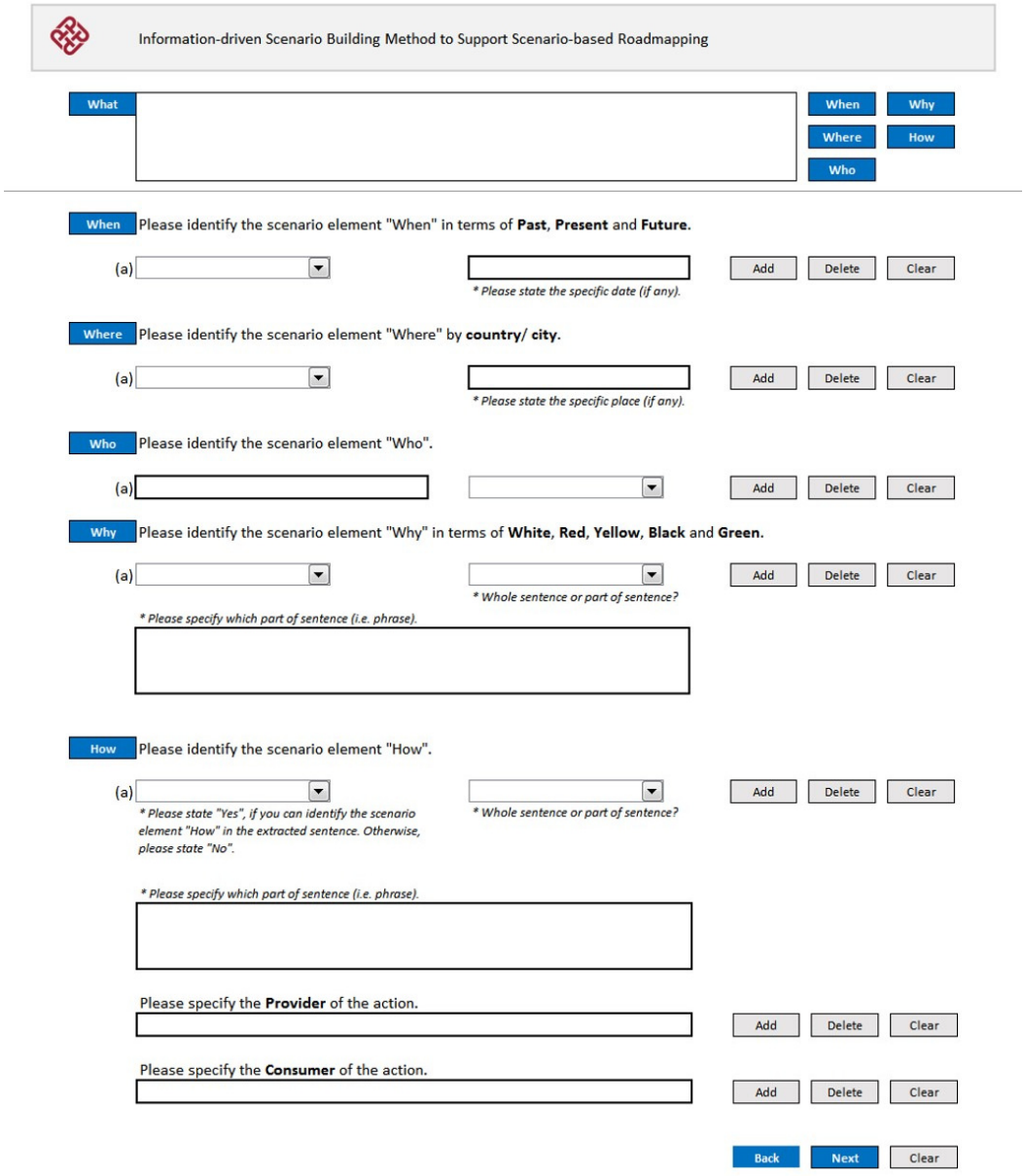


Figure 4.11 A snapshot of user interface for scenario element identification

Upon completion of the scenario element identification, all the collected information sets are treated as components of scenario narratives in this study. Scenario narratives for supporting the scenario building are constructed in the next step of "Scenario Narrative Generation".

An example of the extracted sentence “However, the local industry will have to compete with international brands, such as ITS, SGS and TUV, which have already set up operations in many parts of the mainland to provide service at a cost lower than the Hong Kong service providers.” is used to demonstrate how to identify the scenario elements “what”, “when”, “where”, “who”, “why” and “how” as described in the following sections, respectively.

4.4.1 Scenario element “what”

Scenario element “what” represents what issues are mentioned that are related to the possible future scenario, which can be described in terms of scenario, event, action or a combination of them, etc. In general, the scenario element “what” can be identified in two ways (i.e. micro and macro levels). Noun phrases in the extracted sentence of the document can be used to identify the scenario element “what” at micro level. On the other hand, all the headings in the document can be used to describe the scenario element “what” at macro level, and include the title of the document, titles and subtitles of chapters and sections, and captions of figures and tables. As a result, the hierarchical tree can be used for the identification of the scenario element “what” at macro level that is mentioned in Section 4.2.2.

4.4.2 Scenario elements "who", "where" and "when"

Scenario element "who" represents stakeholders who get involved in the issues (i.e. scenario, event and action), which can be a person, party, organization or a combination of them. Scenario element "where" represents the venue for happening scenarios, events and actions, which can be a city, country, and specific place. In general, noun phrases in the extracted sentence can be used to identify both the scenario elements "who" and "where". Scenario element "when" represents the time of occurrence, such as date and time span of the scenario, events, and actions, which can be described in terms of past, present, and future. The "past" represents the past issues that have already happened (i.e. an event/action that happened in the past). The "present" represents the current issues that are happening, or are continuing (i.e. events/actions that happen in the present). The "future" represents the future issues that have yet to happen (i.e. events/actions that will happen in the future). In general, the scenario element "when" can be identified in two ways. Tenses of verb phrases in the sentences can be used to identify the scenario element "when" in terms of past, present and future issues. On the other hand, the specific date of the past, present and future issues can also be identified by noun phrases.

A snapshot of user interface for scenario element identification in terms of "when", "where" and "who" is illustrated in Figure 4.12.

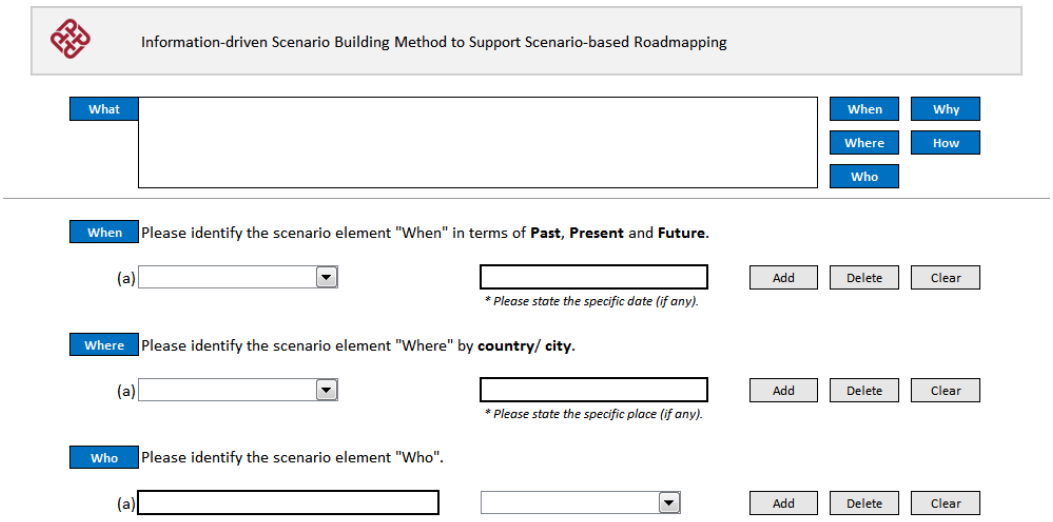


Figure 4.12 A snapshot of user interface for identification of scenario elements "when", "where" and "who"

An example of the identification of scenario elements "when", "where" and "who" is illustrated in Figure 4.13. "Future" and "Past" are identified as scenario elements "when" using a list containing choices of "Past", "Present" and "Future", whereas "Hong Kong" and "China" are identified as scenario elements "where" using a list of countries and other areas. A specific place is also identified from the extracted sentence. A total of six scenario elements "who" are identified in the extracted sentence, such as "local industry", "international brands", "ITS", "SGS", "TUV" and "Hong Kong service providers".

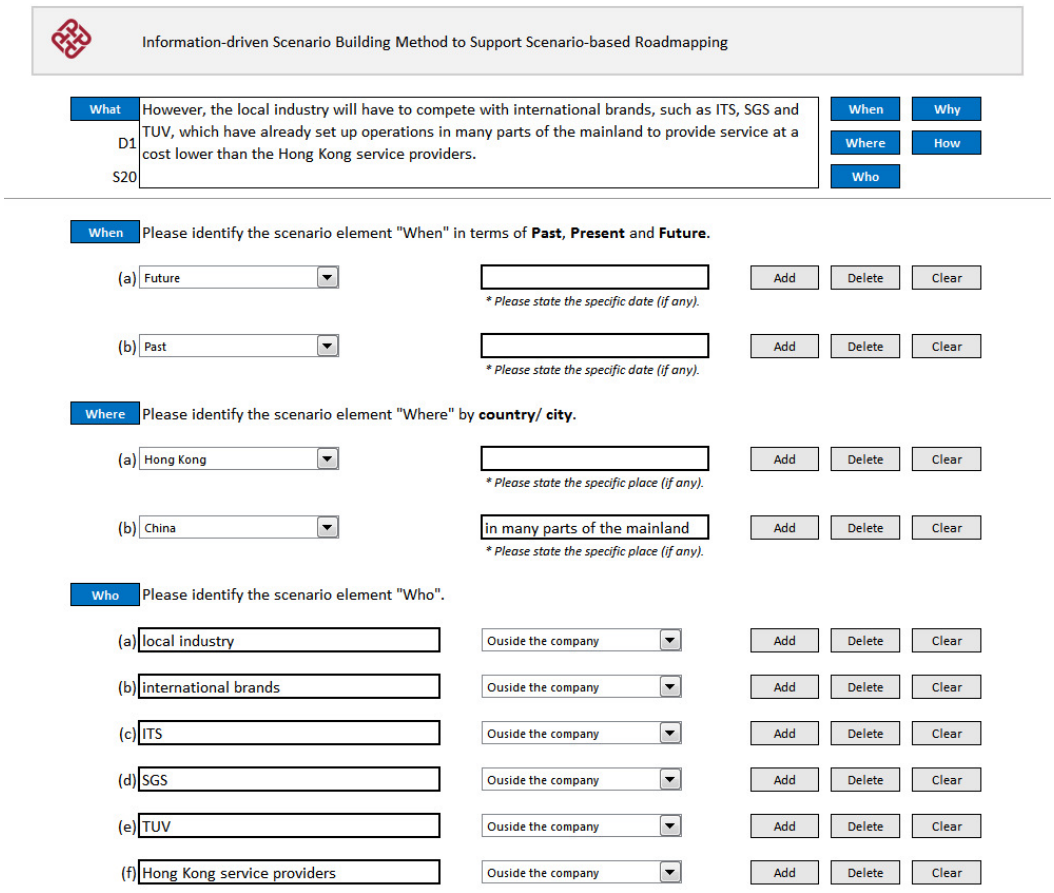


Figure 4.13 Example for identification of scenario elements "when", "where" and "who"

4.4.3 Scenario element "why"

Scenario element "why" represents reasons with justification, intention or motive why the issues (i.e. scenario, event or action) may or may not occur or work. There are five types of scenario element "why" that can be identified, such as information (i.e. hard facts), emotion (i.e. future forecast), optimism (i.e. enablers), discernment (i.e. barriers) and creativity (i.e. future forecast), based on the principle of six thinking hats (i.e. white, red, yellow and black thinking hats)

mentioned in Chapter 3. A snapshot of user interface for identification of scenario element "why" is shown in Figure 4.14.

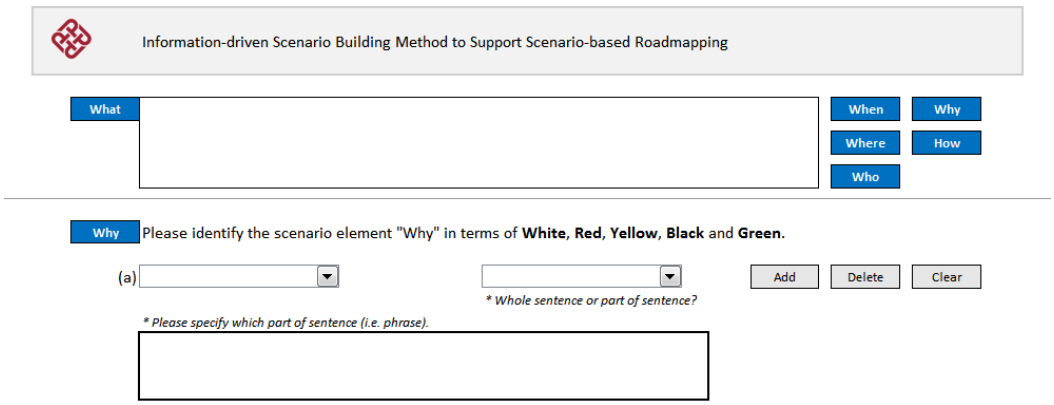


Figure 4.14 A snapshot of user interface for identification of scenario elements "why"

By using white and red thinking hats, information is used to provide the information with justifications why the scenario may or may not occur or work, which can be data, facts, information known and information needed. On the other hand, emotion is used to provide the intuitive information without justification why the scenario may or may not occur or work, which can be opinion and future forecast. In general, tenses of verb phrases in the sentences can be used to identify these two types of scenario element "why". According to the results of the scenario element "when", past and present issues can be identified as "information" type of the scenario element "why", since the past issues have already happened and present issues are happening, or are continuous, such as hard facts. Future issues

can be identified as “emotion” type of the scenario element “why”, since the future issues will happen later, such as future forecast.

By using yellow and black thinking hats, information on the positive side can be identified by type of optimism, such as i.e. positive impacts, enablers, benefits, values, or opportunity. Information on the negative side can be identified by type of discernment, such as negative impacts, barriers, difficulties, dangers, potential problems, or risks. In general, both types of scenario element “why” can be identified by noun phrases and adjective phrases.

In the process of scenario element “why” identification, whole or part (i.e. phrase) of the extracted sentence can be identified in terms of which color of the thinking hats. An example of the scenario element “why” identification is illustrated in Figure 4.15. The whole sentence is identified as scenario element “why” in black, since it describes a challenging issue that will happen in the scenario. The first half of the extracted sentence “the local industry will have to compete with international brands, such as ITS, SGS and TUV,” is identified as scenario element “why” in green, since it describes the future forecast that will happen in the scenario. The last part of the extracted sentence is identified as scenario element “why” in white, since it describes the hard facts in the scenario.

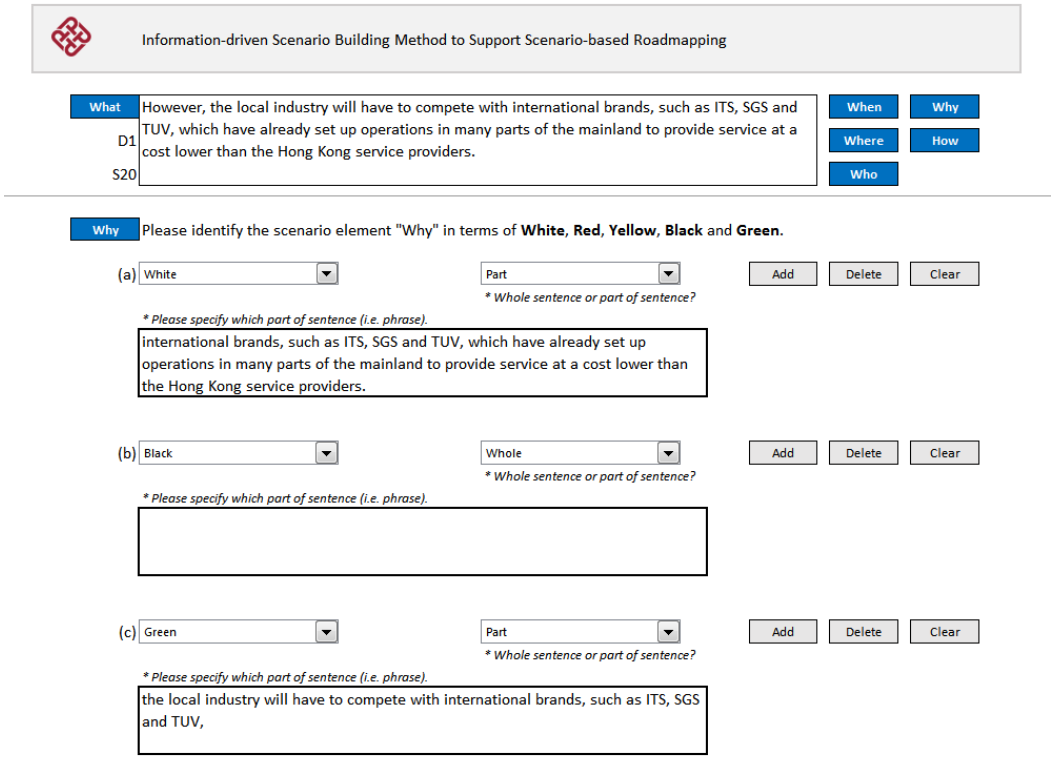


Figure 4.155 Example for identification of scenario elements "why"

4.4.4 Scenario element "how"

Scenario element "how" represents the issues (i.e. actions) regarding how to deal with future scenarios, which can be described in terms of possibilities, alternatives, suggestions, possible solutions, action plans or new ideas. In general, the sentence is composed of a subject, a verb and an object, which can be identified as the scenario element "how". By using subject-action-object (SAO) structure, verb and noun phrases in the extracted sentence can be used to identify the scenario element "how". Moreover, the scenario element "who" can be used to identify the subject and object, that are provider and consumer. "Provider" represents a person, party,

organization or a combination of them involved in the scenario, acting as a subject to perform the scenario, event, or action. “Consumer” represents a person, party, organization or a combination of them involved in the scenario, acting as an object to be affected by the scenario, event or action. A snapshot of user interface for identification of scenario element “how” is shown in Figure 4.16.

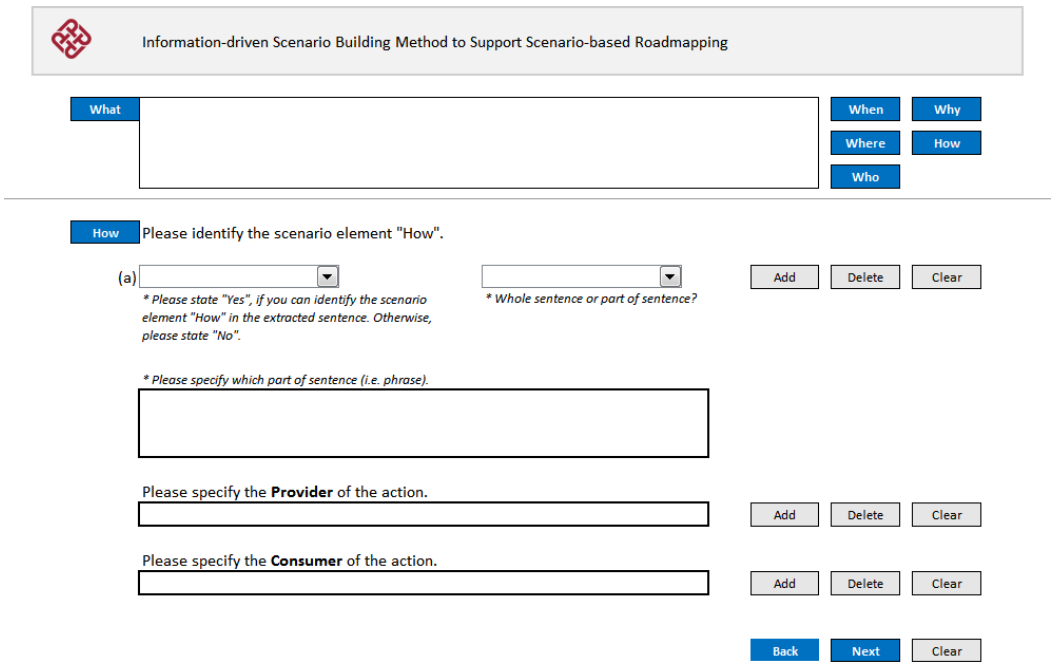


Figure 4.16 A snapshot of user interface for identification of scenario element “how”

An example of the scenario element “how” identification is illustrated in Figure 4.17. Two actions are identified as scenario elements “how” in the extracted sentence. The provider and consumer of the action “the local industry will have to compete with international brands, such as ITS, SGS and TUV,” are “local industry” and “international brands, such as ITS, SGS and TUV”. The provider of

the action "which have already set up operations in many parts of the mainland to provide service at a cost lower than the Hong Kong service providers." is "international brands, such as ITS, SGS and TUV" and no consumer can be identified in this action.

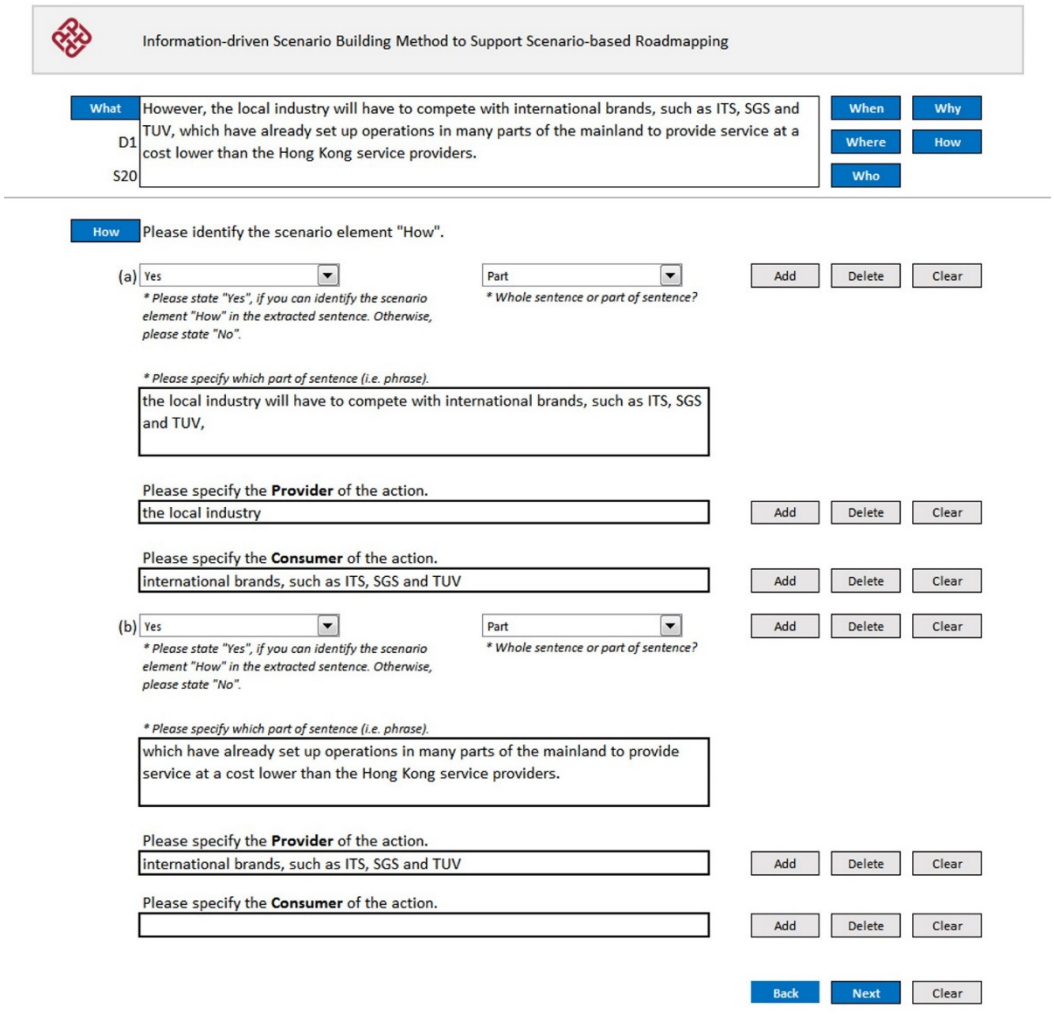
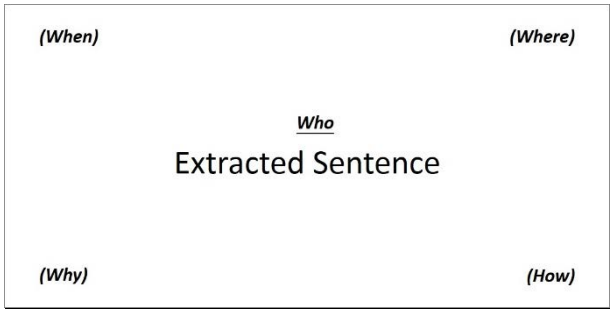


Figure 4.17 Example for identification of scenario element "how"

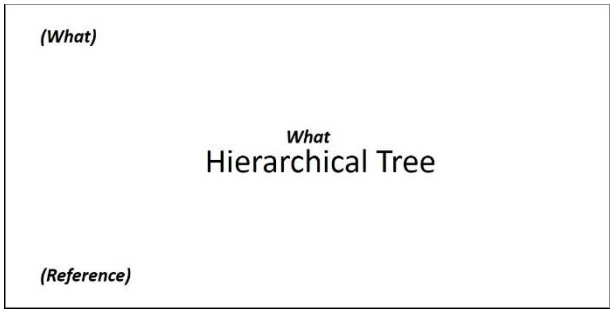
4.5 Scenario Narrative Generation

Generation of scenario narratives is the firth phase of the proposed scenario building method (i.e. Phase 5) which aims to generate the narratives of the possible

future scenarios, in order to facilitating the development process of scenario building. For establishment of well-structured scenario-oriented information, a method for generation of scenario narrative is designed and developed. Each extracted sentence represents a scenario narrative. A tag contains a scenario narrative that is presented in terms of scenario elements "what", "when", "who", "where", "why", and "how". Layout and format of the tag are shown in Figure 4.18. Front and back sides of tag are illustrated in Figure 4.18 (a) and (b), respectively.



(a)



(b)

Figure 4.18 Format of tag (a) front and (b) back sides

In the front side of the tag, the scenario narrative is placed in the middle, whereas scenario elements "when" and "where" are shown at the top left corner and top

right corner, and scenario elements "why" and "how" are shown at the bottom left concern and the bottom right concern. On the back side of the tag, the components of scenario element "what" are placed at the top, middle and bottom that include the position of the scenario narrative located in the document (i.e. document code number, section numbering, sentence code number), information captured from the hierarchical tree (i.e. document name, headings of the chapter and section) and references of the document. Moreover, the characteristics (i.e. formats and locations) of scenario elements shown on the tag are described in Table 4.13.

Table 4.13 Characteristics of six scenario elements

Scenario elements	Format	Location
What	• (Document code number, Section numbering, Sentence code number)	• Top of the back side
	• Headings referring to document code number and section numbering	• Middle of the back side
	• (Author, Publication year)	• Bottom of the back side
When	• (Past/Present/Future, Specific date)	• Top left corner of the front side
Where	• (City/Country, Specific place)	• Top right corner of the front side
Who	• Person/party/organization/a combination of them	• Words highlighted in the extracted sentence
Why	• Color of thinking hats (i.e. White/ Red/Yellow/Black/Green)	• Bottom left corner of the front side
How	• Event/action	• Bottom right corner of the front side

Three extracted sentences are used to demonstrate how to generate the scenario narratives tags by using the scenario elements that included “Hong Kong's testing and certification industry has grown substantially since the 1980s.” (i.e. Example 1), “The Hong Kong Accreditation Service (HKAS) under the Innovation and Technology Commission (ITC) provides accreditation service for laboratories, certification bodies and inspection bodies through the Hong Kong Laboratory Accreditation Scheme (HOKLAS), Hong Kong Certification Body Accreditation Scheme (HKCAS) and Hong Kong Inspection Body Accreditation Scheme (HKIAS).” (i.e. Example 2) and “However, the local industry will have to compete with international brands, such as ITS, SGS and TUV, which have already set up operations in many parts of the mainland to provide service at a cost lower than the Hong Kong service providers.” (i.e. Example 3).

According to the layout and formats mentioned above, three scenario narrative tags are generated in terms of scenario elements “what”, “when”, “where”, “who”, “why”, and “how”, as shown in Figure 4.19 (a) and (b), Figure 4.20 (a) and (b) as well as Figure 4.21 (a) and (b), respectively. Moreover, descriptions of each scenario narratives (i.e. examples 1, 2 and 3) are summarized in terms of six scenario elements in Table 4.14.

(Present, 1980) ***(Hong Kong)***

Hong Kong's testing and certification industry has grown substantially since the 1980s.

(White) ***(Event)***

(a)

(D1, 0, S1)

D1 = Testing and Certification Industry in Hong Kong
0 = Testing and Certification Industry in Hong Kong

(Hong Kong Trade Development Council (HKTDC), 2015)

(b)

Figure 4.19 Example 1 of scenario narrative tag

(Present) ***(Hong Kong)***

The Hong Kong Accreditation Service (HKAS) under the Innovation and Technology Commission (ITC) *P1* provides accreditation service for laboratories *C1*, certification bodies *C2* and inspection bodies *C3* through the Hong Kong Laboratory Accreditation Scheme (HOKLAS), Hong Kong Certification Body Accreditation Scheme (HKCAS) and Hong Kong Inspection Body Accreditation Scheme (HKIAS).

(White) ***(Action, P1, C1, C2, C3)***

(a)

(D1, 0.3, S14)

D1 = Testing and Certification Industry in Hong Kong
0.3 = Services Providers

(Hong Kong Trade Development Council (HKTDC), 2015)

(b)

Figure 4.20 Example 2 of scenario narrative tag

[1](Future), [2](Past) ***[1](Hong Kong, China), [2](China)***

However, [1](the local industry^{P1} will have to compete with international brands^{C1,P2}, such as ITS^{C1,P2}, SGS^{C1,P2} and TUV^{C1,P2},) [2](which have already set up operations in many parts of the mainland to provide service at a cost lower than the Hong Kong service providers).

[1](Action 1, P1, C1)
[2](Action 2, P2)

(Black); [1](Green), [2](White)

(a)

(D1, 0.4.3, S20)

D1 = Testing and Certification Industry in Hong Kong
0.4 = Industry Development and Market Outlook
0.4.3 = Market Opportunities and Recent Developments

(Hong Kong Trade Development Council (HKTDC), 2015)

(b)

Figure 4.21 Example 3 of scenario narrative tag

Table 4.14 Six scenario elements of Examples 1, 2 and 3

Scenario elements	**Examples**
What	• Example 1: *(D1, 0, S1)* Example 2: *(D1, 0.3, S14)* • Example 3: *(D1, 0.4.3, S20)*
	• Example 1: D1 = Testing and Certification Industry in Hong Kong 0 = Testing and Certification Industry in Hong Kong • Example 2: D1 = Testing and Certification Industry in Hong Kong 0.3 = Services Providers • Example 3: D1 = Testing and Certification Industry in Hong Kong 0.4 = Industry Development and Market Outlook 0.4.3 = Market Opportunities and Recent Developments
	• Examples 1, 2, and 3: *(Hong Kong Trade Development Council (HKTDC), 2015)*
When	• Example 1: *(Present, 1980)* • Example 2: *(Present)* • Example 3: *[1](Future), [2](Past)*
Where	• Examples 1 and 2: *(Hong Kong)* • Example 3: *[1](Hong Kong, China), [2](China)*
Who	Example 1: testing and certification industry Example 2: Innovation and Technology Commission (ITC), laboratories, certification bodies, inspection bodies • Example 3: local industry, international brands, ITS, SGS and TUV, Hong Kong service providers
Why	• Examples 1 and 2: *(White)* • Example 3: *(Black); [1](Green), [2](White)*
How	• Example 1: *(Event)* • Example 2: *(Action, P1, C1, C2, C3)* • Example 3: *[1](Action 1, P1, C1), [2](Action 2, P2)*

Scenario narrative tags can be used in the following cases, such as

- The narrative can be used individually as scenario-oriented data and information for the participants to generate possible future scenario; and
- The narrative can be used directly to generate information-driven scenario-based roadmap. An example of information-driven scenario-based roadmap is shown in Figure 4.22.

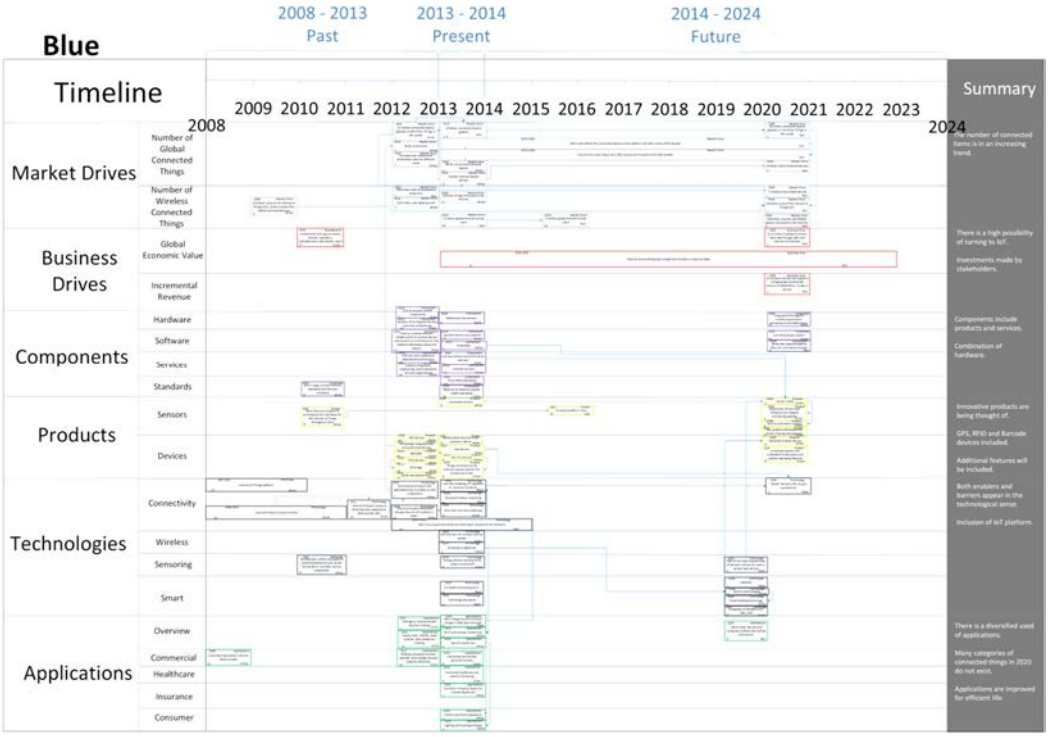


Figure 4.22 Example of information-driven scenario-based roadmap

In this example, total of 100 scenario narratives are used to generate the roadmap that means total 100 tags are placed on the roadmap. If there are totally 100 tags, with 30 white tags, 30 red tags, 20 yellow tags, 5 black tags and 15 green tags. As

a result, the utilization rate of scenario narrative in terms of thinking hats is given as follows:

White: $\frac{30}{100} \times 100\% = 30\%$

Red: $\frac{30}{100} \times 100\% = 30\%$

Yellow: $\frac{20}{100} \times 100\% = 20\%$

Black: $\frac{5}{100} \times 100\% = 5\%$

Green: $\frac{15}{100} \times 100\% = 15\%$

Moreover, a schematic diagram for utilization rate of scenario narrative in terms of thinking hats is shown in Figure 4.23.

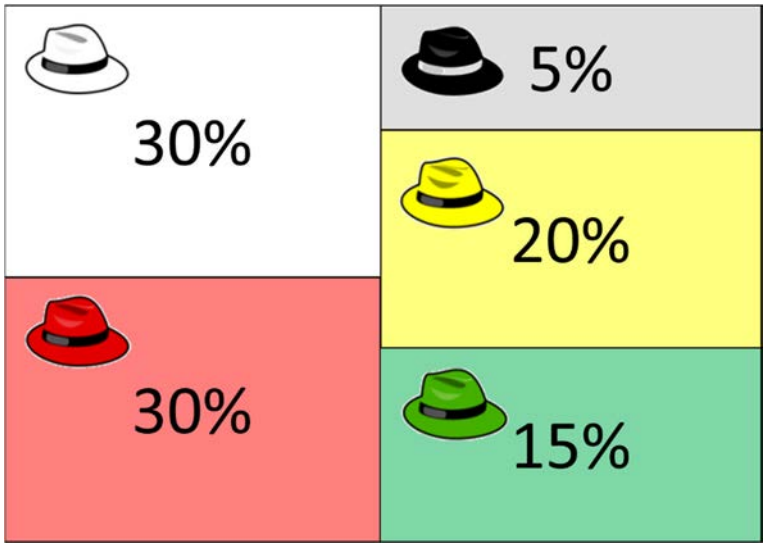


Figure 4.23 Schematic diagram for utilization rate of scenario narrative in terms of thinking hats

4.6 Summary

This chapter presents an information-driven scenario building (IDSB) method as a useful tool to provide scenario-oriented data and information for supporting the implementation of the multi-perspective scenario-based roadmapping (MSBRM) method. A process for the implementation of the proposed IDSB method was presented to identify scenario elements and generate scenario narrative tags for building possible future scenarios. The proposed method provides companies a practical scenario building process to collect data and information (i.e. Phase 1), construct metadata of documents (i.e. Phase 2), extract scenario-oriented keywords (i.e. Phase 3), identify the scenario elements (i.e. Phase 4), and generate the scenario narrative (i.e. Phase 5) for generating possible future scenarios qualitatively and systematically. For performance evaluation of the proposed MSBRM and IDSB methods, a series of experiment investigation was conducted and are presented in Chapter 5.

Chapter 5

Experimental Validation and Performance Evaluation

The multi-perspective scenario-based roadmapping (MSBRM) method presented in Chapter 3 was designed and developed for the organizations to generate possible future scenarios with positive and negative impacts, assess and select plausible future scenarios by a series of assessment and selection criteria, as well as embedded the scenario(s) into the roadmap(s). Moreover, the methodology of the information-driven scenario building (IDSB) method was described in Chapter 4, which was designed and developed for the identification of scenario elements to facilitate the implementation of the MSBRM method.

Before the implementation of the MSBRM and IDSB methods in the selected reference sites, a series of experiments was conducted to evaluate the performance of the proposed methods. This chapter presents two series of experimental investigation (i.e. experiment A and experiment B) for the evaluation of the performance of the MSBRM and IDSB methods, respectively. The corresponding experimental results and user feedbacks are used for the evaluation of the proposed methods.

5.1 Experiment A - Performance Evaluation of the MSBRM Method

In Experiment A, a series of experiments were conducted for a comparative study between the traditional roadmapping method and the MSBRM method. It aims to validate the performance of the MSBRM method and reveal the limitations and advantages of both methods. Since the purpose for the development of the MSBRM method is to overcome the limitations of conducting roadmapping by the traditional approach, it is required to demonstrate how effective the MSBRM method is compared with the traditional roadmapping method based on the "T-Plan: Fast Start Technology Roadmapping" developed by University of Cambridge (Phaal et al., 2001b). For the traditional roadmapping approach, T-Plan was selected to conduct the comparative study in this experiment. Justifications for selecting T-Plan for comparative study in this experiment are as follows: -

(a) T-Plan is one of the well-known market-available roadmapping methods to identify alternative technology "roads" for meeting certain performance objectives. It is widely used by the public and private organizations, such as government, academic and research institutions and many different industry sectors.

(b) The deliverables of both roadmapping methods are the same that is an

operational action plan, so both roadmapping approaches are applicable to use for comparative study.

In the present study, Experiment A was conducted in two parts so as to implement the traditional roadmapping approach (i.e. Experiment A1) and the MSBRM method (i.e. Experiment A2), respectively. Moreover, a questionnaire was purposely designed for collecting the feedback from the participants, which is shown in Figure 5.1.

Feedback Form (1)

By Likert-type scale, you are offered a choice of five responses (i.e. 5 = strongly agree, 4 = somewhat agree, 3 = neutral, 2 = somewhat disagree, 1 = strongly disagree) to express how they agree or disagree with a particular statement.

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

Figure 5.1 A feedback form used in Experiment A

5.1.1 Experimental procedures

A generic procedure for the performance evaluation experiment was designed purposely, as shown in Figure 5.2.

Figure 5.2 Generic procedure of Experiment A

At the beginning of the workshop, an introduction to the experiment and the roadmapping methods was presented to all the participants to ensure that they had a common understanding of the purpose and procedures of the experiments and roadmapping methods. Before the implementation of the roadmapping, the participants were divided into two groups and required to read the guidelines of the roadmapping activity. In the process of roadmapping, two groups were assigned a topic to generate a roadmap according to the guidelines. A package of experimental materials was provided to each group, including a roadmap framework (i.e. A0-size flip charts), pens, pencils, sticky notes and draft papers.

After completing the roadmapping, the results were obtained and a discussion was conducted for disseminating the results of the roadmap as well as sharing the experience of the roadmapping, in order to collect their feedback on the roadmapping performance qualitatively. Last but not least, each participant was required to complete a questionnaire to evaluate the roadmapping performance results quantitatively.

5.1.2 Performance evaluation workshop

A two-day workshop was conducted for the evaluation of the performance of the two roadmapping methods, respectively. A total of five participants were invited to attend the workshop. For comparative study, the participants participated in Experiment A1 on the first day of the workshop (i.e. workshop A1), and Experiment A2 was conducted on the second day of the workshop (i.e. workshop A2). Snapshots of the workshop are shown in Figure 5.3.

Figure 5.3 Snapshots of the workshop in Experiment A

In workshop A1, two roadmaps were generated by two groups of participants using the traditional T-Plan approach, as shown in Figure 5.4 and Figure 5.5. In workshop A2, eight possible future scenarios (i.e. four positive and four negative), two preliminary roadmaps and one organizational roadmap were collected, as shown in Figure 5.6 (a), (b), (c) and (d), Figure 5.7 (a) and (b) as well as Figure 5.8, respectively.

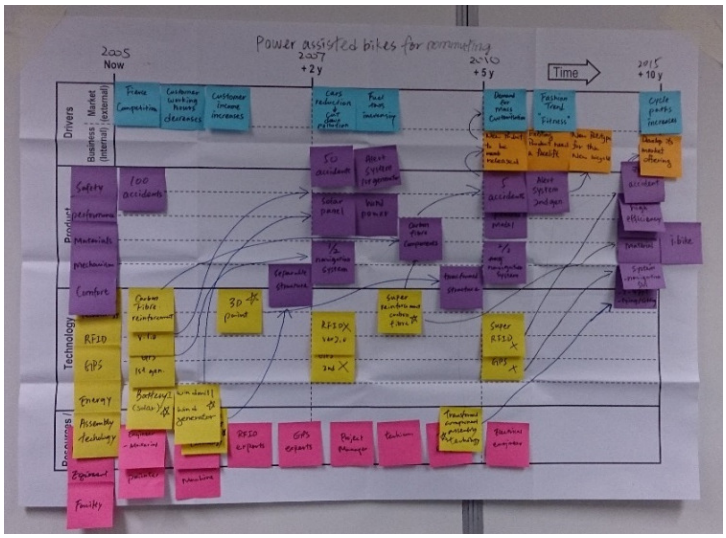


Figure 5.4 Snapshots of the roadmaps generated by group 1 in workshop A1

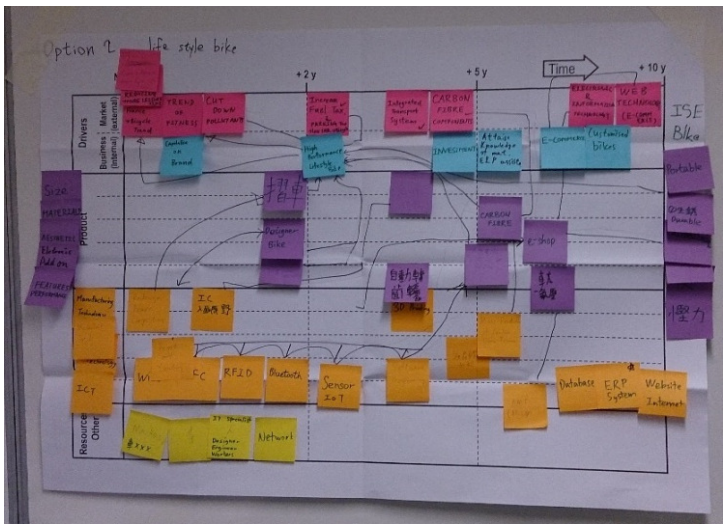
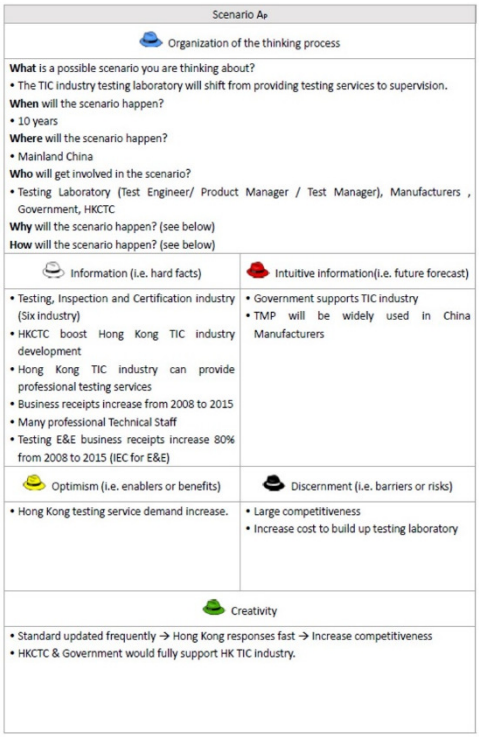
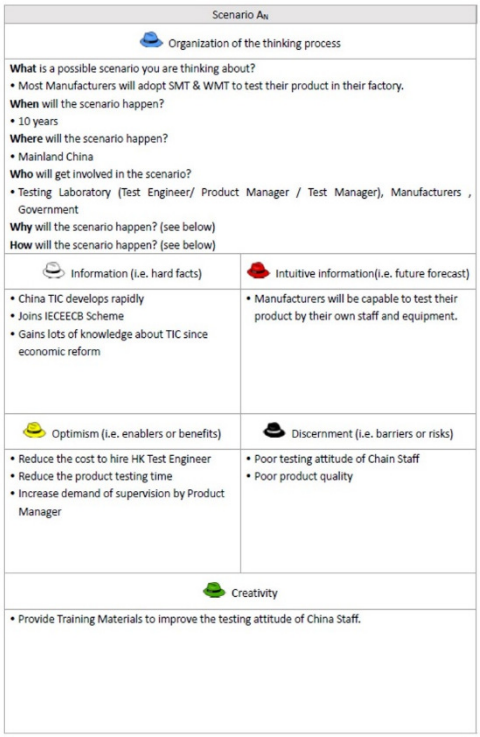
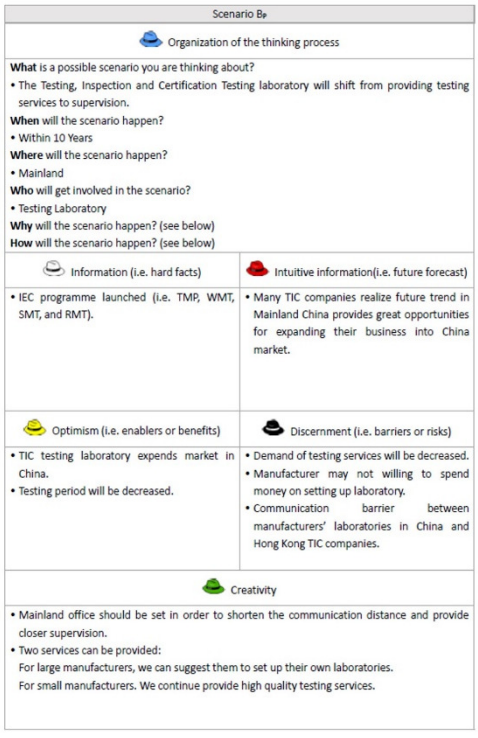


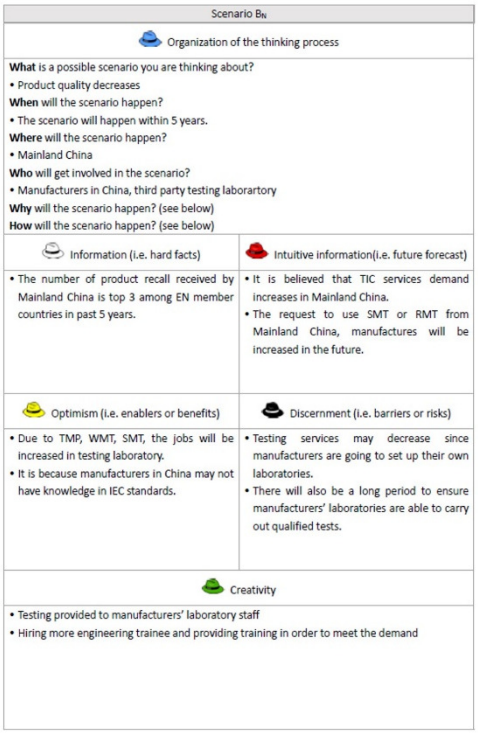
Figure 5.5 Snapshots of the roadmaps generated by group 2 in workshop A1


Scenario A_P
Organization of the thinking process
What is a possible scenario you are thinking about?
• The TIC industry testing laboratory will shift from providing testing services to supervision.
When will the scenario happen?
• 10 years
Where will the scenario happen?
• Mainland China
Who will get involved in the scenario?
• Testing Laboratory (Test Engineer/ Product Manager / Test Manager), Manufacturers , Government, HKCTC
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)
• Testing, Inspection and Certification industry (Six industry)
• HKCTC boost Hong Kong TIC industry development
• Hong Kong TIC industry can provide professional testing services
• Business receipts increase from 2008 to 2015
• Many professional Technical Staff
• Testing E&E business receipts increase 80% from 2008 to 2015 (IEC for E&E)
• Government supports TIC industry
• TMP will be widely used in China Manufacturers
Optimism (i.e. enablers or benefits)
Discernment (i.e. barriers or risks)
• Hong Kong testing service demand increase.
• Large competitiveness
• Increase cost to build up testing laboratory
Creativity
• Standard updated frequently → Hong Kong responses fast → Increase competitiveness
• HKCTC & Government would fully support HK TIC industry.

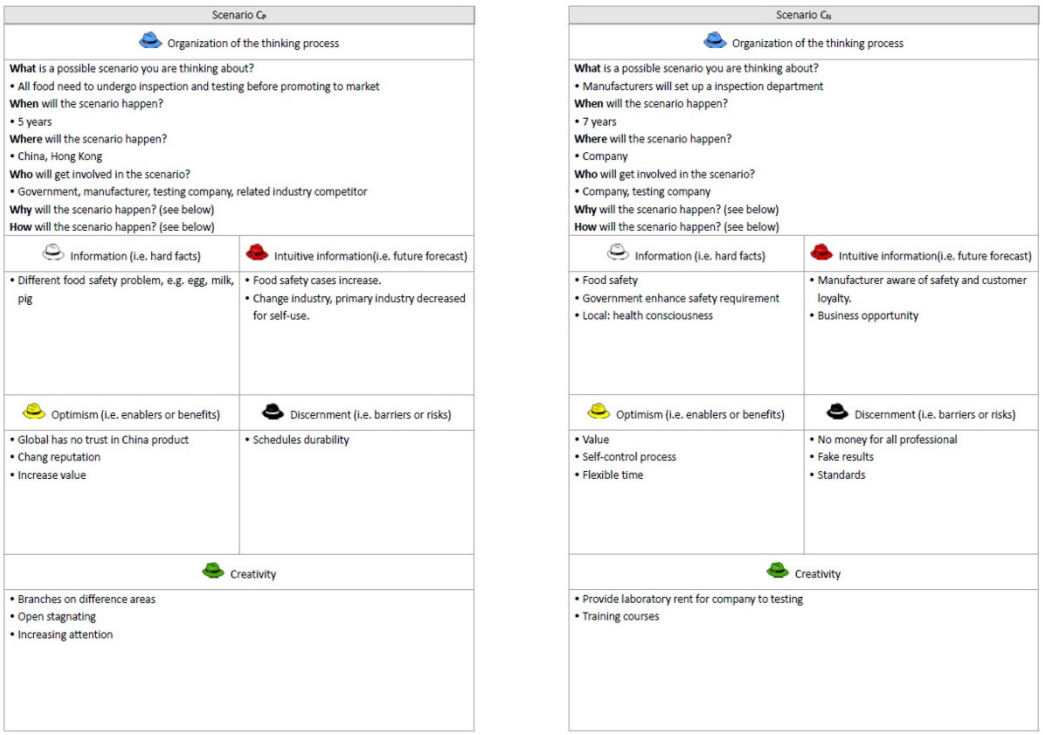

Scenario A_N
Organization of the thinking process
What is a possible scenario you are thinking about?
• Most Manufacturers will adopt SMT & WMT to test their product in their factory.
When will the scenario happen?
• 10 years
Where will the scenario happen?
• Mainland China
Who will get involved in the scenario?
• Testing Laboratory (Test Engineer/ Product Manager / Test Manager), Manufacturers , Government
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)
• China TIC develops rapidly
• Joins IECEECB Scheme
• Gains lots of knowledge about TIC since economic reform
• Manufacturers will be capable to test their product by their own staff and equipment.
Optimism (i.e. enablers or benefits)
Discernment (i.e. barriers or risks)
• Reduce the cost to hire HK Test Engineer
• Reduce the product testing time
• Increase demand of supervision by Product Manager
• Poor testing attitude of Chain Staff
• Poor product quality
Creativity
• Provide Training Materials to improve the testing attitude of China Staff.

(a)


Scenario B_P
Organization of the thinking process
What is a possible scenario you are thinking about?
• The Testing, Inspection and Certification Testing laboratory will shift from providing testing services to supervision.
When will the scenario happen?
• Within 10 Years
Where will the scenario happen?
• Mainland
Who will get involved in the scenario?
• Testing 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)
• IEC programme launched (i.e. TMP, WMT, SMT, and RMT).
• Many TIC companies realize future trend in Mainland China provides great opportunities for expanding their business into China market.
Optimism (i.e. enablers or benefits)
Discernment (i.e. barriers or risks)
• TIC testing laboratory expends market in China.
• Testing period will be decreased.
• Demand of testing services will be decreased.
• Manufacturer may not willing to spend money on setting up laboratory.
• Communication barrier between manufacturers' laboratories in China and Hong Kong TIC companies.
Creativity
• Mainland office should be set in order to shorten the communication distance and provide closer supervision.
• Two services can be provided:
For large manufacturers, we can suggest them to set up their own laboratories.
For small manufacturers. We continue provide high quality testing services.


Scenario B_N
Organization of the thinking process
What is a possible scenario you are thinking about?
• Product quality decreases
When will the scenario happen?
• The scenario will happen within 5 years.
Where will the scenario happen?
• Mainland China
Who will get involved in the scenario?
• Manufacturers in China, third party testing laborartory
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)
• The number of product recall received by Mainland China is top 3 among EN member countries in past 5 years.
• It is believed that TIC services demand increases in Mainland China.
• The request to use SMT or RMT from Mainland China, manufactures will be increased in the future.
Optimism (i.e. enablers or benefits)
Discernment (i.e. barriers or risks)
• Due to TMP, WMT, SMT, the jobs will be increased in testing laboratory.
• It is because manufacturers in China may not have knowledge in IEC standards.
• Testing services may decrease since manufacturers are going to set up their own laboratories.
• There will also be a long period to ensure manufacturers' laboratories are able to carry out qualified tests.
Creativity
• Testing provided to manufacturers' laboratory staff
• Hiring more engineering trainee and providing training in order to meet the demand

(b)



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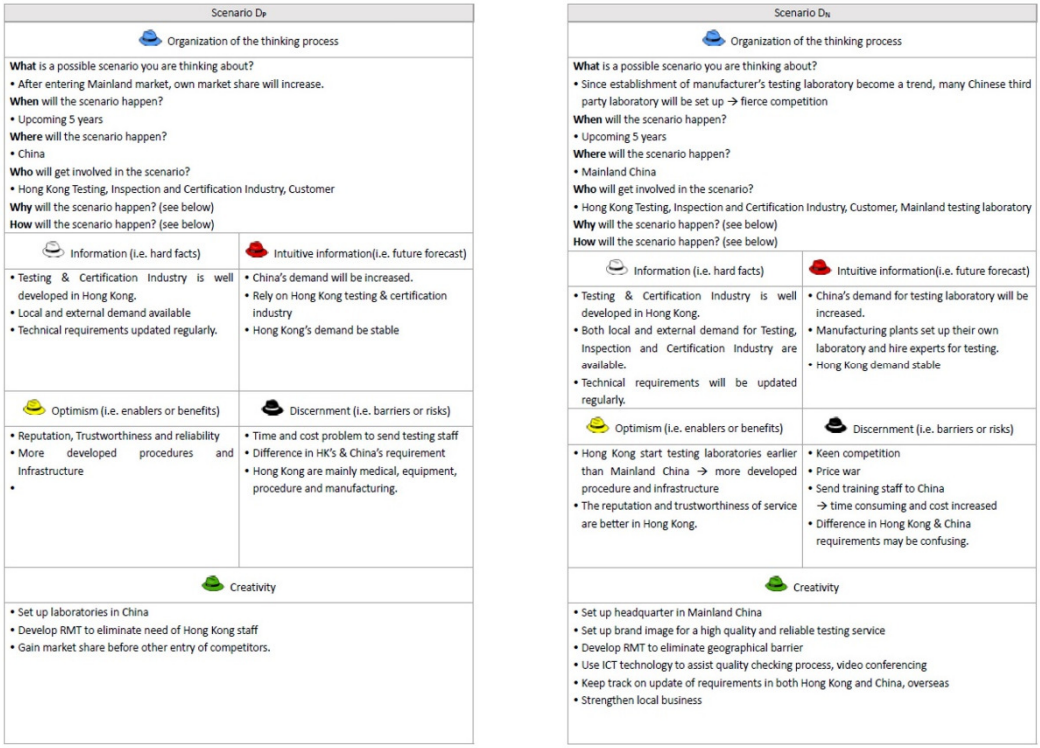
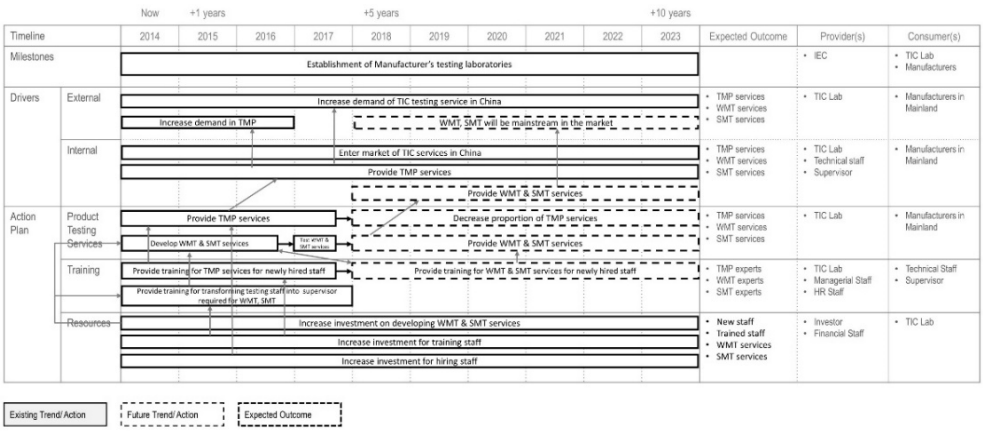
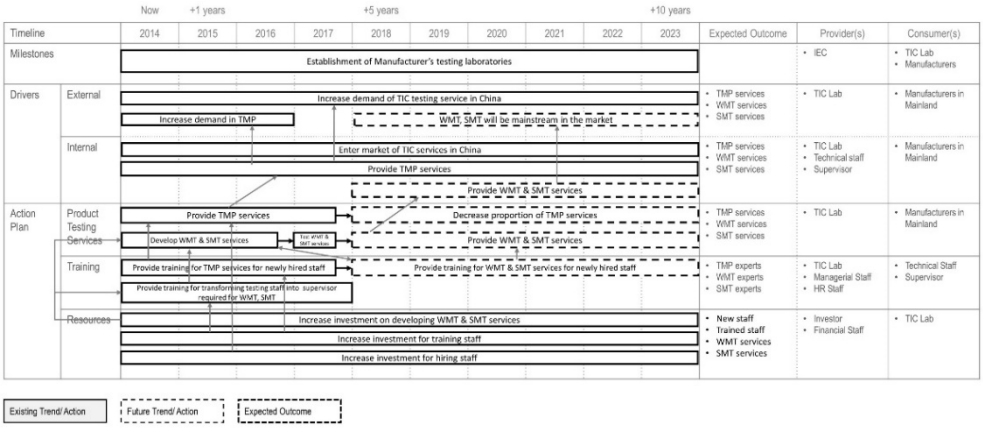


(d)

Figure 5.6 Snapshots of eight scenarios generated in workshop A2



(a)



(b)

Figure 5.7 Two preliminary scenario-based roadmaps generated in workshop A2

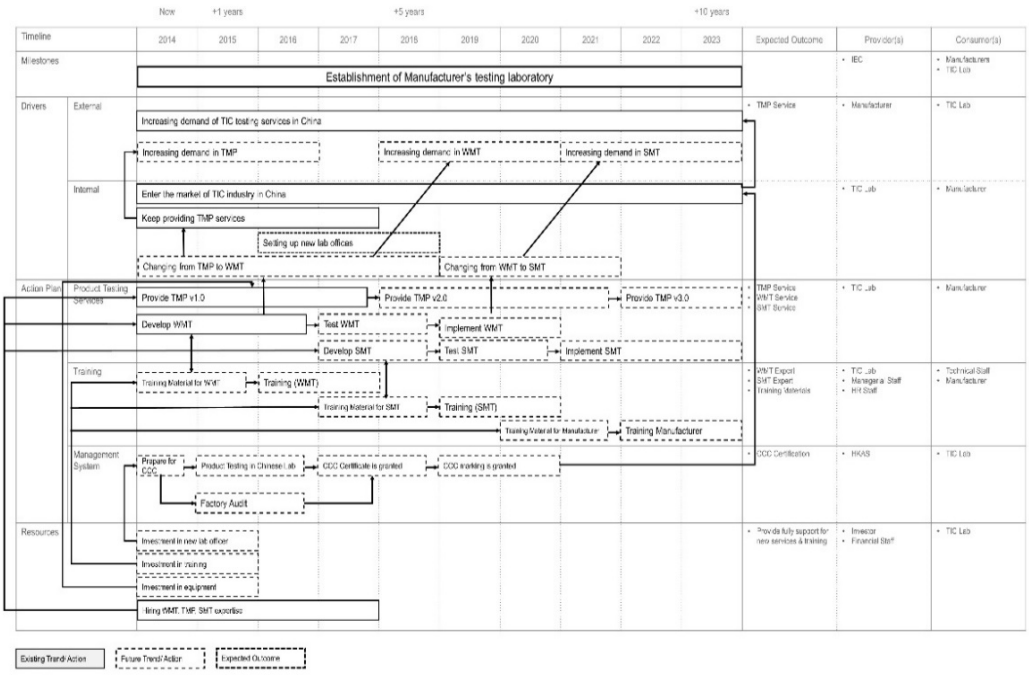


Figure 5.8 One organizational scenario-based roadmap generated in workshop A2

5.1.3 Results of the performance evaluation

To evaluate the performance of the MSBRM method, a feedback form was purposely designed for the collection of feedback from the participants, and contained a total of 11 statements. On a Likert-type scale, the respondents were offered a choice of five responses (i.e. 5 = strongly agree, 4 = agree, 3 = neutral, 2 = disagree, 1 = strongly disagree) so as to express whether they agreed or disagreed with a particular statement. After the completion of all the phases of the T-Plan and MSBRM method, the participants in the workshop were invited to evaluate the performance of the traditional T-Plan and the MSBFM method by using feedback form (1) and form (2), respectively. Table 5.1 and Table 5.2 show the results of the performance evaluation of the T-Plan and MSBRM methods, respectively.

According to the feedback collected from the participants, they strongly agreed that the MSBRM method stimulated the participants to formulate some ideas that they had not thought of before the implementation of the MSBRM activity. With regard to the deliverables of the MSBRM method, they expressed that the possible scenarios can be built as shown by the results which 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 MSBRM 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 the 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 5.1 Performance evaluation results of T-Plan in workshop A1

Statements	User 1	User 2	User 3	User 4	Average
1. The outputs are able to generate possible scenarios that may happen in the future.	3	4	3	4	3.50
2. The outputs provide a better understanding of the positive impacts of future scenarios.	3	3	3	3	3.00
3. The outputs provide a better understanding of the negative impacts of future scenarios.	3	3	3	3	3.00
4. The outputs are shown by the results to identify plausible scenarios that may happen in the future.	3	4	4	4	3.75
5. The outputs provide various solutions for the future changes.	3	3	5	3	3.50
6. The proposed method can help us to implement the roadmapping easily.	4	4	3	3	3.50
7. The proposed method stimulated the participants to formulate some ideas that they hadn't thought of before.	4	3	4	4	3.75
8. The proposed method is helpful for decision-making.	4	5	5	3	4.25
9. The proposed method is helpful for strategic planning	3	3	4	3	3.25
10. The proposed method is helpful for forecasting.	3	4	5	4	4.00
11. You will encourage others to apply the proposed method for strategic planning and forecasting.	3	3	3	3	3.00

Table 5.2 Performance evaluation results of the proposed MSBRM method in workshop A2

Statements	User 1	User 2	User 3	User 4	Average
1. The outputs are able to generate possible scenarios that may happen in the future.	4	4	5	4	4.25
2. The outputs provide a better understanding of the positive impacts of future scenarios.	4	4	4	4	4.00
3. The outputs provide a better understanding of the negative impacts of future scenarios.	4	3	4	4	3.75
4. The outputs are shown by the results to identify plausible scenarios that may happen in the future.	4	4	5	4	4.25
5. The outputs provide various solutions for the future changes.	3	4	5	4	4.00
6. The proposed method can help us to implement the roadmapping easily.	4	4	5	4	4.25
7. The proposed method stimulated the participants to formulate some ideas that they hadn't thought of before.	4	4	5	4	4.25
8. The proposed method is helpful for decision-making.	4	5	5	3	4.25
9. The proposed method is helpful for strategic planning	4	4	5	4	4.25
10. The proposed method is helpful for forecasting.	4	4	5	4	4.25
11. You will encourage others to apply the proposed method for strategic planning and forecasting.	4	4	4	4	4.00

5.2 Experiment B - Performance Evaluation of the Proposed IDSB Method

In Experiment B, a series of experiments was conducted for comparative study of the scenario building of the multi-perspective scenario-based roadmapping (MSBRM) method and the information-driven scenario building (IDSB) method, which aims to validate the performance of the IDSB method and reveal the limitations and advantages of both methods. Since the purpose of the development

of the IDSB method is to facilitate the development process of scenario building by the MSBRM approach, it was necessary to demonstrate how effective the scenario building process of the IDSB method is.

In the present study, Experiment B was conducted in two parts to implement the scenario building process of the MSBRM method (i.e. Experiment B1) and that for the IDSB method (i.e. Experiment B2), respectively. Moreover, a questionnaire was purposely designed for collecting the feedback from the participants, which is shown in Figure 5.9.

Feedback Form (1)

By Likert-type scale, you are offered a choice of five responses (i.e. 5 = strongly agree, 4 = somewhat agree, 3 = neutral, 2 = somewhat disagree, 1 = strongly disagree) to express how they agree or disagree with a particular statement.

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

Figure 5.9 A feedback form used in Experiment B

5.2.1 Experimental procedures

At the beginning of the workshop, an introduction of the experiment and the information-driven scenario building (IDSB) method were presented to all participants so as to ensure that they had a good understanding of the purpose and procedures of the experiments and scenario building method. Before the implementation of the scenario building, the participants read the guideline of the scenario building activity. In Experiment B1, the participants generated a pair of possible future scenarios according to the guidelines. In Experiment B2, two documents (i.e. D1 and D2) were selected as scenario-oriented information for scenario element identification. Before generating the scenarios, document D1 and document D2 were used to firstly identify the scenario elements “what”, “when”, “where”, “who”, “why” and “how”. After identifying the scenario elements, each participants generated a pair of possible future scenarios, according to the guidelines. Extracted sentences of the document D1 (HKTDC, 2015) and document D2 (Hong Kong Productivity Council (HKPC), 2014) are shown in Appendix D.

A package of experimental materials was provided to each participant, including a number of worksheets for the identification of scenario elements together with stationery items (e.g. pens, pencils, highlighter pens and draft papers). To collect

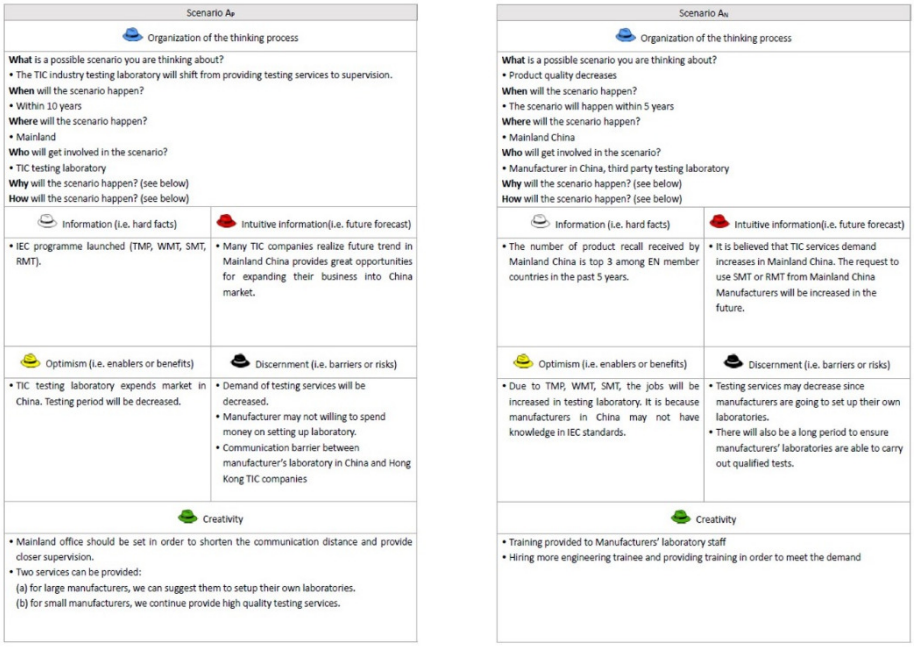
the feedback from the participants regarding the performance of the roadmapping qualitatively, the results were analyzed and a discussion was conducted after completing the scenario building process so as to disseminate the results of the generated scenarios as well as sharing the experience of the scenario building process,. Last but not the least, each participant completed a questionnaire to evaluate the scenario building performance results quantitatively.

5.2.2 Performance evaluation workshop

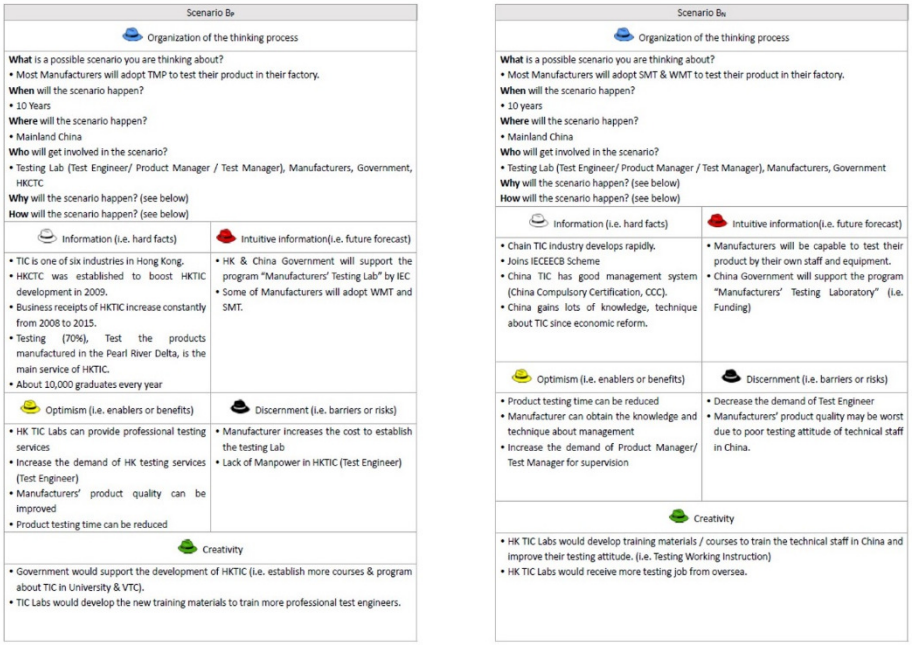
A one-day workshop was conducted for performance evaluation of two scenario-building methods, respectively. A total of four participants were invited to attend the workshop. For comparative study, the participants participated in Experiment B1 in the morning session of the workshop (i.e. workshop B1), while Experiment B2 was conducted in the afternoon session of the workshop (i.e. workshop B2). Snapshot of the experiment is shown in Figure 5.10.

Figure 5.10 Snapshot of Experiment B

In workshop B1, eight scenarios were generated using the MSBRM approach (i.e. four positive and four negative), as shown in Figure 5.11 (a), (b), (c) and (d). In workshop B2, eight possible future scenarios (i.e. four positive and four negative) were collected, as shown in Figure 5.12 (a), (b), (c) and (d).



(a)



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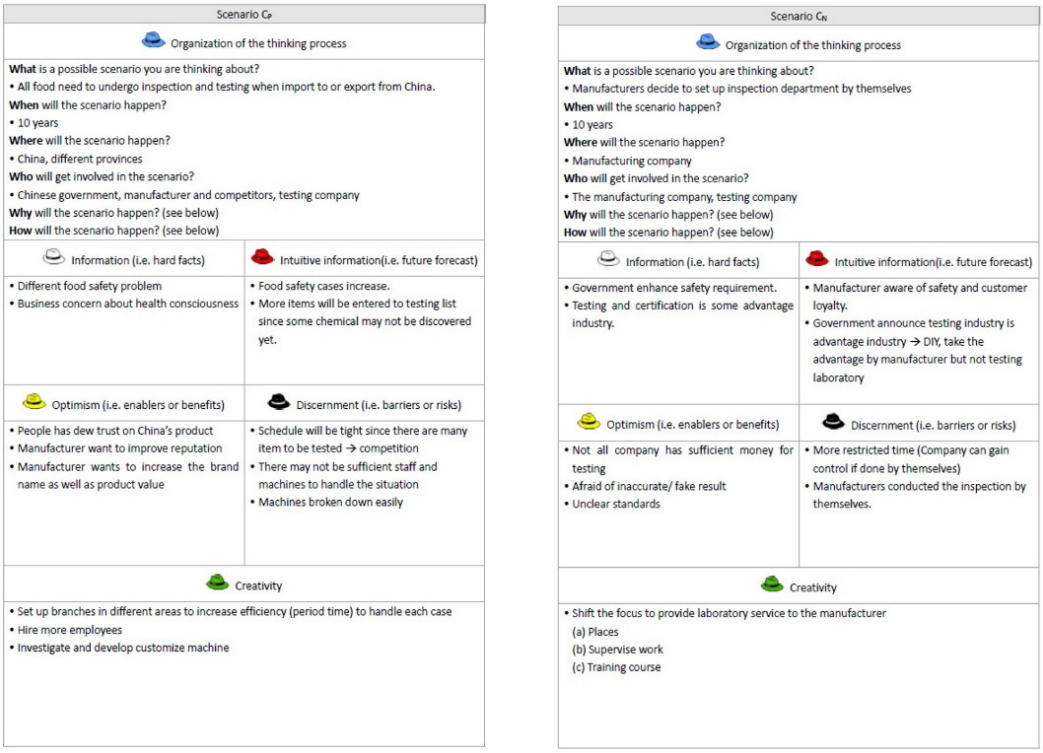


Scenario C_P

Organization of the thinking process

What is a possible scenario you are thinking about?
- All food need to undergo inspection and testing when import to or export from China.

When will the scenario happen?
- 10 years

Where will the scenario happen?
- China, different provinces

Who will get involved in the scenario?
- Chinese government, manufacturer and competitors, testing company

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)
• Different food safety problem • Business concern about health consciousness	• Food safety cases increase. • More items will be entered to testing list since some chemical may not be discovered yet.
Optimism (i.e. enablers or benefits)	**Discernment (i.e. barriers or risks)**
• People has dew trust on China's product • Manufacturer want to improve reputation • Manufacturer wants to increase the brand name as well as product value	• Schedule will be tight since there are many item to be tested → competition • There may not be sufficient staff and machines to handle the situation • Machines broken down easily

Creativity

- Set up branches in different areas to increase efficiency (period time) to handle each case
- Hire more employees
- Investigate and develop customize machine

Scenario C_N

Organization of the thinking process

What is a possible scenario you are thinking about?
- Manufacturers decide to set up inspection department by themselves

When will the scenario happen?
- 10 years

Where will the scenario happen?
- Manufacturing company

Who will get involved in the scenario?
- The manufacturing company, testing company

Why will the scenario happen? (see below)

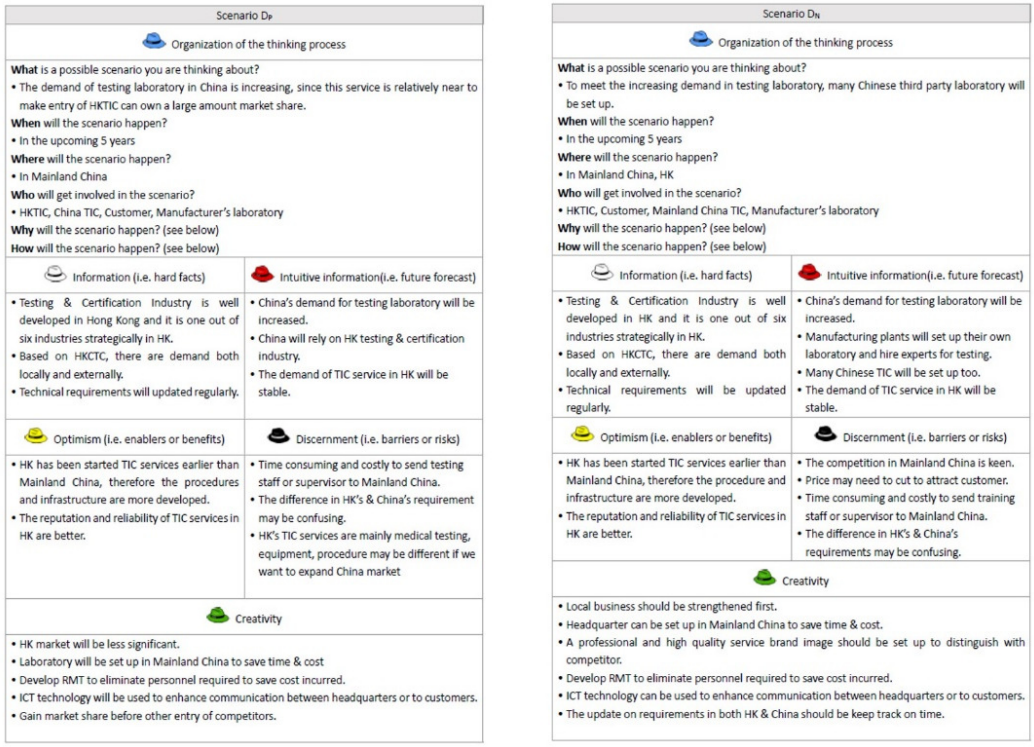
How will the scenario happen? (see below)

Information (i.e. hard facts)	Intuitive information(i.e. future forecast)
• Government enhance safety requirement. • Testing and certification is some advantage industry.	• Manufacturer aware of safety and customer loyalty. • Government announce testing industry is advantage industry → DIY, take the advantage by manufacturer but not testing laboratory
Optimism (i.e. enablers or benefits)	**Discernment (i.e. barriers or risks)**
• Not all company has sufficient money for testing • Afraid of inaccurate/ fake result • Unclear standards	• More restricted time (Company can gain control if done by themselves) • Manufacturers conducted the inspection by themselves.

Creativity

- Shift the focus to provide laboratory service to the manufacturer
  (a) Places
  (b) Supervise work
  (c) Training course

(c)



Scenario D_P

Organization of the thinking process

What is a possible scenario you are thinking about?
- The demand of testing laboratory in China is increasing, since this service is relatively near to make entry of HKTIC can own a large amount market share.

When will the scenario happen?
- In the upcoming 5 years

Where will the scenario happen?
- In Mainland China

Who will get involved in the scenario?
- HKTIC, China TIC, Customer, Manufacturer's 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)
• Testing & Certification Industry is well developed in Hong Kong and it is one out of six industries strategically in HK. • Based on HKCTC, there are demand both locally and externally. • Technical requirements will updated regularly.	• China's demand for testing laboratory will be increased. • China will rely on HK testing & certification industry. • The demand of TIC service in HK will be stable.
Optimism (i.e. enablers or benefits)	**Discernment (i.e. barriers or risks)**
• HK has been started TIC services earlier than Mainland China, therefore the procedures and infrastructure are more developed. • The reputation and reliability of TIC services in HK are better.	• Time consuming and costly to send testing staff or supervisor to Mainland China. • The difference in HK's & China's requirement may be confusing. • HK's TIC services are mainly medical testing, equipment, procedure may be different if we want to expand China market

Creativity

- HK market will be less significant.
- Laboratory will be set up in Mainland China to save time & cost
- Develop RMT to eliminate personnel required to save cost incurred.
- ICT technology will be used to enhance communication between headquarters or to customers.
- Gain market share before other entry of competitors.

Scenario D_N

Organization of the thinking process

What is a possible scenario you are thinking about?
- To meet the increasing demand in testing laboratory, many Chinese third party laboratory will be set up.

When will the scenario happen?
- In the upcoming 5 years

Where will the scenario happen?
- In Mainland China, HK

Who will get involved in the scenario?
- HKTIC, Customer, Mainland China TIC, Manufacturer's laboratory

Why will the scenario happen? (see below)

How will the scenario happen? (see below)

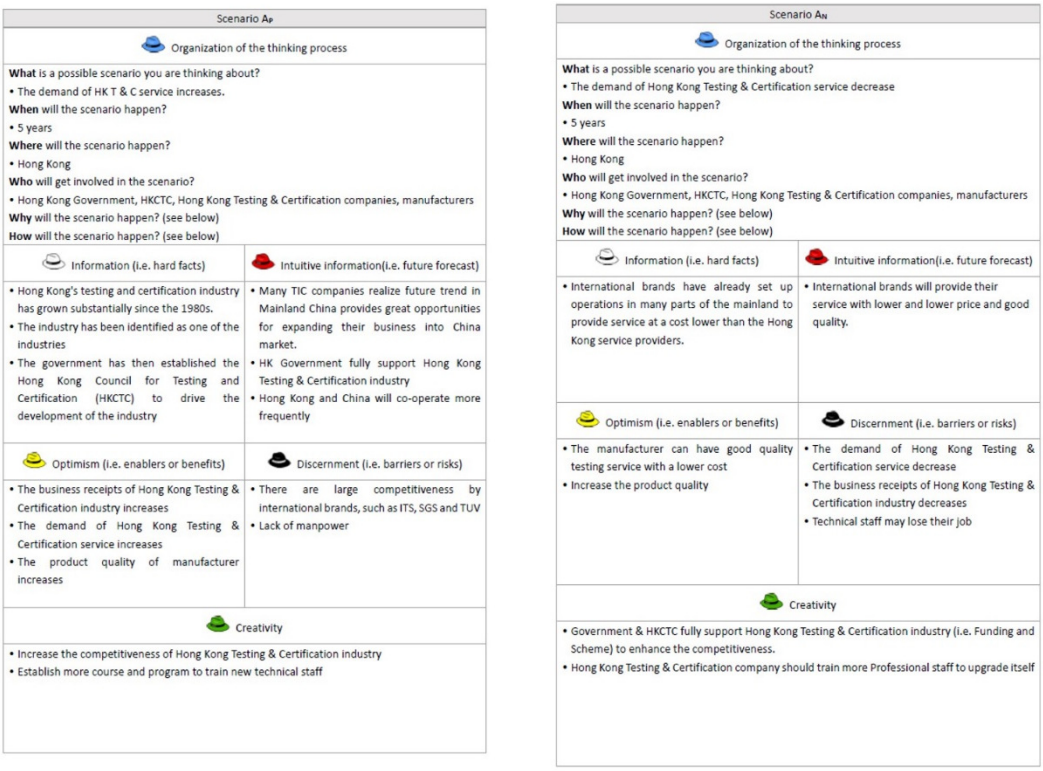
Information (i.e. hard facts)	Intuitive information(i.e. future forecast)
• Testing & Certification Industry is well developed in HK and it is one out of six industries strategically in HK. • Based on HKCTC, there are demand both locally and externally. • Technical requirements will be updated regularly.	• China's demand for testing laboratory will be increased. • Manufacturing plants will set up their own laboratory and hire experts for testing. • Many Chinese TIC will be set up too. • The demand of TIC service in HK will be stable.
Optimism (i.e. enablers or benefits)	**Discernment (i.e. barriers or risks)**
• HK has been started TIC services earlier than Mainland China, therefore the procedure and infrastructure are more developed. • The reputation and reliability of TIC services in HK are better.	• The competition in Mainland China is keen. • Price may need to cut to attract customer. • Time consuming and costly to send training staff or supervisor to Mainland China. • The difference in HK's & China's requirements may be confusing.

Creativity

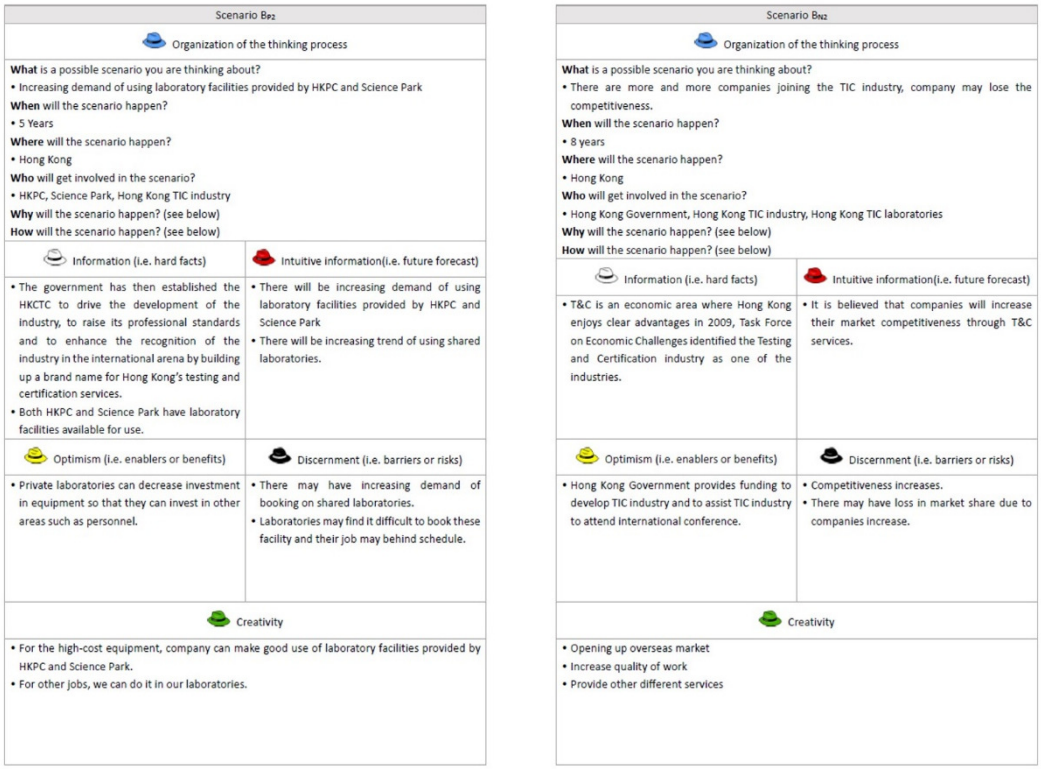
- Local business should be strengthened first.
- Headquarter can be set up in Mainland China to save time & cost.
- A professional and high quality service brand image should be set up to distinguish with competitor.
- Develop RMT to eliminate personnel required to save cost incurred.
- ICT technology can be used to enhance communication between headquarters or to customers.
- The update on requirements in both HK & China should be keep track on time.

(d)

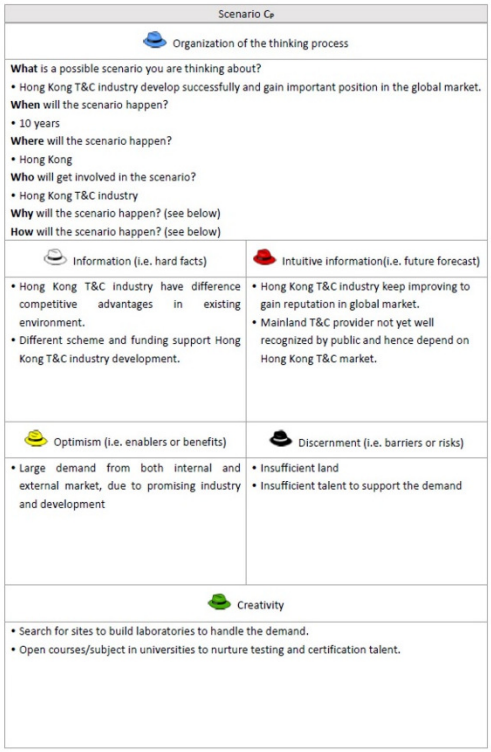
Figure 5. 11 Snapshots of eight scenarios generated in workshop B1

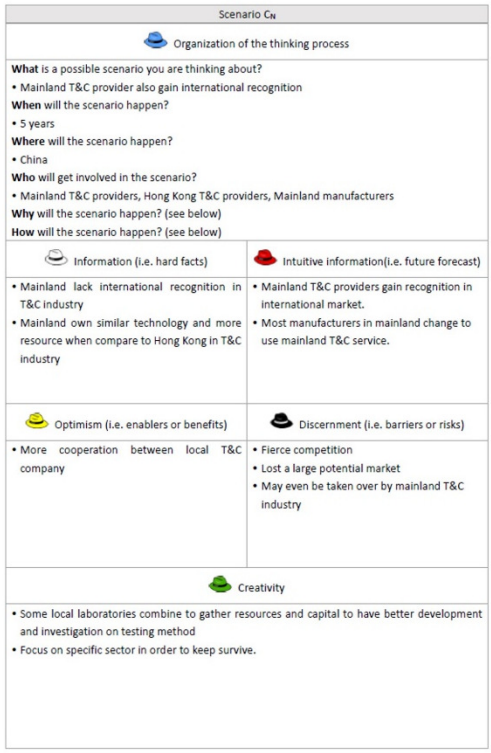

Scenario A_P
Organization of the thinking process
What is a possible scenario you are thinking about?
• The demand of HK T & C service increases.
When will the scenario happen?
• 5 years
Where will the scenario happen?
• Hong Kong
Who will get involved in the scenario?
• Hong Kong Government, HKCTC, Hong Kong Testing & Certification companies, 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)
• Hong Kong's testing and certification industry has grown substantially since the 1980s.
• The industry has been identified as one of the industries
• The government has then established the Hong Kong Council for Testing and Certification (HKCTC) to drive the development of the industry
• Many TIC companies realize future trend in Mainland China provides great opportunities for expanding their business into China market.
• HK Government fully support Hong Kong Testing & Certification industry
• Hong Kong and China will co-operate more frequently
Optimism (i.e. enablers or benefits)
Discernment (i.e. barriers or risks)
• The business receipts of Hong Kong Testing & Certification industry increases
• The demand of Hong Kong Testing & Certification service increases
• The product quality of manufacturer increases
• There are large competitiveness by international brands, such as ITS, SGS and TUV
• Lack of manpower
Creativity
• Increase the competitiveness of Hong Kong Testing & Certification industry
• Establish more course and program to train new technical staff
Scenario A_N
Organization of the thinking process
What is a possible scenario you are thinking about?
• The demand of Hong Kong Testing & Certification service decrease
When will the scenario happen?
• 5 years
Where will the scenario happen?
• Hong Kong
Who will get involved in the scenario?
• Hong Kong Government, HKCTC, Hong Kong Testing & Certification companies, 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)
• International brands have already set up operations in many parts of the mainland to provide service at a cost lower than the Hong Kong service providers.
• International brands will provide their service with lower and lower price and good quality.
Optimism (i.e. enablers or benefits)
Discernment (i.e. barriers or risks)
• The manufacturer can have good quality testing service with a lower cost
• Increase the product quality
• The demand of Hong Kong Testing & Certification service decrease
• The business receipts of Hong Kong Testing & Certification industry decreases
• Technical staff may lose their job
Creativity
• Government & HKCTC fully support Hong Kong Testing & Certification industry (i.e. Funding and Scheme) to enhance the competitiveness.
• Hong Kong Testing & Certification company should train more Professional staff to upgrade itself

(a)

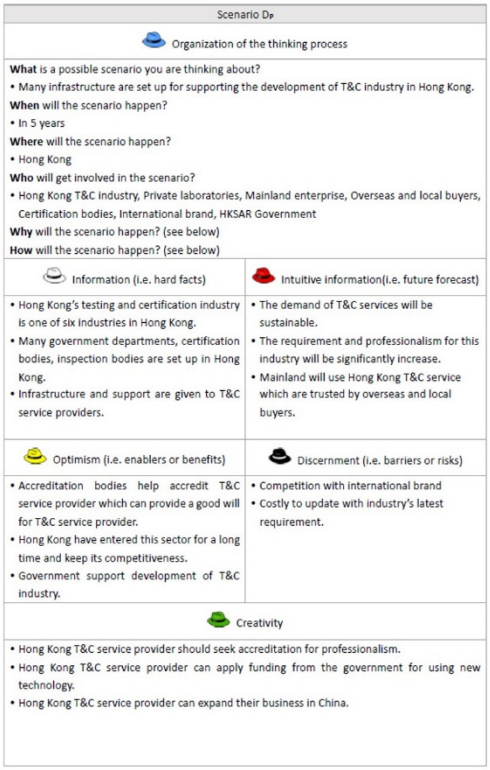

Scenario B_{P2}
Organization of the thinking process
What is a possible scenario you are thinking about?
• Increasing demand of using laboratory facilities provided by HKPC and Science Park
When will the scenario happen?
• 5 Years
Where will the scenario happen?
• Hong Kong
Who will get involved in the scenario?
• HKPC, Science Park, Hong Kong 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)
• The government has then established the HKCTC to drive the development of the industry, to raise its professional standards and to enhance the recognition of the industry in the international arena by building up a brand name for Hong Kong's testing and certification services.
• Both HKPC and Science Park have laboratory facilities available for use.
• There will be increasing demand of using laboratory facilities provided by HKPC and Science Park
• There will be increasing trend of using shared laboratories.
Optimism (i.e. enablers or benefits)
Discernment (i.e. barriers or risks)
• Private laboratories can decrease investment in equipment so that they can invest in other areas such as personnel.
• There may have increasing demand of booking on shared laboratories.
• Laboratories may find it difficult to book these facility and their job may behind schedule.
Creativity
• For the high-cost equipment, company can make good use of laboratory facilities provided by HKPC and Science Park.
• For other jobs, we can do it in our laboratories.
Scenario B_{N2}
Organization of the thinking process
What is a possible scenario you are thinking about?
• There are more and more companies joining the TIC industry, company may lose the competitiveness.
When will the scenario happen?
• 8 years
Where will the scenario happen?
• Hong Kong
Who will get involved in the scenario?
• Hong Kong Government, Hong Kong TIC industry, Hong Kong TIC laboratories
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)
• T&C is an economic area where Hong Kong enjoys clear advantages in 2009, Task Force on Economic Challenges identified the Testing and Certification industry as one of the industries.
• It is believed that companies will increase their market competitiveness through T&C services.
Optimism (i.e. enablers or benefits)
Discernment (i.e. barriers or risks)
• Hong Kong Government provides funding to develop TIC industry and to assist TIC industry to attend international conference.
• Competitiveness increases.
• There may have loss in market share due to companies increase.
Creativity
• Opening up overseas market
• Increase quality of work
• Provide other different services

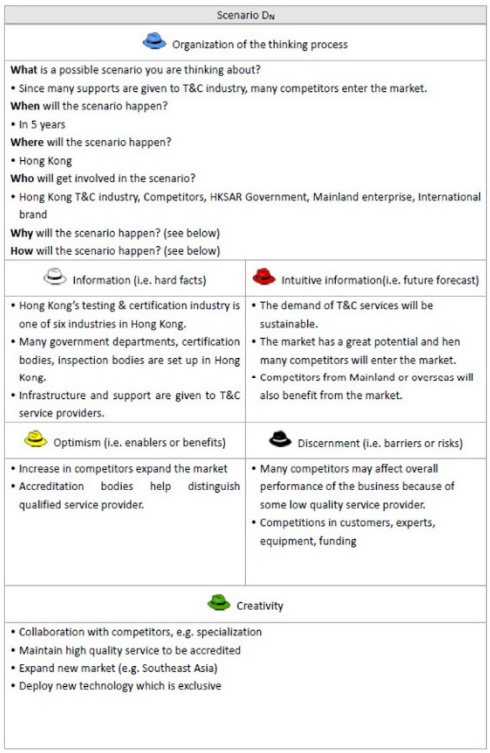
(b)





(c)





(d)

Figure 5.12 Snapshots of eight scenarios generated in workshop B2

5.2.3 Results of performance evaluation

To evaluate the performance of the proposed IDSB method, a feedback form was purposely designed for the collection of feedback from the participants which contained a total of 11 statements. On a Likert-type scale, the respondents were offered a choice of five responses (i.e. 5 = strongly agree, 4 = agree, 3 = neutral, 2 = disagree, 1 = strongly disagree) to express how they agreed or disagreed with a particular statement. After completion of all the phases of the MSBRM and IDSB methods, the participants in the workshop were invited to evaluate the performance of the two methods by using the feedback forms (1) and (2), respectively. Table 5.3 and Table 5.4 show the results of the performance evaluation of the MSBRM and IDSB methods, respectively.

According to the feedback collected from the participants, they strongly agreed that the proposed IDSB method stimulated the participants to generate possible future scenarios using the scenario elements. With regard to the deliverables of the IDSB method, they expressed that the possible scenarios can be built easily and effectively by using the scenario elements so as to describe what may happen in the future in terms of 5W1H and various thinking perspectives. They also agreed that the IDSB method is able to provide more informative scenario-oriented information for generating the plausible scenario(s) that may happen in the future

which provided a better understanding of hard facts, future forecast, actions, providers and consumers, and positive (i.e. opportunities, enablers) and negative impacts (i.e. challenges, barriers) in future scenarios. They also agreed that the proposed IDSB method really facilitated the scenario building process which is helpful for strategic planning, forecasting and decision-making.

Table 5.3 Performance evaluation results of the proposed MSBRM method in workshop B1

Statements	User 1	User 2	User 3	User 4	Average
1. The outputs are able to generate possible scenarios that may happen in the future.	4	4	5	4	4.25
2. The outputs provide a better understanding of the positive impacts of future scenarios.	4	4	4	4	4.00
3. The outputs provide a better understanding of the negative impacts of future scenarios.	4	3	4	4	3.75
4. The outputs are shown by the results to identify plausible scenarios that may happen in the future.	4	4	5	4	4.25
5. The outputs provide various solutions for the future changes.	3	4	5	4	4.00
6. The proposed method can help us to implement the roadmapping easily.	4	4	5	4	4.25
7. The proposed method stimulated the participants to formulate some ideas that they hadn't thought of before.	4	4	5	4	4.25
8. The proposed method is helpful for decision-making.	4	5	5	3	4.25
9. The proposed method is helpful for strategic planning.	4	4	5	4	4.25
10. The proposed method is helpful for forecasting.	4	4	5	4	4.25
11. You will encourage others to apply the proposed method for strategic planning and forecasting.	4	4	4	4	4.00

Table 5.4 Performance evaluation results of the proposed IDSB method in workshop B2

Statements	User 1	User 2	User 3	User 4	Average
1. The outputs are able to generate possible scenarios that may happen in the future.	3	5	5	4	4.25
2. The outputs provide a better understanding of the positive impacts of future scenarios.	4	5	4	5	4.50
3. The outputs provide a better understanding of the negative impacts of future scenarios.	4	4	4	5	4.25
4. The outputs are shown by the results to identify plausible scenarios that may happen in the future.	5	4	4	4	4.25
5. The outputs provide various solutions for the future changes.	4	5	3	4	4.00
6. The proposed method can help us to implement the roadmapping easily.	3	5	5	5	4.50
7. The proposed method stimulated the participants to formulate some ideas that they hadn't thought of before.	3	5	5	4	4.25
8. The proposed method is helpful for decision-making.	3	4	5	5	4.25
9. The proposed method is helpful for strategic planning	3	5	5	5	4.25
10. The proposed method is helpful for forecasting.	3	5	4	4	4.00
11. You will encourage others to apply the proposed method for strategic planning and forecasting.	4	4	5	4	4.25

5.3 Summary

The experimental validation and performance evaluation of the proposed MSBRM and IDSB methods has been conducted. In the experiment A, the performance of the MSBRM method was evaluated as compared with the traditional roadmapping method. According to the feedback from the participants, it is found that the overall performance of MSBRM method is better to the traditional roadmapping, especially for strategic planning. The finding indicates that the MSBRM method

may be more effective than the traditional roadmapping method.

In the experiment B, the performance of IDSB method was evaluated as comparison with the MSBRM method. According to the feedback from the participants, the performance evaluation of the IDSB and MSBRM methods are similar. However, it is found that the quality of the scenario generated by the participants has a greatly difference. By using the scenario building process of the IDSB method, the content of the scenario is well-structured and informative, as compared with the scenario generated by using the MSBRM method.

On the completion of the experimental validation and performance evaluation, two case studies are conducted for demonstrating the capabilities of two proposed methods (i.e. MSBRM and IDSB) in two reference sites.

Chapter 6

Implementation and Case Study

To realize the capability of the multi-perspective scenario-based roadmapping (MSBRM) and the information-driven scenario building (IDSB) methods, two case studies were conducted in a global Testing, Inspection and Certification (TIC) company and an Information and Communication Technology (ICT) company in Hong Kong.

6.1 Case Study I – Implementation of the MSBRM Method in a Testing, Inspection and Certification (TIC) company

To realize the capability of the MSBRM 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 with offices located in 50 countries. Company T established its Hong Kong office in 1996 which provides various testing, product certification, and management system certification services for electrical and electronic products.

6.1.1 Prerequisite preparation and scenario team formation of the MSBRM 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 to provide various services to assist product manufacturers to 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 the implementation of the proposed scenario-based roadmapping activity. The target company wanted to explore the future scenarios for the establishment of manufacturers' testing laboratories in Mainland China. With regard to the company needs, the MSBRM 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 MSBRM activity.

They also invited participants in the company who would be involved in the activity to attend the meeting. Hence, the MSBRM method was introduced to all the participants.

6.1.2 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 in Table 6.1. Detailed definitions of CBTL, TMP, WMT, SMT and RMT are given in Appendix E (adapted from IEC, 2007).

Table 6.1 Descriptions of TMP, WMT, SMT and RMT programmes

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

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

6.1.3 Development of the scenario building worksheet

In this case, the target company wished 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 3.3, 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. A snapshot of the guideline for scenario building is shown in Figure 6.1 and a full version of the guideline for scenario

building is illustrated in Appendix F.

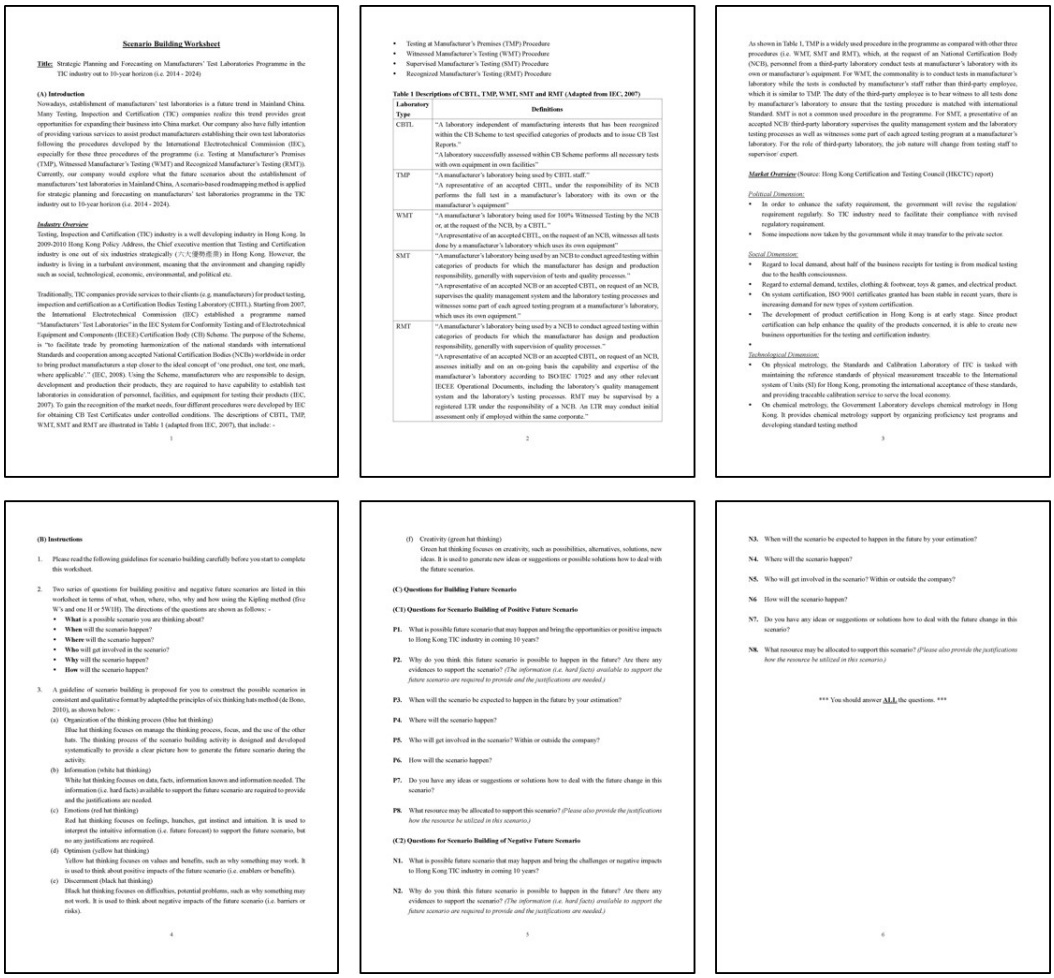


Figure 6.1 Snapshot of the guidelines for scenario building

In the introduction, the background of the study, purpose, and scope of the MSBRM activity were described, and information about the industry and a market overview was 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 the possible future scenario 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 possible future scenario 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.)*

6.1.4 Development of a scoring system and assessment form

According to Phase 4 of the proposed MSBRM method as mentioned in Section 3.4, the scoring system and assessment form for the case study were developed, as

shown in Table 6.2 and Table 6.3. Ranges of the estimated market share and relative weightings of individual criteria were determined by managerial staff of the target company.

Table 6.2 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

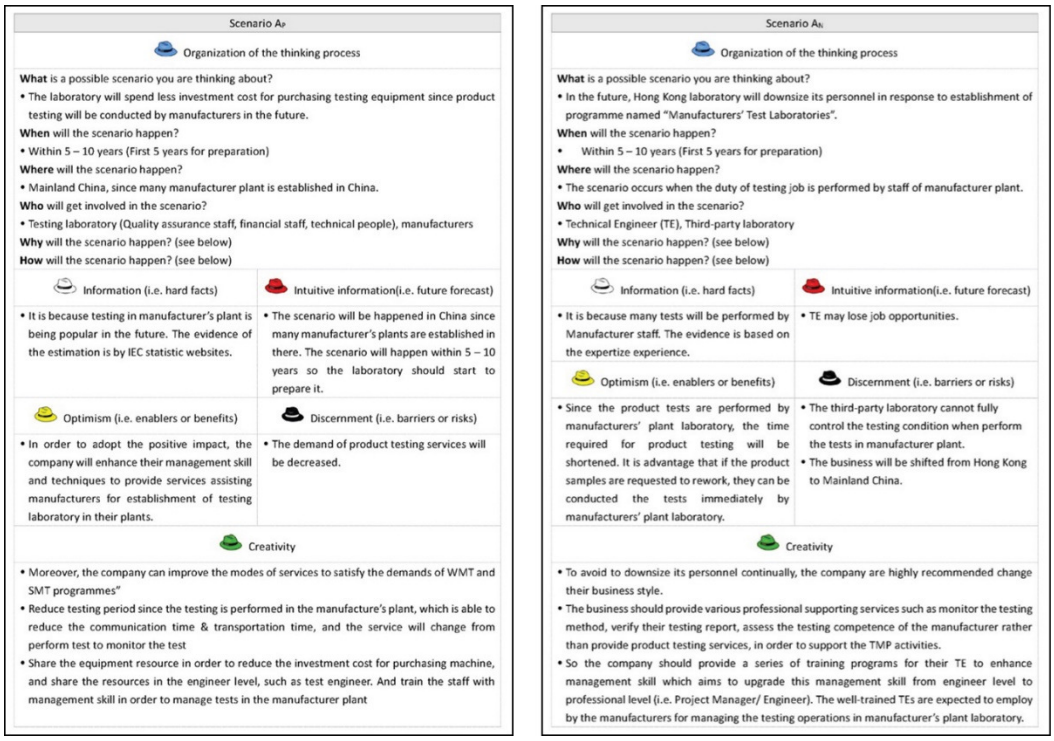
Table 6.3 Assessment form for the case study

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		

6.1.5 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 6.1.3. Upon 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. $\mathbf{A_P}$, $\mathbf{B_P}$ and $\mathbf{C_P}$) future scenarios and three negative (i.e. $\mathbf{A_N}$, $\mathbf{B_N}$ and $\mathbf{C_N}$) future scenarios. Snapshots are shown in Figure 6.2 (a), (b), and (c), and full versions of the completed worksheets are illustrated in Appendix G. 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. $\mathbf{A_P}$, $\mathbf{A_N}$, $\mathbf{B_P}$, $\mathbf{B_N}$, $\mathbf{C_P}$, $\mathbf{C_N}$) were checked for validity in terms of consistency, relevance, and completeness. Validation results of the scenarios are shown in Figure 6.3 (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 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)

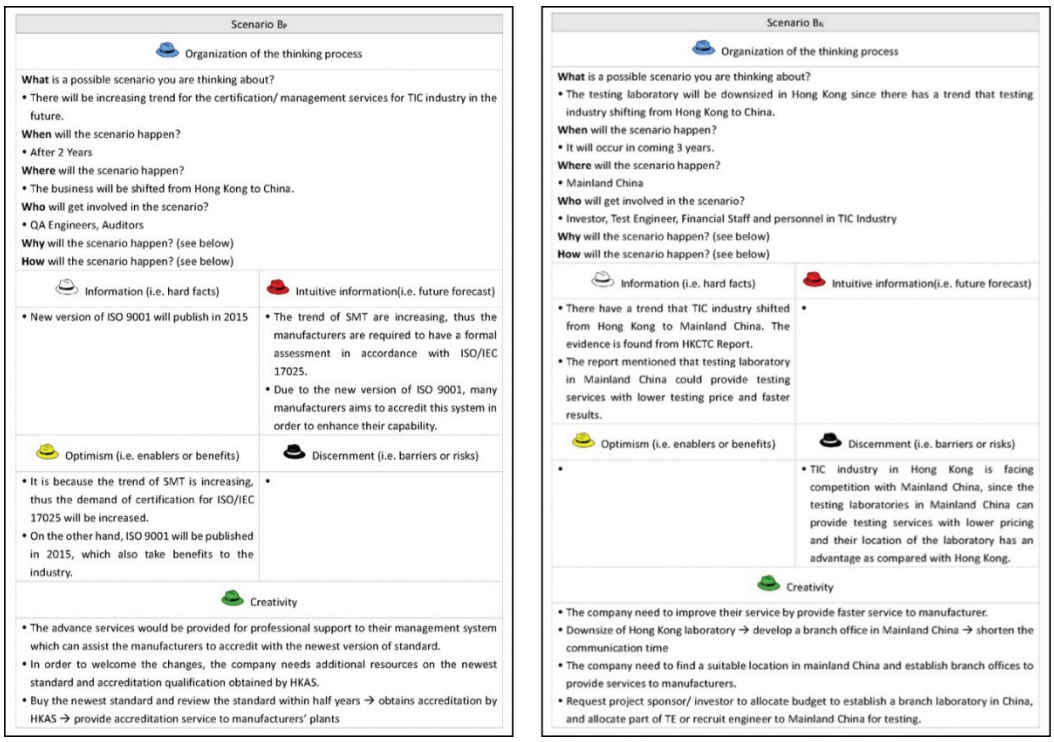
How will the scenario happen? (see below)

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.

(a)



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)

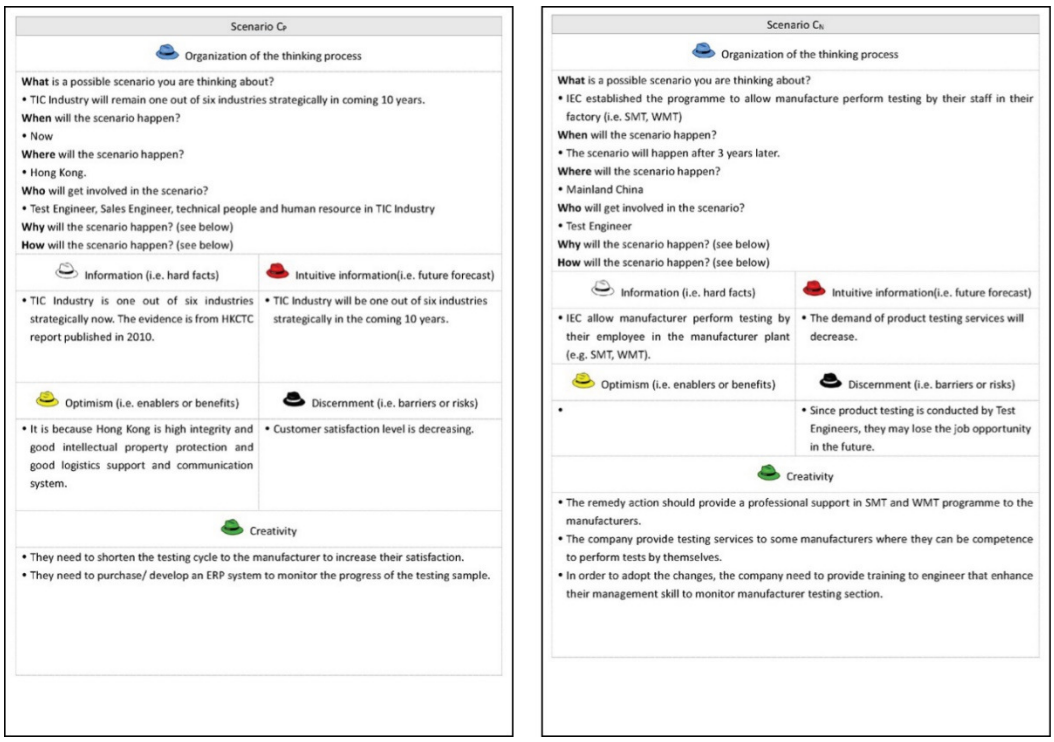
How will the scenario happen? (see below)

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.

(b)



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.

(c)

Figure 6.2 Snapshots of the completed worksheets for (a) scenarios A_P and A_N, (b) scenarios B_P and B_N, and (c) scenarios C_P and C_N

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

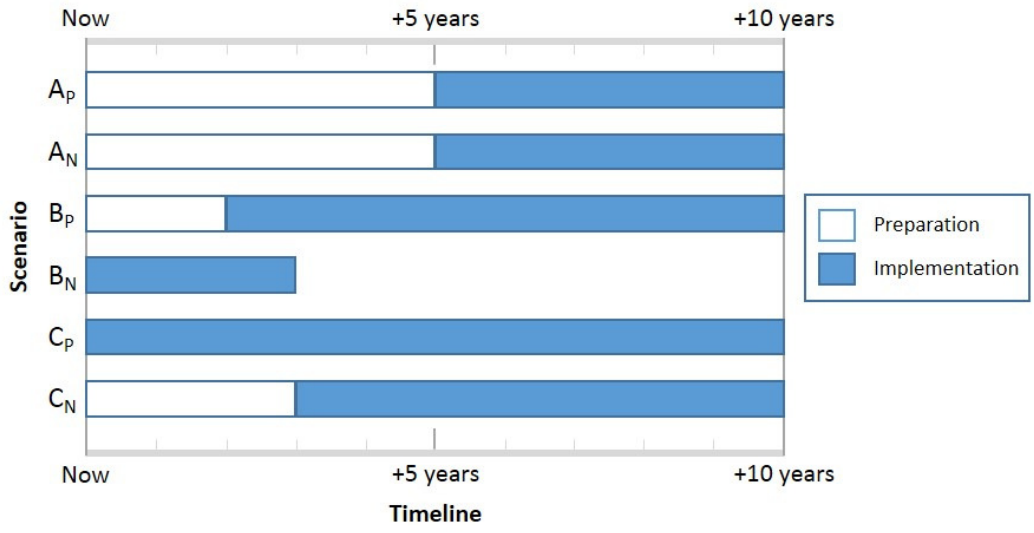
According to the scoring system as illustrated in Table 6.2, these six valid scenarios were assessed based on the six criteria by the scenario assessment team using the assessment form as shown in Table 6.3, and the assessment results of possible future scenarios were calculated in terms of the weighted scores and ranking, as shown in Table 6.4. 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.

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 Figure 6.4 (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 6.6 (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 manufacturers, Company T (i.e. target company), personnel of the target company, investors, auditors, competitors, TIC Industry, Hong Kong Accreditation Service (HKAS), IEC, and Hong Kong Council for Testing and Certification (HKCTC).

Table 6.4 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**



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

Scenario **A_P** and scenario **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 MSBRM 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. scenario $\mathbf{A_P}$ and scenario $\mathbf{C_N}$), as shown in Figure 6.5 and Figure 6.6. The preliminary roadmaps demonstrated the action plans individually regarding how to deal with future change within the

time frame based on each selected scenario.

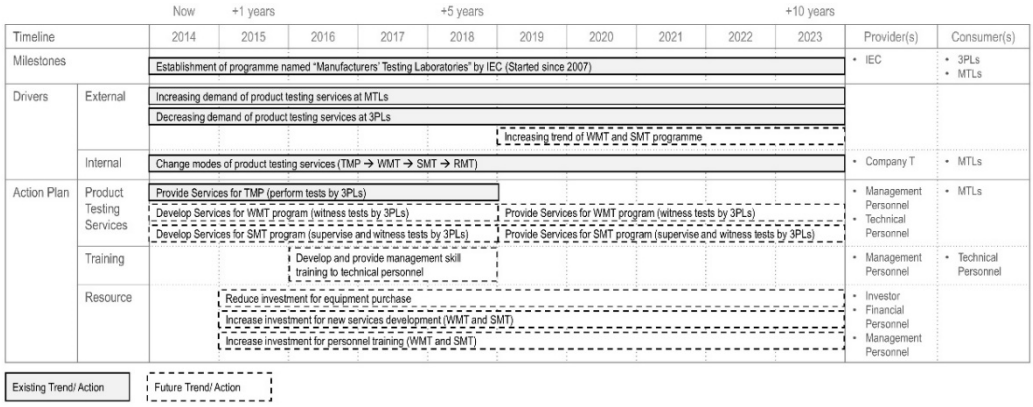


Figure 6.5 Preliminary scenario-based roadmap of scenario A_P

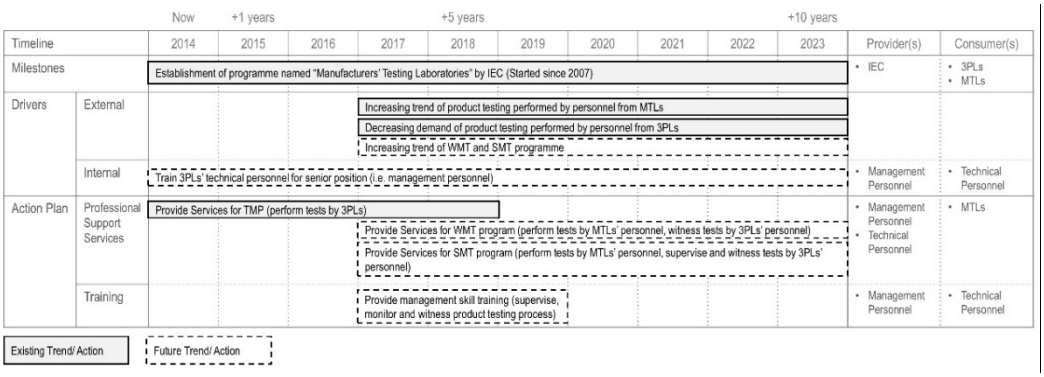


Figure 6.6 Preliminary scenario-based roadmap of scenario C_N

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-out 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. $\mathbf{A_P}$ and $\mathbf{C_N}$) were quite similar and 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 6.7.

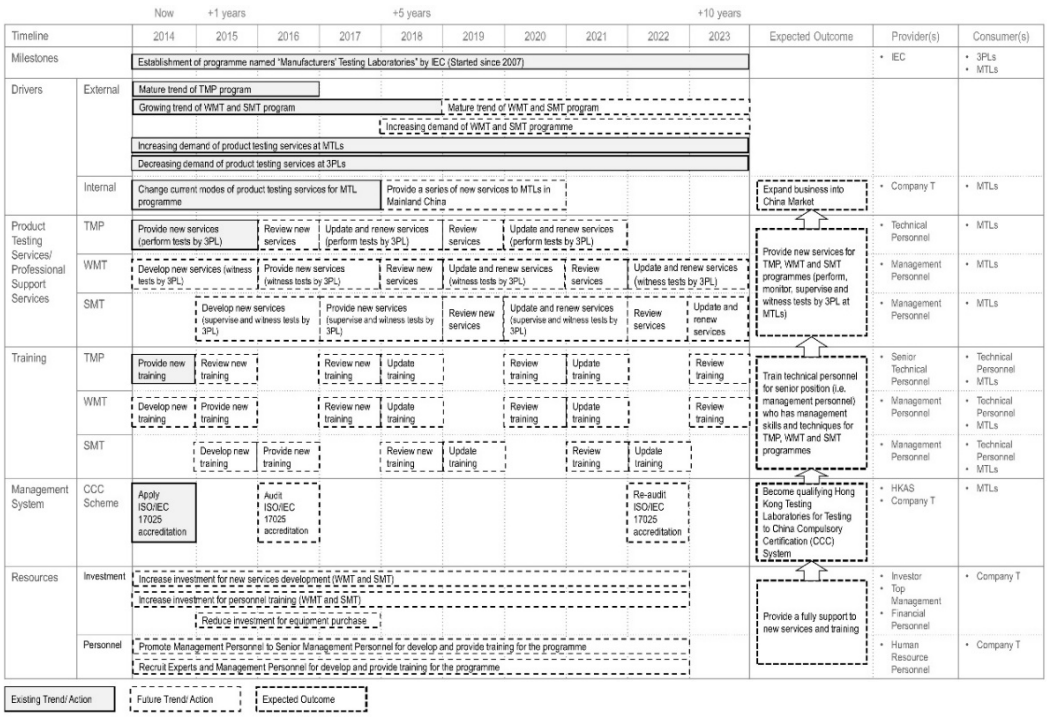


Figure 6.7 A comprehensive scenario-based roadmap for business development of the Manufacturers' testing laboratories programme in the TIC industry based on a 10-year horizon

As shown in Figure 6.8, 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 MSBRM activity according to what plausible future scenarios they can serve (i.e. scenario $\mathbf{A_P}$ and scenario $\mathbf{C_N}$).

To evaluate the performance of the proposed MSBRM 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 MSBRM 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 6.5, they strongly agreed that the proposed MSBRM method stimulated the participants to formulate some ideas that they had not thought of before the implementation of the MSBRM 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.

Moreover, they pinpointed that the scenario-based roadmap was constructed successfully according to the selected scenarios, since the proposed MSBRM 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 MSBRM 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.

Table 6.5 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

6.2 Case Study II – Implementation of the IDSB Method in an Information and Communication Technology Company

To realize the capability of the information-driven scenario building (IDSB) method, a case study was conducted in an Information and Communication Technology (ICT) company in Hong Kong.

6.2.1 Background of the study

The target company called Hong Kong RFID Limited (HK-RFID). Since its establishment in 2004, HK-RFID has become a leading Radio Frequency Identification (RFID) solution provider with headquarter in Hong Kong and mainly provides RFID solutions and consultancy services for efficiency enhancement and location tracking technologies of assets (i.e. luxury and important assets) reaching out to clients worldwide.

In 2005, HK-RFID was an incubatee that joined the Hong Kong Science and Technology Park's Incu-Tech Programme and graduated in 2008. HK-RFID is also a hardware provider that R&D possesses and production capabilities to design and manufacture RFID hardware and wireless systems, such as tags and readers (i.e. passive and active) for applying in various industries (e.g. environmental monitoring, anti-counterfeit, visitor counter). Most of their clients are running business-to-business (B2B) businesses in various sectors such as government, the public sector, financial service sector, etc. Representative clients include the Commerce and Economic Development Bureau as well as Hong Kong Housing Authority (HA) of the Government of the Hong Kong Special Administrative Region (HKSAR), Hong Kong Mass Transit Railway (MTR) Corporation, Hong Kong Convention and Exhibition Centre (HKCEC), Hong Kong and Shanghai

Banking Corporation Limited (HSBC), Sino Land Company Limited, etc. The milestones of the development of the HK-RFID are shown in Fig. 5 (adopted from Hong Kong RFID Limited, 2008). This case study was conducted in two phases in 2013 and 2014.

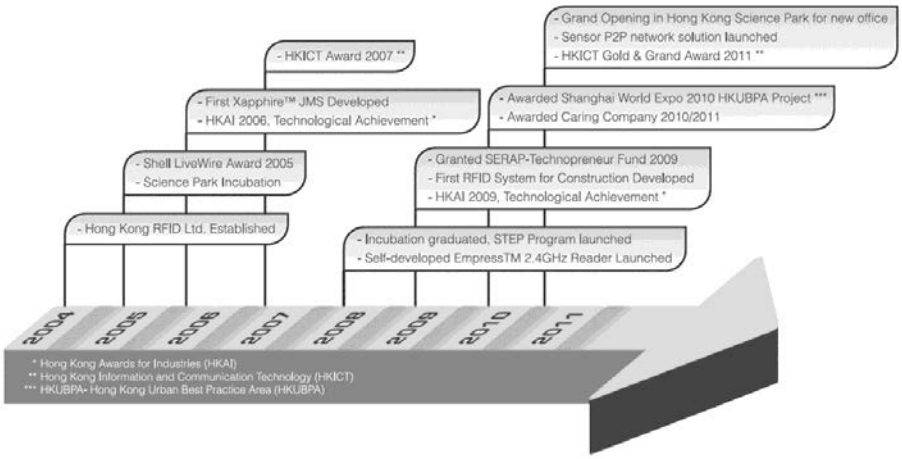


Figure 6.8 Milestones of Hong Kong RFID Limited (HK-RFID) (adopted from Hong Kong RFID Limited, 2008)

6.2.2 Phase 1 – Implementation of technology roadmapping

In 2013, HK-RFID was using the method of brainstorming to generate ideas about the future market, application and technology for strategic planning and forecasting during regular meetings. Encouraged by the top management, regular meetings are conducted within the company and involve a variety of employees from different departments such as business, sales and marketing, R&D, engineering, production and manufacturing, etc. Even though putting much effort into generating ideas for future action plans for product and technology development, several challenges were still faced which are summarized as follows:

(i) Lack of time-effective and systematic tool to plan for long-term corporate development, even though it has a clear picture of the possible future scenario

(ii) Hard to keep balance of commercial and technological functions

(iii) Lack of quantitative measures for evaluating the performance of the roadmap's outcomes

On the whole, the background description of the target organization provides a clear illustration of its existing method for strategic planning for dealing with the challenges in strategic planning and forecasting. In 2013 (i.e. Phase 1), the target company applied the technology roadmapping method for strategic planning and forecasting so as to develop an organizational roadmap of technology development (i.e. RFID technology) out to a 10-year horizon (i.e. 2013 – 2023).

Since the target company has a clear picture of the future scenario, it can conduct the technology roadmapping process directly so as to generate a future organizational action plan. In the section, the result of the case study in Phase 1 is presented and discussed. During the preliminary discussion, the proposed methodology of roadmapping was presented to the organization. According to the needs of the target organization, an inside-out roadmap of technology development of RFID out to a 10-year horizon (i.e. 2013 – 2023) was developed in the phase. The framework of the roadmap was designed and developed which consists of

three major elements in a row, such as (a) trend and driver, (b) application and (c) technology.

According to the elements trend and driver, internal corporate development with a micro view and external environment with a macro view were identified as trends and drivers of business and market, respectively. On the basis of the company business solutions, three significant applications were chosen for technology forecasting, such as Healthcare Management, Location Tracking and Physical Assets Management (PAM). In the technology layer, four core technologies were identified including identification technology, sensor technology, communication technology and security technology which are most influential in regard to these application areas in the whole period between 2013 and 2023.

For good preparation of roadmapping from an inside-out perspective, the published company information was collected to better understand the company background and business strategy in short and medium terms, such as company website, company catalogue, press release and interview scripts released by the media (i.e. newspapers, TV programmes). A preliminary roadmap from an inside-out perspective was generated by the primary data analysis according to the information elicited in the preliminary discussion and published company information as shown in Fig. 6.9. A brief description of the preliminary inside-out

roadmap was delivered at the beginning of the inside-out roadmapping. Afterwards, all the captured information which was put on the preliminary inside-out roadmap was validated and confirmed by the company representative.

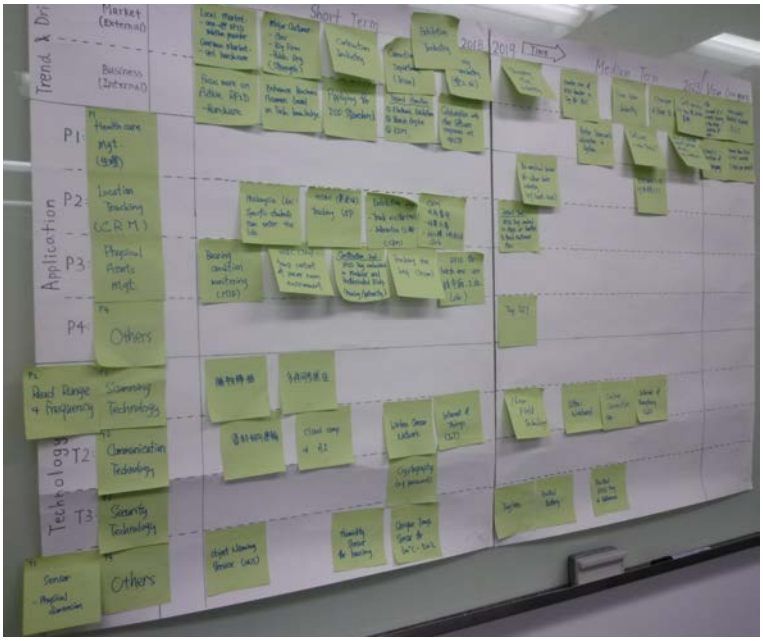


Figure 6.9 Preliminary inside-out roadmap

On the basis of the preliminary inside-out roadmap, inside-out roadmapping was then conducted using group discussion from an inside-out perspective. Three major elements including trends and drivers, application and technology were discussed in short, medium and long terms, respectively. Afterwards, the organizational roadmap of future technological development (i.e. RFID technology) out to a 10-year horizon was developed from an inside-out perspective, as illustrated in Figure 6.10.

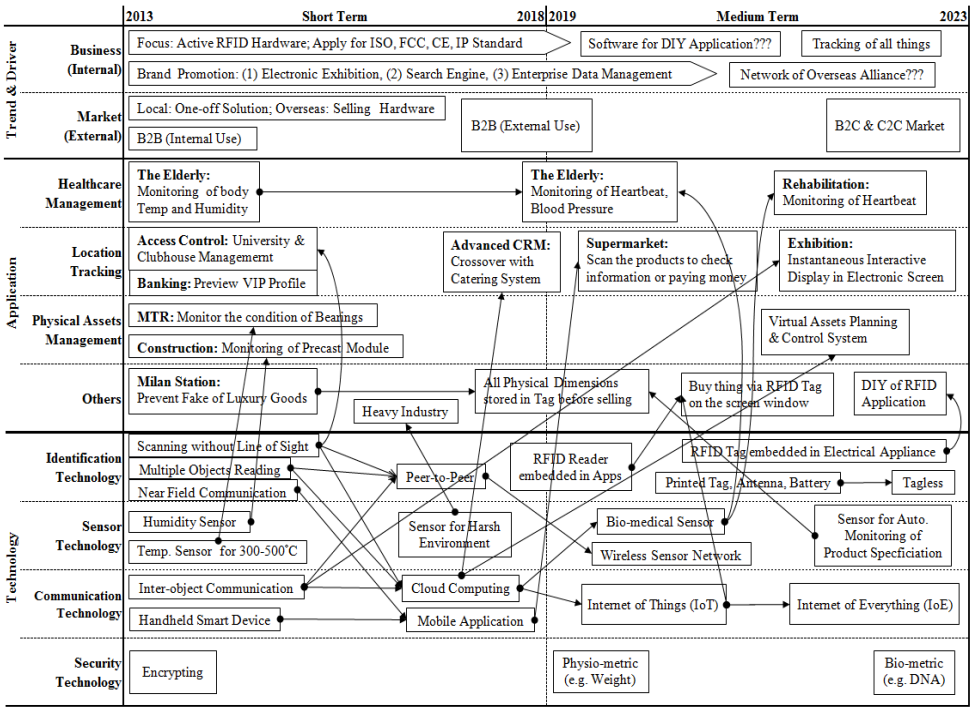


Figure 6.10 An organizational roadmap for technology development (i.e. RFID technology) based on a 10-year horizon (i.e. 2013 – 2023)

Outside-in roadmapping was a monitoring process for evaluating the credibility of the organizational roadmap in secondary data analysis. Two examples of technology intelligences found in outside-in roadmapping were selected and demonstrated in the following sections. Example 1 was about the solution of healthcare monitoring doe elderly people. In example 1, it is recalled that due to the restriction from sensor vendors, the company was not willing to further develop the RFID solution of healthcare management without very strong market demand, but they anticipated that the RFID solution for heartbeat and blood pressure monitoring of the elderly and the disabled will be developed and implemented in the medium term between 2018 and 2019 due to the future ageing population in

Hong Kong.

By conducting the secondary data analysis, Mal (2007) developed the similar RFID solution for wireless heartbeat monitoring. While the outdoor wireless healthcare monitoring with RFID-enhanced video sensor networks was also developed (Alemdar et al., 2010). According to the above technology intelligence found, the solution for heartbeat and blood pressure monitoring of the elderly was suggested to develop and implement in the short term, instead of medium term as illustrated in Figure 6.11.

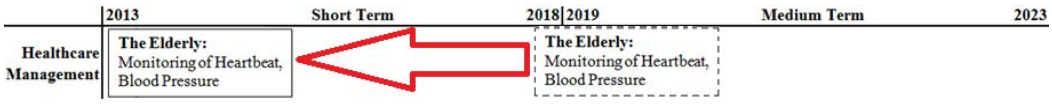


Figure 6.11 Example of validation for solution in Healthcare Management

Example 2 was about the solution of location tracking in supermarket. By applying mobile technology (i.e. mobile device), scanning the product information and settling payment during the shopping were proposed to implement at Toenisvorst in western Germany, respectively (Chibber, 2012; Bosma, 2013). As shown in Figure 6.12, it is a reason why the solution of location tracking in supermarket was suggested to develop and implement in the short term, instead of medium term.

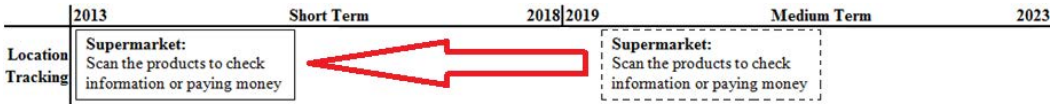


Figure 6.12 Example of validation for solution in Location Tracking

6.2.3 Phase 2 – Implementation of information-driven scenario building (IDSB) method

In Phase 2, the target company was invited to realize the capability of the proposed IDSB method. A trial implementation was conducted to facilitate the company to think about future scenarios of Internet of Things (IoT) technology development. In the process of information acquisition, a total of 15 documents were collected from various electronic sources (i.e. online). In the process of metadata construction, the metadata and hierarchical trees of these documents were captured and constructed, respectively. A list of collected documents are shown in Table 6.6.

As shown in Table 6.6, these documents include nine online articles, two journal articles, one white paper, and three technical reports that are highly related to the development of IoT technologies. In the process of scenario element identification, a total of 129 sentences were selected and extracted as scenario-oriented information for identifying the components of scenario elements in terms of 5W1H.

Table 6.6 List of documents

Code Number	Author (Year)	Document Title	Source
D1	CISCO (2013)	"Connections Counter: The Internet of Everything in Motion"	Electronic source (i.e. online article)
D2	Adler (2013)	"Here's Why 'The Internet Of Things' Will Be Huge, And Drive Tremendous Value For People And Businesses"	Electronic source (i.e. online article)
D3	Stamford (2013)	"Gartner Says the Internet of Things Installed Base Will Grow to 26 Billion Units By 2020"	Electronic source (i.e. online article)
D4	ABI Research (2013)	"More Than 30 Billion Devices Will Wirelessly Connect to the Internet of Everything in 2020"	Electronic source (i.e. online article)
D5	ABI Research (N/A)	"Internet of Everything"	Electronic source (i.e. online article)
D6	Chamberlin (2013)	"28 Internet of Things (IoT) Trends and Prediction Articles for 2013"	Electronic source (i.e. online article)
D7	Smith (2012)	"M2M and Semi at the Core of The Internet of Things"	Electronic source (i.e. online article)
D8	Bradley et al. (2013)	"Embracing the Internet of Everything To Capture Your Share of $14.4 Trillion"	Electronic source (i.e. online article)
D9	Gubbi et al. (2013)	"Internet of Things (IoT): A vision, architectural elements, and future directions"	Electronic source (i.e. online journal paper)
D10	Ziegler et al. (2013)	"IoT6 – Moving to an IPv6-Based Future IoT"	Electronic source (i.e. online journal paper)
D11	Allmendinger (2012)	"Opportunities: Back To The Future – IoT & Smart Systems Evolution Challenges"	Electronic source (i.e. online article)
D12	Karimi and Atkinson (2013)	"What the Internet of Things (IoT) Needs to Become a Reality"	Electronic source (i.e. online white paper)
D13	Xing and Zhong (2010)	"Internet of things and its future"	Electronic source (i.e. online report)
D14	Forrester Consulting (2012)	"Building Value from Visibility"	Electronic source (i.e. online report)
D15	International Telecommunication Union, ITU (2005)	"ITU Internet Reports 2005: The Internet of Things"	Electronic source (i.e. online report)

In the process of generating scenario narratives, a total of 129 scenario narrative tags were generated to support the development of scenario-based roadmapping.

In the process of implementing scenario-based roadmapping, an information-driven roadmap about the future development of IoT technologies based on 10 years (i.e. 2014-2023) was generated by using the scenario narrative tags, as shown in Figure 6.11.

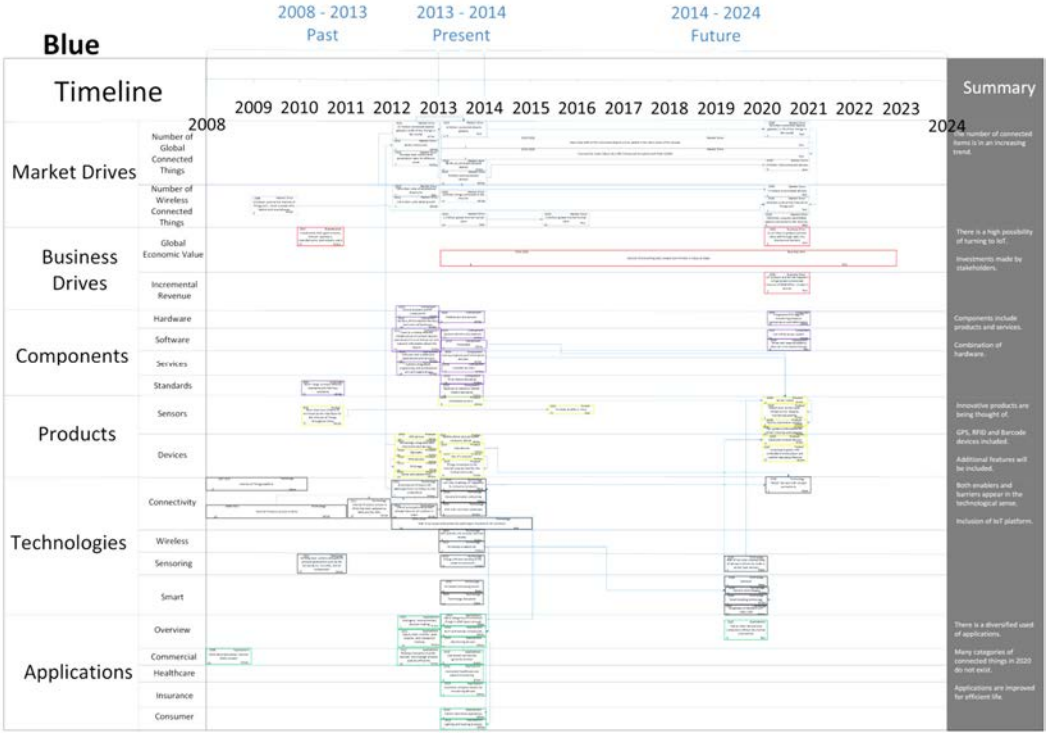


Figure 6.13 An information-driven roadmap about future development of IoT technologies based on 10 years (i.e. 2014 – 2023)

As shown in Figure 6.11, a total of 94 scenario narrative tags were selected to develop a scenario-based roadmap that includes 26 white tags, 18 red tags, 27 yellow tags, seven black tags and 16 green tags. The utilization rate of scenario narrative tags in terms of hard facts (i.e. white), emotions (i.e. red), enablers (i.e.

yellow), barriers (i.e. black) as well as possible solutions and new ideas (i.e. green) was 27.7%, 19.2%, 28.7%, 7.5% and 17%, respectively.

For evaluating the performance of the IDSB method, the Operation Director of the target company was invited to complete the feedback form. The result of the feedback from the company is shown in Table 6.7.

Table 6.7 Feedback results 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 analysis of technological trend.	Agree
9. The proposed method is helpful for strategic planning and forecasting.	Strongly agree
10. You will encourage others to apply the proposed method for strategic planning and forecasting.	Strongly agree

The company expressed that the results of the study were useful and practical for the companies to provide fresh insights for strategic planning and forecasting of IoT technologies development from an outside-in perspective. As compared with the existing method they used, the company made positive comments about the

proposed methodology which is relatively effective and easy to use. Especially, the results of the validation provided a quick view on what others had already done and vice versa and they may initiate the follow-up actions effectively after the completion of the roadmapping. Moreover, the director mentioned that the IDSB method is useful to implement roadmapping easily by using scenario narrative tags. The proposed method also facilitates them to think of some new ideas that they hadn't thought of before. Insights are also provided to the results and the company would use the roadmap outcome in the future. Last but not least, the proposed IDSB method not only allows the company to externalize their insight of the future for strategic planning and forecasting as a one-off task, but also encourages them to keep updating the roadmap in the future.

6.3 Summary

This chapter presented two case studies to demonstrate the capability of the MSBRM and IDSB methods. The case studies were carried out to implement the proposed MSBRM and IDSB methods in Testing, Inspection and Certification (TIC) as well as Information and Communication Technology (ICT) companies, respectively. Encouraging results and positive comments have been obtained in these two case studies. They show that the users are satisfied with the proposed MSBRM and IDSB methods and the results. Moreover, they agreed that the

proposed methods can facilitate the process of strategic planning and technology forecasting, as compared with the traditional methods.

Chapter 7

Overall Conclusion

Nowadays, various companies pay great 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 over the past 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 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 did not embed scenarios into a roadmap or evaluate 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 present study presents a multi-perspective scenario-based roadmapping (MSBRM) method as an effective tool for strategic planning and technology forecasting by combining scenario planning with roadmapping approaches. The proposed MSBRM method provides companies a practical multi-perspective 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. The proposed MSBRM 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 MSBRM 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 MSBRM method was implemented in a Global Testing, Inspection and Certification (TIC) company to realize its capability. The target company

attempted to expand its 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 the 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 MSBRM 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.

By incorporating business information into the strategic planning and forecasting process, the proposed information-driven scenario building (IDSB) method was purposely designed and developed as an information-driven scenario building tool for organizations to facilitate the development process of scenario-based roadmapping. The proposed IDSB method provides companies a practical scenario building process to collect scenario-oriented information, identify scenario elements in terms of 5W1H and generate scenario narratives to develop information-driven roadmaps.

The proposed IDSB consists of five main phases, namely information acquisition (Phase 1), metadata construction (Phase 2), keyword extraction (Phase 3), scenario

element identification (Phase 4), and scenario narrative generation (Phase 5). The proposed IDSB method was implemented in an Information and Communication Technology (ICT) company to realize its capability. A total of 15 documents related to IoT technologies were selected for identification of scenario elements and generation of scenario narratives. By using the IDSB method, the information-driven scenario-based roadmap about the future development of IoT technologies in the next 10 years was generated by 94 scenario narrative tags (i.e. six white tags, 18 red tags, 27 yellow tags, seven black tags and 16 green tags) for strategic planning and technology forecasting. As compared with the existing methods it used for strategic planning and technology forecasting, the company made positive comments about the proposed IDSB method which not only allows the company to externalize insights of future technological trend, but also have a better understanding of the future scenarios for strategic planning and technology forecasting.

Chapter 8

Suggestions for Further Research

To maximize the benefits of scenario-based roadmapping, some suggestions for further research are made in this chapter, which are related to the pre-process, process and post-processing of the proposed multi-perspective scenario-based roadmapping (MSBRM) and information-driven scenario building (IDSB) methods.

8.1 Intelligence-based Roadmapping for Outcome Evaluation of a Scenario-based Roadmap

An intelligence-based roadmapping (iBRM) method is suggested to evaluate the outcomes of the organizational scenario-based roadmap generated by the proposed MSBRM method. By incorporating various intelligences (i.e. market, business, competitive and technology) into the process of strategic planning and decision making, the iBRM method was designed and developed as a post-process of the MSBRM method for organizations to evaluate the credibility of the organizational scenario-based roadmap generated in the MSBRM activity. The suggested process of the proposed iBRM method may consist of four main phases including

intelligence collection (Phase 1), bibliometric analysis (Phase 2), intelligence map generation (Phase 3), and performance evaluation of scenario-based roadmap(s) (Phase 4). The expected outcome is intelligence map(s) that can be used to evaluate the outcome of organizational roadmap(s) generated by the MSBRM method.

To be precise, the action plan of the scenario-based roadmap is required to be validated by external intelligence through search engine, patent and publication databases to see whether the similar ideas of solutions/applications/services/ technologies were advanced by someone (i.e. competitor). If a similar idea is found, the detail of the similar idea is collected for validation purposes. On completion of the iBRM, the results of external technology intelligence are generated for validation of the preliminary and organizational inside-out roadmap.

8.2 Facilitating scenario-based roadmapping process

By leveraging information and communication technologies (ICT), it is suggested to develop a software tool for facilitating the scenario-based roadmapping process, in order to generating well-structured scenarios in digital format as the expected outcome. In the process of scenario building, the participants can build the possible scenarios (i.e. positive and negative) as well as identify scenario elements (i.e. what, who, when, where, why and how) digitally by using a software tool that has functions of inputting, editing and generating the scenarios. The tool can provide

real-time guidance to assist the participants how to generate scenarios in order to guarantee the quality of scenarios. Also the tool can help to capture the narratives of the scenario automatically in terms of 5W1H, in order to build a scenario narrative pool. In the process of scenario assessment, the tool can help to check the completeness and consistency of the scenarios. In the process of roadmapping, the tool can help to develop digital roadmaps easily based on the scenarios.

8.3 Computational information-driven scenario building method

A computational information-driven scenario building method is suggested to designed and developed for distinguishing scenario elements from scenario-oriented information in order to generating various scenario narratives systematically, according to the framework of the proposed IDSB method. By utilization of scenario narratives, a number of possible future scenarios can be generated automatically. This not only allows organizations to save time and effort to generate scenario narratives, but it also help organizations to generate a number of possible scenarios computationally.

The development of the integrated platform will enhance the automation of technology assessment processes which will not only save time and manpower resources but also enable an organization to keep pace with the knowledge cycle in technology innovation and compare itself with other organizations in the

industry. This is particularly important when managing R&D activities and strategic planning for technology management so that the enterprises can remain competitive in the global market.

8.4 Applications in other industries

In the present study, the proposed MSBRM and IDSB methods were implemented in two case studies at Testing, Inspection and Certification (TIC) and Information and Communication Technology (ICT) organizations. In the other words, two proposed methods were studied in service-oriented industry and technology-intensive industry in Hong Kong, respectively. Since the proposed framework of these two methods were designed and developed as generic tools, they are suggested to be applied to other industries, especially manufacturing industry.

In the manufacturing industry, various practitioners (i.e. product designers, engineers and manufacturers) are paying increasingly attention to the concept of servitization in their product design, engineering and manufacturing activities. They are maintaining their competitive advantage due to the pressure of globalization and they are shifting their business models from selling products to selling a total solution (i.e. integrated product-services) (Dinges et al., 2015; Foresight, 2013; Neely, 2008; Wise and Baumgartner 1999). However, the process

of the existing servitization is still product-oriented, and ineffective to respond to user needs.

To address the key issues mentioned above, the proposed methods will be suggested to use as product-service tool for manufacturers to build possible future scenarios which aim to effectively respond to user needs, and facilitate a product-service process which targets to provide total solutions for consumers. It also provides manufacturers with insights into how they can have a better understanding of possible future scenarios with positive and negative impacts and implement proactive product-service solutions with action plans for future changes.

Appendices

Appendix A – Comparison of the existing scenario-based roadmapping approaches

Appendix B – Full list of part-of-speech (POS) tagging

Appendix C – List of non-alphanumeric tokens

Appendix D – Documents D1 and D2 used in experiment B

Appendix E – Definitions of CBTL, TMP, WMT, SMT and RMT

Appendix F – Full version of the guideline for scenario building

Appendix G – Full versions of the completed worksheets

Appendix A – Comparison of the existing scenario-based roadmapping approaches

Table A1 Comparison of the existing scenario-based roadmapping approaches

Method	Jovane (2003)	Strauss & Radnor (2004)	Pagani (2009)	Saritas & Aylen (2010)
Domain	Technology Foresight	Strategic Planning	Foresight	Foresight
Purpose	Future assessment	Corporate planning	Strategic Thinking	Policy & strategy making
Focus on	Alternative future	Alternative future	Alternative future	Alternative future
Level	National & Supranational	Organizational	Industrial	National
View of thinking	Macro view (i.e. macro thinking)	Micro view (i.e. micro planning)	Macro view (i.e. macro thinking)	Macro view (i.e. macro thinking)
Process				
Scenario building	×	○	○	○
Scenario assessment	×	×	○	×
Scenario selection	×	×	×	×
Roadmapping	×	×	×	×
Integration of scenarios in a roadmap	×	○	×	×
Outcome				
Scenario	• Macro level • Multiple • Qualitative	• Micro level • Multiple • Qualitative	• Macro level • Multiple • Quantitative	• Macro level • Multiple • Quantitative
Scenario-based roadmap	N/A	• Strategic & operational level • Multiple	N/A	N/A

Table A2 Comparison of the existing scenario-based roadmapping approaches (Cont'd)

Method	Kajikawa et al. (2011)	Hey (2012)	Thorleuchter et al. (2012)	Geum et al. (2014)
Domain	Foresight	Foresight	Emergency Management	Scenario Planning
Purpose	Risk assessment & management	Impact assessment	Emergency management	Long-term planning
Focus on	Risk & uncertainty	Impact of future	Alternative future	Alternative future
Level	National	National	National	National
View of thinking	Macro view (i.e. macro thinking)	Macro view (i.e. macro thinking)	Macro view (i.e. macro thinking)	Macro view (i.e. macro thinking)
Process				
Scenario building	×	×	×	×
Scenario assessment	×	×	○	○
Scenario selection	×	×	×	×
Roadmapping	×	×	×	○
Integration of scenarios in a roadmap	×	×	×	×
Outcome				
Scenario	N/A	N/A	N/A	N/A
Scenario-based roadmap	N/A	N/A	N/A	N/A

Table A3 Comparison of the existing scenario-based roadmapping approaches (Cont'd)

Method	Cagnin and Könnölä (2014)	Kikuchi et al. (2014)	Lee et al. (2015a)	Amer et al. (2016)
Domain	Foresight	Foresight	Strategic Planning	Strategic Planning
Purpose	Future studies	Technology development	Technology planning	Future studies
Focus on	Alternative future	Alternative technology	Impact assessment	Alternative future
Level	National	National	Organizational	National
View of thinking	Macro view (i.e. macro thinking)	Macro view (i.e. macro thinking)	Micro view (i.e. micro planning)	Macro view (i.e. macro thinking)
Process				
Scenario building	○	○	×	○
Scenario assessment	○	×	×	○
Scenario selection	×	×	×	○
Roadmapping	○	×	○	○
Integration of scenarios in a roadmap	×	×	×	○
Outcome				
Scenario	• Macro level • Multiple • Qualitative	• Macro level • Multiple • Quantitative	N/A	• Macro level • Multiple • Qualitative
Scenario-based roadmap	N/A	N/A	N/A	• Strategic level • Multiple

Appendix B – Full list of part-of-speech (POS) tagging

(Source: Santorini, B. (1990), 'Part-of-Speech Tagging Guidelines for the Penn Treebank Project', Retrieved on 25 August, 2016 from https://catalog.ldc.upenn.edu/docs/LDC99T42/tagguid1.pdf.)

Number	Tagger Code	Description
1	CC	Coordinating conjunction
2	CD	Cardinal number
3	DT	Determiner
4	EX	Existential there
5	FW	Foreign word
6	IN	Preposition or subordinating conjunction
7	JJ	Adjective
8	JJR	Adjective, comparative
9	JJS	Adjective, superlative
10	LS	List item marker
11	MD	Modal
12	NN	Noun, singular or mass
13	NNS	Noun, plural
14	NNP	Proper noun, singular
15	NNPS	Proper noun, plural
16	PDT	Predeterminer
17	POS	Possessive ending
18	PRP	Personal pronoun
19	PRP$	Possessive pronoun
20	RB	Adverb
21	RBR	Adverb, comparative
22	RBS	Adverb, superlative
23	RP	Particle
24	SYM	Symbol
25	TO	To
26	UH	Interjection
27	VB	Verb, base form
28	VBD	Verb, past tense
29	VBG	Verb, gerund or present participle
30	VBN	Verb, past participle
31	VBP	Verb, non-3rd person singular present

32	VBZ	Verb, 3rd person singular present
33	WDT	Wh-determiner
34	WP	Wh-pronoun
35	WP$	Possessive wh-pronoun
36	WRB	Wh-adverb

Appendix C - List of non-alphanumeric tokens

(Adapted from LLNL, 2007)

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Appendix D – Documents D1 and D2 used in experiment B

Table D1 Extracted sentences in Document D1 (HKTDC, 2015)

Code Number	Extracted sentence
S1	Hong Kong's testing and certification industry has grown substantially since the 1980s.
S2	The industry is comprised of about 700 establishments, most of which were private laboratories, employing a total of some 17,000 people.
S3	The industry provides testing and inspection services for consumer products manufactured in the Pearl River Delta for overseas buyers, and certification services for such products as well as for the relevant quality management systems.
S4	The industry has been identified as one of the industries which Hong Kong has clear advantage.
S5	The Hong Kong Council for Testing and Certification has been established to enhance the professional standards and recognition of Hong Kong's testing and certification services in the international arena.
S6	Given a robust accreditation system and a good international reputation, Hong Kong is well positioned to act as an independent third party to provide quality certification and product testing services for mainland enterprises to boost the confidence of overseas and local buyers.
S7	The industry provides a high volume of testing and inspection services for consumer products manufactured in the Pearl River Delta, such as toys and children's products, electrical and electronic goods, and textiles and garments upon the requests of overseas buyers.
S8	Many laboratories and certification bodies in Hong Kong are accredited.
S9	The Hong Kong Accreditation Service (HKAS) under the Innovation and Technology Commission (ITC) provides accreditation service for laboratories, certification bodies and inspection bodies through the Hong Kong Laboratory Accreditation Scheme (HOKLAS), Hong Kong Certification Body Accreditation Scheme (HKCAS) and Hong Kong Inspection Body Accreditation Scheme (HKIAS).
S10	As of August 2015, there were 208 accredited laboratories/ proficiency testing providers/reference material producers, 23 accredited certification bodies and 20 accredited inspection bodies in Hong Kong.
S11	Private laboratories now seek accreditation on a voluntary basis, but they are strongly encouraged to do so, as testing, certification and inspection services

	accredited by the local accreditation bodies are widely recognized in overseas markets.
S12	Hong Kong, as an international trade centre situated strategically at the door of the huge and rapidly growing mainland market, has potential to develop into a major product testing and certification centre in the region.
S13	By acting as an independent third party in providing services to mainland enterprises, it could help safeguard consumer interests, build up the Hong Kong brand, enhance the competitiveness of local and mainland products in the world market, and create high-end employment opportunities for professionals and skilled-workers.
S14	Establishing Hong Kong as a testing and certification centre is in line with the objective of upgrading the Pearl River Delta into "a world-class base for advanced manufacturing industries", as set out in the National Development and Reform Commission's Outline of the Plan for the Reform and Development of the Pearl River Delta (2008-2020).
S15	However, the local industry will have to compete with international brands, such as ITS, SGS and TUV, which have already set up operations in many parts of the mainland to provide service at a cost lower than the Hong Kong service providers.
S16	In 2008, the Task Force on Economic Challenges identified the testing and certification industry as one of the industries which Hong Kong has clear advantage, considering that this industry could benefit the economy in the medium and long term.
S17	The government has then established the Hong Kong Council for Testing and Certification (HKCTC) to drive the development of the industry, to raise its professional standards and to enhance the recognition of the industry in the international arena by building up a brand name for Hong Kong's testing and certification services.
S18	Both the Hong Kong Productivity Council (HKPC) and the Hong Kong Science and Technology Parks Corporation (Science Park) have laboratory facilities available for use by private testing laboratories.
S19	Examples include HKPC's special chamber for testing of electromagnetic compatibility and Science Park's equipment for testing LED lightings.
S20	By making use of these facilities, testing laboratories will not need to make a huge investment on equipment if their business volume for particular tests is not high.
S21	As the general public is putting increasing emphasis on environmental protection, there will be more tests related to the "green" elements of consumer products manufactured on the mainland as well as those for environmental samples in Hong Kong.

S22	On the other hand, given the wider adaptation of ICT nowadays, there will be opportunities for further development of testing and certification services in this trade, such as third-party software testing and a software product certification scheme.
S23	Under the Supplement VII and VIII to CEPA, testing organisations in Hong Kong are allowed to co-operate with designated mainland certification bodies to undertake product testing for the China Compulsory Certification (CCC) System for all existing products processed in Hong Kong that require CCC.
S24	These testing organizations have to be accredited by Hong Kong Accreditation Service to be capable of performing testing for the relevant products under the CCC System.
S25	Under the Supplement IX to CEPA, on a pilot basis in Guangdong Province, the scope of certification services that can be undertaken by Hong Kong testing organizations has extended to cover food.
S26	Besides, testing and certification organizations in Hong Kong are allowed to cooperate with the mainland testing and certification organizations in respect of acceptance of testing data (results).

Table D2 Extracted sentences in Document D2 (HKPC, 2014)

Code Number	**Extracted sentence**
S1	Testing and Certification (T&C) is an economic area where Hong Kong enjoys clear advantages.
S2	With its high level of integrity and credibility, an internationally recognized accreditation system, high technical competence, and its close geographical proximity to Mainland China, Hong Kong's T&C industry is well-positioned to use its competitive advantages to maximize its promising development potential.
S3	A thriving T&C industry is essential to support Hong Kong's manufacturing and trading industries, and contributes to the development of the city as a business services centre.
S4	The T&C industry also plays an integral role in both the local and regional economies.
S5	To drive the development of the T&C industry, the Hong Kong SAR Government has set up the Hong Kong Council for Testing and Certification (HKCTC).
S6	The Council has formulated a market-oriented development plan and selected a number of trades that have good opportunities to promote the use of T&C services.

S7	Given today's rapidly changing global business environment, vigorous development of technology and quickly-evolving standards and regulations, new development opportunities are swiftly opening up for the local T&C industry.
S8	However, the availability of an open platform for exploring new T&C business opportunities between T&C service providers and potential users of various business sectors is limited.
S9	Therefore, we recommend extending the business network across sectors and regions by arranging periodic business matching or networking sessions in Hong Kong, as well as exploring opportunities to strengthen business relationships with peers and users on the Mainland, and identifying ways to achieve sustainable growth in the T&C industry in both regions.
S10	To suit the evolving need of T&C practitioners to acquire new and advanced T&C knowledge and skills, we recommend raising the profile and maximizing the support of existing training assistance schemes, such as the New Technology Training Scheme (NTTS), among T&C practitioners.
S11	The development of new international standards is also crucial to the industry, as this introduces new solutions to meet the industry's emerging needs.
S12	We recommend encouraging practitioners to participate in the development of international standards through support schemes and exploring the possibility of hosting international seminars and conferences with regard to standardization in Hong Kong.
S13	Currently, various government departments and public bodies organize numerous learning events for T&C practitioners in various locations.
S14	In order to provide a centralized knowledge transfer focal point to help practitioners conveniently acquire skills and knowledge, we recommend establishing a one-stop centralized knowledge transfer platform for T&C practitioners to synergize the benefits of knowledge accumulated through different channels and local institutions.
S15	Testing and certification industry provides testing, inspection and certification services in general.
S16	The T&C industry has over 50 years of history in Hong Kong, developing under the voluntary regime of standards and certification that in general models on many other advanced economies.
S17	In its early years, the industry focused mainly on providing services for the manufacturing industry in Hong Kong.
S18	At present, the major economic activities of the T&C industry are technical testing and analysis; cargo inspection, sampling and weighting; and medical and X-ray laboratory services.2

S19	Employing a large number of professionally trained staff, the T&C industry has, on average, been able to achieve a relatively high profit margin.
S20	In 2012, the industry employed 12,780 people and contributed about HK$5.8 billion (0.3%) to Hong Kong's Gross Domestic Product (GDP).3, 4
S21	The total business receipts of private independent T&C companies amounted to a total of HK$10.9 billion in 2012, recording an increase of about 27% compared to 2009 (approx. HK$8.6 billion).5
S22	Globally, two major factors have contributed to a positive outlook for the T&C industry: compliance risks due to ever-increasing regulatory requirements around the world and increasing public awareness of corporate social responsibility.
S23	In recent years, several large international markets, such as the European Union and the United States, have strengthened regulatory controls and extended producer responsibilities in numerous areas, product safety and environmental aspects being just two examples.
S24	Many other countries and regions, including the Mainland, have also introduced their own regulations or surveillance schemes to monitor product stewardship.
S25	To demonstrate their compliance with these requirements to buyers, consumers or government authorities, producers often need to conduct certain testing or obtain third party certification or assurance.
S26	Thus, T&C services are becoming increasingly important across the supply chain, especially for companies which export products to international markets.
S27	Many companies are motivated to go even beyond regulatory compliance in pursuit of improving their corporate social responsibility, and choose to comply with voluntary industry standards such as ENERGY STAR and ISO standards.
S28	With the international situation creating continuous momentum and numerous T&C opportunities, the industry has experienced the significant growth during 1997-2012 with a CAGR (Compounded Annual Growth Rate) of 5-6 percent and is expected to keep developing at this speed in the coming year.
S29	It was also estimated that the value of the global T&C market had reached approximately US$113.1 billion (approx. HK$880 billion) in 2010.6
S30	Besides benefiting from the trends in international and domestic markets, the T&C industry in Hong Kong also has a number of competitive advantages that have contributed to the development of the industry:
S31	Hong Kong hosts the base for many international T&C organizations in the Asia-Pacific region.
S32	The Hong Kong T&C industry has a long history of adopting global best practices and accessing the knowledge and experience of international markets.

S33	The professional expertise and services of the local T&C industry are well recognized both domestically and internationally.
S34	Our geographical and cultural proximity to the Pearl River Delta allows Hong Kong to provide T&C services to the Mainland manufacturing industries, also known as "the Workshop of the World".7
S35	Having robust accreditation management systems that are in line with international conventions and norms enhances the Hong Kong T&C industry's credibility against competitors in the region.
S36	Under multilateral recognition arrangements,8 conformity assessment results issued by accredited establishments in Hong Kong are recognized by 86 mutual recognition arrangement partners in 68 economies.9
S37	Consisting of professionals with a high level of integrity, credibility, technical and linguistic competence, particularly crucial to the knowledge-based sector, the T&C industry in Hong Kong is able to stay competitive and thrive in the global market.
S38	The potential of the T&C industry in Hong Kong was first identified by the Hong Kong SAR Government in the new millennium, when Hong Kong was still suffering the effects of the global economic downturn.
S39	It was the government's belief that, in addition to consolidating core industries, new industries must also be explored.
S40	In 2009, the Task Force on Economic Challenges identified the Testing and Certification industry as one of six industries that enjoy clear advantages and have potential for further development; stating that Hong Kong had the potential to develop into a major regional product T&C centre.10
S41	HKCTC was established in the same year to drive the development of the industry, raise the professional standards and enhance the recognition of the industry in the international arena.11
S42	HKCTC also formulated a three-year market-driven industry development plan to promote the development of the industry.
S43	According to the Supplement VII to X of the Mainland and Hong Kong Closer Economic Partnership Arrangement (CEPA), trade liberalization measures are introduced for local industries, including T&C sector.
S44	Accredited testing organizations in Hong Kong can perform testing services for the purpose of food and other voluntary product certification for Guangdong on a pilot basis,13 and perform product testing for the China Compulsory Certification (CCC) System for all existing products processed in Hong Kong which require CCC.14
S45	The continuous opening of the China market may present more business prospects for T&C service providers in Hong Kong.

S46	In light of a positive global market outlook, Hong Kong's local competitive advantages and the government's recent initiatives to develop the industry, this study was conducted to help the T&C industry in Hong Kong identify a number of mainstream trends which may bring significant development potential to the industry.
S47	Over and above the efforts made by the Hong Kong SAR Government to aid the development of the T&C industry, further support and business opportunities may be created by building synergy with local research and educational institutions and by establishing T&C industry partnership with other sectors.
S48	Such synergy and cooperation will fuel the overall development of Hong Kong's T&C capacity.
S49	This study has identified two feasible strategies to speed up the growth of the T&C industry: Strengthening business development; and Enhancing professional development.
S50	As part of the Government's initiatives, different funding schemes, such as the Innovation and Technology Fund (ITF) and the Research and Development (R&D) Cash Rebate Scheme, are now available to local T&C service providers to help them build business capacity.
S51	A total funding amount of nearly HK$20 million has been granted to support research and development of new testing technologies.67
S52	A range of promotional approaches, including seminars, forums, trade fairs are also available to T&C service providers for enriching their business opportunities.
S53	In addition to the above initiatives, the following three focus areas can be further strengthened to help enhance the medium- to long-term business development of local T&C industry: Building Joint Expertise Among Testing Facilities of Local Institutions, Extending Business Network Across Sectors and Regions, Providing Incentives and Recognition
S54	In Hong Kong, there are a number of research and educational institutions which specialize in various aspects of technical expertise and provide a variety of testing facilities.
S55	In view of the growth in market demand and the implementation of the Mainland and Hong Kong Closer Economic Partnership Arrangement (CEPA), local T&C service providers may make use of the resources and knowledge from the single channel to strengthen their capability to provide additional T&C services, such as testing for the China Compulsory Certification (CCC) System.
S56	The government has been promoting the cooperation between the Mainland and Hong Kong on T&C through various channels, including CEPA.

S57	According to the Supplement VII to CEPA, the Mainland has been gradually opening up its market to Hong Kong testing organizations.
S58	Several Hong Kong testing organizations have also reached agreement with Mainland certification bodies to undertake testing under CCC for products processed in Hong Kong.
S59	With trade continuing to be liberalized under CEPA, more and more business opportunities in the Mainland are being presented to Hong Kong's T&C industry.
S60	To accelerate cross-border collaboration on T&C services between Guangdong and Hong Kong, we recommend that the local T&C industry proactively explores opportunities to strengthen their business relationships with peers and users on the Mainland, and jointly identifies ways to achieve sustainable growth of the T&C industry in the two regions.
S61	Despite the fact that third-party certification can provide added value and commercial advantages to companies, the extra cost of certification and the intensive manpower involved often deters companies from seeking newly launched certification schemes.
S62	In Hong Kong, there are a number of government funding schemes which provide support to encourage the use of T&C services.
S63	For example, the Innovation and Technology Fund (ITF) encourages enterprises in developing new T&C technology, whereas the SME Development Fund (SDF) offers funding support to SMEs in applying new T&C services.
S64	We recommend assessing the potentials to enhance these existing funding schemes and make them prominent to the public so that companies, especially the SMEs, can utilize T&C services to seek and achieve newly launched certifications accredited under the Hong Kong Certification Body Accreditation Scheme (HKCAS).
S65	The impact is expected to be long-term, since companies will increase their market competitiveness through T&C services and likely renew their certification after the initial cycle.
S66	Meanwhile, local T&C service providers will also gain access to a broader range of business opportunities.
S67	In recent years, the Government has committed to both recruiting "fresh blood" to the T&C industry and enhancing the skills of existing practitioners.
S68	Learning programmes and courses geared towards nurturing future talent have been arranged by different organizations, including the Vocational Training Council (VTC) and local universities.
S69	Technical seminars and short courses have also been arranged for existing practitioners to enhance their professionalism and capabilities.

S70	Under the New Technology Training Scheme (NTTS), practitioners can obtain funding support to attend training in new technology pertinent to their business.
S71	Furthermore, under the Qualifications Framework (QF) being introduced for the T&C industry, the Specification of Competency Standards (SCS) is under development, aiming to map out the development pathways along which practitioners can progress along their career ladders.69
S72	While the industry has responded positively and welcomed these initiatives, there are concerns about whether existing initiatives for practitioners will be able to cope with the growing demands from the market.
S73	These demands, which range from more overseas exposure to expanded support for new T&C services, have yet to be addressed.
S74	In view of the above, the enhancement of T&C professional development could focus on the following three areas: Developing T&C Professionalism through Maximizing the Support of Existing Training Assistance Platforms, Encouraging Practitioners' Participation in the Development of International Standards, Establishing a One-stop Centralized Knowledge Transfer Platform for T&C Practitioners.
S75	At present, local employers wishing to acquire new technology for commercial applications and persons sponsored by their employers to attend relevant training sessions are able to apply for sponsorship and receive certain training grants, such as the NTTS scheme.
S76	In 2010-2011, T&C-related subjects such as ISO 14064 Carbon Auditor Training were listed among the top ten NTTS subsidized training courses.
S77	We recommend seeking ways to raise the profile and maximizing the support of the existing training assistance schemes in order to suit the evolving training needs of T&C practitioners.
S78	For example, to identify funding opportunities within the existing schemes' structure to assist practitioners to attend local or overseas training courses and conferences which are related to new T&C content yet to be widely applied in Hong Kong.
S79	Furthermore, funding support could be given for courses and conferences that are in line with the Qualifications Framework and the Specification of Competency Standards to facilitate professionalism development within the T&C industry.
S80	The development of new international standards is crucial to the industry, as this introduces new solutions to meet the industry's emerging needs.
S81	New international standards are usually developed by technical committees from different organizations such as the ISO (International Organization for Standardization) and the IEC (International Electrotechnical Commission).

S82	These committees are made up of qualified representatives from industry stakeholders such as research institutes, government authorities, consumer bodies and international organizations.
S83	In Hong Kong, the Product Standards Information Bureau (PSIB), under the Innovation and Technology Commission (ITC) is the authorized representative which encourages interested parties to take part in standards development.
S84	The PSIB also represents Hong Kong in different international standards organizations.
S85	We recommend seeking opportunities to facilitate and encourage T&C practitioners to participate in the development of international standardization.
S86	One of these opportunities would be to assist T&C practitioners to participate in meetings and processes for the international standards development.
S87	HKCTC, HKAS and other Government departments and public bodies have been actively organizing learning and technical events at which T&C practitioners can enhance their capabilities and absorb new skills.
S88	Between 2009 and 2013, over 260 technical seminars and training events have been delivered by the aforementioned organizations.70
S89	While there are numerous types of events organized in various locations, a one-stop centralized knowledge transfer focal point would be helpful to allow T&C practitioners to benefit from knowledge accumulated through different channels.
S90	In view of the above, we recommend exploring the feasibility of establishing a one stop centralized platform which helps practitioners conveniently acquire the necessary knowledge and skills to carry out T&C services.
S91	The capacity of this knowledge transfer platform could also be further enhanced by leveraging resources and through the joint efforts of different research, training and educational institutions in Hong Kong.
S92	In order to empower the Hong Kong T&C Industry, WE RECOMMEND Strengthening business development by Building joint expertise among testing facilities of local institutions to further enhance the scope of T&C service capacity and provide a “one-stop shop” solution for the industries; Extending business network across sectors and regions by arranging periodic business matching or networking sessions in Hong Kong as well as exploring opportunities to strengthen their business relationships with peers and users on the Mainland, and identify ways to achieve sustainable growth of the T&C industry in the two regions; and Providing incentives and recognition which directly benefit businesses that actively achieve newly-launched certifications and utilize T&C to gain market competitiveness; by offering both economic incentives and high profile recognitions such as an award scheme.

S93	WE ALSO RECOMMEND Enhancing professional development by Developing T&C professionalism through maximizing the support of existing training assistance platforms to suit the evolving needs of T&C practitioners; Encouraging practitioners' participation in the development of international standards through support schemes, as well as exploring the possibility to host international seminars and conferences with regard to standardization in Hong Kong; and Establishing a one-stop centralized knowledge transfer platform for T&C practitioners to synergize benefits from knowledge accumulated through different channels and a range of local institutions.

Appendix E – Definitions of CBTL, TMP, WMT, SMT and RMT

Table E1 Definitions of CBTL, TMP, WMT, SMT and RMT (Adapted from IEC, 2007)

Terms	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."

Appendix F – Full version of the guideline for scenario building

Scenario Building Worksheet

Title: Strategic Planning and Forecasting on Manufacturers' Test Laboratories Programme in the TIC industry out to 10-year horizon (i.e. 2014 - 2024)

(A) Introduction

Nowadays, establishment of manufacturers' test laboratories is a future trend in Mainland China. Many Testing, Inspection and Certification (TIC) companies realize this trend provides great opportunities for expanding their business into China market. Our company also have fully intention of providing various services to assist product manufacturers establishing their own test laboratories following the procedures developed by the International Electrotechnical Commission (IEC), especially for these three procedures of the programme (i.e. Testing at Manufacturer's Premises (TMP), Witnessed Manufacturer's Testing (WMT) and Recognized Manufacturer's Testing (RMT)). Currently, our company would explore what the future scenarios about the establishment of manufacturers' test laboratories in Mainland China, A scenario-based roadmapping method is applied for strategic planning and forecasting on manufacturers' test laboratories programme in the TIC industry out to 10-year horizon (i.e. 2014 - 2024).

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' Test 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 test 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. The descriptions of CBTL, TMP, WMT, SMT and RMT are illustrated in Table 1 (adapted from IEC, 2007), that include: -

1

- 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

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."

2

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.

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

3

(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 W's and one H or 5W1H). The directions of the questions are shown as follows: -
   - **What** is a 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 of 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)
   Blue hat thinking focuses on manage the thinking process, focus, 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 how to generate the 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 the future scenario are required to provide and the justifications are needed.
   (c) Emotions (red hat thinking)
   Red hat thinking focuses on feelings, hunches, gut instinct and intuition. It is used to interpret the intuitive information (i.e. future forecast) to support the future scenario, but no any 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 the future scenario (i.e. enablers or benefits).
   (e) Discernment (black hat thinking)
   Black hat thinking focuses on difficulties, potential problems, such as why something may not work. It is used to think about negative impacts of the future scenario (i.e. barriers or risks).

4

(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 W's and one H or 5W1H). The directions of the questions are shown as follows: -
   - **What** is a 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 of 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)
   Blue hat thinking focuses on manage the thinking process, focus, 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 how to generate the 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 the future scenario are required to provide and the justifications are needed.
   (c) Emotions (red hat thinking)
   Red hat thinking focuses on feelings, hunches, gut instinct and intuition. It is used to interpret the intuitive information (i.e. future forecast) to support the future scenario, but no any 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 the future scenario (i.e. enablers or benefits).
   (e) Discernment (black hat thinking)
   Black hat thinking focuses on difficulties, potential problems, such as why something may not work. It is used to think about negative impacts of the future scenario (i.e. barriers or risks).

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

(C) Questions for Building Future Scenario

(C1) Questions for Scenario Building of Positive Future Scenario

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

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

P3. When will the scenario be expected to happen in the future by 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 how to deal with the future change in this scenario?

P8. What resource may be allocated to support this scenario? *(Please also provide the justifications how the resource 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 the challenges or negative impacts to Hong Kong TIC industry in coming 10 years?

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

5

N3. When will the scenario be expected to happen in the future by 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 how to deal with the future change in this scenario?

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

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

6

Appendix G – Full versions of the completed worksheets

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	

(a)

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.	

(b)

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	

(c)

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.	

(d)

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.	

(e)

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.	

(f)

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