SYSTEM DESIGN TO INTEGRATE THE EVALUATION OF TECHNOLOGY ROADMAP STATUS INTO A WEB-BASED APPLICATION

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Patience, discipline and passion are the most critical characteristics to be successful in doing something. This thesis is a result of my learning and development under the above critical characteristics. It's hard to be confident to success when you know you are lacking either. But it’s harder if you don’t know how to find it to fulfill. I would like to express my sincere appreciation to my parents who are good examples for discipline in any activities they did. I noticed that the things they did systematically come from their patience and passion.

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การออกแบบเพื่อบูรณาการการประเมินสถานะของแผนที่นำทางการพัฒนาเทคโนโลยีเข้ากับเว็บแอพพลิเคชั่น

SYSTEM DESIGN TO INTEGRATE THE EVALUATION OF TECHNOLOGY ROADMAP STATUS INTO A WEB-BASED APPLICATION

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บทคัดย่อ

แผนที่นำทางการพัฒนาเทคโนโลยีเป็นกระบวนวิธีเชิงกลยุทธ์ที่เชื่อมโยงกลยุทธ์ทางธุรกิจและการพัฒนาเทคโนโลยีให้สอดคล้องกัน ประโยชน์ที่ได้จากการทำแผนที่นำทางนี้ จะช่วยสนับสนุนผู้บริหารในการตัดสินใจสำหรับการวางแผนและลงทุนทางด้านเทคโนโลยี ระบบตรวจสอบสถานะแผนที่นำทางจึงเป็นสิ่งที่สำคัญเพื่อใช้ในการทบทวนแผนที่นำทางซึ่งได้รับผลกระทบจากการเปลี่ยนแปลงของปัจจัยภายนอก นอกจากนี้ การพิจารณาถึงทางเลือกของแผนที่นำทางจะช่วยให้การนำไปใช้ สอดคล้องกับสภาพแวดล้อมทางธุรกิจจริงมากยิ่งขึ้น แม้ว่ารูปแบบการประเมินสถานะของแผนที่นำทางและการสร้างสถานการณ์ทางเลือกสำหรับแผนที่นำทางจะได้รับการศึกษาแล้วก็ตาม แต่ยังเป็นเพียงแค่แนวคิดเท่านั้น เพื่อให้แนวคิดดังกล่าวสามารถนำไปปฏิบัติได้จริงและสะดวกต่อการนำไปประยุกต์ใช้ จึงมีความจำเป็นที่จะต้องแปรสภาพให้อยู่ในรูปแบบที่สามารถดำเนินการได้

เพื่อช่วยให้ผู้บริหารตอบสนองต่อการเปลี่ยนปลงที่มีผลกระทบต่อแผนที่นำทางได้อย่างทันท่วงที งานวิจัยนี้ได้บูรณาการการวิเคราะห์สถานการณ์เข้ากับการประเมินสถานะแผนที่นำทางและแปรสภาพจากรูปแบบแนวคิดไปสู่ระบบประมวลผลในรูปของเว็บแอพพลิเคชั่น

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SYSTEM DESIGN TO INTEGRATE THE EVALUATION OF TECHNOLOGY ROADMAP STATUS INTO A WEB-BASED APPLICATION

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ABSTRACT

Technology Roadmapping (TRM) is the strategic approach to link between business strategy and the development of technologies. The key benefit of TRM is to help management enabling their decision making to support technology plan and investment. The monitoring system of a roadmap status is necessary in order to review a roadmap according to the effects of changes from external factors. Moreover, considering to options of a roadmap can help the use of a roadmap corresponding with actual business environments. Although, the evaluation model of TRM status signal and scenario building for a roadmap have been studied but they are still at the conceptual level. To enhance the practicality and the ease of use, more works are needed to turn it into an operationalizable form.

To help management respond to changes impacting their current roadmap in a timely manner, this research has integrate scenario analysis into the evaluation of a roadmap status and turn this conceptual model into an computerized system in a form of web-based application.

KEY WORDS: TECHNOLOGY ROADMAPPING / TRM / WEB-BASED APPLICATION / SYSTEM DESIGN / SCENARIO PLANNING

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CHAPTER I
INTRODUCTION

Currently, globalization has made business environment change rapidly and tend to be more complex. Every dimension of change such as social, technological, economic, environmental and political has an impact to business unavoidably. Therefore, adaptability becomes a big issue of business to improve its competitiveness.

In organization level, firms in various industries and various sizes try to develop capabilities that lead to competitive advantage. But those firms are affected by the above change, especially in technology and market. It is difficult to achieve sustainability under the uncontrollable factors. On the other hand, it is extremely challenging to find a strategic approach to managing uncertainty in accordance with the current status of the firm to achieve the sustainable competitiveness. To respond to changes in technological and market environment, a firm has to develop their technology plan as an integral part of their overall strategic plan (Porter, 1991). And the most critical challenges of today's organization are the development of a strategic plan linking business strategy, product development, technology and R&D activities (Scott, 2001). For the reasons mentioned above, the firm has necessary to know activity of key success drivers how they relate to opportunities, threats, customer needs, products and technology. Technology Roadmapping (TRM) is the answer of these linkage.

TRM has been widely used to visualize an organization's strategies by linking all critical components (i.e. external factors, internal factors and targets for development) together. The process of developing a technology roadmap can support a management team in formulating strategies and making decision. TRM also helps to consider how to select the right technologies for investment, and how to allocate scarce resources to support technology development (Nauda and Hall, 1991). A roadmap is the finished product of a roadmapping process. The finished roadmap addresses the fundamental management questions (i.e. what, why, how). The targets for development layer or focal point indicating *what* target the organization are aiming for. The external factors or requirements layer such as business drivers indicating *why* the organization is interested in this target. The internal factors or organizational capabilities layer indicating *how* the organization is going to achieve this target.

A roadmap is a snapshot of all critical components at the time of developing it. However, due to the rapid changes in business environments, the roadmap sometime doesn't reflect the changing situations after its development. Occasionally, the roadmap becomes obsolete. Therefore the management problem focusing in this research is on how to keep a roadmap alive. To prevent a roadmap from being obsolete, many organizations have scheduled a periodical review to identify the status of roadmap. However, what if the changes happen before the scheduled review period. If that is the case, then what should an organization do? Would it be a better case if an organization can constantly know the status of its roadmaps whether it is still valid? If so, an organization does not have to continue doing something not relevant anymore.

In the other side, if any business drivers change, a roadmap may not respond corresponding with actual business environments. Is there any other possible option for a roadmap? Would it be a better case if an organization can obviously know the options of a roadmap as a frame for consideration. This research tries to analyze the changes in key drivers or external factors of the roadmap. The analysis leads to the identification of the influencing drivers (key uncertainties), which is used in scenario analysis as input information to develop alternative roadmaps. The original roadmap is called a base case. The alternative roadmaps which obtained from scenario analysis can be separated into two main cases. The best-case scenario, a case which the key uncertainties lead to positive situations. On the other hand, the worst-case scenario is a case which the key uncertainties are negative or go against the objective of the roadmap.

To address the challenge of making the evaluation model for TRM status signal actually works as well as building options for the roadmap, this research has design a computerized system of the evaluation model to indicate the status of a roadmap in a form of web-based application to help management responding any change in the business environment in a timely manner and has analyze business driver change to identify influencing drivers from external factors to build scenarios of a base-case roadmap.

1.1 Research Rationale

The uncertainty is well known as a most critical obstacle of business operation. Many external factor analysis frameworks has been widely used especially technological factor which is an obvious key driver of business change. Linking these external factors together with internal factors of business for analysing to improve strategic plan is the main purpose of using TRM.

Technology Roadmapping (TRM) have been studied by several scholars (Bray & Garcia, 1997; Vatananan & Gerdsri, 2010; Fenwick, Daim & Gerdsri, 2009). But in attempting to address the issue of keeping a roadmap process alive, reviewing a roadmap is a key challenge for an organization (Strauss & Radnor, 2004; Kostoff & Schaller, 2001). The analytical approach for evaluating TRM status, which take into account the changes from external factors, is proposed (Vatananan & Gerdsri, 2011). However, their study was still at the conceptual and analytical level. Therefore, there is a room for bringing the proposed TRM status evaluation model into an operationalizable level or computerized it. So that in the future, the management team can constantly monitor changes and make any adjustment in a timely manner as needed. Moreover, if any business drivers change, a roadmap should be able to respond to current business environments immediately. Is there any other possible option for a roadmap built before business change?

The aim of this research to find out the conceptual framework integrating scenario analysis into the evaluation of a roadmap status from these two above focal points will lead to increasing efficiency for a roadmap. This is a truly high value added in using TRM as a strategic tool in uncertainty or risk management.

1.2 Research Objectives

To design the computerized system of the evaluation model for the status of a roadmap in a form of web-based application and analyse a roadmap according to different scenarios.

1.3 Research Questions

To complete the goal of turning the evaluation model into a web application prototype based on the evaluation model of status signal for a roadmap and scenario concept, this research questions are separated into two questions as follows;

1.3.1 What should be considered as the conceptual framework integrating scenario analysis into the evaluation of a roadmap status ?

1.3.2 How the proposed framework can be operationalized ?

1.4 Research Contribution

1.4.1 To integrate scenario analysis into the evaluation of a roadmap status.

1.4.2 To turn the integration of scenario analysis and the evaluation of a roadmap status into a web application.

1.5 Scope of Study

This study aims to designing a system based on System Development Life Cycle (SDLC) concept as shown in Figure 1.1. Integration of logical part (Evaluation model) and physical part (Web user interface) are the main parts in this research.

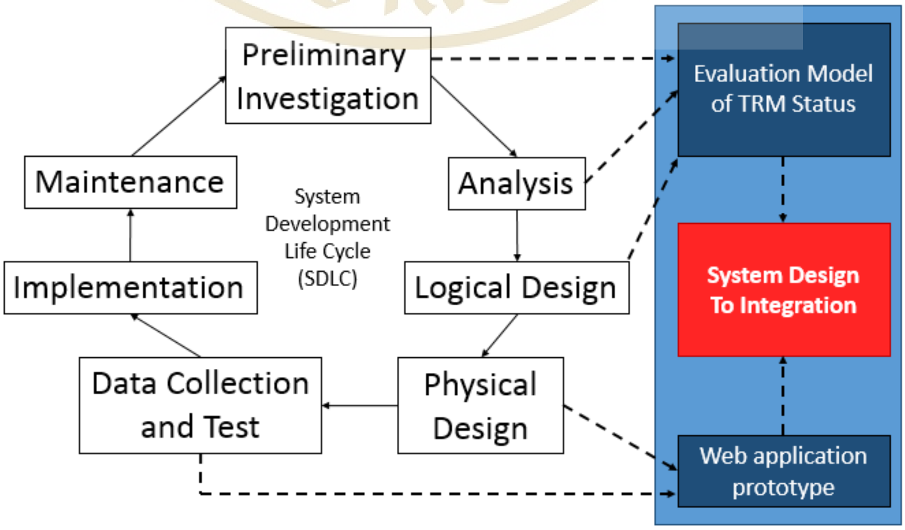


Figure 1.1 Scope of study related to System Development Life Cycle (SDLC)

This research will cover the knowledge area of

- Technology Roadmapping (TRM)
- Scenario-based Approach
- Analytical Approach
- System Analysis and Design

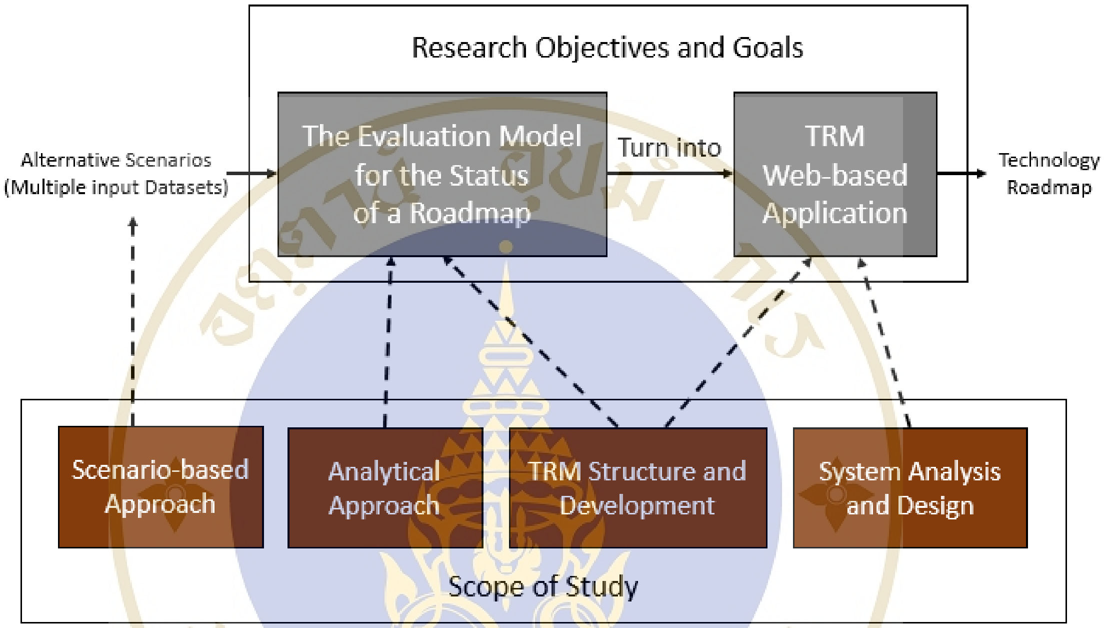


Figure 1.2 Scope of study related to research objectives and goals

CHAPTER II
LITERATURE REVIEW

2.1 Technology Management and Strategy

Definition of Technology Management and Strategy

Technology become a big issue of current business operation. Aligning business and technology together is a strategic activity of success organizations by creating significant business returns (Weiss and Anderson, 2004). Challenges of managing in technology has increased steadily. Future trends, changing environment, aligning business and technology strategy, understanding internal and external factors, environmental uncertainty, R&D and innovation, risk in high technology, measuring and controlling (Thamhain, 2005) are examples of necessary handling for business success in the long run.

Technology Management is described as tools or techniques, to solve complex business operation issues and finding new opportunities under technological consideration and appropriate business conditions. There are many dimensions of tools or techniques and their characteristics of catalogues (Farrukh, Phaa and Probert, 1999). Management tools or techniques could be a document, framework, process or system which enable to define the clear objective such as making decision, forecast, analysis or else (Brady et al., 1997). Technology Strategy is described as key driver to drive technological innovation in different organizations. On the other hand, technology strategy played as the planning role that guides the accumulation and deployment of technological resources and capabilities (Gupta, 2009).

Technology Management in Objectives of Forecasting

Because the major portion of development in any business sector depends on technological change. So an organization should consider to technology forecasting for worthwhile investment and utilization in the future.

From the Future Oriented Technology Analysis (FTA) (Firat, Wei and Madnick, 2008). There are overlapping forms of forecasting technology development and their impacts including Technology Monitoring, Competitive Intelligence, Technology Forecasting, Technology Roadmapping, Technology Assessment and Technology Foresight. But the beginning of the overall process in field of Technology Management should be identified needs for filling gap (Figure 2.1) between future requirements and current capabilities (Gerdsri, Daim and Rueda, 2011). This will be benefit for providing the direction to R&D, policy and planning. And Technology Roadmapping has been utilized as a forecasting and planning tool by assessing technology gaps during the roadmapping process.

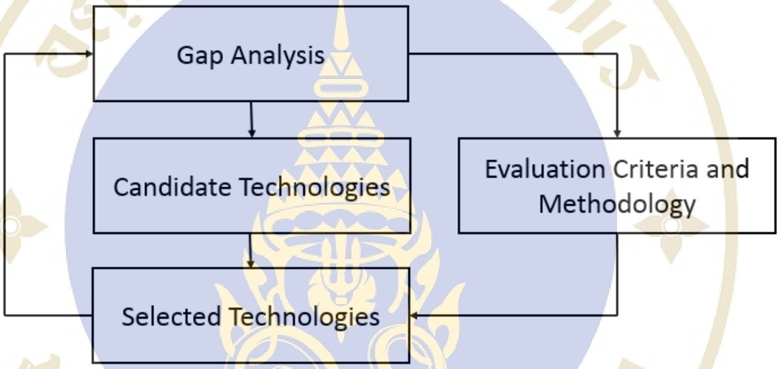


Figure 2.1 Technology assessment process (Tran and Diam, 2011)

2.2 Technology Roadmapping (TRM)

Definition of TRM

TRM is an approach to visualize an organization's strategies by linking all critical components (i.e. external factors, internal factors and targets for development) together. The process of developing a technology roadmap can support a management team in formulating strategies and making decision.

According to Albright (2003), a roadmap is defined as a document that describes a future environment and plan to achieve the objectives under that environment. By specifying down for using TRM in technology management, TRM is known as a widely used technique in forecasting and planning process for future technologies, finding a suitable alternative provision to meet future needs, planning strategy and aligning technology with overall business objectives. Moreover, TRM will provide a tool for selecting which technologies to pursue in what timeframes (Bray and Garcia, 1997). Reaching a consensus about technologies required (Needs-driven), providing forecasting technology development mechanism and providing coordination of technology development framework are major reasons to develop a roadmap (Laube and Abele, 2005).

Roadmap Architecture

TRM process has two concepts in development. First is “Market pull” that refers to the requirement for a new product from the market place. Second is “Technology push” that focuses on R&D to push the new invention onto the market without proper consideration in consumer needs. Based on these development concepts, the generic format of a roadmap (Figure 2.2) performs relations between firm’s capabilities and business requirements (Zurcher and Kostoff, 1997) as time-based activities (Phaal et al., 2003). Market pull concept has consider from top to bottom that business requirements are the first criterion in business strategy consideration. Oppositely, technology push concept has consider in different direction that technological capabilities are the first criterion in production. Almost TRM architecture is acknowledged in term of "Market pull" (Groenveld, 2007; Willyard and McClees, 1987; Phaal et al., 2003).

In structurally, it consists of two dimensions, horizontal axis is timeline and vertical axis is the layer structure of market, product, technology R&D and resources as shown in Figure 2.2. With clear graphical meaning, it is provided for exploring and communication in organization as well (Lee et al., 2005; McCarthy et al., 2001; Geum, 2011).

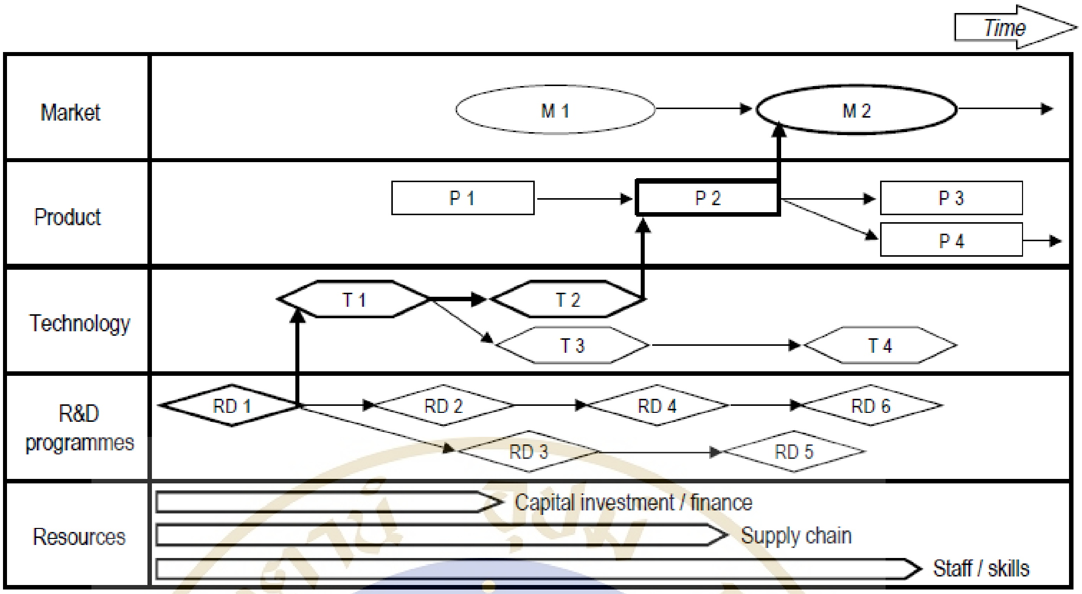


Figure 2.2 Generic roadmap artifact (Phaal et al., 2003)

Analysis of TRM

The analysis at each step of the roadmap development (Albright and Kappel 2003; Phaal, Farrukh et al., 2004) include roadmapping process analysis, market analysis, product analysis, technology analysis and resource analysis. The roadmapping process analysis has consider to linkage between market, product, technology and resource together with presenting the result of analysis in a form of roadmap. Market analysis has consider to market needs and its direction happening in the future by analyzing driving forces of change and market prioritization. STEEP analysis, which consist of Social, Technological, Environmental, Economic and Political, is a commonly used tool for external factor analysis. Details in each factor include:

S – Social, a factor relate directly to living conditions in society along with culture, tradition, faith and core values. These indicate to market characteristic as well as the ways to reach the desired market target. The example of social factors:

- Increasing or decreasing of population
- Sex and age
- Lifestyle
- Media consumption
- Shopping behavior
- Quality of life

T – Technology, a factor closely related with knowledge and innovations affecting business operation. Currently, responding to rapid change and extensive knowledge by tracking technologies is necessary for decision making planning. The example of technological factors. The example of technological factors:

- Fundamental technologies
- Accessing to technologies, markets or target audiences
- Education, research and technology development
- Rate of change or the emergence of innovations

E – Environment, a factor which is critical for specific industries associated with the production. The example of environmental factors:

- Weather conditions
- Air, soil and water pollution
- Management and recycling system
- Waste disposal system

E – Economic, a factor which indicate demand and supply, size of market, global and local trends. The example of economic factors:

- Deflation, inflation and interest rate
- Exchange rates of various currencies
- Unemployment rate
- Minimum wage

P – Politic, a factor happened from government administration or policies during that time. This factor affects investment and doing business in the country. The example of politic factors:

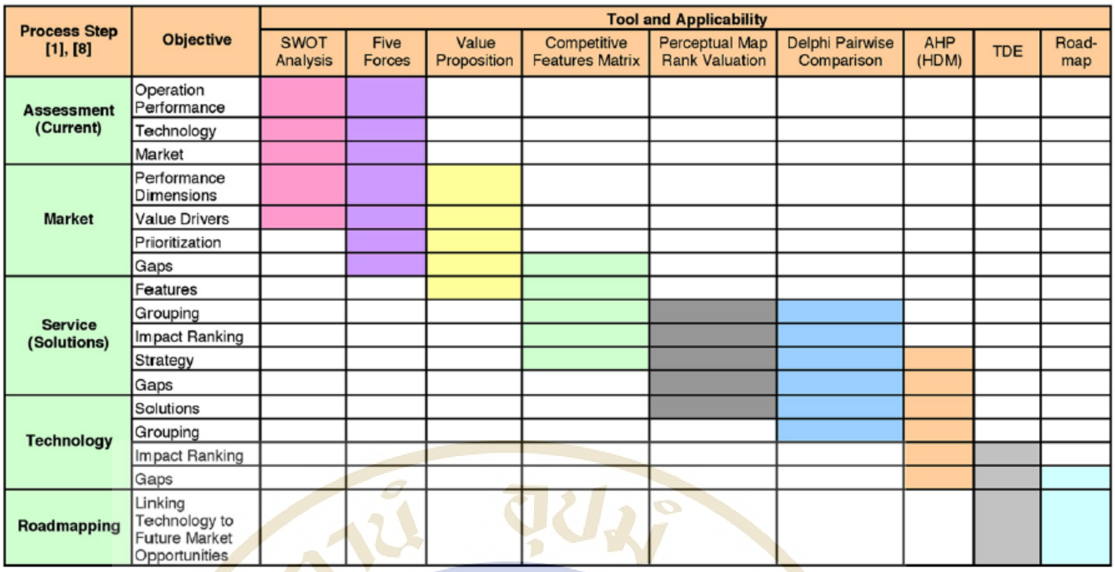
- Stability of government
- Corruption issues in the country
- Independence and freedom on doing business
- Regulations and prohibitions on doing business
- Regulatory control of imports and exports
- Taxation and tax fees

Product analysis focuses on product shape, functionality and performance. Technology analysis has target to find appropriate technologies for product research and development. By considering the characteristics of technology, assessing the existing organizational capabilities, assessment to determine technology gaps that can be used to strengthen the ability to develop products as needed. Resource analysis give a process to investigate the availability of resources and organization need of use.

Application of TRM

In current study of TRM found that it has been widespread and pervasive utilization. Its definition has been described many ways which still has the same primary meaning. But the additional meaning in detail has been explained as a part of the research itself following different contexts. For example, Tam (2013) described using TRM to accelerate the overall R&D process in order to deliver an earlier uptake of the specific energy technology into the marketplace, Diam (2011) presented the fundamental concepts of TRM that demonstrates the modification of technology roadmaps for convergence of technologies for services over broadband.

Some researches developed a flexible connector to link market analysis and final strategic process for decision making together. A new approach, which applied from the Value Road Map concept (Dissel and Phaal, 2006) called Value Driven Technology Road Mapping (VTRM) (Figure 2.3) by integrating marketing and decision methodologies, was presented by Fenwick, Daim and Gerdsri (2009). It used marketing tools on initial phases for assessment of current operation performance, technology including market analysis, then it used decision making models for presenting opportunity linked to market, products, technologies and R&D on the technology roadmaps.



Process Step [1], [8]	Objective	Tool and Applicability								
		SWOT Analysis	Five Forces	Value Proposition	Competitive Features Matrix	Perceptual Map Rank Valuation	Delphi Pairwise Comparison	AHP (HDM)	TDE	Road-map
Assessment (Current)	Operation Performance									
	Technology									
	Market									
Market	Performance Dimensions									
	Value Drivers									
	Prioritization									
	Gaps									
Service (Solutions)	Features									
	Grouping									
	Impact Ranking									
	Strategy									
	Gaps									
Technology	Solutions									
	Grouping									
	Impact Ranking									
	Gaps									
Roadmapping	Linking Technology to Future Market Opportunities									

Figure 2.3 VTRM process and tools (Fenwick, Daim and Gerdsri (2009)

Implementing TRM is dynamic as well as many existing forms depended on organization environments. The T-Plan ‘fast-start’ approach (Figure 2.4) has been developed which aims to support technology strategy and planning initiatives for a firm by establishing the key linkages between technology resources and business drivers (Phaal, Farrukh and Probert). Gerdsri, Vatananan and Dansamasatid (2009) presented implementation step in commonly used, including different stages, significant roles of key players and elaboration to change in order to match with the implementation. Analysis at each step of Implementing TRM (Figure 2.4) help to close gaps, monitor risks and integrate elements between market, product and technology (Albright and Kappel, 2003; Phaal et al., 2004).

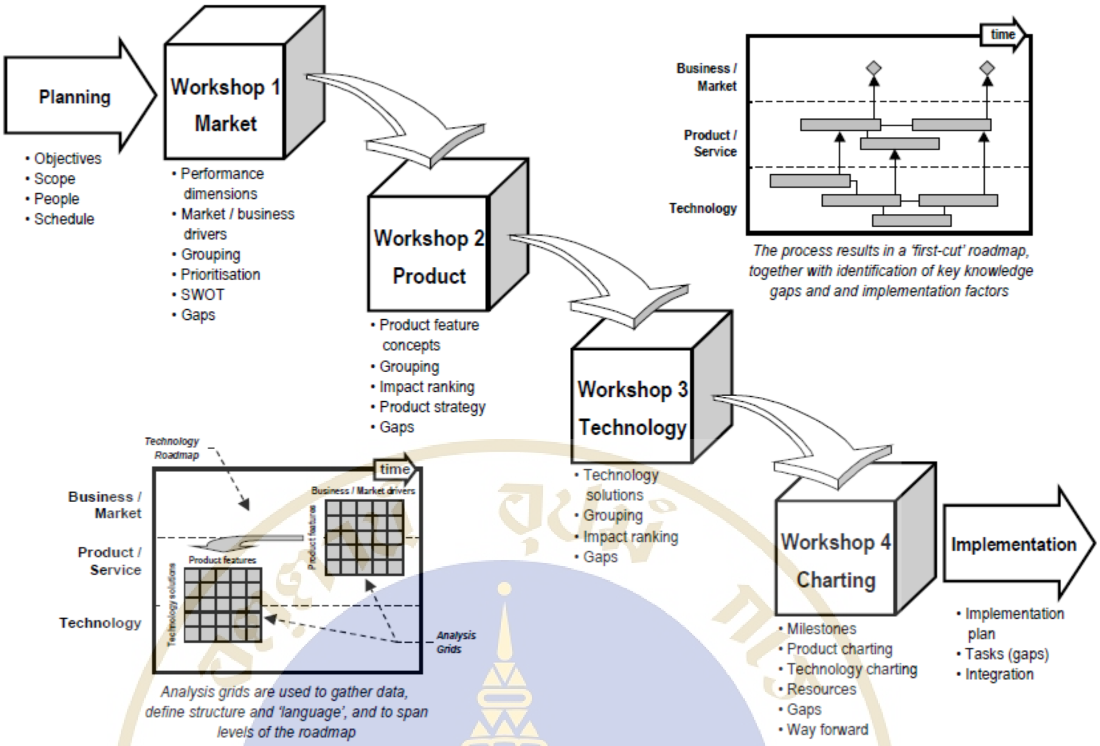


Figure 2.4 T-Plan: standard process steps, showing linked analysis grids (Phaal, Farrukh and Probert, 2001)

Benefits of TRM

TRM can be applied to determine where new technology can be used at the appropriate time (McCarthy, 2003). Vatananan and Gerdsri (2010) has classified an organization advantages into two major categories. The individual benefit perspective includes dialog and strategic communication (Phaal and Muller, 2007; Phaal and Muller, 2009; Li et al., 2005), enhancing understanding and information sharing (Kostoff and Schaller, 2001; Phaal and Muller, 2007; Nonaka, 1991) and understanding team members (Bray and Garcia, 1997; Brown and O'Hare, 2001; Wells et al., 2004; Dessel et al., 2006; Holmes and Ferrill, 2006). The organizational benefit perspective includes integration of processes and policies (Garcia and Bray, 1997; Probert and Shehabuddeen, 1999), building the connection between business units and/or markets suppliers partners competitors (Kameoka et al., 2003; Rinne and Gerdsri, 2003) and improving their decision making process (Garcia and Bray, 1997; Brown and O'Hare, 2001; Albright and Kappel, 2003; Wells et al., 2004).

2.3 Analytical Approach

An analytical approach refers to an appropriate process to break a problem down into the smaller pieces necessary to solve it. So it is widely used in various applications related to the analysis of the importance of elements in the form of a hierarchy. A hierarchical model by applying the Analytic Hierarchy Process (AHP) for value measurement (Gerdsri and Kocaoglu, 2007) (Figure 2.5) is an example of TRM analysis. The system thinking approach must be applied to the analysis to capture the change of elements - business, markets, products, technology, R&D, and resources – and the impacts of those changes on an organization over time.

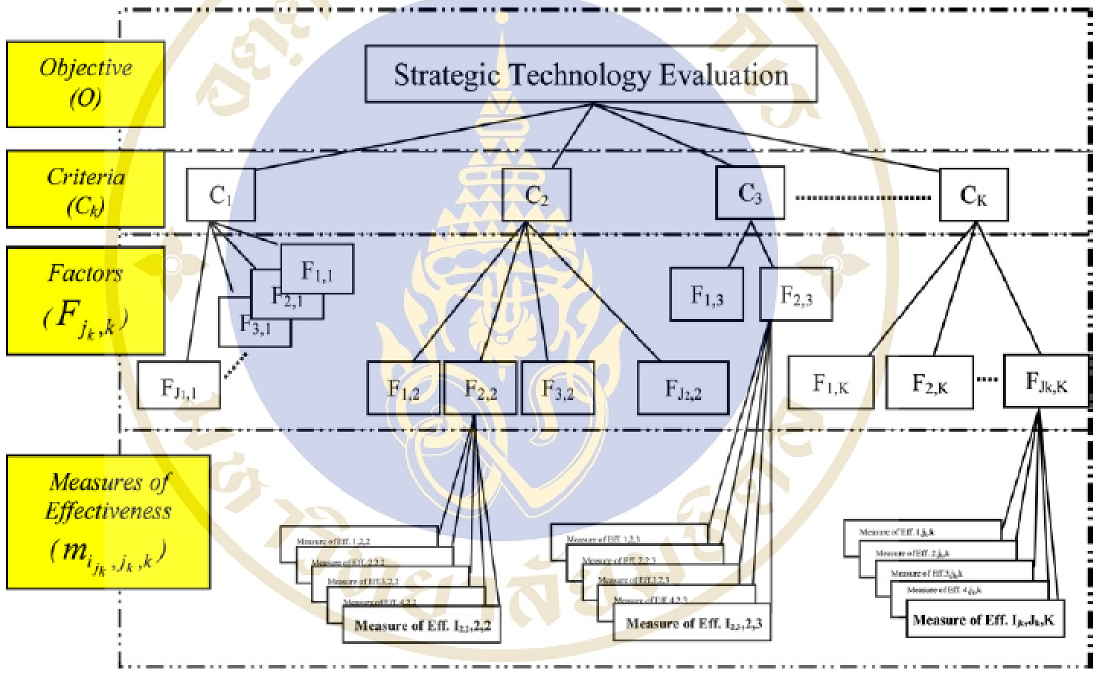


Figure 2.5 A proposed hierarchical model using a semi-absolute value measurement (Gerdsri and Kocaoglu, 2007)

Vatananan and Gerdsri (2011) presented an evaluation model. The hierarchy model has been constructed from key drivers and its sub drivers to identify the status of a roadmap by providing a decision making signal to maintain, update or revise a roadmap on appropriate time.

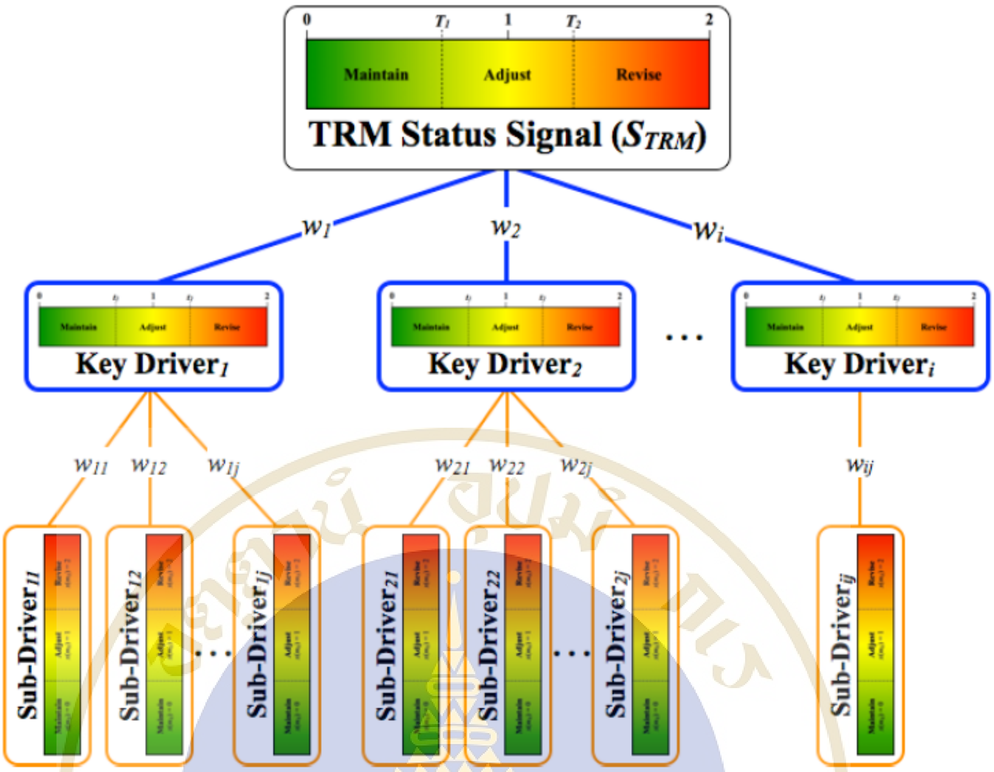


Figure 2.6 Evaluation model hierarchy (Vatananan and Gerdsri, 2013)

2.4 Scenario-based Approach

Scenario planning, scenario thinking or scenario analysis use to make flexible long-term plans as a strategic planning and involve aspects of systems thinking. The most important part of scenario planning is scenario development. This core process is concerned about creating actual stories for the future. Bishop, Hines and Collins (2007) has concluded the current state of scenario development. About alternative futures, there are many techniques with its description for diverse objectives.

Wulf, Meißner and Stubner (2010) presented six steps of the scenario-based approach to strategic planning (Figure 2.7) that allows for a quicker and easier application in practice. It was built upon traditional approaches by focused on two core requirements of innovative strategies – multiple options and integration of external and internal perspectives to strategy development. Trend and Uncertainty Analysis on Impact/ Uncertainty Grid (Figure 2.8) is used to identify key uncertainties for this approach.

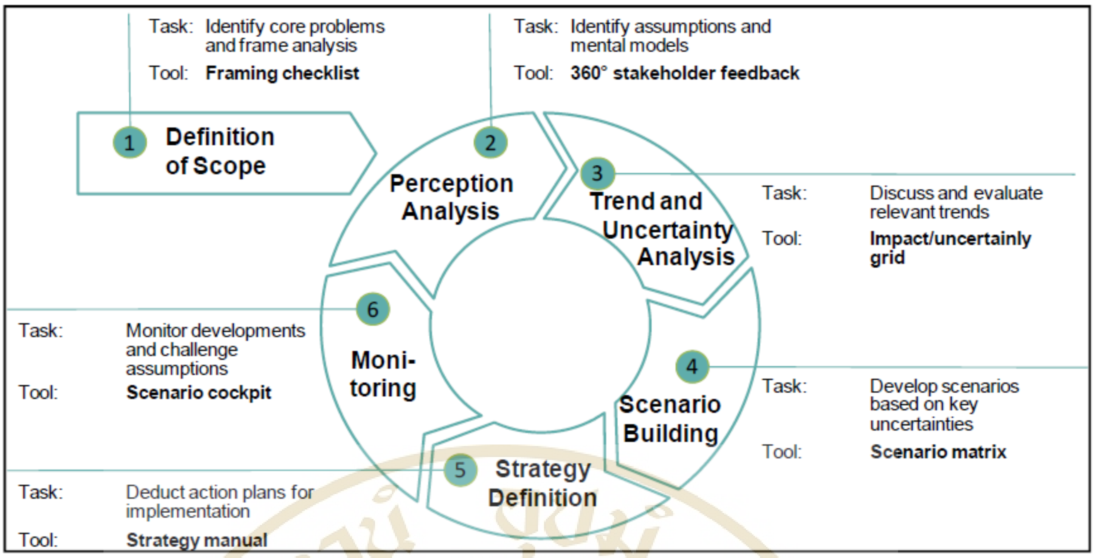


Figure 2.7 Overview of the scenario-based approach to strategic planning

Wulf, Meißner and Stubner (2010)

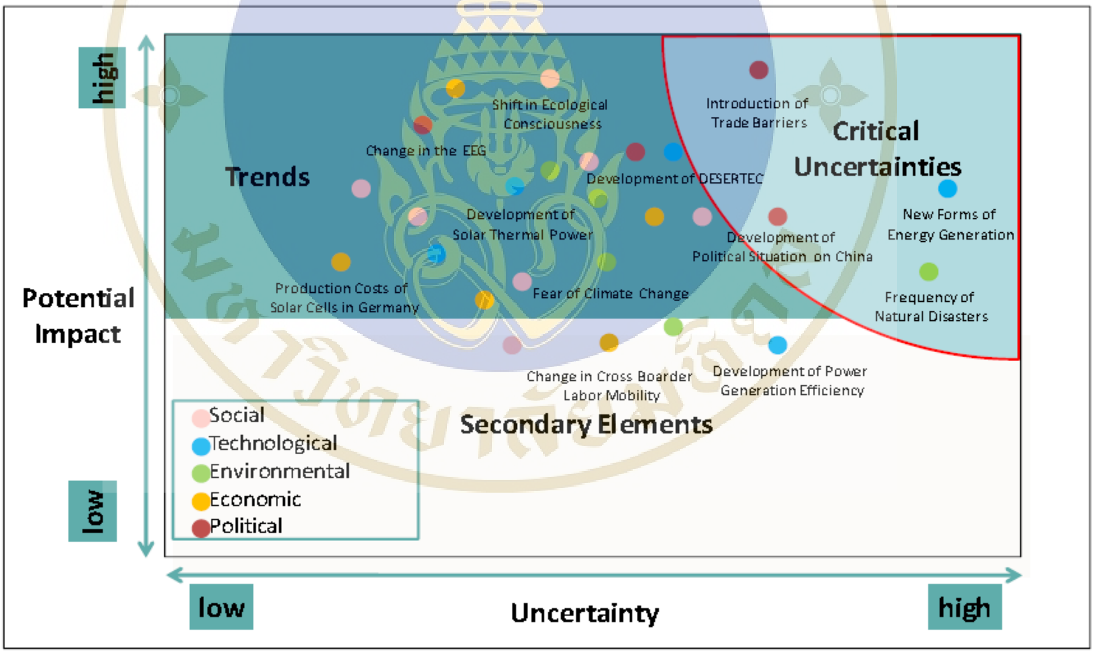


Figure 2.8 Trend and uncertainty analysis on Impact/ Uncertainty grid

Wulf, Meißner and Stubner (2010)

2.5 Scenario-based Roadmapping

Because of uncertainty happened at the first step of developing TRM, where external drivers are considered, it affects until the final step which provide information for making decision. A roadmap, which is the final product, is only represented as single option despite of having multiple possible options from uncertain environments. Scenario planning has been applied to create stories for different roadmaps in the same circumstances. Combining of scenario planning and roadmapping (Saritas and Aylen, 2010) by using scenarios 'before' the roadmapping exercise, using scenarios 'during' the roadmapping exercise or using scenarios 'after' the roadmapping exercise can offer "the best of both worlds." (Strauss and Radnor, 2004). The six steps of science and technology from roadmapping preparation to scenario building (Figure 2.9) by technology-push, requirements-pull approach is presented by Lizaso and Reger (2004) including preparation, system analysis, scenario projection, scenario building, time assessment and roadmapping. There are also various techniques applied to bringing both tools together (Kim and Park, 2004).

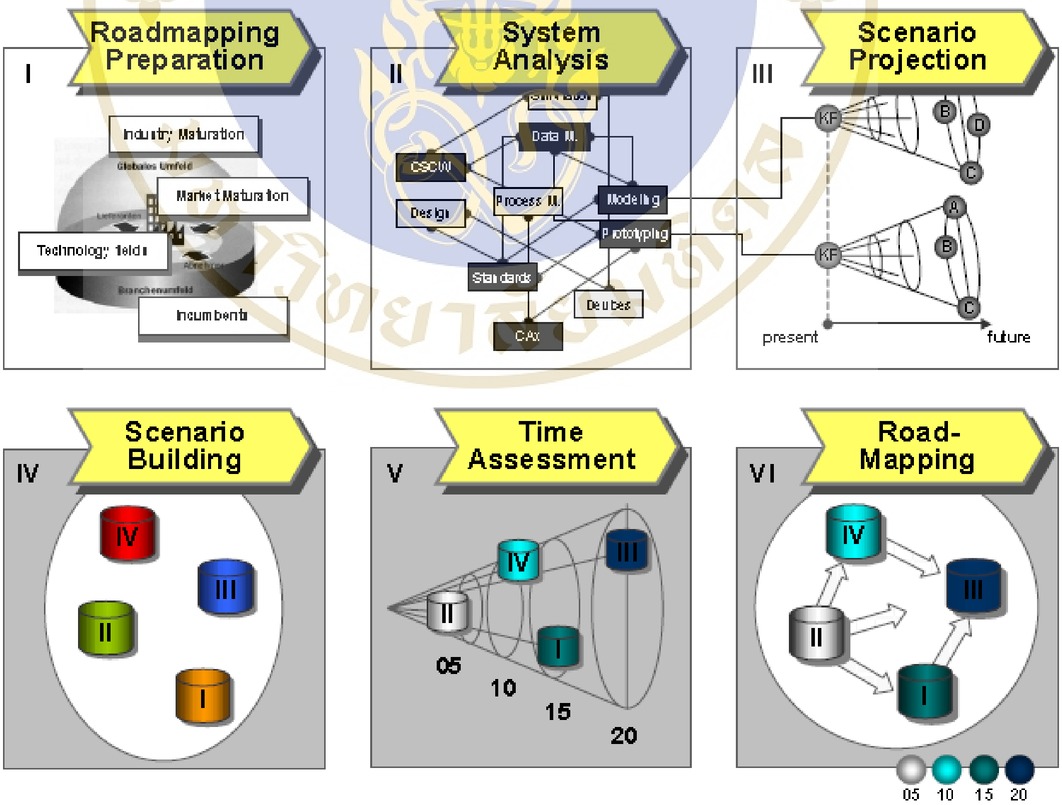


Figure 2.9 Six steps of science and Technology Roadmapping process (Lizaso and Reger, 2004)

2.6 System Analysis and Design

Analysis and designing a system are importance parts of Software Development Life Cycle (SDLC). Beginning from considering the appropriate development model help the project to success with explicit process to plan. In terms of software, a basic type of SDLC model is the sequential models. And the most basic of all sequential models is the Waterfall model (Wallin and Land, 2005) (Figure 2.10) that fits for a small team or individual and requires rapid development.

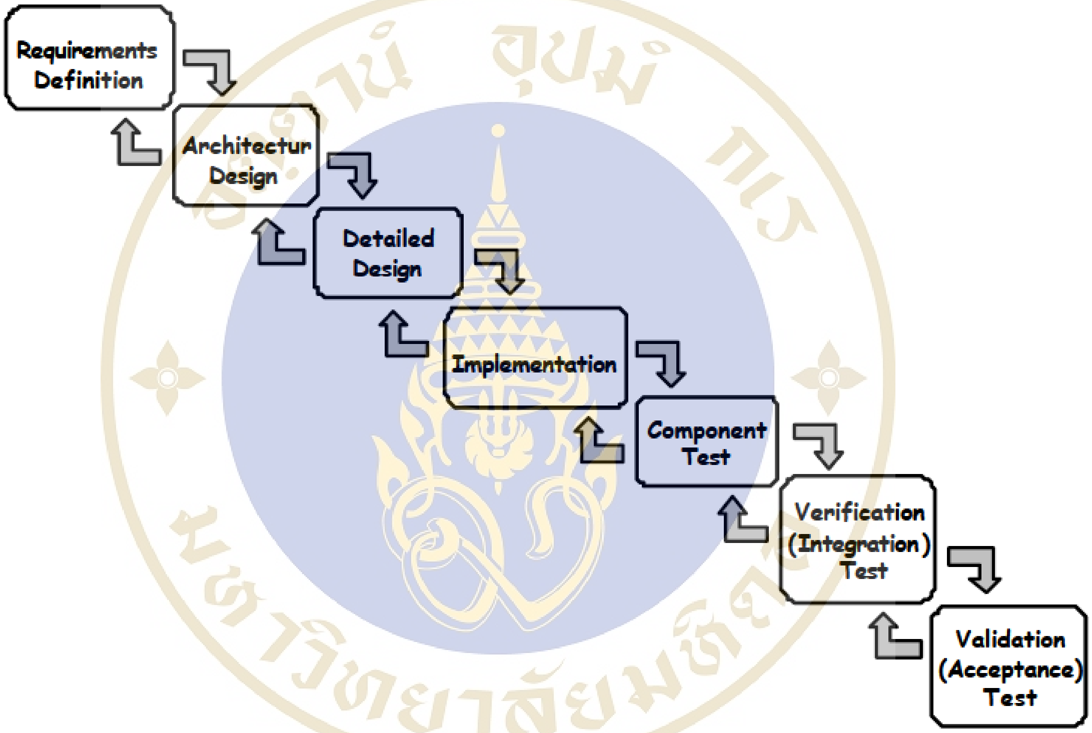


Figure 2.10 The waterfall development lifecycle model (Wallin and Land, 2005)

Furthermore, in the age of customer centricity, the proper factors of User eXperience (UX) is also considered to design and develop web based application. The good design always consider the requirements of user experience at all time spans which have mainly three factors including context (i.e. physical, technical and information), user (i.e. motivation, resources and expectations) and system (i.e. properties, functions and design) (Roto et al., 2011)(Figure 2.11).

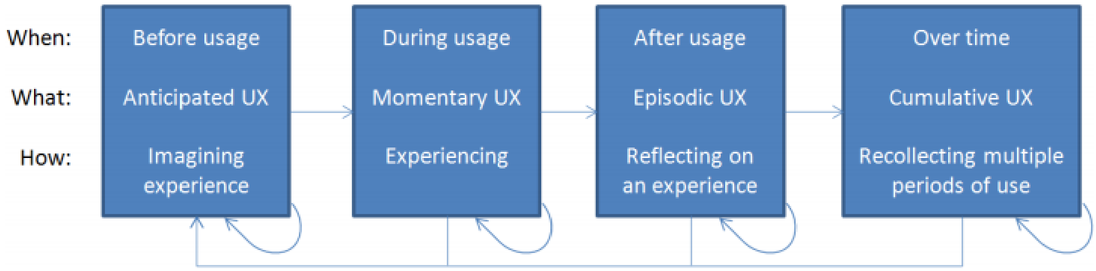


Figure 2.11 Time spans of user experience (Roto et al., 2011)

CHAPTER III
RESEARCH METHODOLOGY

An objective of this research is to understand Technology Roadmapping process that can be capped for an organization appropriately and effectively. Then a computerized system had been developed focusing on ease of use and good functionality for common usage. This study also aims to explore the knowledge of Scenario Planning and find how to integrate scenario analysis into the roadmapping process as well as assembling it to the computerized system.

Because the author has working experience that associated with technology especially in designing system and software. Furthermore, the software industry is still much appropriate to apply Technology Roadmapping responding to rapid change of business which is a critical characteristic of software technology and industry. In term of rapid change in software industry, it is not only internal technology and other resources in research and development but also external factors as market needs. The market needs come from user behaviour, preferring to consume high-tech and high-touch products like smart devices, smart platforms and smart applications, but user behaviour may lead technology (Market pull) or caused from technology (technology push). The key point is that both internal and external environments of doing business in software industry are directly affected from technology. That means the rapid change occurs in the level of research and development through the market level of the roadmap.

The author believe that applying Scenario-based Technology Roadmapping for a software firm will be an appropriate case study to give the apparent results to analysis.

3.1 Research Design and Framework

In the methodology part, the process of identifying the key drivers and sub drivers which impact the roadmap, a group of top management of a case organization regarding the issues about the changes is interviewed in Social, Technology, Environment, Economic and Politic which may impact an organization's roadmap. Then, the operation team is involved in the deciding the measurement values which is associated with each key drivers. This study applies the System Development Life Cycle (SDLC) which have six phases including preliminary investigation, analysis, system design, data collection and test, implementation, and maintenance. To complete this computerized system, the study has involved with the system design phase in SDLC (Figure 3.1). The system design can separate into logical and physical design. The logical design is necessary for providing a solution to integrate the evaluation model into the application. Linking the evaluation result to graphical display is one of the important tasks for logical design. The physical design is emphasized to explicitly separate data acquisition between management level and operational level.

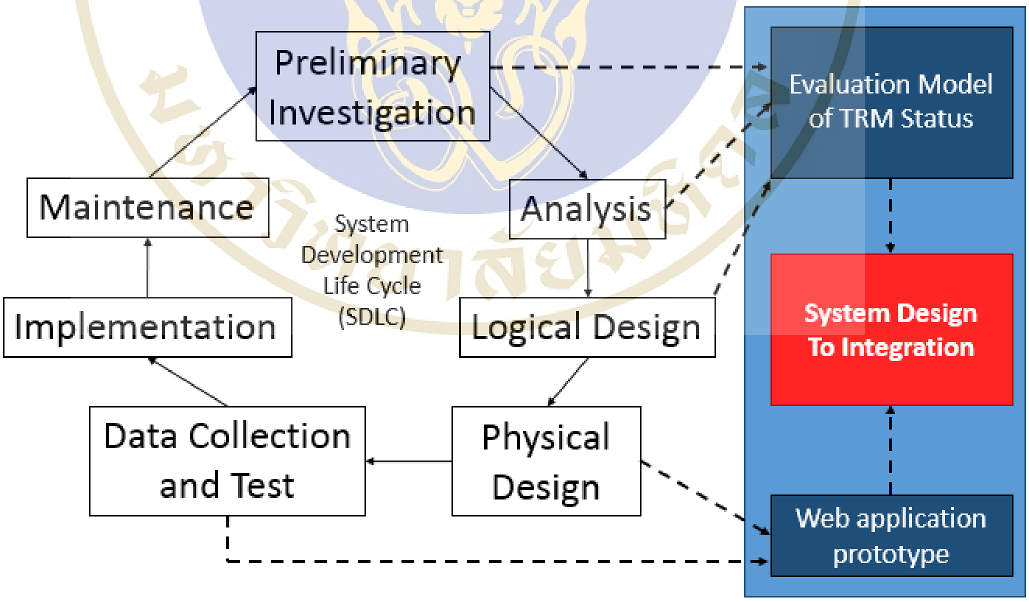


Figure 3.1 Research framework related to System Development Life Cycle (SDLC)

From the conceptual framework (Figure 3.2), the assigned external factors as key drivers and sub drivers will be provided and input data into scenario analysis framework. This study has apply trend and uncertainty analysis as a core process for scenario analysis to extract influencing drivers. Classification of best-case and worst-case scenario with extracted influencing drivers lead to producing the options of a roadmap comparing with a base case in current situation.

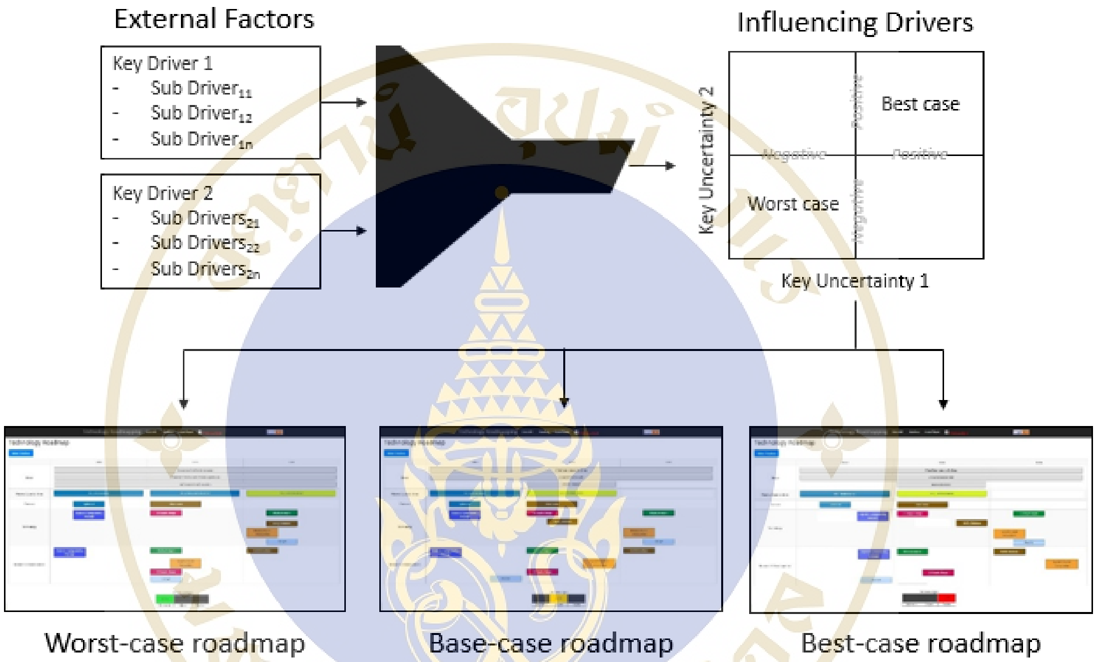


Figure 3.2 Conceptual framework

3.2 Research Workflow

This research is organized into five parts (Figure 3.3). The first part is literature review then defines the scope and objective. The second part designs a system both physical and logical part then develops a web-based application focusing on the status signal for a roadmap. The third part collects data to process and test on developed application. The fourth part analyses roadmapping data based on scenario analysis. The last part is conclusion and recommendation on the usability and usefulness of the system.

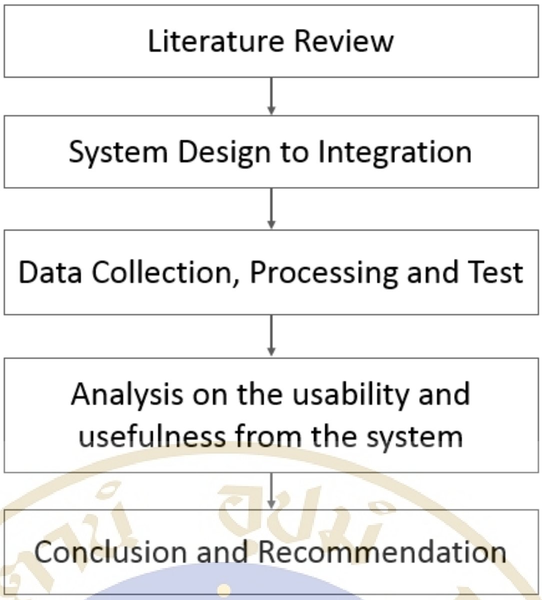


Figure 3.3 Research workflow

3.2.1 Literature review (Chapter II)

From the scope of study related to research objectives and goals of this research, the literature covers the knowledge area of Technology Roadmapping, evaluation of TRM status, Scenario-based Approach, Analytical Approach and System Analysis and Design (Figure 3.4).

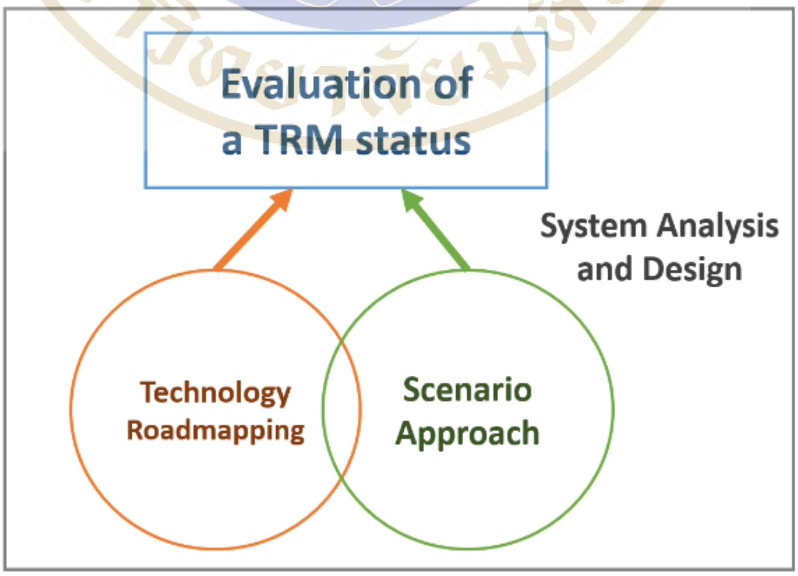


Figure 3.4 Scope of literature review

3.2.2 System design to integration (Chapter IV)

In this section, integration of the status signal evaluation model, scenario model and computerized system model is a part of logical part. To extract the key factors for good functionality and ease of use, physical design have to cogitate the user experience as the first priority.

3.2.3 Data collection, processing and test (Chapter III, V)

In-depth executive interviews with open-ended and discovery-oriented method makes the sufficient collected data and good enough various alternative informations to process. Scenario-based approach is applied to build alternative data for processing on the Technology Roadmapping. This causes the different stories different roadmaps in the same circumstances.

3.2.4 Analysis on the usability and usefulness from the system (Chapter VI)

This section has analyze the result of developed computerized system towards usability and usefulness in business operation.

3.2.5 Conclusion and recommendation (Chapter VI)

This section has discuss on management implication, recommendation, limitation, conclusion and future research.

3.3 Data Collection and Analysis

The required inputs for TRM web application to generate the options of a roadmap are collected by interviewing executives. In-depth executive interviews with open-ended and discovery-oriented method makes the sufficient collected data and good enough various alternative information to process. This method is not just questions and answers but record the communicated information repeatedly to get the most accurate information (Pereira, Pedrosa, Simon and Matovelle). The open-ended questions on interview such as:

- What is the organization's goals? This question is geared towards management vision what the main target they are trying to achieve including development direction they focused.
- What about the current situation and resources? This question leads to identifying company's status, gap analysis, opportunities and threats.
- What factors are positive/negative to develop or improve the company? This question helps to find out sub drivers associated with key drivers.
- What about the current industry trends? This question helps to find out the challenge and uncertainties that may occur.

Collecting data consists of two worksheets to collect and discuss under the condition and guidance during the process.

The first worksheet (Table 3.1) contains sub drivers associated with key drivers that categorized into Social, Technological, Economic, Environmental and Political which used in analyzing external factors affecting to business. For management level tasks, each drivers have to determine the value of relative importance, level of confidence and tolerance limits. The relative importance represents the intensity of what drivers are respected to an organization's objectives and should be considered sequentially. It has significant for product planning as well as supporting technology consistent with product development according to market needs. The level of confidence represents approximate accuracy of information. The tolerance limits indicate the level of impact from any change in the measurement value of drivers on the roadmap. Its interval causes a deviation from the baseline value of each sub drivers. These tolerance limits are important to operationalize the evaluation of key drivers from the roadmap. For operational level tasks, the measurement value should be measured periodically up on appropriate business condition (Vatananan and Gerdsri, 2013).

Table 3.1 STEEP analysis for the evaluation model for the status signal of a roadmap

Management Level									Operational Level
Key Drivers	Sub Drivers	Relative Importance	Level of Confidence	Tolerance Limits					Measurement Value
				T2-1	T1-0	Mbase	T0-1	T1-2	
Social									
Technologal									
Economic									
Environmental									
Political									

The second worksheet contains the value of potential impact and uncertainty of each sub drivers that align with the first worksheet. The potential impact could be the same meaning with the relative importance from the first worksheet. The uncertainty value refers to changed opportunity or sub driver's unstable degree. These two values are components on impact/uncertainty grid (Figure 3.5), a tool for trend and uncertainty analysis which is an approach for scenario planning. In this analysis phase, the sub drivers are then ranked by their degree of uncertainty as well as their potential impact in order to identify the most crucial environmental drivers (Wulf, Meißner and Stubner, 2010). The higher degree of potential impact and uncertainty they have, the higher rank of being an influencing driver they get.

No	Sub Drivers	Potential Impact	Uncertainty

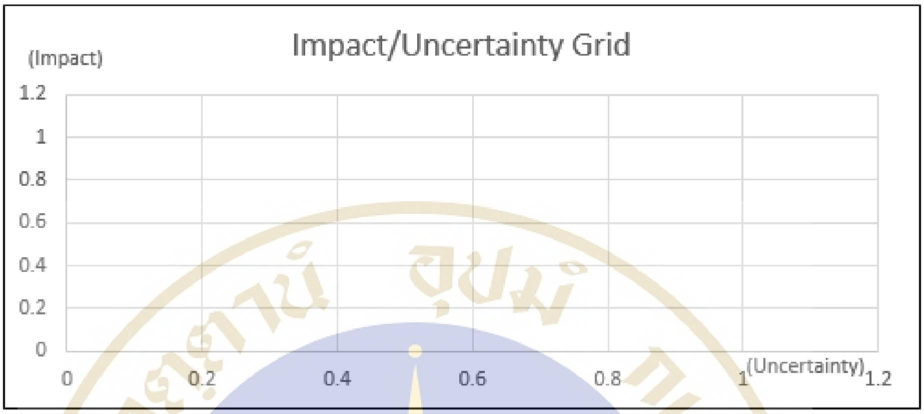


Figure 3.5 Trend and uncertainty analysis (Impact/Uncertainty grid)

Two most influencing drivers are considered as key uncertainties for classification of scenarios. A scenario matrix (Figure 3.6) purposes to describe the degree of situation. And the degree of situation depends on the degree of key uncertainties. Two most extreme situations, consisting of negative-negative and positive-positive key uncertainties, are described to the best situation as well as the worst situation. The best situation or a best-case scenario does not necessarily indicate as the positive-positive key uncertainties. It depends on the correlation which is the degree of relationship between a sub driver and its key uncertainty. This is the same rationale as the worst situation or a worst-case scenario. That's mean a worst-case scenario could be indicated as the positive-positive key uncertainties.

After producing the base-case scenario, Technology Roadmapping process will be repeated to produce the worst-case and the best-case scenario under the same current situation as base-case scenario. As a result, there are three roadmaps provided from three scenarios on this scenario-based roadmapping. The analysis of the results is based on roadmaps comparison and opportunity of use.

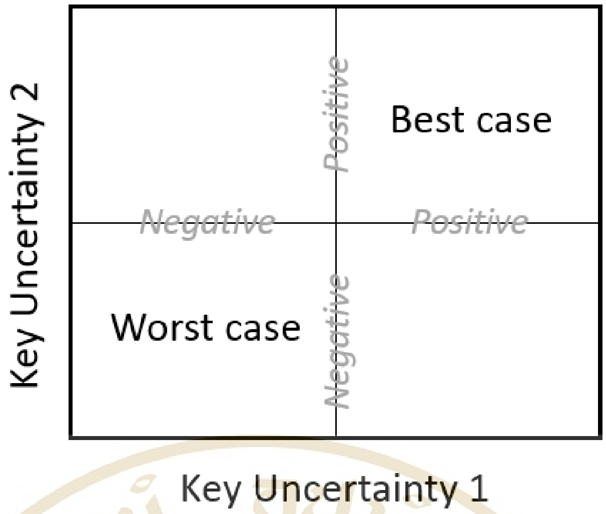


Figure 3.6 Identifying two key uncertainties for a scenario matrix

CHAPTER IV
SYSTEM DESIGN

4.1 System Workflow

There are two methods using this TRM web application to generate the roadmap comprising of Single-Scenario Single-Roadmap and Multiple-Scenario Multiple-Roadmap.

4.1.1 Single-Scenario Single-Roadmap

From system workflow (Figure 4.1), the system operation starts with gathering key drivers and sub drivers to determine potential impact and uncertainty value by expert opinion. The management level defines key drivers along with their values. The operational level measures the value of drivers same as defined by management level from operation periodically. These two steps may use a worksheet as shown in Figure 3.5 or direct input into web application (Figure 4.5-4.6). After that, the roadmapping team will follow the steps as shown in Figure 4.3 to produce a roadmap. These steps are part of generic roadmapping process.

4.1.2 Multiple-Scenario Multiple-Roadmap

From system workflow (Figure 4.2), after defining values by management level and measuring values by operational level as same as the Single-Scenario Single-Roadmap method. These defined values are plotted on impact/uncertainty grid to indicate which sub drivers should be meticulously considered. Two influencing drivers, which have two most values from potential impact and uncertainty, is used to build scenarios. The sub drivers and its values provided from each scenario will feed into web application to generate the options of a roadmap.

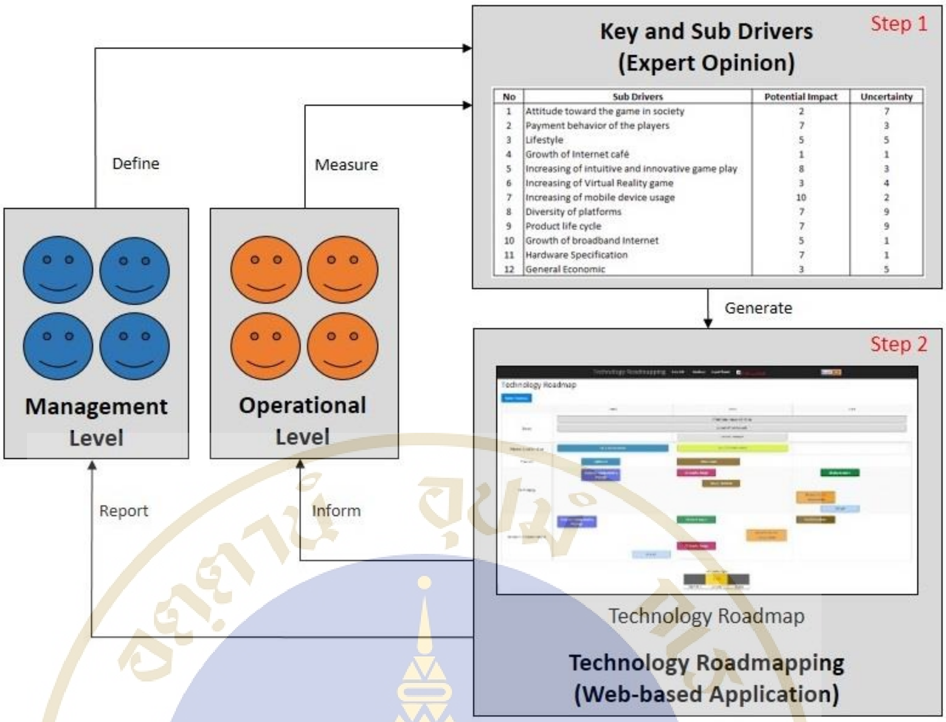


Figure 4.1 System workflow: Single-Scenario Single-Roadmap

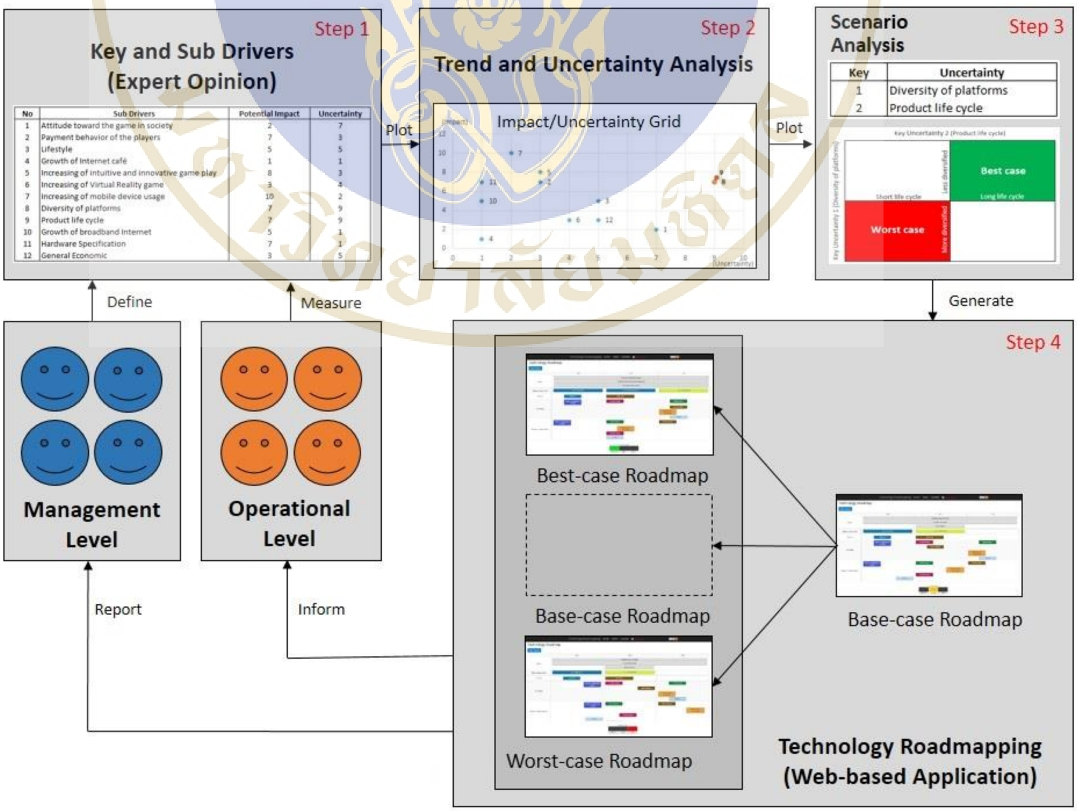


Figure 4.2 System workflow: Multiple-Scenario Multiple-Roadmap

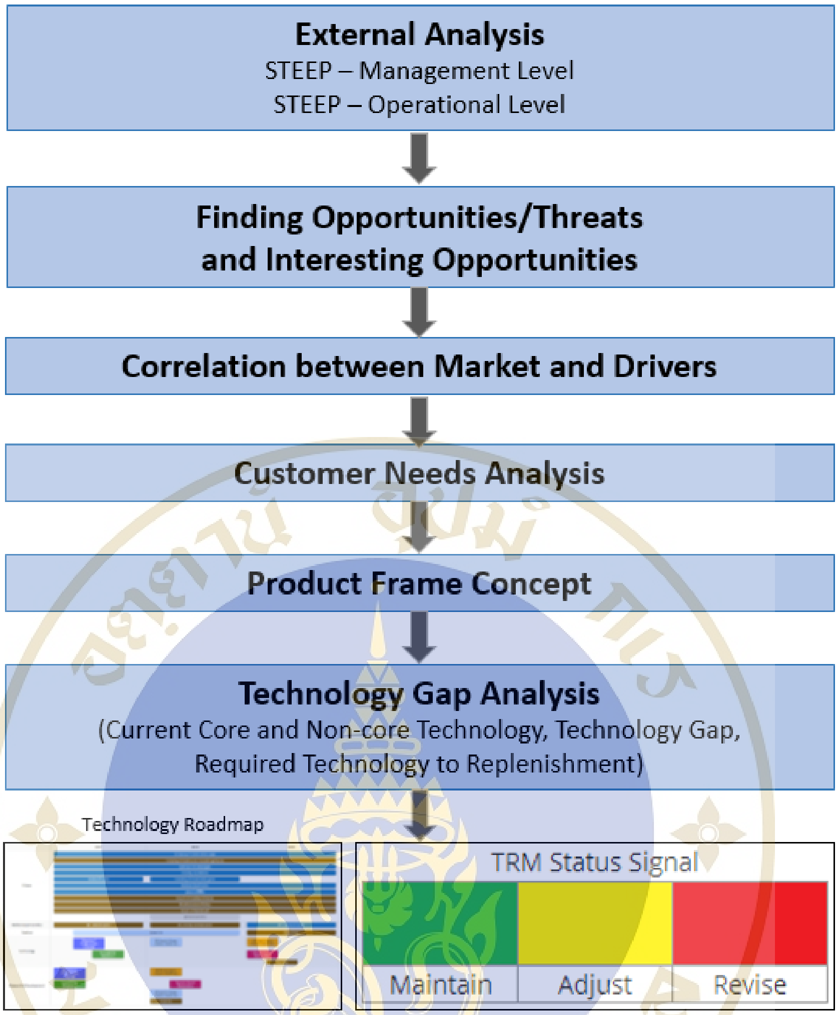


Figure 4.3 Application flowchart

4.2 Logical Design

The logical design purposes to turn the conceptual evaluation model for the status of a roadmap into an operationalizable form (Figure 4.4). It needs an extended programming code adding on the main line of programming code. This code operates like a calculation method named Analytical Hierarchy Process (AHP) on the conceptual evaluation model. This part has also related to aligning the process or sequence of processing. System performance in terms of processing speed, accuracy of results and system stability is based on the design in this section.

4.3 Physical Design

The physical design purposes to graphically display as a status signal and user interface of an input form for external factor analysis. The input form has separate into the management level part (Figure 4.5) and the operational level part (Figure 4.6). The status signal of a roadmap (Figure 4.7) includes green light status represented as 'Maintain' signal, yellow light status represented as 'Adjust' signal and red light status represented as 'Revise' signal. A ‘Maintain’ signal indicates environment change within an anticipated range that recommended to maintain a roadmap in its present state and operate the roadmapping process as usual. An ‘Adjust’ signal indicates that a change in the sub drivers has some effect on the roadmap and recommends an adjustment. A ‘Revise’ signal indicates a severe impact from a change in an organization’s environment on their roadmap that recommended a revision (Vatananan and Gerdsri, 2013).

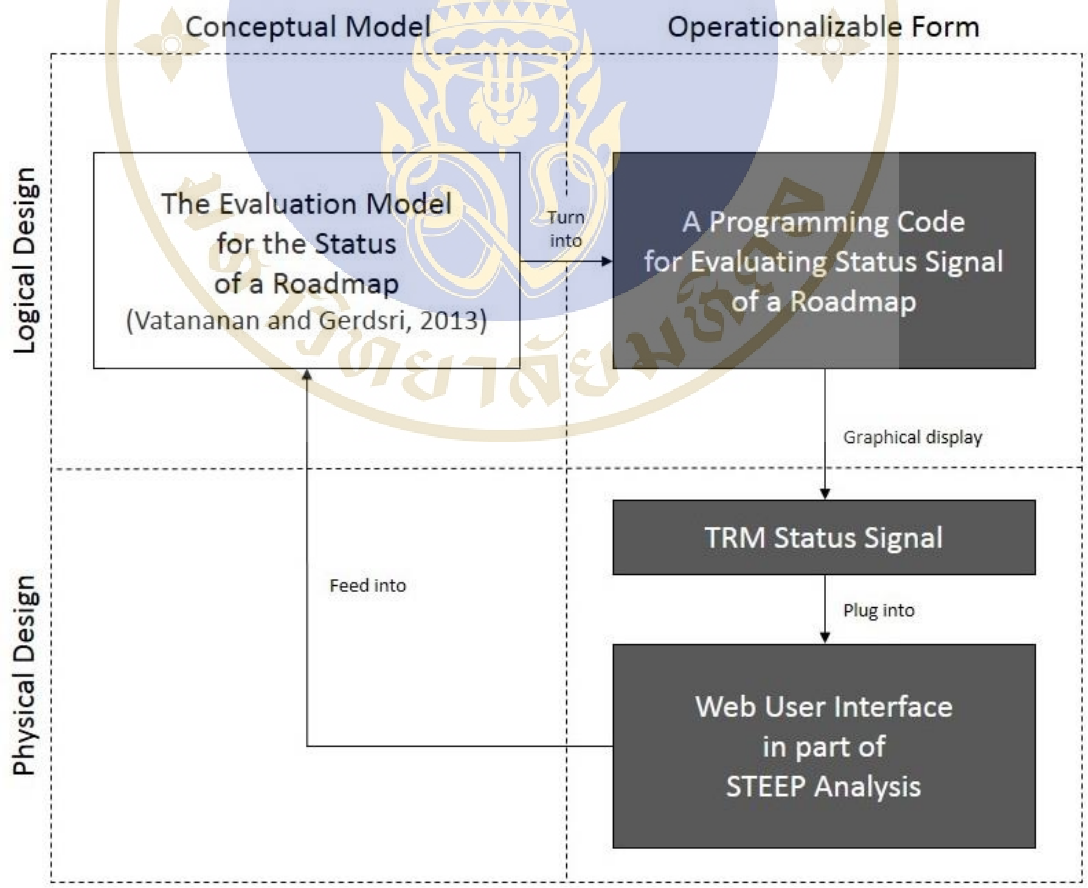
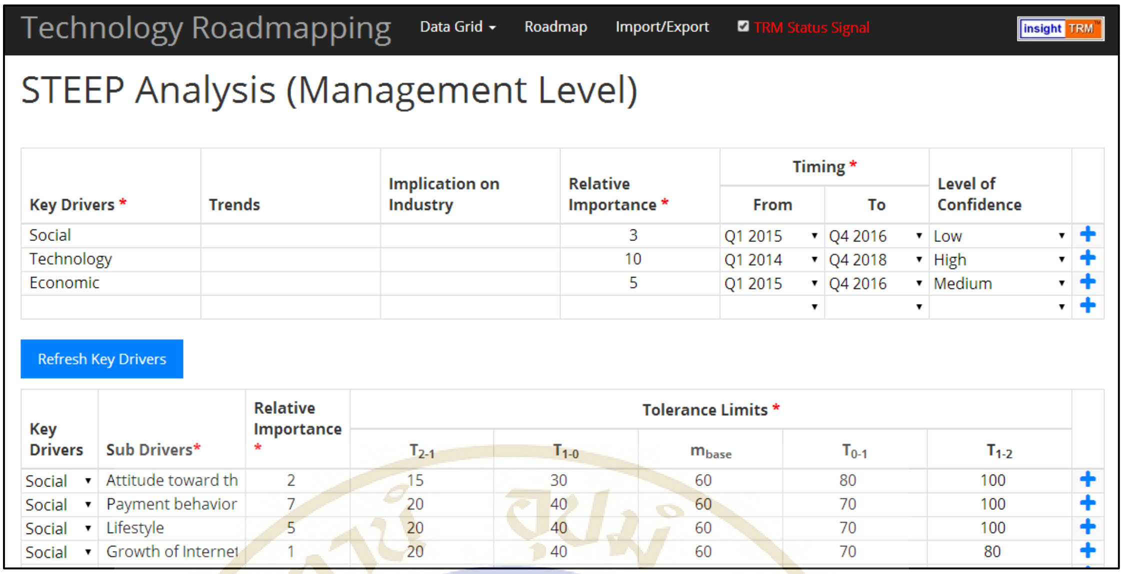


Figure 4.4 Tasks on logical and physical design



Technology Roadmapping | Data Grid | Roadmap | Import/Export | TRM Status Signal | insight TRM

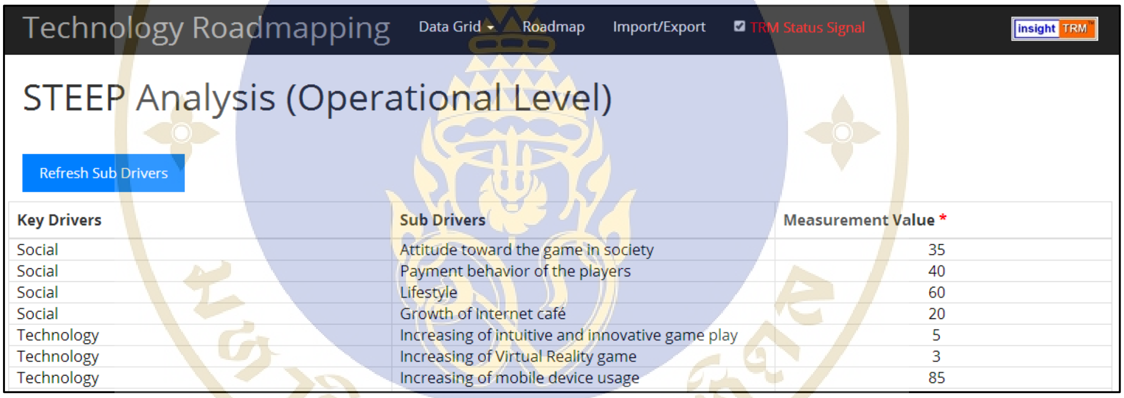
STEEP Analysis (Management Level)

Key Drivers *	Trends	Implication on Industry	Relative Importance *	Timing * From	Timing * To	Level of Confidence
Social			3	Q1 2015	Q4 2016	Low
Technology			10	Q1 2014	Q4 2018	High
Economic			5	Q1 2015	Q4 2016	Medium

Refresh Key Drivers

Key Drivers	Sub Drivers*	Relative Importance *	Tolerance Limits * T_{2-1}	T_{1-0}	m_{base}	T_{0-1}	T_{1-2}
Social	Attitude toward th	2	15	30	60	80	100
Social	Payment behavior	7	20	40	60	70	100
Social	Lifestyle	5	20	40	60	70	100
Social	Growth of Internet	1	20	40	60	70	80

Figure 4.5 Physical design: STEEP analysis for management level



Technology Roadmapping | Data Grid | Roadmap | Import/Export | TRM Status Signal | insight TRM

STEEP Analysis (Operational Level)

Refresh Sub Drivers

Key Drivers	Sub Drivers	Measurement Value *
Social	Attitude toward the game in society	35
Social	Payment behavior of the players	40
Social	Lifestyle	60
Social	Growth of Internet café	20
Technology	Increasing of intuitive and innovative game play	5
Technology	Increasing of Virtual Reality game	3
Technology	Increasing of mobile device usage	85

Figure 4.6 Physical design: STEEP analysis for operational level

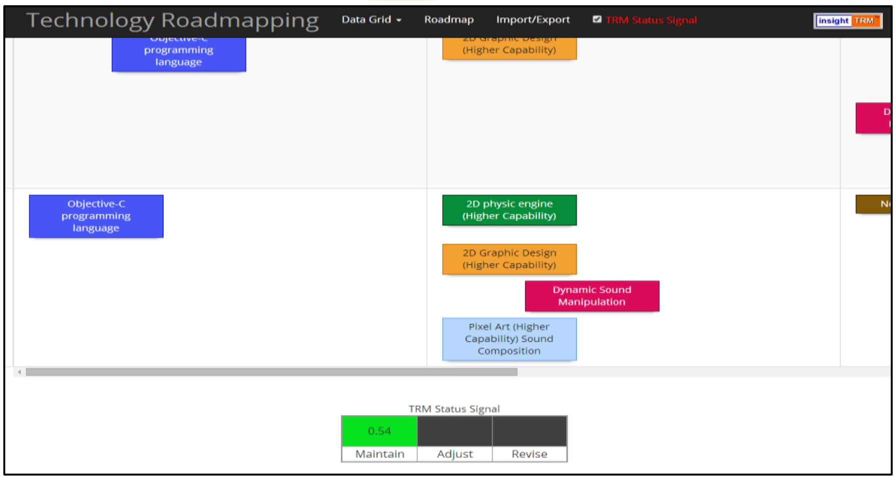


Figure 4.7 Physical design: TRM status signal

CHAPTER V
RESEARCH RESULTS

5.1 A Case Example

The developed web application for evaluating the status of a roadmap is tested and validated by using collected data of a software company in Thailand. This four years established software firm was run by unclear direction and strategy, but interested in strategy development to increase competitiveness and sustainable growth. This company already had a roadmap to guide product research and development. This roadmap should be able to support a long term objectives to expanding products and services into the regional markets.

5.1.1 Background of the case example

The Silly Studio company limited started operation in 2010 by two shareholders. They were an outsourcing software firm focusing on developing windows based applications. After that, they began to develop websites and there was an increasing trend. They had developed their own CMS (Content Management System), a core system or platform for rapid website development. But they found that Wordpress CMS, which was the most popular one, has better functions, better features and more flexibility. They had change software production direction from windows-based to web-based and from their CMS to Wordpress in the end. Meanwhile, the first quarter of the second year, the company began to develop games on mobile phone and had continuous improvement on their development process. So, the company has received many offers from customers for mobile application development and mobile responsive website. However, the game development of company was not smooth. They had problem about resources such as capital, personnel and skills. Therefore, there decided to focus on website on mobile first, then improved their skills together with increasing revenue to develop game on mobile later.

5.1.2 Current situation

Software industry has the intense competition of business and fast change business environment in terms of knowledge, technology and business model. These are all direct impact the company capabilities, resources and operation that should be improved all the time. Moreover, there are currently very short life cycle of using software. New technologies used to plan, develop or support the software development could evolve or change anytime. Therefore, this case study has a very interesting challenge how TRM can produce an effective roadmap to support their direction as well as strategic planning.

Possible changes has a characteristic of only single winner in one technology category. For example, Facebook is the single winner in social network category. Meanwhile, the runner-up and other places have a big gap to close the winner. This situation make the small software firm like Sylli Studio must quickly focus on the right technology carefully. In current software industry does not require high technical skills but require innovative ideas, user experience design and good presentation which are important skills for responding market needs especially steady increase of smartphone popularity. The company's main target market is Generation-Y consumer who prefers social media and e-commerce as the key online interactions.

5.1.3 Future outlook

Software and game trends in the future depend on current technology research and development. This factor is based on forecasted consumer behaviour. For example, Virtual Reality (VR) and Augmented Reality (AR) has been predicted and planned to be a popular application in parts of business, education and entertainment. So, graphical technology which includes computer software and hardware, will be promoted to higher priority for research and development supporting direction of industry.

5.1.4 Executive interviews

The executives provide a set of data based on product development and technology capabilities. They mentioned what factors related to their current situation of business are able to be used as the drivers in external factor analysis (Table 4.1).

5.2 Scenario Analysis

Although platforms or Operating Systems (OS) on smartphone have not much choices for customer but they usually satisfy to choose up-to-date version for their new devices. Updating their devices to new OS version is also an easy option in general. Customer satisfaction as well as consumer behavior contain many factors that a firm should respond for competitive advantage. The produced games and softwares should target on popular platforms of smartphone. This perspective in choosing target can guarantee the good direction. To upgrade products supporting popular OS, a firm has the increasing cost for product development and marketing activities. A most critical factor of investment risk comes from short life cycle of products. From executive interviews and the result of the highest value on potential impact and uncertainty, they decided to use diversify of platforms and product life cycle to be the key uncertainties of scenario analysis.

This section shows the sub drivers of base-case scenario as well as their potential impact and uncertainty value in the usual business situation (Table 5.1). Then use influencing drivers generated from trend and uncertainty analysis (Figure 5.1) to separate base-case scenario into two different scenarios. The change of influencing drivers or key uncertainties lead to different results (Figure 5.2). The worst-case scenario shows how a negative shift of influencing drivers leads to a worst-case roadmap. The best-case scenario demonstrates how a positive shift of influencing drivers leads to a best-case roadmap.

Table 5.1 Scenario analysis: The measurement value of potential impact and uncertainty in a usual business situation

No	Sub Drivers	Potential Impact	Uncertainty
1	Attitude toward the game in society	2	7
2	Payment behavior of the players	7	3
3	Lifestyle	5	5
4	Growth of Internet café	1	1
5	Increasing of intuitive and innovative game play	8	3
6	Increasing of Virtual Reality game	3	4
7	Increasing of mobile device usage	10	2
8	Diversity of platforms	7	9
9	Product life cycle	7	9
10	Growth of broadband Internet	5	1
11	Hardware Specification	7	1
12	General Economic	3	5

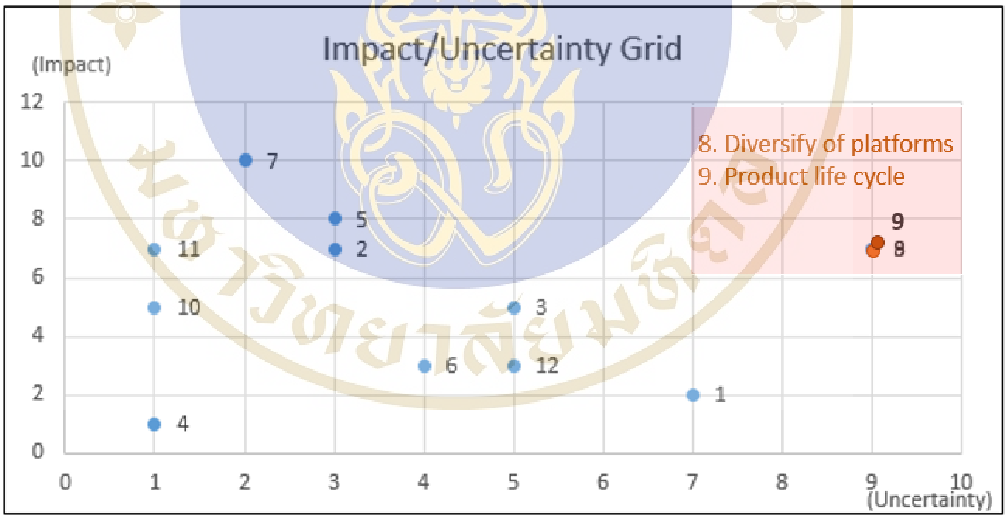


Figure 5.1 Scenario analysis: Trend and uncertainty analysis (Impact/Uncertainty grid)

5.2.1 Base-case scenario

This case (Table 5.2) describes the current usual situation that there are no any concern about economic. Mobile device usage has increase with releasing new hardware technologies incessantly. But high graphical technology like Virtual Reality is still not much popular in current time. This may be caused from customer behaviour that interested in playing intuitive and innovative game. The online transaction on e-commerce and purchasing mobile application and game provide the most convenience way what the company have to support. A roadmap produced under this condition named Base-case roadmap is shown as Figure 5.3.

5.2.2 Best-case scenario

From trend and uncertainty analysis (Figure 5.2), diversification of platforms stay on a positive situation that means there is less change smartphone platforms. Product life cycle also stay on a positive situation indicating a launched game is consumed in the market for a long time.

This case (Table 5.3) describes that the economics is the same situation as Scenario A. The lifestyle is more uncertain but not effect to payment behaviour and mobile device usage of the game players. The driver of increasing of mobile device usage has been reduced relative importance from this cause. The diversity of platforms, product life cycle and hardware specification has also been reduced relative importance because the company can operate business as usual or having better business situation than Scenario A. Therefore, the company has a stable business environment. This phenomenon is good outlook for software and game consumption. The consumer plays more games and frequently purchases. A roadmap produced under this condition named Best-case roadmap is shown as Figure 5.4.

5.2.3 Worst-case scenario

From trend and uncertainty analysis (Figure 5.2), diversification of platforms stay on a negative situation that means there is much change smartphone platforms. Product life cycle also stay on a negative situation, indicating a launched game is consumed in the market for a short time.

This case (Table 5.4) describes that the economic situation is worse than Scenario A. Its relative importance has been increased for surveillance. This phenomenon effects to lifestyle that the consumer is more careful on spending including of mobile device usage. The consumer only uses mobile device for necessary tasks. The payment behavior of game players has been increased because it related to product channels that company should focus on this point to get more selling opportunities. The product life cycle and hardware specification has been reduced relative importance because the industry looks slow down without any change. A roadmap produced under this condition named Worst-case roadmap is shown as Figure 5.5.

The impact/uncertainty level of key uncertainties for each scenario is shown as Figure 5.2. It describes the difference level of product life cycle and diversity of platforms between base-case scenario and its options.

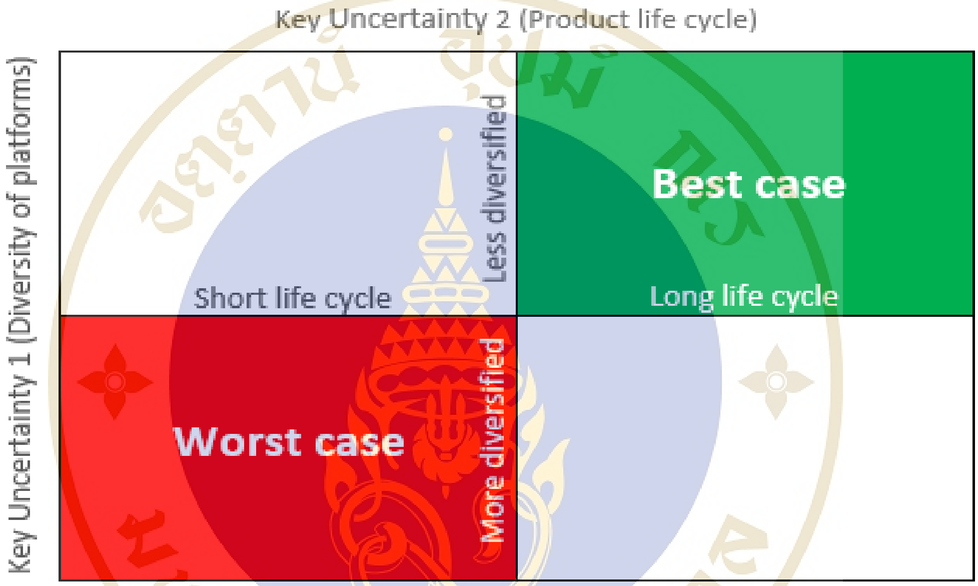


Figure 5.2 Scenario matrix of the case example

5.3 Technology Roadmapping on Computerized System

Table 5.2 Base-case scenario: The relative importance and tolerance limits of key/sub drivers

Management Level									Operational Level
Key Drivers	Sub Drivers	Relative Importance	Level of Confidence	Tolerance Limits					Measurement Value
				T2-1	T1-0	Mbase	T0-1	T1-2	
Social		3	Low						
	Attitude toward the game in society	2		15	30	60	80	100	35
	Payment behavior of the players	7		20	40	60	70	100	40
	Lifestyle	5		20	40	60	70	100	60
	Growth of Internet café	1		20	40	60	70	80	20
Technological		10	High						
	Increasing of intuitive and innovative game play	8		0	10	15	20	40	5
	Increasing of Virtual Reality game	3		0	10	15	30	40	3
	Increasing of mobile device usage	10		20	40	60	80	100	85
	Diversity of platforms	7		30	40	50	80	100	50
	Product life cycle	7		3	6	12	18	24	6
	Growth of broadband Internet	5		20	30	70	80	100	40
	Hardware Specification	7		10	30	60	80	100	50
Economic		5	Medium						
	General Economic	3		20	40	50	70	100	35

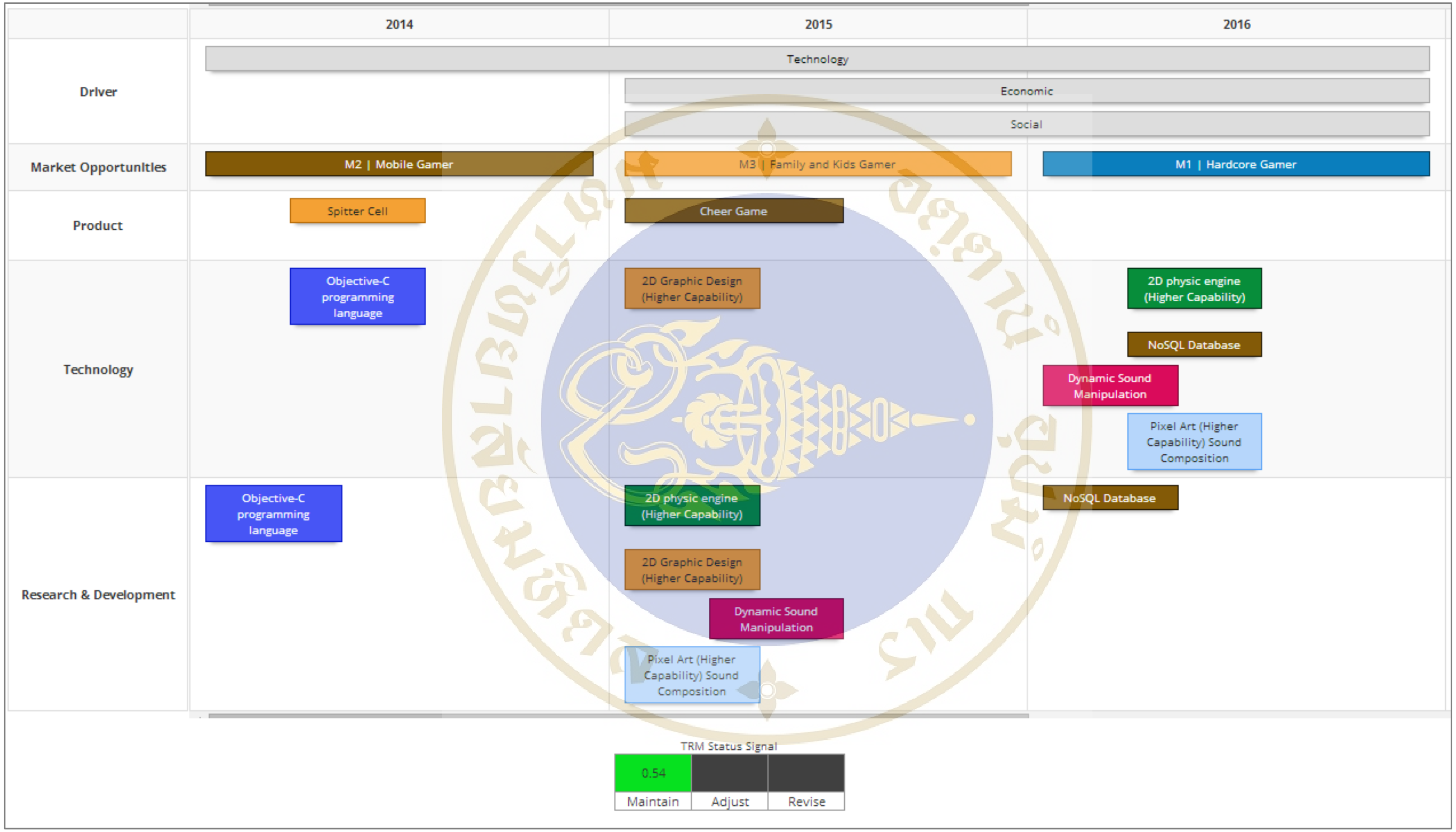


Figure 5.3 Base-case roadmap

Table 5.3 Best-case scenario: The relative importance and tolerance limits of key/sub drivers

Management Level									Operational Level
Key Drivers	Sub Drivers	Relative Importance	Level of Confidence	Tolerance Limits					Measurement Value
				T2-1	T1-0	Mbase	T0-1	T1-2	
Social		3	Low						
	Attitude toward the game in society	2		15	30	60	80	100	35
	Payment behavior of the players	7		20	40	60	70	100	40
	Lifestyle	8		20	40	60	70	100	60
	Growth of Internet café	1		20	40	60	70	80	20
Technological		10	High						
	Increasing of intuitive and innovative game play	8		0	10	15	20	40	5
	Increasing of Virtual Reality game	3		0	10	15	30	40	3
	Increasing of mobile device usage	5		20	40	60	80	100	85
	Diversity of platforms	4		30	40	50	80	100	50
	Product life cycle	4		3	6	12	18	24	6
	Growth of broadband Internet	5		20	30	70	80	100	40
	Hardware Specification	4		10	30	60	80	100	50
Economic		5	Medium						
	General Economic	3		20	40	50	70	100	35

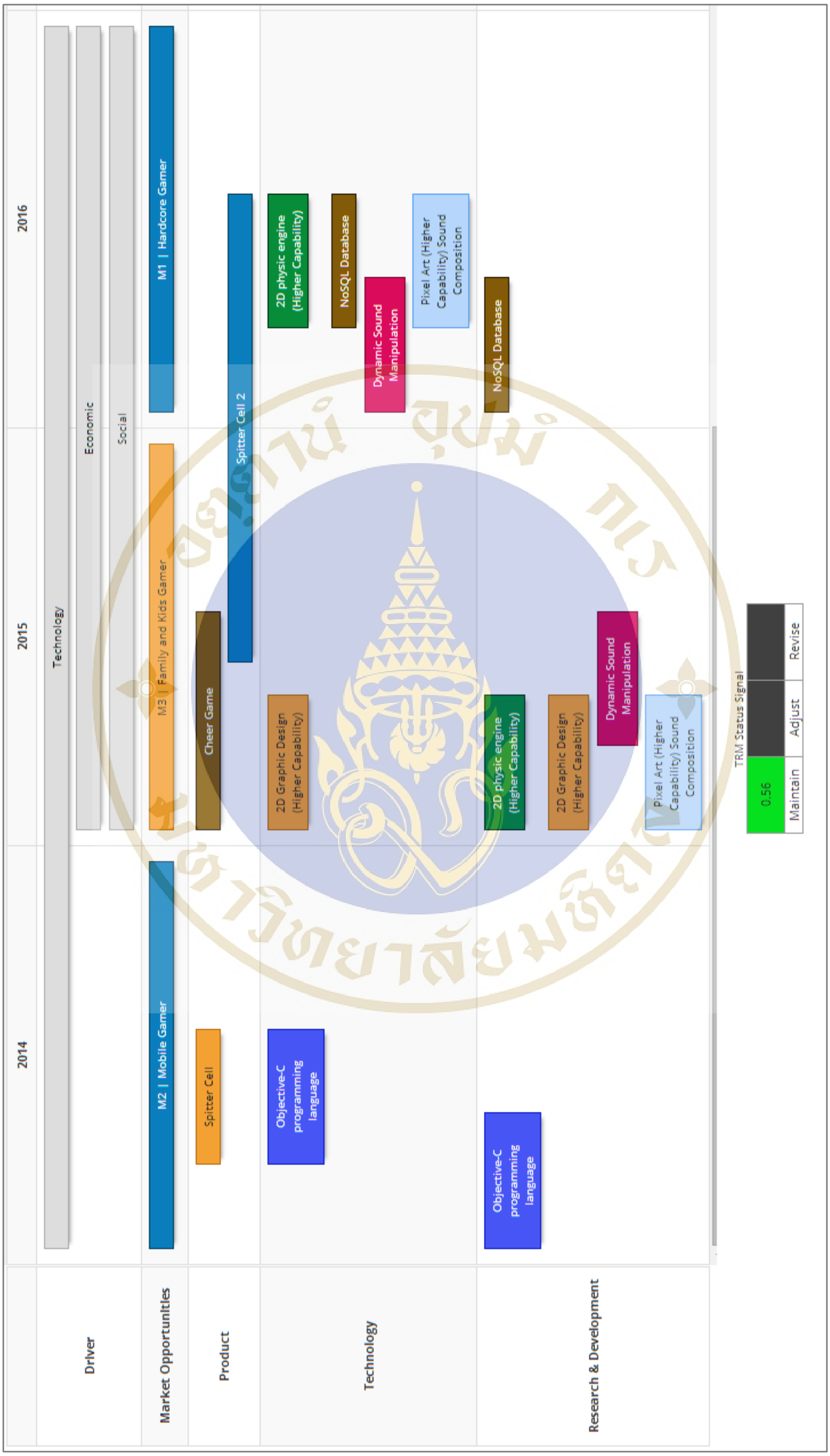


Figure 5.4 Best-case roadmap

Table 5.4 Worst-case scenario: The relative importance and tolerance limits of key/sub drivers

Management Level									Operational Level
Key Drivers	Sub Drivers	Relative Importance	Level of Confidence	Tolerance Limits					Measurement Value
				T2-1	T1-0	Mbase	T0-1	T1-2	
Social		1	Low						
	Attitude toward the game in society	2		15	30	60	80	100	35
	Payment behavior of the players	10		20	40	60	70	100	40
	Lifestyle	7		20	40	60	70	100	60
	Growth of Internet café	1		20	40	60	70	80	20
Technological		10	High						
	Increasing of intuitive and innovative game play	3		0	10	15	20	40	5
	Increasing of Virtual Reality game	1		0	10	15	30	40	3
	Increasing of mobile device usage	10		20	40	60	80	100	85
	Diversity of platforms	7		30	40	50	80	100	50
	Product life cycle	5		3	6	12	18	24	6
	Growth of broadband Internet	5		20	30	70	80	100	40
	Hardware Specification	5		10	30	60	80	100	50
Economic		7	Medium						
	General Economic	5		20	40	50	70	100	35

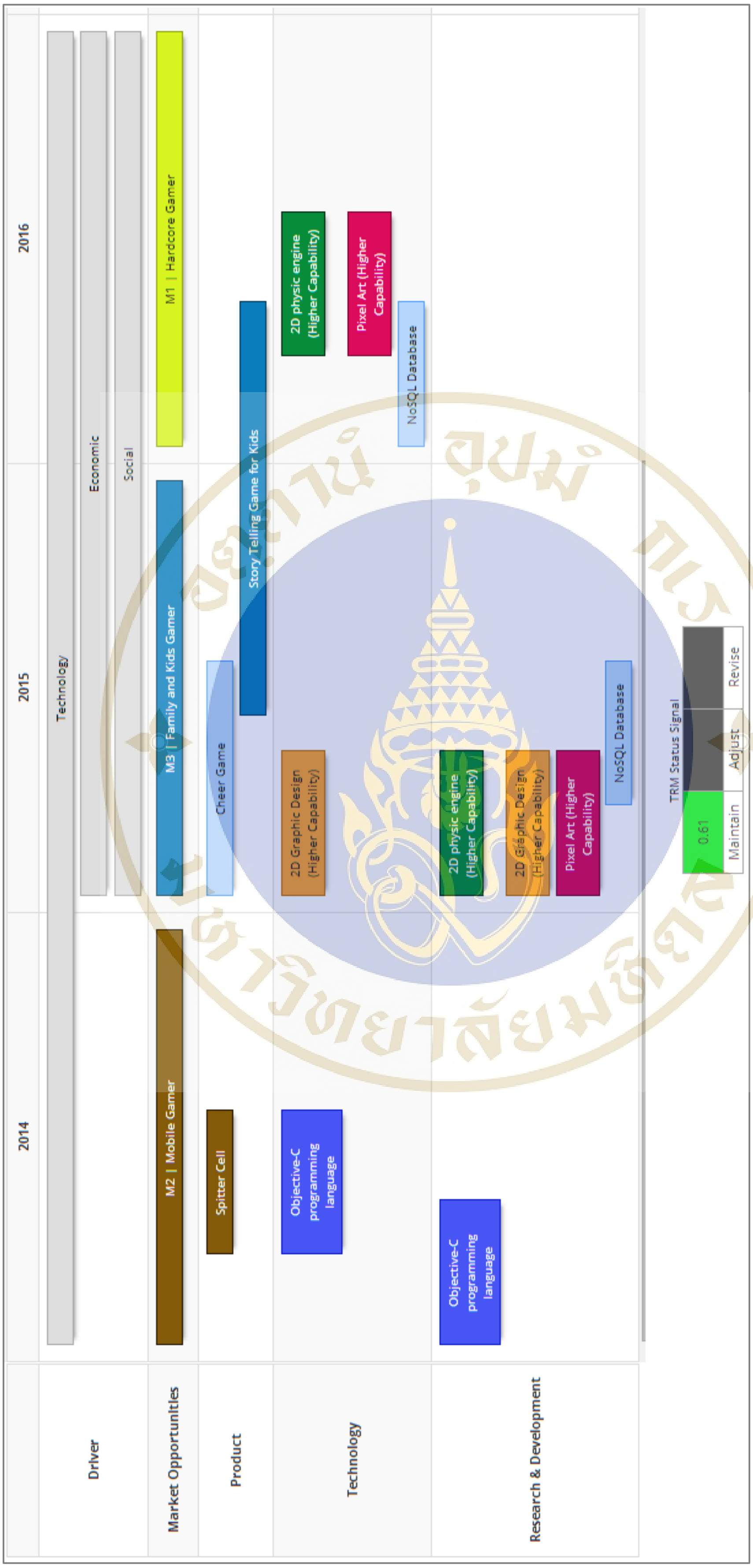


Figure 5.5 Worst-case roadmap

5.4 Feedback from Users

5.4.1 How do you feel towards the optimization and application of TRM in this format ?

It was a great opportunity to revise and raise some concerns regarding the changes of uncontrollable issues such as social attitude, general economic and to foresee how it may affect our direction. However, the process needs to be revised again from year to year to make it fits into our business field because we are small business and in technology field.

5.4.2 How useful is this TRM application to your organization ?

From our current circumstances, it is quite useful when it comes into the direction of product development because it can be a part that help us decide which product to go or discard when the situation occur.

5.4.3 Regarding organization strategy, how can this TRM application help your analysis and strategy formulation?

It was a good indicator tool to let us know when to change the strategy before time. The more frequent we use this tool, the more accuracy we achieved.

5.4.4 Regarding flexibility of use, how can your organization change to bring TRM be a part of strategy development in practical ?

The product development strategy can be adapted to this TRM and also TRM can be adapted to be used for a single product strategy as well. We may use it to analyze and/or determine the specific product strategy to make it more profitable.

5.4.5 What are your expectations from using TRM ?

We expect the results of it that could be practical enough for our business to adapt into it and also the clear guidances that the TRM provided.

CHAPTER VI
DISCUSSION AND RECOMMENDATION

The aim of this research is to develop a web application for TRM process. The main outcome of this research is a computerized system to assess the roadmap status signal. The signal indicates the roadmap status whether to maintained, adjusted or revised. Therefore, this computerized system can help a management team to know the suitable action and reduce the time in analysis and decision-making process. As a result, the web application produces a roadmap and its status signal to consideration.

6.1 Research Finding

According to the literature reviews and doing this research, the author found that TRM can be used to advantage for the technology planning of an organization as well. But the effective framework as well as the appropriate platform are important barriers to apply TRM for an organization in practical. A web-based application can be the effective operationalizable platform to eliminate this barrier. The STEEP analysis can also be the appropriate framework to analyze external factors as well.

On the other hand, are there any opportunities else to increase benefit and efficacy for TRM ?. The evaluation of status signal for a roadmap and the scenario planning are the answer of this question. The evaluation of status signal for a roadmap identify the status of consistency between developed technology and business environment. The scenario planning builds the alternative roadmaps from current single roadmap. These two approaches give the way to unlock the potential of TRM. The evolution from Single-Scenario Single-Roadmap as usual TRM process, to Multiple-Scenario Multiple-Roadmap as advanced TRM process, this progress give an impressive additional value to TRM.

6.2 Discussion

About the current understanding or theory in the innovation management, many organizations have used a roadmap to guide their innovation activities. Those organizations also face the similar challenges in monitoring the status of their roadmaps whether their roadmaps are still valid given the changes of external business drivers. With the development of web-based application, it will help management to analyze and adjust their innovation plan appropriately according to the changes impacted on the roadmap.

The challenges of roadmap operationalization are such as what are the most effective tools that can be used to analyse the roadmap components. There are five main elements combining in a roadmap which consist of driver, market opportunities, product, technology, and research and development. Every elements managed by the application are able to connect to each other rationally. The designing takes the structural relationships or connections between roadmap's links and nodes into consideration to ensure the alignment among different segments on web application form. In other words, the structural relationship of application can help to systemize the practitioner's communication which is unstructured data. To achieve the target of communication and learning performance which are the same content expecting to improve in every organizations, an operationalizable form of TRM is a good solution in practical for TRM process including other collaboration activities.

The practitioners, who use this operationalizable form or a web-based application, are able to focus on the impact of changes in business drivers on a roadmap. Because this computerized system can identify the status as a guide to the appropriate timing for any action. For example; a “Maintain” signal recommends to maintain a roadmap and continues to operate the roadmapping process as usual. An “Adjust” signal recommends to adjust a roadmap because a change in the key drivers has effect on the roadmap. A “Revise” signal recommends to revise a roadmap because there is a severe impact from a change in an organization’s environment on a roadmap. Alignment of management level part and operational level part on a web form can help these two levels of staff working together in monitoring the status of a roadmap. Furthermore, one of the most benefit of web-based application is to allow the practitioners accessing the system anytime, anywhere.

In case study, the author found that it is very convenience to collect data from participants by using this web application. It may be hard to understand the sequence of TRM processing on web application in the first time and it is surely harder if an organization has never know TRM before. The author decided to communicate by using a worksheet because of this reason. From the participant's feedback, the author believe that this web application can let the organization manage internal resources in accordance with market needs in a timely manner.

The author has described a computerized system in context of the roadmapping process as above. The relation between this research and TRM environment (Figure 6.1) describes how the computerized system participates with TRM environment in context of implementation stage. And the same figure also indicates what internal components and external components are contained to this system. An efficient platform or operationalizable system (Orange block) contains the scenario approach and the evaluation model of status signal. The evaluation model has been transformed from conceptual level by adding a part of programming code. This system is used to operate between development stage and integration stage of TRM implementation (Blue block)(Gerdsri, Vatananan and Dansamasatid, 2007). The TRM environment includes business uncertainty, external factor analysis and decision support information (Grey blocks). The business uncertainty is a source of finding critical drivers to feed in the external factor analysis. The first two components perform as the input of TRM process. The decision support information is a set of useful data for management processing from the computerized system. This component performs as the output of TRM process (Light grey block).

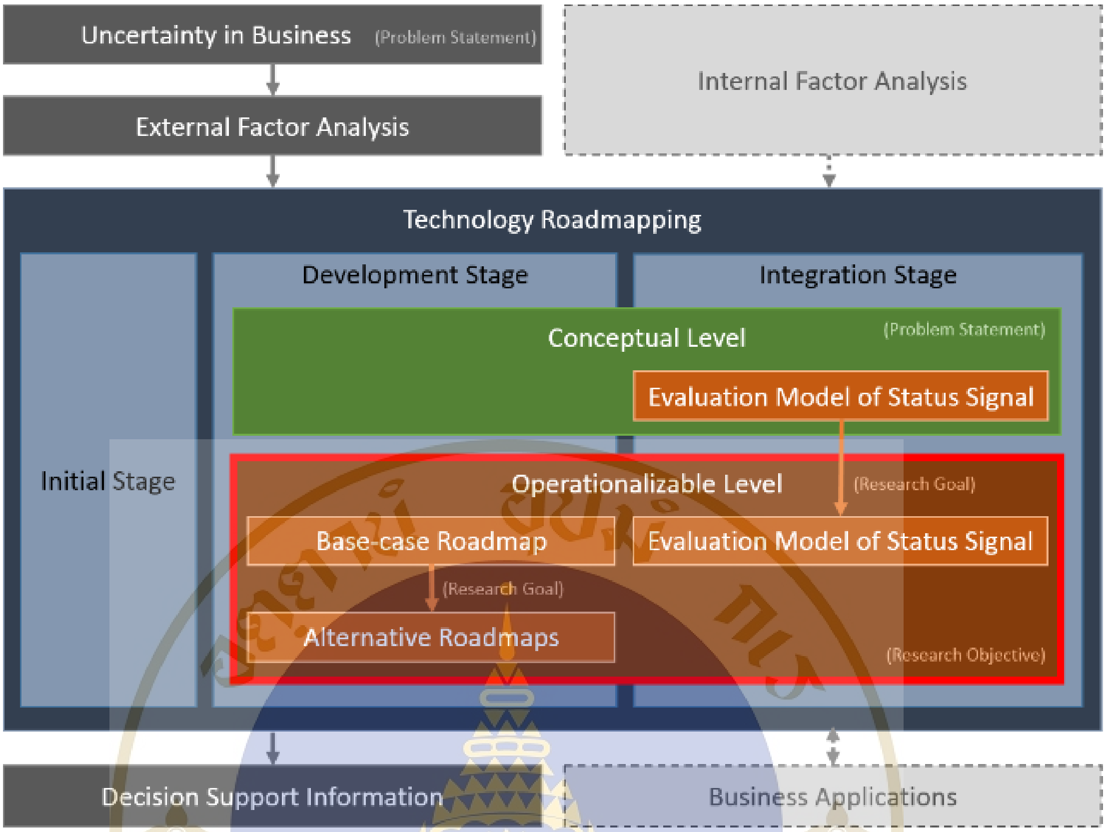


Figure 6.1 The relation between this research and TRM environment

6.3 Recommendation

From the study, the author found the interesting points which include:

- Before the roadmap production process, the scenario approach should be used meticulously for deeper understanding and getting more explicit scenario.
- There should have preparation period for participants to understanding the TRM background before joining the process. This will help participants in better extracting beneficial data to process.
- This system will be a higher performance system if it has connect with the internal factor analysis and external business applications as shown in Figure 6.1.

6.4 Limitation

There are no any limitations for the Single-Scenario Single-Roadmap method but for the Multi-Scenario Multi-Roadmap method, there are an existing limitation that the roadmapping team can produce a roadmap with a roadmapping process but cannot produce multiple roadmaps within a single roadmapping process. This may good already that a roadmap is produced by a single process independently.

Moreover, the overall limitations include:

- The evaluation model has only evaluate external factors excluding internal factors of an organization. Some issues from inside resources such as technology, should be assessed before product development.
- The status signal displaying on a roadmap has only show the status of big picture consisting of all key drivers and sub drivers, but lack of displaying the status signal for each key driver and sub driver specifically. If the application can produce specific the status signals for both key drivers and sub drivers, an organization will be able to identify appropriate drivers to maintain, update or revise. These independent status signals are also impact to the overall status signal of a roadmap.
- The output processed from the web application can be saved to a generic format but it still cannot use with other standard business applications. It may sound better if the data format can be direct used or converted from an additional function provided by this existing application.
- This system designs for all industries. Customising for specific industry will make the overall roadmapping process more effective.

6.5 Future Work

To close gap of limitations, the author found opportunities to improve the system including:

- Additional external factor analysis will help decision making for management more effective with a better class of TRM web application.
- Adding the status signal to all drivers is a good solution for identifying to appropriate focal point to maintain, update or revise.

- Changing data format to usable type with general business applications will help practitioners reducing the time to conversion and ease of use with actual business operation.
- The title of elements on the roadmap should design for changeable. It helps more flexible and fit for each case.
- The graphical display for the status signal still can modify to be a better sense of business perspective.

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