Risk Management of Research and Development of Land-Based Vehicles

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ABSTRACT

When a new vehicle is developed, risk factors that affect schedule, cost, scope, and performance can lead to failure and negatively affect military expansion and preparedness. This study employed the Delphi method to interview domain experts and determine the key risks for vehicle development, discovering a total of six dimensions and 27 risks, including 9 critical risks. We constructed a risk profile and a risk management Web site to monitor risk, further developing organizational strategies to reduce risk, maintain new product development stability, and achieve product development goals.

Keywords: new product development, risk management, mind mapping, Delphi method

陸用載具研發風險管理之研究

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摘 要

每一新式載具研究開發時，常面臨無法達到時程、成本、範疇及性能目標的風險因素，它可能使開發計畫失敗，甚至衝擊到建軍備戰。本研究運用德菲法訪談領域專家，以辨識載具開發的關鍵風險，發現關鍵風險計有「開發技術」等 6 個構面 27 項風險，重要關鍵風險計有「構型變更頻繁」等 9 項，並繪製風險圖像及建置風險管理網站，以利風險之處置及監控，進而發展組織之風險策略，以期降低風險，維持新產品開發穩定性，並達成產品開發的目標。

關鍵詞：新產品開發，風險管理，心智圖法，德菲法

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I. INTRODUCTION

Military strategies, enemy threats, and operational requirements characterize the development of vehicle weapon systems. Compared to general goods, the development of vehicle weapon systems involves substantial resources, lengthy manufacturing and testing periods, and overcoming complex and variable challenges. These uncertainty factors define the risks. Thus, how to determine and reduce risk is an important aspect of product development.

Numerous research and development (R&D) projects have shown that identifying risk factors at the beginning of a project reduces the problems that lead to failure. Risk management involves using numerous methods and tools to identify, evaluate, analyze, and manage risks within the product's life cycle to achieve the specified goals.

This study examines vehicle weapon systems, particularly tanks and armored vehicles. During the R&D stage, various key risks are identified and discussed. Combat armored vehicles have two R&D design methods. The first method is exterior to interior, that is, the maximum weight and size of the vehicle determines the interior subsystems, such as the engine and the transmission. The second method is interior to exterior, that is, the subsystems are selected before the exterior size is determined. Tanks that are employed on the frontline of a battlefield directly engage in combat; thus, the overall structure includes a weapon system, power system, protection system, communication system, electrical system, suspension system, transmission system, and other special equipment.

R&D projects typically include scheduling, cost assessment, quality control, procurement, product integration, and team management processes. In addition, weapon R&D projects emphasize system engineering, integrated logistics support systems, and implementation tests, evaluations, and verification. These projects require staff with professional knowledge and experience in product design, component standardization, production technology, mold production, assembly tools, process planning, inspection standards, methods, process flows, equipment use, the operation and maintenance procedure, troubleshooting, weapons performance testing, designing and developing information systems, and database setup.

These case study products, designed for operational requirements, are used to counter enemy attacks. Investigative projects typically include the conceptual design, demonstration, engineering development, production and manufacturing, implementation, and maintenance stages. These stages not only require substantial human and financial resources, but also lengthy periods of production and testing. In addition, the integration of multi-domain technologies, the procurement of material, and follow-up maintenance remain significant challenges.

Therefore, the purpose of this study is to identify, evaluate, quantify, and rank the risks of vehicle development. This study also uses the mind mapping technique to visualize the product development risks to clarify the risk items. This allows the project manager to use different risk management measures and invest appropriate resources to reduce risks and/or monitor risks.

This study employed the Delphi method to interview domain experts to identify the key risks of vehicle development. We identified 27 risk factors and classified them into the following six dimensions: development technology, production, error management, schedule management, cost management, and integrated logistics support. Through empirical analysis, we determined the nine most important risks: frequent configuration changes, inconsistent inspection standards, unclear requirements, scheduling changes, unsuitable tool planning, inaccurate cost estimates, flawed scheduling control, incomplete technological data, and unclear level of repair. Subsequently, we used the mind mapping technique to create a risk map and establish a risk management web site. The map enhances current understanding of risk distribution management, and monitoring, which facilitates the development of strategies to reduce risks, maintain new product development (NPD) stability, and achieve product development goals.

This paper is organized as follows: Section 2 presents a literature review; Section 3 explains the research methods and design; Section 4 reviews the data analysis results; Section 5 outlines the development of a risk profile and risk management web site; and Section 6 provides the conclusions.

II. LITERATURE REVIEW

By reviewing relevant theories and literature in this section, we define our research concepts and the relationships between them. First, we introduce the concepts of new product development and risk management. Then, we explain the risk profile, the mind mapping technique, and other literature data. Finally, we provide a comprehensive review of literature.

2.1 New Product Development and Risk Management

Souder [1] defined a new product as "a product that has never been owned." This is true regardless of previous market existence. Kotler [2] suggested that the following types of new products exist: (1) original products; (2) improved products; (3) modified products; and (4) new brands. Sampson [3] argued that a new product has the following three characteristics: (1) satisfies needs, wants, or desires; (2) possesses outstanding performance compared to other products; and (3) benefits from an imaginative combination of product and communication.

Cooper [4] proposed the seven stages of NPD: (1) generation of innovative ideas; (2) initial assessment; (3) concept review; (4) product development; (5) prototype testing; (6) trial sales; and (7) product introduction. The NPD process includes four steps: (1) concept generation: converting customer requirements to concept descriptions; (2) product plans: defining development results, costs, and outcomes, and the purposes of each product concept; (3) production engineering: transforming product purposes into detailed blueprints; and (4) manufacturing engineering: designing work flow, tools/equipment, and component processing procedures [5].

According to Cooper et al. [6], specific time is allocated for each NPD stage, such as concept and prototype development, prototype testing, market development, manufacturing startup, and marketing startup. NPD is a multi-stage, multi-disciplinary process, involving the management of interfaces between R&D, marketing, engineering, and manufacturing [7].

Maidique and Zirger [8] identified two factors that influence the successful launch of a new product, namely process-related properties (controllable) and choice-related properties (uncontrollable). Process-related properties have a closer relationship with the successful innovation and production of new products. These processes are influenced by 11 key factors: unique and excellent products, strong market orientation, adequate preoperational preparations, clear initial definition of new products, distinctive decision making when selecting a strategy, excellent planning and execution, an organizational structure that provides an innovative environment, implementation preparations and resource investments, the role of senior management, the speed of R&D and production, and a disciplined multistage new product development process. Boehm and DeMarco [9] created a knowledge database for risk management that enables the continual development of risk management skill and can be used easily by all stakeholders. The tools used include prototypes with a risk focus, specification, testing, formal verification, configuration management, and quality assurance.

Browning et al. [10] recommended solving these problems using the risk value method. This method reduces uncertainty during the product development stage and increases customer value by improving affordability. Keizer et al. [11] presented the Risk Diagnosing Methodology, which can enable a firm to identify and assess the relevant product development risks during the development of new products. The relevant risks can be categorized into technical risks, organizational risks, and marketing risks.

Cooper [12] asserted that if an organization uses its resources and capabilities to create a new product or improve an existing product, its processes can be considered new product development processes. Cooper focused on knowledge management systems and cooperation tools and used the results to develop a solution for managing new product development risks. Choi and Ahn [13] presented a risk analysis model to identify the risk factors of a product development process. This model can also be used to analyze the impact of risk factors on product development items and can be expanded into a framework of risk management. Thus, this model can assist in protecting against various risk factors.

Traditionally, design, resource, and manufacturing process management is required to complete a product. However, each department is only responsible for its own duties; therefore, the design department designs products without considering the manufacturing feasibility. If the design team considers the entire manufacturing process when designing the product, team members from different departments may influence each decision in the design phase. The gradually increasing complexity would render the organization and assigning of tasks difficult. Thus, to accomplish tasks in such an environment, a multifunctional project team is required to reduce the overlapping activities. During NPD, the product development risks are considered to demarcate the responsibilities and identify the optimal arrangements.

One of the greatest challenges faced by a company is developing new products with limited capital and human resources and when the stakeholders are requesting an increase in dividend payments. NPD is expensive, time-consuming, and influenced by current technology and market conditions [14]. Thus, although NPD is a decisive process that encourages competitiveness, it is also characterized by inherent high risk and uncertainty [15].

Project risk management is crucial for assessing and reducing NPD project risks. Drexel [16] defined project risk as a possible event that may negatively affect project goals. Risk degree involves the quantity of disclosed negative events and possible outcomes. Risk classification allows for convenient identification and management. Project risk management involves planning, identification, analysis, response planning, and monitoring, and the purpose is to increase the probability of positive project events and reduce the probability of negative project events [17]. Chrissis et al. [18] contended that risk management is continuous and should focus on issues that negatively affect important goals.

In summary, effective risk management in NPD projects involves essential elements to prevent risk occurrence, namely, to identify and confirm risks using any feasible method; to measure potential risk-induced losses; to adopt suitable preventative methods; and to introduce a risk-conscious culture, efficient work procedures, experienced and skilled staff, and consistent applications.

2.2 Mind Mapping and Risk Profile

Buzan [19] stated that mind mapping is a display of radiant thinking, which is a natural human thinking method. A mind map is similar to a city map. The central topic, similar to a city center, expresses the most important idea. The main roads that extended from the city center are the thoughts that extend from the main idea. The secondary roads extending from the main roads represent the secondary thoughts.

Wycoff [20] explained that the mind mapping method is a complete-brain learning technique, as proposed by the head of the U.K. Brain Foundation Tony Buzan. Mind mapping is a visual diagram that expresses thoughts using keywords and images, fully employs the characteristics of left and right brain functions, and freely presents ideas and concepts. Hanf [21] reasoned that mind mapping is a graphic expression of thinking. The learning method of mind mapping is very simple and easily accepted by the public. Mind mapping facilitates learning and work by enhancing memory and increasing thought clarity [22].

Based on radiant thinking, mind mapping describes how human brains process thoughts and messages; different ideas are connected through relationship hooks. Aydin and Balim [23] stated that mind maps can either be hand-drawn or produced in a computer environment. Numerous software programs facilitate digital mind mapping. These types of software programs typically include a variety of illustrations and pictures.

A mind map comprises four major characteristics:

(1) An onset position that contains a central topic node.
(2) Ideas radiate from the central node to the secondary node in a parent-child relationship.
(3) The final structure adopts a hierarchy of

linked nodes.

(4) A keyword or picture connects each linking node/branch.

Using a concept map can assist in accommodating and organizing a large amount of information. Mind mapping also includes the thought integration of a concept map. Thus, mind mapping can benefit learning and enhance teaching. Mind maps can also display thoughts and creative ideas using visual diagrams.

Risk profiles were initially developed as part of the Sedan risk analysis schema to provide conventional risk assessment [24]. Risk profiles have been used to support industry risk assessments, for example, in the design of a large-scale distributed system to support the maintenance of aero-engines [25]. Risk profiles can supplement common risk assessments with useful new metrics. Risk profiles have an important application in criteria risk analysis because they facilitate links between the systematic analysis of threat paths in a system model, attackers who may be outside the field of the model, and security detection [26]. Additionally, risk profiles may be used to identify and prioritize disposal risks. By using risk profiles in this way, risk process models may be further developed to quantitatively assess the identified risks [27].

In summary, a risk profile employs concepts that are applicable to all industries and corporate organizations. A risk profile indicates the risk location and builds hierarchical connections between risks. The risk identification mentioned in this study involves recalling implicit risks. After searching and coordinating risk, the graphic interface presented in the risk profile enables guidance, sharing, and interaction. The diagram presented by mind mapping includes visualized text and graphics. In the diagram, the connections between risks are clearly presented, facilitating the sharing of risk information within an organization.

2.3 The Delphi Method

Schmidt et al. [28] developed a reliable list of common risk factors and employed an accurate data collection method known as a “sequential Delphi survey,” which generates a list of ranked risk factors. The Delphi method allows experts who cannot attend a formal meeting to provide feedback through questionnaires [29]. Tummala and Burchett [30] suggested that the Delphi method can achieve consistency by using questionnaires to collect risk or historical data within a category, followed by anonymously collecting expert assessments.

Today, the Delphi method is widely applied in various fields by government agencies and academic units for technologies, budgets, and life quality. The Delphi method is also among the important decision-making tools for resource monitoring and assessment [31].

III. RESEARCH METHODS AND DESIGN

We interviewed experts and used the Delphi method to investigate the key risks of developing new land vehicle products to understand the core values of risk management, and develop a risk profile suitable for the organizational characteristics. This section explains the research domain and research framework and details the implementation steps of the Delphi method.

This study used the qualitative research procedures of a Delphi method interview and determined the key risks of land-based vehicle NPD. Then, mind mapping was employed to visualize the risk profile. Figure 1 shows the risk management process.

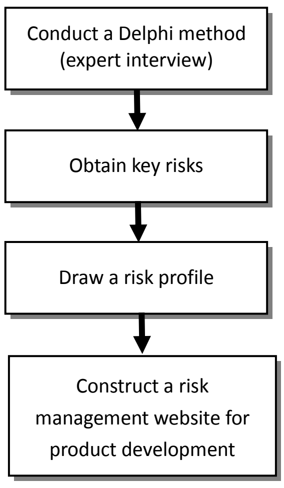

Fig. 1. The risk management process.

The Delphi method integrates the opinions of a group of experts in written format. First, an questionnaire survey was designed. Then, the questionnaires were distributed among the target participants (scholars, experts, and workers who have conducted in-depth research on the issue, hereafter called "experts"). After receiving the completed questionnaires, we collated the responses into a narrative questionnaire, which we returned to the same group of experts. The experts indicated whether they were in favor of the discussion topic. Subsequently, we organized the expert opinions, completed the analysis table, and compiled questionnaires for the next round. Then, each expert was asked to complete, add, or modify the questionnaire until they reached a consensus. The operational steps are described below (see the flowchart shown in Fig. 2).

(1) Questionnaire Design
To ensure the questionnaire fully covered the research topic, we emphasized the topic and collected and summarized related literature. The experts were instructed to proofread the questionnaire and provide suggestions after a pretest. Based on the experts' suggestions, the first draft of the questionnaire was modified to ensure the content validity of the questionnaire.

(2) Expert Selection
The experts making predictions must have sufficient professional knowledge, experience, and wisdom. We selected experts who satisfied one of the following criteria:(a) currently or previously employed as a public enterprise manager with more than 10 years practical experience relevant to their expertise; (b) possess a PhD with full-time experience relevant to their expertise, or more than 5 years research experience; (c) have a master's degree with full-time experience relevant to their expertise, or more than 7 years research experience; (d) a professional or technical employee with professional certificates and more than 6 years related experience. Based on these criteria, 15 people who were currently or previously involved in vehicle systems development were selected as the expert team in this study.

(3) The first open questionnaire survey was conducted.

(4) Expert opinions were collected in the first round of the questionnaire.

(5) Experts' opinions were organized into a table for analysis, and the questionnaires for the next round were developed. Then, each expert was instructed to complete, add, or modify the questionnaire.

(6) The modified questionnaire and additional comments from the experts were collected.

(7) The opinions of the experts were integrated to obtain a comprehensive and consistent result. If the purpose could not be achieved, the processes designing a questionnaire, collecting questionnaires, and performing statistical analysis were repeated to reach a final consensus.

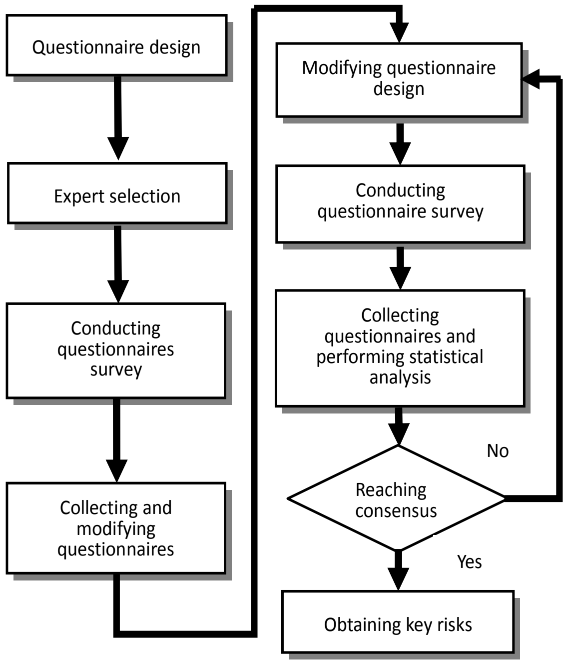

Fig. 2. The Delphi method flowchart.

IV. DATA ANALYSIS RESULTS

This section explains the research method and processes. First, the Delphi method was used to design questionnaires. Then, the questionnaire survey for the experts was conducted and the results were analyzed to identify the risks and dimensions of this study. After the experts reached a consensus, the report on "the key risks of land vehicle NPD" was completed.

For the first questionnaire survey, we distributed 15 expert questionnaires and collected 15 completed questionnaires for a response rate of 100%. To assess the dimensions of key risks, an ascending scale from 1 to 9 was designed (1: Disagree strongly; 2: Tend to disagree; 3: Disagree; 4: Somewhat disagree; 5: Neutral; 6: Somewhat agree; 7: Agree; 8: Tend to agree; and 9: Strongly agree). The value indicated the experts' degree of agreement with the key risks.

After collecting the responses to the first expert questionnaire, we used SPSS and Microsoft Excel statistical software for data statistical analysis of the mean, quartile deviation, median, and the standard deviation. The mean is the average value of the member scores. A higher value indicates that the experts consider the key indicator highly important. This study set the mean of each key risk at ≥ 7 (7 is their initial agreement with the evaluation scale) to indicate that the item was recognized by the experts. The quartile deviation represents the opinion difference between members whose scores are between 25% and 75% when the member scores are ranked from low to high. Larger values indicate a greater difference among member opinions. The quartile deviation is the standard for judging the dispersion degree of expert opinions. According to Fahety [32], in a 1 to 9 ascending evaluation scale, if the quartile deviation is ≤ 0.6, then expert opinions reach consistency. When member scores are ranked sequentially, then the value in the middle is the median. Standard deviation is the dispersion of member scores and individual opinion differences. The larger the number, the greater the opinion differences among members.

Below we present the data analysis results of the first expert questionnaires. Table 1 shows the statistical results of the first questionnaire, which comprises 29 key risks. Of which, the five key risks "materials that are difficult to obtain," "inadequate patent management," "material management not informationized," "delayed development schedule," and "inappropriate facility planning," obtained means < 7 and quartile deviations > 0.6, indicating that the experts did not consider them to be key risks. In the second questionnaire survey, the experts were asked whether those items should be removed from the questionnaire. Additionally, some experts suggested that "improper tool planning," "schedule changes," and "cost changes" were three key risks that were important for risk management and should be included in the discussion. Therefore, we added these three items to the second questionnaire survey.

The second questionnaire included the statistical analysis table of the first questionnaire. Each expert was instructed to complete, add, and modify the questionnaire. We distributed 15 questionnaires, and 15 completed questionnaires were returned for a response rate of 100%. After collecting the data, the SPSS and Microsoft Excel statistical software calculated the mean, quartile deviation, median, and standard deviation. Additionally, the experts reached a consensus. Table 2 shows the statistical results of the second questionnaire.

The Delphi method was used to establish a consensus regarding the key aspects of nursing care in Australian critical nursing care programs by domain experts [33]. The Delphi method has been widely used to achieve a consensus on numerous issues. Using the Delphi method enables easy identification and an equal distribution of potential participants from four key constituencies [34].

The experts must have knowledge and research experience relevant to the topic of this study. The second stage involves providing the experts with a series of statements related to the questionnaire to encourage them to discuss their specific comments and suggestions. This approach facilitates the process of amending the questionnaire by integrating the experts' opinions and perspectives and compiling their comments on the questionnaire responses. Then, the results were distributed among members of a discussion group to conduct further analysis or provide suggestions to modify the items. Thus, the questionnaire was assessed and modifying in this manner until a consensus was achieved.

Table 2 shows the 27 key risk factors. The factors that are considered very important (i.e., the mean is greater than 8) include "frequent configuration changes," "inconsistent inspection standards," "unclear requirements," "schedule changes," "improper tool planning," "inaccurate cost estimates," "flawed schedule management," "incomplete technological data," and "unclear level of repair." These risks require special management during vehicle development. Response strategies and proper resources are necessary to avoid impacting product development and mass production.

Table 1. Statistical analysis of the first questionnaire survey

Key risk dimensions	Key risks	Mean	Quartile deviation	Median	Standard deviation
Development technology	Unclear requirements	8.33	0.50	8.00	0.65
	Frequent configuration changes	8.17	0.50	8.00	0.72
	Adoption of new technology	7.75	0.25	8.00	0.45
	No consideration of human-machine interfaces	7.75	0.50	8.00	0.87
	Materials that are difficult to obtain	6.25	1.25	6.00	1.22
Production	Fuzzy standard working procedures	8.33	0.50	8.50	0.78
	Inconsistent inspection standards	8.00	0.50	8.00	0.74
	Poor quality control	7.67	0.50	8.00	0.65
	Rework	8.25	0.50	8.00	0.75
Management errors	Poor execution of human resource management	7.75	0.50	8.00	1.06
	Blocked contract management	7.83	0.50	8.00	0.94
	Poor performance management	8.33	0.50	8.50	0.78
	No procurement management standards	8.58	0.25	9.00	0.79
	Inadequate patent management	6.50	0.75	8.00	0.87
	Material management not informationized	6.08	0.75	6.00	1.00
Schedule management	Insufficient activity resources	7.75	0.50	8.00	0.87
	Insufficient planning	7.92	0.50	8.00	0.67
	Flawed schedule management	8.33	0.50	8.50	0.78
	Inappropriate scheduling	8.17	0.50	8.00	0.72
	Delayed development schedule	6.08	0.75	6.00	1.00
Cost management	Inaccurate cost estimates	7.92	0.50	8.00	0.67
	Material cost changes	8.08	0.50	8.00	0.67
	Large budget increase	7.50	0.50	7.50	1.00
	Loose cost control	7.75	0.50	8.00	0.87
Integrated logistics support	Unclear level of repair	8.17	0.50	8.00	0.72
	Incomplete technological data	7.67	0.50	8.00	0.98
	Education training not conducted	8.33	0.50	8.50	0.78
	Failure analysis error	7.92	0.25	8.00	0.79
	Inappropriate facility planning	6.50	0.75	7.00	0.90

V. ESTABLISHING A RISK PROFILE AND A RISK WEB SITE

Graphical representation can enhance learning speed and long-term memory retention. For the key risks obtained using the Delphi method, this study applies mind mapping thought integration techniques, displays the risks using a diffusion thinking model, and combines the risk profile concepts using Mind Manager software. Using a hierarchical model, we created a visual integration graphic of risks. Visualization presents analyzed data in visual form. The output results typically adopt the form of a risk profile.

Based on the rules of mind mapping, this study created a risk profile (shown in Fig. 3.) using the key risks shown in Table 2. The process was as follows:

(1)First, select a central topic node, which is “risk profile of NPD” for this study.

(2)Connect the central node and the subnodes of development technology, production, error management, scheduling management, cost management, and full logistics support that extend from the central node in a parent-child relationship.

(3)A risk profile presents a hierarchical structure that connects each node.

Table 2. Statistical analysis of the second questionnaire survey

Key risk dimensions	Key risks	Mean	Quartile deviation	Median	Standard deviation
Development technology	Unclear requirements	8.35	0.25	8.00	0.74
	Frequent configuration changes	8.39	0.50	8.00	0.65
	Adoption of new technology	7.92	0.13	8.00	0.67
	No consideration of human-machine interfaces	7.83	0.50	8.00	0.72
Production	Fuzzy standard working procedures	7.67	0.50	8.00	0.65
	Inconsistent inspection standards	8.36	0.13	8.00	0.67
	Poor quality control	7.92	0.50	8.50	0.78
	Rework	7.92	0.25	8.00	0.74
	Improper tool planning	8.33	0.50	8.50	0.78
Management errors	Poor execution of human resource management	7.92	0.50	8.00	0.67
	Blocked contract management	7.97	0.25	8.00	0.74
	Poor performance management	7.83	0.50	8.00	0.72
	No procurement management standards	7.67	0.50	8.00	0.67
Schedule management	Insufficient activity resources	7.83	0.50	8.00	0.72
	Insufficient planning	7.92	0.50	8.00	0.67
	Flawed schedule management	8.20	0.50	8.00	0.72
	Inappropriate scheduling	7.67	0.50	8.00	0.98
	Scheduling changes	8.30	0.50	8.00	0.65
Cost management	Inaccurate cost estimates	8.25	0.50	8.00	0.75
	Material cost changes	7.67	0.50	8.00	0.67
	Large budget increase	7.35	0.50	8.00	0.65
	Loose cost control	7.92	0.50	8.00	0.67
	Cost changes	7.83	0.50	8.00	0.72
Integrated logistics support	Unclear level of repair	8.08	0.13	8.00	0.67
	Incomplete technological data	8.17	0.50	8.00	0.72
	Education training not conducted	7.67	0.50	8.00	0.67
	Failure analysis error	7.75	0.50	8.00	0.62

(4)Each connector/branch contains the risks shown in Table 2. In the figure, risks with a mean greater than 0.8 are indicated with the ★ symbol and a sequential value to enable the experts to understand the importance of risks.

Figure 3 shows a hierarchical risk breakdown structure map. In the risk profiles, risks are disassembled into risks that are easy-to-manage, increasing the efficiency and accuracy of risk analysis and risk evaluation. Based on job demands, the risk profiles can continue to be unfolded to enable the team members to clearly understand the risk connections.

The risk profiles developed using the Mindjet Mind Manager software can be employed to quickly establish a risk management Web site using the in-built tools (as shown in Fig. 4.). This Web site presents a risk diagram evaluated by the experts. Through the Internet or the Intranet, project staff can browse various risk content and connect with the organization management system to form a superior risk management structure. Then, an organization can include the analyzed risk parameters, risk occurrence rates, and impact values in the Web site, allowing this data to be shared with the team members to improve vehicle research scheduling, costs, and resource investments.

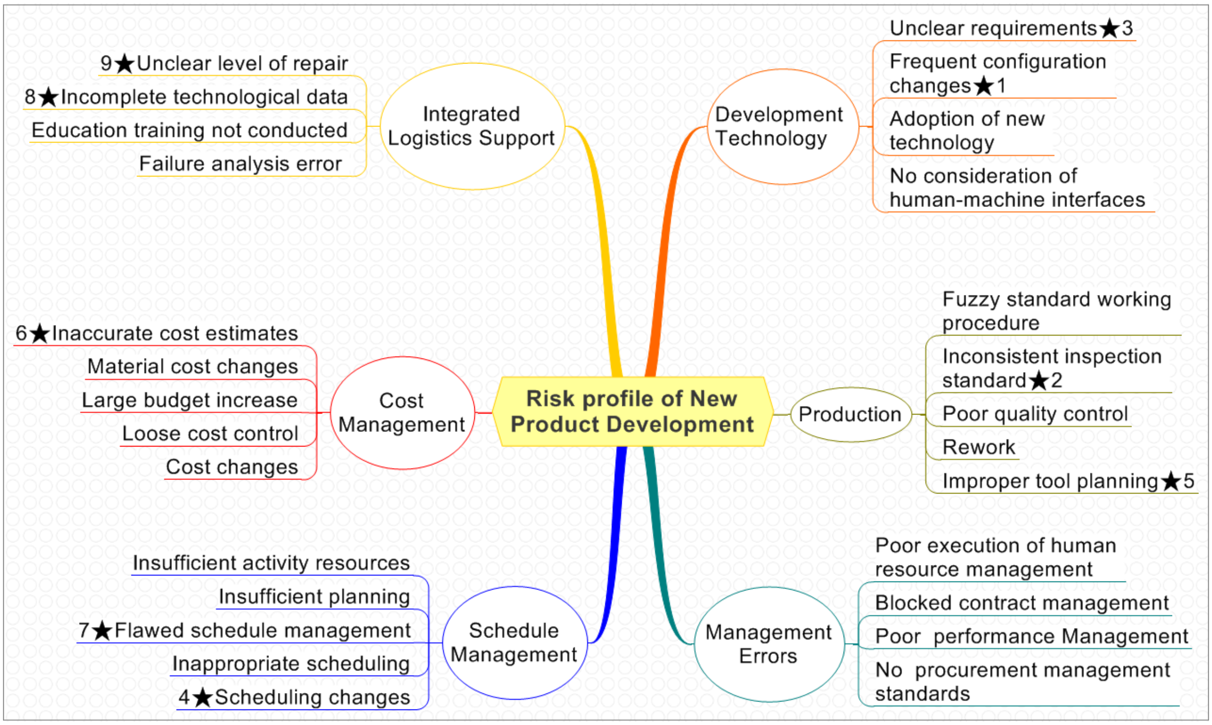

Fig. 3. Risk profile of NPD.
Note: Mean ≥ 7, Quartile deviation < 0.6

We referenced the experts' opinions to define the dimensions and risk factors. The experts were interviewed using the Delphi method to explore the vehicle NPD risks; the results identified the following six dimensions: "development technology," "production," "management errors," "schedule management," "cost management," and "integrated logistics support." These dimensions included 27 risks. Then, the risk profiles were used to control and understand the risks by applying risk management techniques in risk control meeting. The members who attended the meetings determined the ranking of each risk factor. The ranking options were extreme risk, high risk, moderate risk, and low risk. Specific processes to develop a project risk response and risk solution include the following: (1) Risk avoidance: eliminating as much of the activity risks as possible; (2) reducing the inclusion of audits and compliance research and development projects to obtain technical control; (3) reduce the influence and impact; (4) and risk transfer: encouraging other groups to assume or share part of the risk. Risk monitoring and risk control involves the development of effective policies, procedures, or actual practice changes that eliminate or reduce project risks.

VI. CONCLUSION

Based on the statistical results, the 27 key risks identified in this study belong to the following six dimensions: development technology, production, errors management, scheduling management, cost management, and full logistics support. The nine important key risks include frequent configuration changes, inconsistent inspection standards, unclear requests, scheduling changes, improper tool planning, inaccurate cost estimates, flawed progress management, incomplete technological data, and unclear level of repair, which account for 33.33% of the total risks. Organizations should implement risk control and consider investing in more resources. Self-management and adaptability should also be further evaluated.

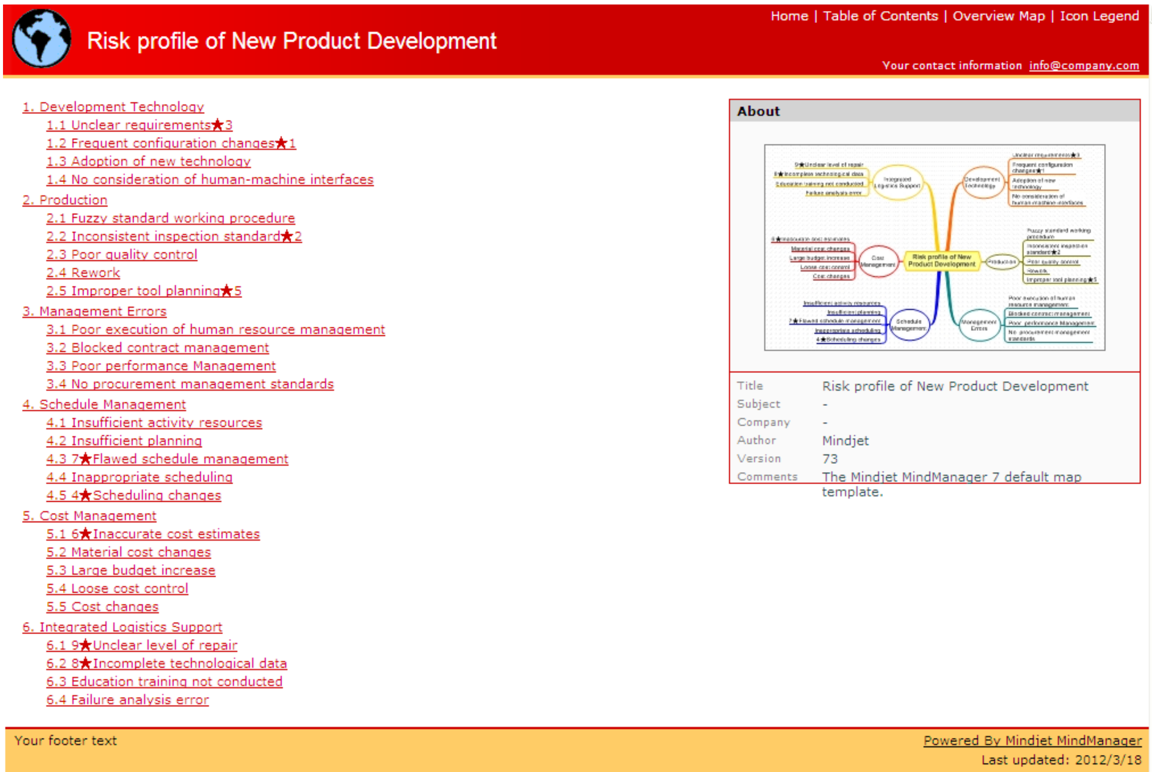

Fig. 4. Web site of NDP risk profile.

This study used the Delphi method to obtain a consistent perspective of vehicle product development. The mind mapping method transformed implicit risk, including expert thoughts, experiences, and wisdom, into a visualized diagram. The diagram shows the risk images provided by field experts. The risks are connected to form a risk structure that is suitable for NPD. This study employed quantitative rankings of the various key risks, created a risk profile, and established a risk Web site, which was managed and monitored to encourage the vehicle development team to consider the concept of risks. Thus, the organization's original resources can be further integrated and the risks can be monitored and handled effectively.

However, organizational environments vary. New risks should be observed and identified continuously. Therefore, risk diagram and website information should be updated to obtain immediate risk information. Through risk assessments, management, and monitoring, risk management is deeply integrated into ordinary product development processes. Finally, organizations must employ internal and external communication and share risk events to shape the organization's risk management culture and effectively build risk management ability to achieve the organizational goals and increase performance.

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