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A Study on R&D Performance Maximization Portfolio Analysis Technique Using AHP

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Abstract

R&D portfolio is a strategy tool to make investment on the basis of business strategy by enhancing the alignment of business strategy and R&D strategy. The R&D portfolio has three main purpose: strategy alignment, value maximization, and balance. Therefore, to maximize the R&D performance in the research institute of L Company in Korea, this study tries to apply AHP technique to suggest a portfolio analysis plan that makes up for the R&D portfolio improvement plan being performed.

Key Words: *R&D Portfolio, R&D Strategy, Business Strategy, AHP, Portfolio Analysis.*

Introduction

R&D portfolio consists of one and more R&D projects. The tool is used to determine each position of multiple R&D projects to be evaluated in certain criteria, to judge comprehensively the meaning of each position and overall balance, and thereby to establish an action plan and make a strategy decision on resource distribution. With the use of the tool, it is possible to evaluate the profits and risks of an organization systematically from the perspectives of marketability and strategic positioning, to distribute resources to promising projects, and to maximize the future performance.

The purpose of R&D portfolio management is, first, to make the strategic direction of all projects equal and accomplish strategic alignment of business strategy and projects, secondly to achieve the balance of projects which means the balance of resource distribution in the resource constraint circumstance, thirdly to maximize portfolio value which means the maximization of the values of each individual project and the whole portfolio in a research institute. Corporate research institutes should introduce the management system of the R&D portfolio, and operate a proper portfolio system through system materialization and corporate discussion according to their own criteria.

Therefore, this study chose a corporate research institute in Korea and analyzed the R&D projects that the institute had performed in a given period in order to analyze the R&D portfolio to maximize R&D performance. Also, to examine the indicators chosen for the analysis, it applied AHP technique based on questionnaire survey. In the conclusion section of this study, the research results are summarized, and improvements and a future research direction were suggested.

Theoretical Background

R&D Portfolio

A portfolio is a set of various items that have correlations with each other. The key to the concept of portfolio is to create the biggest overall benefit by designing the balanced and optimal items in

consideration of their correlations in the set (Turnbull, 1990). The portfolio technique has been applied to various areas, including strategy management, marketing, and R&D management. In order to help decision makers to design a portfolio in their circumstances, a variety of portfolio models have been developed. A portfolio model has difficulties in terms of the validity of dimension setting, the objectivity of the dimension based evaluation and classification criteria of each item, and the establishment of the strategy for items in the same classification, and the collection of proposed strategies (Armstrong & Brodie, 1994; Derkinderen & Crum, 1984; Day, 1977). Nevertheless, when other decision-making tools are used in parallel on the basis of the understanding of the difficulties, it is possible to help to make an effective decision (Olsen & Ellram, 1997).

R&D project management with the use of portfolio technique requires the determination of project priority prior to project planning and management. Through regular portfolio management, it is necessary to evaluate, choose, and prioritize a new project and readjust the priority of existing projects and stop them. In addition, it is needed to plan and manage R&D projects in line with business strategy or technical strategy.

Table 1: Available indicators by analysis type

Analysis types	Available indicators		Remarks
Competitiveness-Attractiveness	Competitive Positioning (e.g., market share, business size, competitive edge, brand power, human resource, R&D ability, marketing, quality, learning competence)	Attractiveness (e.g., market share, market size, market potential, technical maturity, life cycle, application period)	BCG Matrix GE/Mckinsey Matrix ADL Matrix
Risk-Compensation	Risk/Success Possibility (e.g., satisfaction with customer needs, technical possibility, satisfaction with corporate core competence)	Expected Return (e.g, sales, NPV, IRR, market value)	Risk Reward (Risk Return) Analysis method
Invested Resources-Development Period	Development Cost, Business Cost, Labor Investment	Development Period, Business Period	Cost Timing Analysis method
Novelty	Technical Novelty	Market Novelty	
Usability-Attractiveness	Technical Development Possibility (technical possibility, technical maturity, development difficulty, regulations, laws)	Market Attractiveness (e.g., market growth, consumer flow, market size, life cycle, sales market area)	
Strategic Positioning-Effectiveness	Strategic Positioning (e.g., management policy alignment, strategic importance, strategic suitability)	Economy/Profitability (e.g., rate of return, NPV, payback period)	
Cost-Effect	Cumulative Compensation Size	Cumulative Development Cost	

Portfolio analysis and management process requires each of the following; First, it is required to select portfolio analysis types and indicators. In other words, it is necessary to choose analysis types that live up to the strategy and portfolio management purpose of a research institute, and set forth evaluation indicators and criteria by analysis type. Secondly, as a R&D project portfolio analysis, it is necessary to analyze the management plan of each R&D project and portfolio by type. Thirdly, in order to redesign a R&D project portfolio, it is required to readjust a R&D project portfolio, draw R&D problems, and find a strategic direction.

R&D portfolio analysis types and indicators are chosen and evaluated in accordance with the purpose of portfolio analysis and management. Given the management strategy and circumstances of each firm, it is general to use 2-3 types. To display a position on matrix, it is necessary to make scaling of indicators and change them to a score.

As a general method of displaying data, bubble diagram or cumulative bar graph is used. However, it is necessary to use an uncomplicated diagram graph tool in order for decision-makers to understand analysis results easily. The portfolio analysis on all R&D projects should guarantee that any persons with sound common sense and reasonable judgment ability can draw the same suggestions and conclusions.

AHP Technique

AHP (Analytic Hierarchy Process) that was developed in the 1970s by Thoma Saaty, a professor at the Wharton School, University of Pennsylvania, is a technique for determining decisions on the basis of multiple criteria. The technique is used to classify multiple attributes hierarchically, make pair-wise comparison of the classified attributes to find its weight, and thereby to solve complicated decision-making problems efficiently and evaluate an optimal alternative (Saaty, 1980).

The AHP systematically integrated the concepts and techniques that existed already but failed to be used in their interaction, and has been evaluated as a methodology to solve diverse decision-making problems effectively in the real world that has multiple alternatives and conflicting factors (Choi D, 2014).

The four axioms to be considered in the AHP application process are presented as follows (Vargas, 1990). The first one is reciprocal comparison, which means that decision makers can conduct reciprocal comparison of two elements in the same level and can present intensity of preference as a converse condition. The second one is homogeneity, which means that weight can be presented with bounded scale in a limited range. The third one is independence, which means that the characteristics and contents in the same level should not be related to each other when relative weight is evaluated. The fourth one is expectation, which means that hierarchical structure is assumed to be constructed perfectly in the way of satisfying the decision-making purpose.

AHP is comprised of four steps. In the step 1, decision hierarchy is set up. In the step 2, pair-wise comparison of elements are conducted. In the step 3, consistency is checked. In the step 4, results are drawn and priorities are determined. More specifically, in the step 1, or the step of decision hierarchy setup, relevant elements become hierarchized, and the hierarchy is divided into decision goal, relevant decision-making elements in the upper level, and decision-making elements in the lower level. The elements should be applied to pair-wise comparison in the next step 2, so that they should be independent of each other and levels of the hierarchy should be dependent. In the lower level, the elements should be more narrowed down.

In this case, Saaty recommends that the number of the elements for the evaluation criteria should not exceed 9. In the step of pair-wise comparison of the elements, decision-makers' preference of the elements of the hierarchy is measured on the basis of pair-wise comparison with 9-points scale. When there are n elements to compare, n(n-1)/2 times of comparison are required. In the step 3, or the consistency check

step, it is judged whether the results of a questionnaire survey have consistency logically. The extent of consistency is calculated with Consistency Index (CI) and Consistency Ratio (CR). In this case, if inconsistency index is more than 0.1, the answers of the questionnaire are judged to be contradictory, and if it is lower than 0.2, the answers are accepted. In this procedure, it is possible to increase reliability of the results. In the last step 4, or the step to draw results and determine priorities, the weight and priorities of evaluation criteria are decided on the basis of the values of the examined answers, and thereby it is possible to come to the optimal alternative.

In the US, AHP technique has been used as the means to determine strategic goals in diverse areas, including military, diplomacy, and management. Its effectiveness has been verified. According to Saaty (2008), Jo Geun-tae and Jo Yong-gon and Gang Hyeon-su (2003), Kim Yong-jeong (2013), AHP technique generally has the following usefulness, features, and strengths as shown in the below [Table 2].

Table 2 : Features & Strengths, and Usefulness of AHP Technique (Park S, 2015)

Features	Description
Complexity	To solve a complicated problem, the model integrates deductive approach and systematic approach.
Consistency	It is possible to check logical consistency for the judgment on priorities.
Hierarchy structuring	System components are classified in different levels, and human natural thinking process of grouping similar elements in each level is reflected.
Interdependence	It deals with interdependence of system components, and does not insist on linear thinking.
Judgement & consensus	It does not argue consent but integrates representative results from diverse judgments.
Measurement	It provides a method to measure and prioritize intangible things.
Process repetition	It is possible to change a definition of a problem, and correct judgment and understanding through repetition.
Synthesis	It provides the integrated final value of each alternative.
Tradeoffs	It helps to choose the optimal alternative based on a goal through relative priorities of system components.
Unitly	It is a simple and easy model with strong adaptability to solve a variety of unstructured problems.

Study Method

Selection of Analysis Subject, Analysis Type, and Evaluation Indicator

This study selected 28 projects (including unapproved projects) of the R&D projects in the research institute of L Company as of X, 201X and analyzed them with the use of AHP technique. A list of evaluation indicators was prepared by analysis type, and a questionnaire survey was conducted with research teams. After that, indicators that meet analysis purpose was chosen. With the use of literatures related to portfolio analysis and the technical value evaluation models already developed, evaluation indicators and evaluation methods were selected.

Table 3: Evaluation indicators and methods

Analysis types	Evaluation indicators		Description in detail	Evaluation methods
Competitiveness-Attractiveness	Competitiveness	Market share	Evaluates how much a relevant product has market share.	M/S
		Business size	Evaluates how big the sales of a relevant product are	Sales
		Competitive edge	Evaluates whether there are any competitive products of a relevant product and its relative competitive edge	5-points scale
		R&D ability	Evaluates technical development ability and product making ability	5-points scale
	Market attractiveness	Market growth	Evaluates how much a relevant market grows	CAGR
		Market size	Evaluates how big the size of a relevant market is	Market size
		Competition structure	Evaluates the competition structure of a relevant product	5-points scale
		Customer needs	Evaluates market demands	5-points scale
Risks-Profits	Success possibility	Technical success probability	The possibility of technical development success	5-points scale
		Commercial success probability	The possibility of market entrance success	5-points scale
		Strategic success probability	The possibility of meeting the strategic direction of development division/research institute	5-points scale
	Expected return	Sales contribution	Evaluates how much is contributed to the sales of research institute	Sales contribution rate
Invested Resources-Period	Invested resources	Research cost or Human resource investment	The state of the distribution of the cost and human resources invested in development	Research cost, M/Y
	Development period	Business period	Development period (short-term/mid-term/long-ter)	Business point

Development of Evaluation Criteria

The evaluation criteria to set a position on portfolio were determined. Five-point scale based qualitative evaluation indicators (competition structure, customer needs, success possibility) and quantitative evaluation indicators (market share, business size, market growth, market size) were applied. Evaluation criteria were drawn in reference to management plan index of the research institute and the business validity analysis index of strategy division.

Table 4 : Competitiveness vs Attractiveness Evaluation Criteria

Evaluation indicators		Evaluation criteria				
		1 point	2 points	3 points	4 points	5 points
Competitiveness	Market share (M/S after five years)	Less than 1%	1%~2%	2%~3%	3%~5%	More than 5%
	Business size (future 5-years cumulative sales)	Less than KRW 10 billion	KRW 10-30 billion	KRW 30-50 billion	KRW 50-100 billion	KRW More than 100
	Competitive edge	Lower technical competitiveness than competitors; therefore, there is the problem with survival	Technology is not developed enough to develop products independently; therefore staying still as a follower	Following a new technology; therefore, maintaining a certain extent of technical competitiveness	Suggesting a new technology or a direction	Leading the direction or speed of technical development
	R&D productivity	Idea stage	R&D stage	Development completion stage	Product making stage	Completion of products, or manufacturing & sales
Attractiveness	Market growth (future 5-years CAGR)	Less than 10%	10%~20%	20%~30%	30%~50%	More than 50%
	Market size	Less than KRW 1 trillion	KRW 1-2 trillion	KRW 2-3 trillion	KRW 3-5 trillion	More than 5 trillion
	Competition size	Fierce competition of relevant firms; the monopoly of a market by a strong competitor firm or product	Fierce competition of relevant firms; the oligopoly of a market by a strong competitor firm or product	Multiple competitor firms and products; no leading firm, and market separation	A small number of competitor firms and products; no leading firm, and market separation	Almost no competitor firms and products; the influence on business operation
	Customer needs	A very few demands for the developed technology/product	A few demands for the developed technology/product	Somewhat demands for the developed technology/product	Large demands for the developed technology/product	Very large demands for the developed technology/product

Table 5 : Risks vs Profits Evaluation Criteria

Evaluation indicators		Evaluation criteria				
		1 point	2 points	3 points	4 points	5 points
Risks	Technical, commercial, and strategic success probabilities	Very low	Low	Neither high nor low	High	Very high
Profits	Expected return (sales contribution rate)	Less than 1%	1%~3%	3%~5%	5%~10%	More than 10%

Analysis on weight of evaluation indicators with the use of AHP

AHP technique was applied to draw relative weight of each detailed evaluation indicator in competitiveness-attractiveness analysis and success probability-expected return analysis. The result of the AHP technique application showed that consistency index of all types was evaluated to be lower than the baseline 0.10. Therefore, the weight of each indicator was found reliable.

Table 6 : Results from Pair-wise Comparison of Elements and Consistency Index Examination

Upper indicators	Lower indicators	Weight	Multiplication of weights	Ratio
Competitiveness	Market share	0.36	1.45	4.04
	Business size	0.21	0.85	4.02
	Competitive edge	0.31	1.26	4.03
	R&D ability	0.12	0.47	4.02
Consistency Index (CI)		0.009		
Attractiveness	Market share	0.30	1.21	4.01
	Market size	0.41	1.65	4.02
	Competition structure	0.13	0.52	4.01
	Customer needs	0.16	0.64	4.02
Consistency Index (CI)		0.005		
Success Probability	Technical success probability	0.17	0.52	3.01
	Commercial success probability	0.44	1.34	3.03
	Strategic success probability	0.39	1.17	3.02
Consistency Index (CI)		0.010		

Result Analysis

Competitiveness and attractiveness were analyzed in four sections. Competitiveness was put in the horizontal axis, and attractiveness in the vertical axis. In the condition, section 1 has large attractiveness of the market and high internal competitiveness so that it is the market leading section. Section 2 has unattractive market, but high competitiveness which means the expectation of high profitability. Section 3 has large market attractiveness, but requires the security of competitiveness in the market. Section 4 has low market attractiveness and low competitiveness so that the projects in the section need to be reviewed. According to the analysis, around 50% were located in the section 4, so that compared to market attractiveness, internal competitiveness was low overall. In the case of the projects in the sections 1 and 3,

it is necessary to find projects with large market demands and high growth possibility. In the case of the projects in the sections 2 and 4, it is necessary to conduct technical portfolio analysis on each project and thereby to establish a detailed strategy to secure competitiveness.

Based on cumulative sales of each project, competitiveness and attractiveness were analyzed in four sections. Competitiveness was put in the horizontal axis, and attractiveness in the vertical axis. Section 1 features KRW 1,754.5 billion of cumulative sales and 78.4% of sales percentage. Section 2 has KRW 168 billion and 7.5%. Section 3 has KRW 234.5 billion and 10.5%. Section 4 has KRW 80.5 billion and 3.6%. According to the analysis, for the projects in the sections 3 and 4, it is necessary to improve sales, and especially, by improving competitiveness the projects in the section 4, it is possible to put them in the section 2 and therefore it is expected to increase sales percentage. That indicates that the development division or the research institute needs to establish a plan to secure technical competitiveness.

Risks and profits were also analyzed in four sections. Risk indicators ranging from technical, commercial, and strategic success probabilities to calculated success possibility were put in the horizontal axis, and profit indicator (sales contribution rate) was put in the vertical axis. Section 1 has a high success possibility of technical development and business, and the expectation of a high profit. Section 2 has a high success possibility of technical development and business, but a low profit. Section 3 has a higher risk of development than expected return. Section 4 has a low profit and a low development risk. According to the analysis, the R&D projects in the section 1 contributed to more than 90% of the total sales of the research institute. It proved that the R&D projects accounting for around 90% of the sales had a high success possibility. The projects that had less than 1% contribution amounted to around 60%, and the projects that had more than 1% contribution had a large deviation. Therefore, it was found that a very few projects had a great deal of the profitability (sales) of the research institute.

Based on sales contribution rate, risks and profits were also analyzed. On the basis of 1% sales contribution, the projects were classified into the projects with more than 1% and the projects with less than 1%. The projects with more than 1% sales contribution accounted for 37% of all projects analyzed in this study. Given that the projects in the section 2 has the highest success possibility but 1.7% sales contribution, it is necessary to conduct technical portfolio analysis on each project and find a plan to maximize profits. If the portfolio is redesigned in the direction of increasing the sales of most R&D projects which have low profitability, though a high success probability, it is expected to improve largely the expected return of the R&D projects in the research institute.

In the analysis on invested resources and period, the business period was classified into short-term period (less than 5 years), mid-term period (less than 10 years), and long-term period (more than 10 years. It is necessary to distribute resources on the assumption that the adequacy ratio of each period is 70%, 20%, and 10%. In fact, in the case of research cost, the short-term, mid-term, and long-term investment ratios were very similar to the ratios in the adjustment plan. In the case of research manpower, it is considered that it is necessary to move them to short-and long-term business projects from mid-term projects and readjust the manpower.

Invested resources and project types were analyzed. In the case of the planned investment in research, existing business accounted for 5%, and new business 95%. In the case of the planned investment in research manpower, existing business accounted for 10%, and new business 90%. Given that for the sales, the ratio of existing business and new business is 55% and 45% respectively, it is considered that it is necessary to set the resource investment ratio of existing business and of new project to 50% and 50%, respectively. In addition, by reflecting the readjustment plan for research cost and research manpower investment according to business term, for existing business and new business, it is necessary to set short-term projects, mid-term projects, and long-term projects to 35%, 10%, and 5%, respectively.

Conclusion and Discussion

R&D portfolio management is a series of processes to plan balanced investments in each project choose proper projects according to strategy from the overall corporate perspective. In terms of portfolio management, it is important not only to choose proper projects that will be put in portfolio, but to make a careful and resolute decision on the projects that will be thrown away. R&D portfolio management framework is divided into four main points. First, it is necessary to establish a portfolio strategy to separate investments according to project features. Secondly, it is necessary to perform sufficient preliminary reviews on projects to evaluate and choose projects that contribute to improve insight. Thirdly, it is necessary to analyze and change a portfolio of projects from the viewpoint of portfolio. Fourthly, it is necessary to internalize portfolio management in organization. Lastly, it is necessary to perform R&D portfolio analysis annually and use the analysis results to continue to manage the portfolio of all projects in a research institute.

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