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기술경영 경쟁력 측정지표의 개발

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Towards Measuring Competitiveness : A Management of Technology Approach

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■ Abstract ■

This study aims to develop a framework to measure MOT competitiveness of enterprises while proposing a concept called management of technology competitiveness (MOTC). The framework of MOTC based on both resource-based view and competence-based view is consisted of technology competitiveness and management competitiveness. A variety of metrics to measure MOTC are extracted through substantial literature review. As technology competitiveness metric, this study examines R&D investment, R&D workforce, R&D facilities, intellectual property assets, and utilization of information and communication technology; as metric of management competitiveness, leadership competitiveness, maturity of the R&D systems, collaboration and partnership, learning and innovation, and commercialization are considered. We then confirm and derive the multi-dimensions of MOTC through its reliability and validity analysis. The study is expected to provide useful guidelines and references for enterprises' self-evaluation of technology and management competitiveness that is equally applicable to small, medium, and large enterprises that must compete in the global marketplace.

Keywords : Management of Technology(MOT), Management of Technology Competitiveness (MOTC), Resource-Based View, Competence-Based View

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1. Introduction

Recently, the Korean government as well as industries has shown a great interest in the management of technology (MOT). Since 2006, the Korean government has aggressively pursued the development of MOT manpowers by providing financial support to universities, while enterprises have sought to find and educate talents that are capable of promoting the management of technology competitiveness (MOTC). As a result, MOTC of Korean enterprises has increased considerably over the past 10 years. In particular, the number of research centers operated by Korean enterprises has rapidly increased since the latter part of the 1990's. Enterprise R&D resources have also drastically increased in the ensuing years. There has also been a steady increase in the number of enterprises establishing long-term, company-level technological strategies. Even in the case of R&D activities, trends focusing on new product development or process innovation were more noteworthy than in imitation of technologies from advanced countries or back-engineering systems, indicating the speed with which management of technology competitiveness has expanded.

However, there have been no attempts to measure MOT in a valid and reliable way, which is considered as the main obstacle to the development of scientific studies relating to the management of technology and its practical application. Therefore, this study proposes a concept called management of technology competitiveness (MOTC), which is a framework to measure competitiveness of enterprises in the perspective of MOT. This study will contribute to accurately evaluating an enterprise's management of technology and its potential power. It will provide useful guidelines and a reference for self-evaluation of technology and management competitiveness that is equally applicable to small, medium, and large enterprises that must compete in the global marketplace.

To develop a model to measure a company's management of technology competitiveness, this study first extracted research constructs related to the measurement of competitiveness through MOT-related literature. Research constructs are defined as the conceptual variables considered having relations with MOTC based on literature. The derived research constructs have been used to create final indices after classifying types and examining their associations through brainstorming. These research constructs and their accessorial measuring indices were used in the establishment of the technology competitiveness index group from a resource-based view while the management competitiveness index group from a competence-based view.

The final version of the materialized indices are required to undergo pilot test, with these tests confirming and deriving the multi-dimensions of the management of technology competitiveness through the analysis of their validity and reliability. Validity was examined through confirmatory factor analysis. Internal consistency was verified through Cronbach's alpha tests.

The MOTC measuring tools were finally completed after undergoing all of the previously described processes and procedures, which will make it possible to carry out an array of scientific studies. These tools and processes will pave the way for the institutionalization of MOTC evaluations.

2. Existing Models to Measure Competitiveness

The basic concept of competitiveness takes root in the comparative advantage theory established by Ricardo [40], an economist of classical economics. The concept follows that even if certain goods of a country may be behind those of another country in terms of absolute advantage in international trade, the country may have a relative advantage when the opportunity cost of production is considered. The comparative advantage may explain why profits can be created through mutual trade even if all goods of a country have an absolute advantage over those of other countries.

After that, Porter [66] presented cost leadership and differentiation as the two basic types of competitive advantage. According to his competitive advantage model, competition strategies create high investment profits by responding to rival companies through aggressive or defensive actions after finding a defensive position within that industry. On the other hand, he considered achieving results that were greater than the average within an industry as a sustainable competitive advantage. Accordingly, the concept of competition is defined as the capability to continuously overpower rival companies while creating more than average profits within an industry.

Baldrige's performance excellence framework may be an example of a typical model developed and used to measure such competitiveness. This model was first developed in 1987 to check the excellence of quality management; however, after repeating evolutions in tandem with the changes in the corporate management environment and management issues, it has taken root as a typical model that diagnoses and evaluates the excellence of corporate management and performance. As such, even its name was changed to Baldrige Criteria for Performance Excellence Framework advocating the concept of performance excellence from Malcolm Baldrige National Quality Awards (MBNQA). This framework is now widely used to evaluate the competitiveness of enterprises and organizations, and more importantly, even versions for public institutions, e.g. healthcare and education, have been developed [60].

The International Institute for Management Development (IMD) located in Lausanne, Switzerland has announced the ranking of the national competitiveness of major countries every year since 1989, and the World Competitiveness Index announced through the World Competitiveness Yearbook of IMD is used as an important index for an enterprise to induce foreign capital or to invest overseas. The evaluation factors related to the technology competitiveness of IMD's world competitiveness measuring factors are classified into a technology infrastructure (22 items) and a science infrastructure (23 items), and are composed of items related to R&D investment, R&D workforce, and items related to patents, information and communications [30].

Japan's National Institute of Science and Technology Policy (NISTEP) has been checking and announcing its General Indicator of Science and Technology (GIST) every 3 or 4 years since 1991. Individual indexes related to the measurement of existing scientific technologies may be appropriate to identify a section of scientific technology activities; however, it is difficult for them to understand a country's overall scientific technology activities. To resolve this problem, GIST has reorganized many science and technology indicators into a composite indicator using principal component analysis, the multivariate analysis.

To designate and operate venture firms and to form a venture boom following the foreign exchange crisis, the Small and Medium Business Administration (SMBA) implemented a technology competitiveness evaluation system for small and medium enterprises. Starting in 2001, SMBA designated technology-innovative small and medium enterprises (INNO-BIZ) as eligible for preferential government support as part of the technology innovation promotion program. The program operates a corporate technology competitiveness evaluation system using a reinforced conventional technology competitiveness evaluation system covering small and medium enterprises to identify INNO-BIZ companies.

The technology competitiveness evaluation system's INNO-BIZ assessment criteria include technology development, manufacturing, produced competency and the performance of technology competitiveness. The technological innovation system of INNO-BIZ has selected technology innovation capability, technology commercialization ability, technology innovation management ability, and the performance of technology innovation as evaluation items [28].

To evaluate Korea's technology competitiveness, the study carried out by Lee et al. [42] developed models to evaluate the current position and potential of technology competitiveness from the viewpoint of competition with other countries. The characteristics of this model include temporal dimensions, i.e. not only the current position but also the process and path were used to set up the relevant criteria for evaluating technology competitiveness. The current position represents what has been achieved thus far, and indicates the resource input for technology innovation and results. Process means a method of implementing technology innovation, including mainly the part related to the efficiency of the national technology innovation system. On the other hand, path means the interpretation of competitiveness from the evolutionary viewpoint to determine what effect the inheritance handed over from the past will have on the future.

While there are many evaluation models available designed to measure competitiveness, most of them are taking a macroscopic viewpoint that deals with national competitiveness, not focusing on the competitiveness of each individual enterprise. Therefore, development of a MOTC framework that is capable of measuring the competitiveness of each individual enterprise will be of great help in improving the actual corporate competitiveness as well as, from a scientific aspect, being a foundation for advancing diverse theories and models.

3. A Proposed Framework

Management of Technology (MOT) has not been yet clearly understood. It is a research and educational sector focusing on the processes of managing technology development, implementation of technology development, and its diffusion to the government and the industrial world. In addition to managing the R&D process, it is also interested in creating products or production processes or trading technologies from one organization to another [62]. NRC [62] defines MOT as follows :

> "Management of technology sets up the operational and strategic goals of an organization, and links engineering, scientific and business administration principles in the planning, development, and execution of technological capabilities to achieve such goals."

There are many other definitions of management of technology; however, it can be summarized in general as "management and supporting activities aimed at effectively acquiring, managing and utilizing technologies." The core activities of an enterprise that creates value can be viewed as 'technology development → production → sale,' with MOT effectively managing technology development, the highest part of the value chain. The strategic management of technology focuses on acquiring, managing, and utilizing technologies that can effectively contribute to the achievement of corporate goals, stressing that technology can contribute to implementing corporate strategies [41]. In the meantime, it is necessary to reexamine the concept of 'technology' when handling issues related to the management of technology. From the engineering point of view, technology may be understood as the "set of expertise related to industrial arts" and as a physical process that converts input factors into output factors. From the viewpoint of management, however, technology should be understood as a concept in a broad sense that includes not only the simple physical processes, but also the social arrangement that affects such conversion process. Even when the same processes or facilities are used, productivity, performance and the defect rate of the products being manufactured vary depending on the workers' abilities, expertise, related information, and plant management system. As a result, we can call all factors that affect the quality of product 'technologies' [41].

Unlike the concept of general technology competitiveness or management competitiveness, the concept of management of technology competitiveness (MOTC) has not been presented in the literature. Since the promotion of corporate competitiveness through the management of technology has emerged as the core of corporate competitiveness, it is now necessary to establish the relevant concepts. In the economics of technology, the concept of technology competitiveness is approached mainly as a technology level or technology gap.

It may be useful to provide a macroscopic viewpoint; however, there is a limitation for an individual enterprise to utilize such concepts in analyzing and planning strategies related to technology competitiveness. The typical competitiveness model is the Five Force model proposed by Porter [67], which presents many implications in analyzing an enterprise's competitiveness. However, it has limitations for many excellent enterprises that use management of technology competence as the basis for their competitiveness when conducting in-depth analysis. The model's limitations are the result of the need for analysts to make 3 assumptions : 1) there is no interaction between customers, 2) the source of value is derived from the structural advantage (Formation of barriers to entry), and

3) that plans responding to the behavior of the rival companies can be freely established because uncertainties were not considered. For example, the current competitiveness model is not able to explain accurately how many Korean enterprises, whose competitiveness lagged far behind that of companies in advanced countries, could acquire competitiveness equal to global enterprises of advanced countries in 20 years.

This study therefore combines two theoretical viewpoints to form the concepts of management of technology competitiveness. One is Barney's resource-based view. From the resource-based view, the key factor that determines corporate performance is viewed as the individual enterprise's own competitiveness, i.e. the difference in internal competency rather than external factors such as the business itself or the attractiveness of the industry in which the enterprise operates. Accordingly, this theory may be used to identify the valuable and rare resources not currently owned by enterprises and to offer help to the enterprises that have experienced strategic loss by pointing out that the value of such resources may be imitated through constraints or substitution. In other words, the resource-based theory identifies the most important resources controlled by an enterprise which help increase the possibility for such resources to obtain continuous competitive advantage [3]. Even in this study, resources are defined as tangible and intangible management resources within an organization owning such features as value, rarity, inimitability and unsubstitutability. In connection with this, believing that the R&D stock owned by an enterprise is the resource that increases the technology competitiveness of the enterprise, the degree of R&D investment, R&D workforce, R&D facilities, intellectual property assets, and the utilization of information and communication technology were identified as technology competitiveness items through existing literature studies and brainstorming.

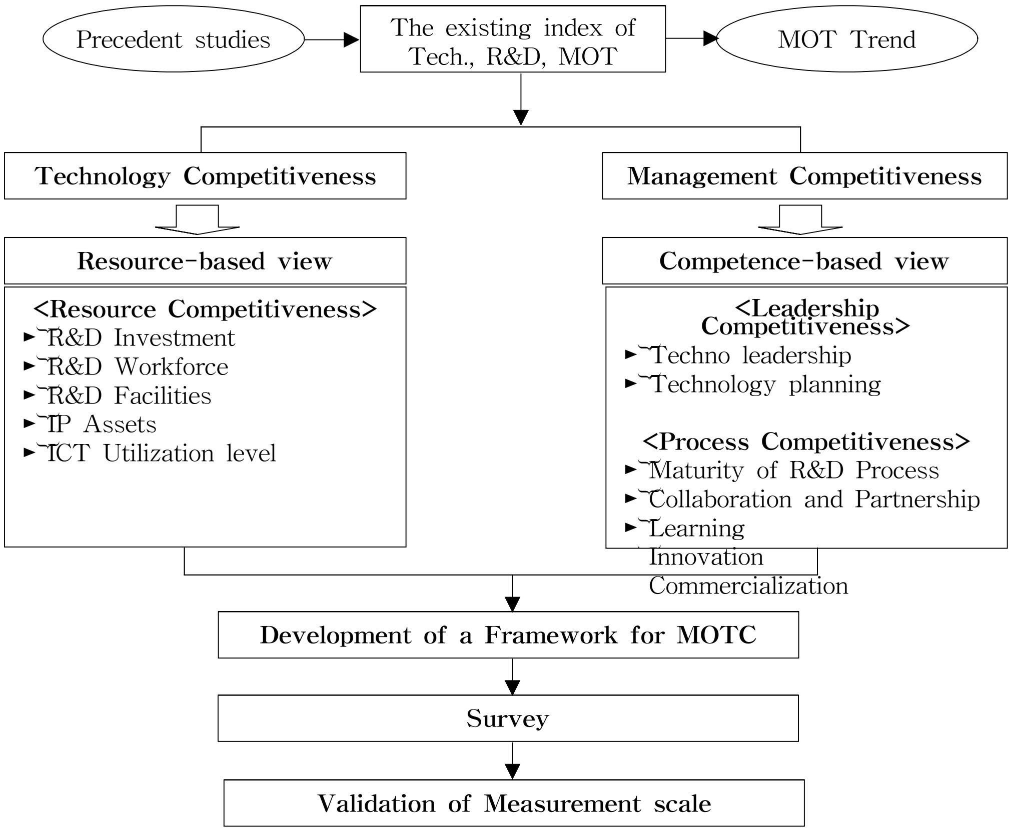
The other one is the competence-based view of Hamel and Prahalad. The competence-based view is the internal competence owned by an enterprise that not only differentiates the company from its rivals but also is the source of competitive advantage that is the core of business success. It is based on the tangible and intangible resources and the organizational competence. Such competence does not disappear through use but is improved through continued learning and collaboration. This means the competence-based view theory explains the core competitiveness competence as the collective learning within an organization. More specifically, learning about how the diversified produced techniques are controlled and how the flow of composite technologies can be integrated for more effective intra-organization communication, which boosts participation and passion for working while crossing over the boundaries of the organizations. Unlike physical production that is exhausted with the flow of time, the core competence for competitiveness is promoted the more it is applied and shared. In addition, the core competence for competitiveness is an engine that develops new projects, and the pattern of diversification and the advancement to market can be decided by the competence for competitiveness, not by the attraction of the market [24]. In this study and according to the core competence concepts presented by Hamel and Prahalad [24], competence relating to the acquisition, management, and utilization of technology owned by an enterprise and the degree of technology leadership are dependent upon management competitiveness, which includes the planning and implementation of R&D processes, collaboration and partnerships, degree of learning, innovation, and the company's commercialization ability. These determinations were made through existing documentary research and brainstorming.

The concept of the management of technology competitiveness proposed as shown in <Figure 1> is a combination of these two concepts. It is created from the combination of corporate technology competitiveness, and management competitiveness and synergy effects. The next chapter will present the results of literature review where these two viewpoints were readjusted and the research constructs belonging to each viewpoint were arranged.

3.1 Measuring Technology Competitiveness Upon a Resource-Based View

3.1.1 R&D Investment

From a resource-based view, R&D investment requires resources, and its outcome becomes a resource that can be used by the enterprise for products or services, i.e. R&D can be



〈Figure 1〉 A Proposed Framework for Developing an Instrument to Measure Management of Technology Competitiveness newly defined from a resource conversion view-point. Quantitative and qualitative input factors are involved in this conversion. While existing literature focus mainly on quantitative input factors, recent literature give more weight to the importance of qualitative factors like the excellence of the input factors. In this respect, R&D investment is obviously considered from the resource-based view, and based on a comprehensive check of literature, this study, in relation to R&D investment, presents the rate of R&D investment increase versus sales, the amount of R&D investment, the ate of original technology investment, and strategic overseas R&D investment. The results are shown in <Table 1>.

3.1.2 R&D Workforce

The people performing R&D, i.e. researchers, are known to be extremely important input factors in acquiring technology competitiveness. The literature related to R&D workforce show that the quantitative and qualitative level of the R&D workforce, and the passion, morals and human relationships they possess are important. The level of competency held by the workforce who support R&D work, e.g. equipment operators, technicians and other supporting personnel, is also an important factor. Accordingly, this study presents the rate of R&D workforce increase, amount of R&D workforce, the excellence of researchers, and the superiority of the research supporting personnel, passion, attitude, morals and human relations as measurement indices. The results are shown in <Table 1>.

3.1.3 R&D Facilities

An enterprise's facilities are the most typical tangible resources. In general, facility investment means that a company is obtaining a source of competitiveness. R&D facilities are major variables that affect technology competitiveness. This study presents R&D facilities' sufficiency, age, and utilization level as measurement indices. The results are shown in <Table 1>.

3.1.4 IP Assets

Intellectual property (IP) assets are the results of R&D as well as the input factors in the commercialization stage. Often, IP assets are regarded as the results of R&D, however, this consideration does not carry much meaning when seen from a resource-based view. This is because IP assets that are viewed as results, in the case of most manufacturers, are not directly related to sales and profits. As a proverb goes 'It takes more than pearls to make a necklace,' or only when utilizing these IP assets can competitive end products and services be delivered to customers, and with subsequent increase in sales and profits can the value of the IP assets be manifested. This study presents the number of patents owned, qualitative level of the patents owned, and the advantage of the developed expertise as measurement indices. The results are shown in <Table 1>.

3.1.5 ICT Utilization Level

The rapid supply of information and communication technology (ICT) that emerged in the latter part of the 1990's has induced significant changes not only to the lifestyle of each individual but also to overall enterprise operation. These changes have had considerable impact on management information systems, production, marketing, finance, accounting and personnel sectors, as well as R&D activities. Today's con-

〈Table 1〉 MOTC Measurement Index in Respect to Technology Competitiveness

Scale (No. of Item)	Item details	Operational definition	References
R&D investment (4)	Rate of R&D investment	R&D investment average increase rate vs. sales during the past 3 years	Lee et al. [42]
	Amount of R&D investment	Level of R&D investment scale when compared with rivals in the typical industry.	Lee et al. [42]
	Rate of original technology investment	Percentage of fundamental research sector, which is difficult to realize results on a short-term basis, of all R&D efforts.	Rosenberg [74]
	Strategic overseas R&D investment	Appropriateness of overseas R&D investment where use of technologies with overseas researchers is actively sought.	Kar et al. [35]
R&D workforce (5)	Rate of R&D workforce increase	Average R&D workforce increase rate during the past 3 years	Lee et al. [42]
	Amount of R&D workforce	Average R&D workforce scale during the past 3 years	Menke [52]
	Excellence of research workforce	Excellence of research workforce	Rivas and Gobeli [71], Ruse and Jansen [75]
	Excellence of research supporting workforce	Excellence of research supporting workforce	Rivas and Gobeli [71], Maccoby [50], Sill [78],
	Passion, attitude, morals and human relations	Research passion carried by researchers, business attitude, morals and human relations with co-workers and seniors	Maccoby [49]
R&D facilities (3)	Sufficiency of R&D facilities	Level of owned facilities needed for R&D	Rivas and Gobeli [71]
	Recency of R&D facilities	Level of technical recency of the owned R&D facilities	Stringer [83]
	Utilization level of R&D facilities	Operating rate of the R&D facilities owned	Stringer [83]
IP assets (3)	Number of patents owned	Level of excellence compared with rivals in the number of patents owned	Brown et al. [5], Tao et al. [85]
	Qualitative level of patents owned	Degree of excellence in the qualitative level of owned patents compared with rival companies.	Brown et al. [5], Tao et al. [85]
	Excellence in development expertise	Level of excellence in the technology and product development expertise compared with rival companies	Tao et al. [85]
ICT utilization level (2)	Level of R&D information	Level of information system infrastructure related to R&D	Kim and Lee [37], Leem et al. [43]
	Utilization level of informatization and communication technology in R&D	Appropriate utilization of information and communication technology by the R&D department	Awazu et al. [2], Gordon et al [21], Hussain et al. [29]

nection of communication between internal and external organizations and between enterprises and laboratories beyond national boundaries has created an environment where real-time communication in research makes it possible for globalization of R&D. According to related literature, ICT is classified into an issue of information infrastructure and the ICT utilization level. This study presents the level of R&D informatization and the utilization level of ICT as a measurement indices. The results in <Table 1> show the utilization level of ICT.

3.2 Measuring Management Competitiveness Upon a Competence-Based View

3.2.1 Techno Leadership

After examining the previous studies related to techno leadership, this study presents the sharing of technical visions, strategic sensitivity, collective commitment and resource mobility as measurement indices shown in <Table 2>.

3.2.2 Technology Planning

In general, technology planning is a concept that exists between the overall process of strategic management of technology and the specific execution plan of technology strategies. According to Jung [34], it can be defined as a function that effectively connects the execution of the technology strategies established as a concept narrower than the strategic decision-making process. Technology planning can be identified as a process of embodying technology strategies. While technology strategies should be creative and innovative, technology planning may follow systematically established methods. For this reason, technology planning plays key roles in the successful execution and evaluation of technology strategies. Due to such conceptual difference, technology planning is established at the business department level rather than at the company level, and the business department handles the problem as to how it achieves the strategic goals based on technologies. During the process of such technology planning, it is necessary to carefully watch the internal and external environment surrounding the business department. This study presents integration with business strategies, technology search, technology portfolio, and technology outsourcing as the measurement indices shown in <Table 2>.

3.2.3 Maturity of R&D Process

Maturity of the R&D process is a concept that indicates how well the R&D system of an enterprise is established, how clearly the business procedures are established and how high is the predictability of the results. The tools corresponding to the operational definition that can be used in the measurement of such concept include the type of R&D system generation and project screening. This study presents the type of R&D system generation and project screening as the measurement indices, as shown in <Table 2>.

3.2.4 Collaboration and Partnership

When collaboration and partnership are viewed in a wide sense, they correspond to the open innovation presented by Chesbrough [7]. The innovation that treats external enterprises and human resources as partners has been carried out thus far in the form of joint and group ventures, and license agreements. Open innovation includes models of such traditional systems, 〈Table 2〉 MOTC Measurement Index in Respect to Management Competitiveness

Scale (No. of Item)	Item details	Operational definition	References
Techno leadership (4)	Sharing of technical vision	Degree of CTO's participation in the formation and execution of corporate strategy	Smith [80]
	Strategic sensitivity	Ability to promptly recognize the ever-changing technology trends and apply them at site	Doz and Kosonen [17], Doz [16]
	Collective commitment	Degree of members' passionately working towards joint goals.	Doz and Kosonen [17], Doz [16]
	Mobility of resources	Ability to quickly re-dispatch corporate resources, e.g. capital or human resources as needed.	Doz and Kosonen [17], Doz [16], Herfert and Arbige [25], Mohr et al. [55]
Technology planning (4)	Integration with business strategies	Degree of interlocking and integration between business and technical strategies	Van Rooij [89], Lichtenthaler [45]
	Technology search	Degree of collecting and using technical information at the organizational level for use in strategic decision making	Van Wyk et al. [90], van Wyk [91], Lopez Ortega et al. [46]
	Technology portfolio	Ability to select technology development project and assign priority to effectively and efficiently use corporate resources.	Terwiesch and Ulrich [87], Herfert and Arbige [25], Sultan et al. [84]
	Technology outsourcing	Ability to pursue strategic benefits through technical flexibility and leverage	Piachaud [65], Mohr et al. [55]
R&D process maturity (2)	Type of R&D generation	Type of R&D system generation	Lee et al. [42], Shelton[77]
	Project screening based on gateway process	Ability to appropriately and dynamically screen R&D/new products based on the established official gateway process	Rivas and Gobeli [71], Cooper [13], Cooper [9]
Collaboration and partnership (4)	Joint study by industry, academia and research sector	Ability to appropriately use joint studies by industry, academia and research sectors and lead activities.	Burnside and Witkin [6], Konecny et al. [38],
	Joint study with technology suppliers/customers	Ability to appropriately use joint studies with technology suppliers or customers and lead such activity	Wagner [93], Johnson and Filippini [32]
	Coalition with global enterprises	Ability to appropriately use coalition with global enterprises and lead such activities	Jonash [33]
	Excellence of teamwork	Degree of team members' ability and the cooperative capability between team members	Monalisa et al. [56], Fincham and Rhodes [18], Luthans [48]
Learning (4)	Excellence of education programs	Degree of aggressive education on new technology and knowledge	Lee et al. [41]
	Importance of originality	Organization's degree of importance given to originality	Nov and Jones [61], Pelz [64]
	Learning based on follow-up evaluation	Degree of how organization learns from failed tasks and experience	Prather [68], Von Zedtwitz [92]
	Allowable degree of individual studies	Degree of approving or encouraging individual studies	Augsdorfer [1], Rivas and Gobeli [71]

Scale (No. of Item)	Item details	Operational definition	References
Innovation (4)	Open organization culture	Degree of openness regarding the inflow and exchange of external knowledge	Munsch [58], West and Gallagher [94], Chesbrough [7]
	Cooperation and exchanges among departments	Degree of communication among departments	Menke [52], Jain and Triandis [31]
	Idea management system	Degree of operating effective idea management system	Cooper [9], Rochford [72]
	New work methods or technologies are accepted	Degree of how quickly new work methods or technologies are accepted	Rogers [73]
Commer-cialization (7)	Ability to recognize new markets and capture business opportunities	Ability to recognize new markets and capture business opportunities	Miller and Olleros [54], Friga and Chapas [19]
	Technology utilizing competence	Ability to satisfactorily apply owned intel-lectual property rights to products/services.	Spivey et al. [82], Un [88]
	Customer focus	Degree of how faithfully business is performed from the viewpoint of customers when technology is commercialized.	Wagner [93], Desouza et al. [14]
	Risk management ability	Ability to detect unfavorable possibility and take preventive actions to avoid risks related to technology commercialization	Menke [52], Luo et al. [47], Raz et al. [70], Choi and Ahn [8]
	Record of licensing	Degree of licensing owned intellectual property rights to other companies.	Gambardella et al. [20], Kotabe et al. [39], Lichtenthaler [44], Mottner and Johnson [57], Teece [86]
	Records of venture business (JV, CV)	Degree of aggressiveness and performance on venture business (Concept of including all joint and in-house ventures)	Dorf [15], Shah et al. [76]
	Speed of launching new products	Ability to use diverse strategies to reduce development time.	Katz et al. [36]

far-flung partners, and all forms of collaborative acts. In other words, it pursues the inside-out and outside-in of information and collaboration during the stage of forming, developing and commercializing an idea to create and promote values throughout all stages of technology development [13]. This collaboration may generally be classified into joint studies by industry, academia and research sectors, joint studies with technology suppliers/customers, coalition with global enterprises, and the excellence of teamwork-regardless of whether it is an internal or external team. This study presents joint studies by industry, academia and research sectors, joint studies with technology suppliers/customers, coalitions with global enterprises and the excellence of teamwork as the measurement indices shown in <Table 2>.

3.2.5 Learning

After examining the results of earlier studies on learning, this study presents the excellence of education programs, regarding importance of originality, learning from follow-up evaluation, and the allowable degree of individual research activity as the learning measurement indices shown in <Table 2>.

3.2.6 Innovation

After examining the results of previous studies on innovation, this study presents open organizational culture, cooperation and exchanges between departments, idea management system and the acceptance of technology as the innovation measurement indices shown in <Table 2>.

3.2.7 Commercialization

After examining the results of preceding studies on commercialization, this study recognizes new markets and presents the ability to capture resultant business opportunity, technology utilization competence, customer-focus, risk management ability, record of licensing, record of venture (JV and CV), and the speed of launching new products as the commercialization indices shown in <Table 2>.

4. Validation of Measurement Scale

4.1 Data collection

To verify the management of technology competitiveness (MOTC) measuring models, questionnaires were designed and distributed. This study carries out survey designed to discover MOTC factors that influence the performance of domestic businesses in order to propose an alternative measure to enhance the competitiveness of enterprises. Survey indicators were developed through literature reviews on technology competitiveness and management competitiveness. The survey was delivered to 767 manufacturing companies listed on Korean Business Dictionary published by The Korea Chamber of Commerce and Industry in 2010. Responses were collected during the period of 55 days from 2 August 2011 to 15 October 2011 via Myzenic, an online survey software. The survey has 5-point rating scale that consists of very high, high, medium, low and very low. Return rate is around 22.8%.

There were 175 respondents from industries, with an average service period of 13 years. To break down respondents by industry, there were 83 enterprises belonging to electric, electronic and semiconductor industry, 21 enterprises belonging to chemical and energy industries, 33 machine and metal industries, 4 food industries, and 34 other industries. Categorizing them by size revealed 94 large enterprises, 41 middle-sized enterprises, and 40 small and medium-sized enterprises.

4.2 Verification of the Reliability of MOTC Measurement Scale

The reliability of the measured items is verified by checking internal consistency. This method promotes the internal consistency of each item by removing those items that hinder reliability when many items are used to measure identical concepts. Cronbach's alpha coefficient (Coefficient of reliability) is used to verify such internal consistency. The value of coefficient should be greater than 0.6 to obtain desirable results.

The reliability of the measurement items for each scale was verified. The results showed that all Cronbach's α coefficient were greater than 0.6, and since the internal consistency of the measurement items was high, the results were considered significant as shown in <Table 3>.

4.3 Verification of the Validity of MOTC Measurement Scale

Unidimensionality means that measurement items jointly carry one inherent concept, i.e. the measurement items of MOTC constructive concept shows a goodness-of-fit that can accommodate the single factor model. To obtain such unidimensionality, items and conceptual factors, i.e. medium-level items, should be theoretically harmonized, and the reliability and validity of each item that measures specific concepts should be empirically established.

Prior to evaluating the reliability of the structure model carrying multiple conceptual factors, it is necessary to verify the unidimensionality of the component items forming each conceptual factor, and as the next stage, to verify the estimated loading and evaluate the statistical significance of each estimated loading. If there is no statistical significance, we may remove the items or convert them in a way that suits the constructive concepts.

This process of verification is possible through confirmatory factor analysis. If the results of standard confirmatory factor analysis show that each item is loaded onto only a single factor, and if it is confirmed that measurement errors are independent and that the index of the goodness-of-fit of overall structure indicates valid results, the item may be viewed as having unidimensionality.

The validity of items is verified through confirmatory factor analysis while the goodness-of-fit of model is simultaneously evaluated, which may be used as a unidimensionality measurement index. The goodness-of-fit index used to verify unidimensionality includes GFI (Goodness-of-Fit Index : 0.90 or more desirable), AGFI (Adjusted Goodness-of-Fit Index : 0.9 or more desirable), RMSEA (Root Mean

〈Table 3〉 Results of Verifying the Reliability of MOTC Measurement Items

Scale	Number of items	Results of reliability analysis	Cronbach's α
R&D investment	4	4	0.819
R&D workforce	5	5	0.804
R&D facilities	3	3	0.842
IP assets	3	3	0.858
ICT utilization level	2	2	0.868
Techno leadership	4	4	0.789
Technology planning	4	4	0.764
R&D process maturity	2	2	0.721
Collaboration and partnership	4	4	0.788
Learning	4	4	0.818
Innovation	4	4	0.849
Commercialization	7	7	0.819

Square error of approximation : 0.05 or less desirable), and Chi-square (the lesser the better), Chi-square's p value (0.05 or more is desirable).

4.3.1 Validity of the Technology Competitiveness Measurement Scale

Since the number of items in the scale of 'ICT utilization level' in relation to the verification of the validity of technology competitiveness is 2 or less, it was excluded from analysis, and the results of the verification of the remaining scales are as shown in <Table 4>.

The unidimensionality and the goodness-of-fit of the 15 items were verified in relation to the 4 scales of 'Technology competitiveness' and since 2 items did not have unidimensionality they were excluded. The explanations in detail are as follows :

First, the unidimensionality of the items forming 'R&D investment' was verified, and validity and goodness-of-fit were excellent when the item 'Amount of R&D investment' was removed. Since the 'Amount of R&D investment' item correlated highly with other items forming 'R&D investment,' with even the standardized residual being higher than other items, it became subject to removal.

Second, the unidimensionality of the items forming 'R&D workforce' was verified. Validity and goodness-of-fit were excellent when the item 'Rate of R&D workforce increase' was removed. Since the 'Rate of R&D workforce increase' item correlated strongly with other items forming 'R&D workforce' while the standardized residual was also higher than other items, it became subject to removal.

4.3.2 Validity of the Management Competitiveness Measurement Scale

Since the scale of 'R&D process maturity' carries 2 or fewer items in verifying the validity of 'Management competitiveness,' it was removed from analysis. Results verifying the remaining scales are as shown in <Table 5>.

The unidimensionality and the goodness-of-fit of the 27 items in the 6 scales of 'Management competitiveness' were verified, and since 4 items did not have unidimensionality, they were excluded. The explanations in detail are as follows :

First, the unidimensionality of the items forming 'Techno leadership' was verified, and val-

〈Table 4〉 Verification of the Structure Validity of 'Technology Competitiveness'

Scale	R&D investment	R&D workforce	R&D facilities	IP assets
Number of items	4	5	3	3
Unidimensionality measurement items	3	4	3	3
Chi-Square	0.00 (P = 1.0)	0.63 (P = 0.72)	0.00 (P = 1.0)	0.00 (P = 1.0)
RMSEA	0.000	0.000	0.000	0.000
GFI	1.00	1.00	1.00	1.00
Excluded items	Amount of R&D investment	Rate of R&D workforce increase	-	-

〈Table 5〉 Verification of the Structure Validity of ‘Management Competitiveness’

Scale	Techno leadership	Technology planning	Collaboration and partnership	Learning	Innovation	Commercialization
Number of items	4	4	4	4	4	7
Unidimensionality measurement items	3	4	4	3	4	5
Chi-Square	0.00 (P = 1.0)	0.63 (P = 0.72)	6.30 (P = 0.05)	0.00 (P = 1.0)	5.11 (P = 0.08)	9.47 (P = 0.09)
RMSEA	0.000	0.000	0.111	0.00	0.094	0.072
GFI	1.00	1.00	0.98	1.0	0.99	0.98
Excluded items	Strategic sensitivity	-	-	Regarding originality of importance	-	Risk management ability, Record of licensing

idity and goodness-of-fit were excellent when the item ‘Strategic sensitivity’ was removed. Since the ‘Strategic sensitivity’ item correlated highly with other items forming ‘Techno leadership,’ with even the standardized residual being higher than other items, it became subject to removal.

Second, the unidimensionality of the items forming ‘Learning’ was verified. Validity and goodness-of-fit were excellent when the item ‘Regarding originality of importance’ was removed. Since the ‘Regarding originality of importance’ item correlated strongly with other items forming ‘Learning’ while the standardized residual was also higher than other items, it became subject to removal.

Finally, the unidimensionality of the items forming ‘Commercialization’ was verified. Validity and goodness-of-fit were excellent when the item ‘Risk management ability’ and ‘Record of licensing’ were removed. Since the ‘Risk management ability’ and ‘Record of licensing’ items correlated highly with other items forming ‘Commercialization’ while the standardized residual was also higher than other items, it became subject to removal.

5. Conclusion

This study has proposed a concept called management of technology competitiveness (MOTC) and developed a theoretical and normative framework to measure such MOTC.

We have presented research concepts to measure MOTC. As a measurement index, we have developed 5 types of technology competitiveness measurement indices seen from a resource-based view, i.e., R&D investment, R&D workforce, R&D facilities, IP assets, and the utilization of ICT level. It has also developed 7 types of management competitiveness measurement items seen from a competence-based view. Of these indices, techno leadership and the technology planning indices were developed in the framework of leadership competitiveness, while the maturity of the R&D system, collaboration and partnership, learning, innovation, and commercialization, as the process competitiveness measurement index. In addition, the reliability and validity of MOTC measurement items were verified. Of the 46 items making up the MOTC measurement indices, the 6 items that hampered structure validity were excluded leaving 40 items in the final proposal.

This study carries significant meaning in the sense that it is the first attempt to measure the MOTC of enterprises. This study is expected to provide useful guidelines and a frame of self-evaluation for small and medium, middle-sized and large enterprises can promote technology and management competitiveness by themselves through analysis of the correlation between MOTC and corporate performance.

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