Analyzing Technological Capability of the Korean Construction Industry
: Comparison with Cases in U.S., U.K., Japan and Korea

임 대 희* , 이현수** , 박문서***
Lim, Daehee, Lee, Hyun-Soo , Park, Moonseo

Abstract

As the world construction market is rearranged by the level of technological capability, recently the technological capability in construction industry is developing rapidly. The important of measuring and analyzing technological capability in construction industry is gaining more and more emphasis. It enables to grasp the past and present situation of construction industry as well as to foresee changes in the future. However the concept of technological capability cannot be identified easily, as well as it is hard to compare that capability of construction industry among different countries. Although there have been numerous studies conducted on the technological capability of construction industry, most of the studies were in formsof surveys of specialists or industry professionals which lacked objectivity and sound basis for data. This study will be focused on investigating the methodology in exploiting and measuring surface of the earth and developing indicator and process to understand technological capability in construction industry through quantitative and statistical analysis. Then it will verify them through a case study.

Keywords : Technological Capability, Construction Industry, Scoring Model, Principal Component Analysis(PCA)

1. Introduction

1.1 Research backgrounds and objectives

Since the 1990s, the development of information and communication apparatus and establishment of infrastructure has changed many of the work process and environment in construction industry. Moreover as the scale of buildings becomes bigger and higher, the technological capability of construction industry is also remarkably developing. Now it became impossible to survive in the international construction market without it.

* 일반회원, 서울대학교 건축학과, 석사과정(교신저자), daivi33@snu.ac.kr
** 종신회원, 서울대학교 건축학과 교수, 공학박사, hyunslee@snu.ac.kr
*** 종신회원, 서울대학교 건축학과 부교수, 공학박사, mspark@snu.ac.kr
본 연구는 건설교통부 건설교통 R&D정책인프라사업(과제번호 : 06기반구축A03) 결과의 일부임

The importance of measuring and analyzing the technological capability cannot be underestimated anymore. Although there have been numerous studies conducted on the technological capability of construction industry, most of the studies were in forms of surveys of specialists or industry professionals and thus were limited in terms of objectivity and sound data basis. Therefore, in this study, statistical and quantitative analysis will be used to analyze the technological capability of construction industry.

It is not so easy to set the measuring indicator based on industry standard for comparing technological capability. In other words, technologies of construction industry consist of numerous individual technologies which cannot be fit into one big integrated index containing the whole process of technology innovations. Also as the technology itself is originally in form of knowledge information, there is a limit to generalize the quantitative valuation system.

In spite of this limit, the whole purpose of measuring the technological capability lies on understanding the status quo of industrial technological capability and seizing the speed of future change. Technology innovations on the level of country or industry became the major factor for rise in productivity and the driving force of economic growth. Therefore comparing and evaluating the current level of technological capability among countries or industries based on various guidelines could be used as basic information to establish the strategy for technology innovations.

This study will be focused on investigating the methodology in exploiting and measuring the surface of the earth and developing the indicator and process to understand the technological capability of construction industry through quantitative and statistical analysis.

1.2 Research scope and process

In this study, the construction industry will be regarded as one unit to measure the technological capability instead of measuring it by those of each subdivision industries, businesses or items then adding it up to get the technological capability of the whole construction industry. It will also suggest the process to get the technological capability through quantitative and statistical analysis and verify it through a case study.

Research process will be done as follows;

- Analyze and establish the methodology to deduce the technological capability.
- Develop detailed process based on established methodology.
- Practice the case study according to the process.
- Analyze and examine the result of the case study.

2. Methodology

2.1 Measurement of technological capability

Measured value of technology is related to functions of that technology, which quantitatively shows how the technology carries out its functions well. Measured value of individual technology level just tells the ability of what the technology is aimed to achieve and the problem-solving skill. It is especially used when analysts deal with the successive technology approaches. After identifying such features, it is standardized with one or more selected measures that show the level of technology.

2.2 Access

There are two categories, macroscopic and microscopic, in analyzing the technological capability according to its aggregating level and purpose of application. This study measures the technological capability while considering the construction industry as a single unit. Therefore it follows the macroscopic approach method, attempting to approach it based on the industry level. It will be very effective in measuring the input-output structure and efficiency.

2.3 Scoring model

This study will draw the technological capability using scoring model which fits the macroscopic approach method. Scoring model has been used in the field of operation research for evaluating numerous alternatives or prioritizing the orders for a long time. It is used when each alternative has more than one features and the value or importance of the alternative aredepended on combination of several features rather than one characteristic. It is also used to get the technology level when there is no other analyzing method to combine several factors to composite measures.

3 Process

3.1 Conceptualize technological capability

First and foremost, it is required to conceptualize technological capability. Technological capability, as the measured value of technology, can be identified in various ways in accordance with different perspectives.

3.2 Select scoring model

Scoring model should be used as a means to get quantitative deduction and comparison technological. It draws the conclusion by multiplying each factor with weight then adding them up. There are several models for this such as Martino model, state of art(Gordon model) and etc. (Gordon and Munson, 1981)

3.3 Analyze and select factors

Selected factors that reflect the technological capability should be properly grouped. It has always been a problem whether the factors are to be added or multiplied when designing the scoring model.

3.4 Collect and standardize data

To use quantitative method, objectively verified data is necessary. Also all the factors within the period of time for analysis are required. Factors unable to get data cannot be used and if there is not sufficient data, it should be obtained through statistical inference as the next best solution.

At the next process, works such as standardizing factors with different units, multiplying appropriate coefficient, adding constant and convert them to place at between 0 and 100 are done.

3.5 Figure out weight of each factor

To get overall technological capability indicator, weight for each factor should be invested. For investing weight, there are statistical methods like factor analysis, principle component analysis and professional judgment methods such as questionnaire or AHP(analytic hierarchy process) to name a few.

3.6 Calculate and convert indicator

Once the weight of the factor is decided, overall technological capability can be measured by the model that can integrate all the factors. Deduced values at this point are relative values so those can be converted as occasion demands.

4 Case Study : comparison with cases in U.S., U.K., Japan and Korea

4.1 State Choice

Targeted countries for case study are the U.S. with the most developed construction industry, the U.K., the leader of the construction industry in Europe excelling in pioneering new technology, Japan and Korea who are exploiting the world construction market far over Asia. OECD is providing considerable database on construction industry in these countries.

Technological capability of 4 above countries is measured by the 3 process from 1996 to 2005.

4.2 Measuring Process

4.2.1 Conceptualize technological capability

After dividing technological capability into categories of developing capability of Technology and Technological level, conceptualized it by drawing composite technological capability, which is the combination of each index.

- **Developing capability of technology**

Developing capability of technology means the ability to independently develop technology. It consists of variables related to research and development activities, the input of technological innovation. This is more likely to have effect on future technology competitiveness rather than current technological level, meaning it will be actualized in future production activities.

- **Technological level**

Technological level is ability to carry out current operations and solve problems. This is colligation of technology output related to production activities. Technological level is realized as the developed products and progress are used in current producing activities regardless whether it is a self developed one or introduced technology.

- **Composite technological capability**

Composite technological capability means practically integrated technological capability which reflects both

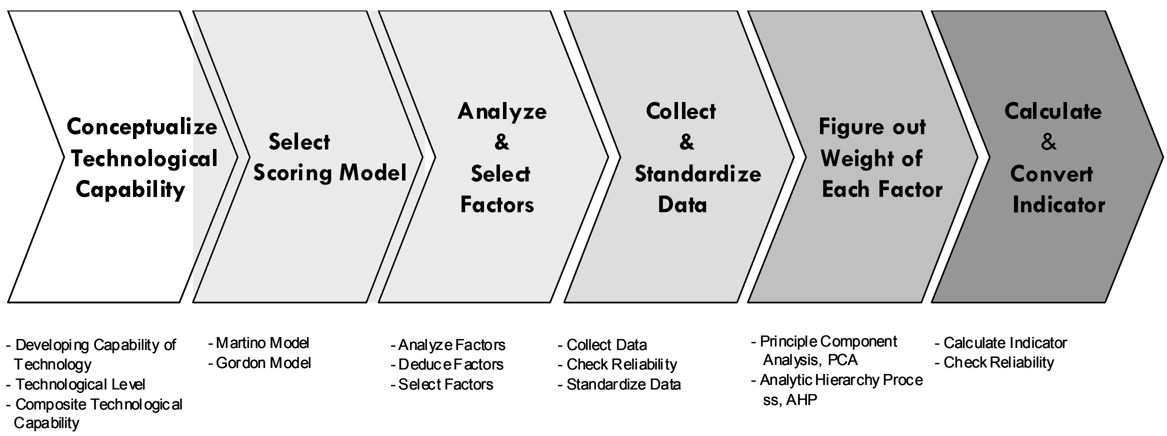

Figure 1. Process

Developing capability of Technology and Technological level. The more Developing capability of Technology enhances the better Technological level will get. It can increase the productivity with advanced technological capability although development capacity is not the only force that determines the technological capability as much as the productivity is not based only upon the technology level.

4.2.2 Select scoring model

State of art(Gordon model) is applied in this case study. The equation of state ofart(Gordon model) is as follows (N: number of factors, XN: N-th factor, XN*: standard of N-th factor, KN: weight of N-th factor)

$$\text{technological capability} = \frac{X_1}{X_1^*}\left(K_2\frac{X_2}{X_2^*} + K_3\frac{X_3}{X_3^*} + K_4\frac{X_4}{X_4^*} + \ldots + K_N\frac{X_N}{X_N^*}\right) \quad (2)$$

4.2.3 Analyze and select factors

Selected factors are as follows, which are supposed to display the targeted indicator

- **Developing capability of technology:** number of researchers, number of researchers per 1000 workers, R&D investment, R&D investment per value added, research expenses per one researcher
- **Technological level:** labor productivity, information society index (ISI), number of patent registration per 1000 workers, value added per GDP, rate of export-import about technique, developing capability of technology
- **Composite technological capability:** It includes all the factors chosen from the list above.

4.2.4 Collect and standardize data

In this study, data are mainly collected from document published by government or official organizations such as the OECD. Technological capability can be obtained only when the data are perfectly gathered.

Process of standardizing items has been done twice. Then lastly, each data has been converted to be placed between 0 and 100.

4.2.5 Figure out weight of each factor

For figuring out weight of each factor, Principal Component Analysis is used. It is one of analysis techniques to abridge or interpret data which is used to explain covariance structure of data by associative sector of the original variable. For example, given that the change, which p number of variable has, is at the p×p level of covariance matrix, if the most parts of this change is explained with k number of main components which is less than those number of p, it could be said that k number of main components already have most of information that p number originally has. Hence principal components analysis reduces the data by substituting the n number of observation value for k number of main components.

4.2.6 Calculate and convert indicator

The weight obtained is multiplied to measure the technological capability. Then it is converted while assuming the U.S. technological capability in 2005 as 100.

4.3 Result

4.3.1 Developing capability of technology

Table 1. Developing capability of technology (1996~2005)

	US	UK	JAPAN	KOREA
1996	89.5	85.3	87.6	93.7
1997	90.6	84.8	85.1	97.5
1998	93.9	84.1	89.5	90.3
1999	100.9	81.8	86.5	88.2
2000	93.6	80.1	87.2	92.6
2001	96.9	81.1	83.3	84.7
2002	95.3	82.3	83.1	93.4
2003	98.2	84.3	85.7	88.1
2004	98.7	85.9	87.4	87.1
2005	100	87.3	87.9	87

(Regarding the U.S. Developing capability of technology in year 2005 as 100.0)

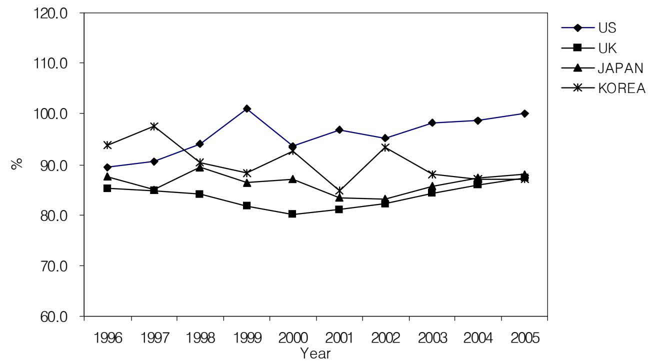

Figure 2. Developing capability of technology (1996~2005)

4.3.2 Technological level

Table 2. Technological level (1996~2005)

	US	UK	JAPAN	KOREA
1996	103.8	71.3	67.9	49.1

1997	99.4	69.1	85.5	50.7
1998	101.5	70.7	78.8	50.8
1999	101.5	74.9	77.3	51.6
2000	99.3	77.5	76.8	58.5
2001	100.8	81.2	75.9	65.7
2002	98.5	80	78	66
2003	96.4	78.6	74.8	65.3
2004	95.8	84.3	76.3	69.2
2005	100	87.2	84.7	70.3

(Regarding the U.S. Technological level in year 2005 as 100.0)

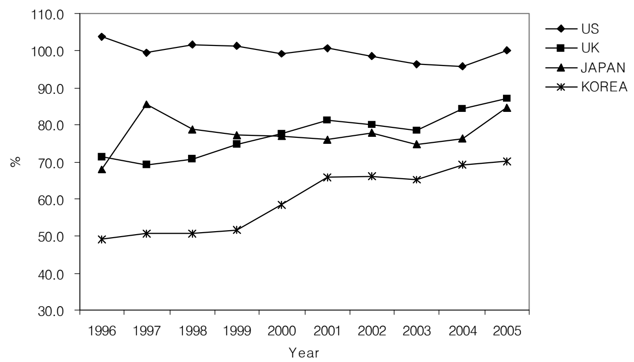

Figure 3. Technological level (1996~2005)

4.3.3 Composite technological capability

Table 3. Composite technological capability(1996~2005)

	US	UK	JAPAN	KOREA
1996	91.2	72	77.7	65.8
1997	91.2	71.7	85.2	67.6
1998	94.5	71	82.8	64.6
1999	99.8	72.1	81	65.1
2000	94.2	73.1	81.7	70.2
2001	97.2	75.7	78.9	71
2002	95.5	77.1	79.5	75.4
2003	97.6	78.4	80.2	75.7
2004	98	82.5	81.7	78.7
2005	100	85.1	86.6	80.4

(Regarding the U.S. Composite technological capability in year 2005 as 100.0)

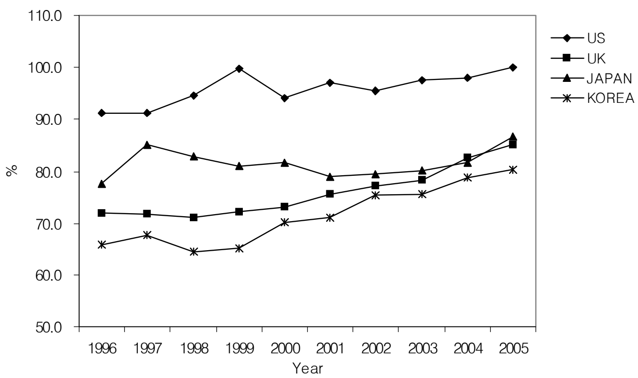

Figure 4. Composite technological capability (1996~2005)

4.4 Verification

Before the analyzing process, validity of measure should be verified and of which, there are certain things to have verifications in beforehand - correlation between a pair of variables and its interpretation on other variables, and identification of matrix hypothesis. The significance of the former has verified through the Keiser-Meyer-Olkin(KMO) measurement and the latter used Barlett's test of sphericity. The analysis of the KMO measurement shows how the correlation between pair of variable is explained by each variable. Generally, if it is higher than 0.90, the correlation is considered as high and choice of variable as appropriate for factor analysis. On other hand, if it is lower than 0.50, the correlation is regarded as ineffective and the selected variable is unsuitable for factor analysis. (Kaiser, 1974) Furthermore, measured value of Barlett's sphericity examines the null-hypothesis that correlation matrix of variables is identity matrix, that is, assumption that correlation among variables is all 0. It should be able to turn down this assumption.

	Kaiser-Meyer -Olkin's Gauge	Bartlett's Examination	
		Kai-Square	P-Value
Developing capability of technology	0.775	208.780	0.000
Technological level	0.802	92.793	0.000
Composite technological capability	0.765	182.763	0.000

Table 4. KMO & Barlett Examine

As a result of this case study, principal component analysis is ascertained as meaningful according to Kaiser's classification(1974). Moreover the result from Barlett's examination of sphericity tells factor analysis would be suitable for it.

5 Analyzing

Regarding the U.S. construction technology capacity in year 2005 as 100, the case study tells that of the U.K., Japan and Korea correspond to 85.1, 86.6 and 80.4 respectively. This means a lot as the number itself.

It also allows each country to see the flow of technological capability in construction industry change for the last decade. It is very significant task as it makes possible to grasp the flow of technological capability of past and present and foresee the future change. This study also contributes to predict the future route of technology development and national competitiveness in international market.

If the technological capability is periodically measured through the process that this study suggests, analysis for longer term would be also feasible.

As much as it has such many merits, there also exist some demerits as stated below. Firstly, the selected factors to measure the technological capability in construction industry vary in its kind and require very professional data. Accordingly, currently developing or the least developed countries where the database is still poorly organized are not free from the limit to measure it. Secondly, generally speaking, the technological innovation means series of procedures which actualizes the technological knowledge from brainstorming new ideas to development, production and popularization of new products or process. Since the range of technological capability measurement could varies in extent of discovering technological ideas, introducing or developing necessary information, converting to usable hardware and software, engineering and producing, it would be hard to select all the factors that include the whole course of technological innovation.

6 Conclusions

This study identified the meaning of technological capability, suggested process for measuring technological capability in construction industry by quantitative and statistical method then verified it through a case study.

The meaning of this study lies under the fact that it gave an example of effective way of measuring technological capability in construction industry based on the level of industry and provided process to understand the flow of technological capability and foresee the speed of future change.

In case of the process based on scoring model, it firstly defined the technological capability, selected the scoring model then collected compatible factors. Afterwards, standardized it through the principal component analysis (PCA), draw the weight value and substituted the standardized data and weight in the scoring model to get the final measure of technological capability.

The case study corresponded the original purpose of measuring technological capability in construction industry quite well.

Comparative study of technological capability which is drawn by other methods will be done next occasion. It is also suggested that the process from this study can be used to measure the technological capability in other industries as well and comparing it to that of construction industry will be interesting field to be explored.

References

1. Griliches, Z., “Productivity, R&D and the Data Constraint”, American Economic Review, 1994, pp1-23
2. Jorgenson, D. W. and Stiroh, K. J., "US economic growth at the industry level", American Economic Review, 2000, pp161 - 168
3. Martino, J. P., "Technological Forecasting for Decision Making", McGraw Hill, New York, 1993
4. OECD, "Main Science and Technology Indicator", OECD PUBLICATIONS, 2005
5. OECD, "National Accounts of OECD Countries", volume 2, OECD PUBLICATIONS, 2006
6. OECD, "Research and Development Expenditure in Industry", OECD PUBLICATIONS, 2005/2006
7. Owens J. "Research and experimental development (R&D) statistics 2003". Economic Trends, 2005, pp28 - 52
8. 홍순기, “제조업의 기술력 측정과 지표개발에 관한 연구”, 과학기술정책연구원, 2005