ANALYSIS OF METHODS TO ASSESS THE TECHNOLOGICAL LEVEL AND CAPABILITIES WITH SUITABLE APPLICATION FOR VIETNAM CONDITION

Nguyen Nam Hai[1]
Department of Technology Appraisal, Examination and Assessment

Nguyen Duc Hoang, Nguyen Khanh Tung
State Agency for Technology Innovation

Abstract:

Assessing the technology level and capability in manufacturing sectors are always very important for enterprises in the process of technology application and innovation as well as for state management agencies in managing science and technology (S&T) activities in various industrial areas. Through the clarification of basic notions related to technology level, technology capability and their assessment as well as analysis of S&T evaluation methods, the authors have clarified the theoretical basis to assess technology level and technology capability in manufacturing sectors. Analyzing the experiences in evaluating technology level and technology capability of other countries in the world and in Vietnam, the authors have clarified the practical basis from which to propose the method to evaluate technology level and technology capability applicable to the conditions of Vietnam. The proposed method and set of indicators for evaluating technology level and technology capability have been piloted and these results will create the basis for drafting the Circular guiding the technology level and technology capability in manufacturing sectors in Vietnam.

Keywords: *Technology level; Technology capabilities; Technology absorption; Technology innovation; Evaluation method; Set of indicators for evaluation.*

Code: *19110401*

1. Introduction

The technology evaluation work in Vietnam started since 1970s. By 1978, the State Committee for Science-Technology (now Ministry of Science and Technology - MOST) issued the system of 30 indicators specific for technology level of industrial production. By 2014, MOST issued Circular No. 04/2014/TT-BKHCN to guide the evaluation of manufacturing technology level. During implementation stages, however, the Circular revealed certain shortages and difficulties which require adjustments and

[1] Author's contact email address: nnhai@most.gov.vn

completions. From another side, regarding the evaluation of technology capabilities, by 2018, MOST assigned State Agency for Technology Innovation to draft and to issue a Circular to guide the evaluation of technology capabilities in manufacturing sectors. The building process of this document shows the large needs of evaluation of technology level and technology capabilities of enterprises while the contents of evaluation works and investigation questionnaires are found to overlap in many aspects. Then there is a need to unify the two processes of assessment of technology level and technology capabilities which would make the evaluation work more convenient and higher effective *(Ta Ba Hung, 1997; Phan Tu Anh, 2006; Nguyen Thi Thu Hang, 2001).*

This paper is to summarize the results of researches for theoretical and practical backgrounds and then to propose an evaluation method of technology level and capabilities to fit the context of Vietnam which would be a platform for drafting a Circular to guide evaluation works of manufacturing technology level and capabilities in manufacturing sectors in Vietnam.

2. Theoretical background for evaluation works of manufacturing technology level and capabilities

2.1. Basic notions

a) Technology level

The notion of technology level appeared on basis of Technology Atlas methodology. According to Circular No. 04/2014/TT-BKHCN, the manufacturing technology level is the class of manufacturing technologies which are classified into 4 levels: advanced, high medium, medium and out-dated. The evaluation of manufacturing technology level of enterprises or manufacturing sectors is based on the achieved levels of the 4 basic components T, H, I and O (Technoware, Humanware, Infoware and Orgaware) *(Ta Ba Hung, 1997; Nguyen Thi Thu Hang, 2001)*.

b) Technology capabilities

Up to now, there exist various approaches in definition of the notion of technology capabilities. According to Lall, "National technology capabilities (also of sectors, facilities) are the capabilities of a country to deploy the existing technologies in effective ways and to respond to technological changes" *(Nguyen Thi Thu Hang, 2001).* According to Vu Cao Dam, "Technology capabilities is the ability to exist, develop and act to carry out technological functions" *(Phan Anh Tu, 2006).*

UNIDO defines the elements forming the technology capabilities which include: capabilities to train human resources, capabilities to conduct fundamental researches, capabilities to test technical means, capabilities to absorb and to adapt technologies, capabilities to provide and to process information.

World Bank proposes to classify the technology capabilities into 3 independent groups *(Nguyen Thi Thu Hang, 2001; Bell, Martin and Keith Pavitt, 1995),* namely:

- Manufacturing capabilities including: production management, manufacturing and maintenance techniques, preservation of production materials and marketing of products;
- Investment capabilities including: project management, project implementation, purchase and training of human resources;
- Innovation capabilities including: creation capabilities and organizational capabilities to introduce new techniques into economic activities.

The above noted approaches show the notion proposed by Lall leads to the largest general definition *(Nguyen Thi Thu Hang, 2001)*.

In summary, the notion of manufacturing technology level and capabilities is the achieved class of the actual technology status, capabilities to organize and to exploit existing technologies, capabilities to conduct research-development-innovation works for manufacturing technologies of enterprises and sectors.

2.2. Some methods for evaluation of technology level and capabilities

In the world, there exist many methods used for assessment of technology level and capabilities. In summary, there are three groups of main methods which are used largely for evaluation works: S&T input-output indicators based evaluation method applied by OECD (1970) and UNESCO (1978), Technology Atlas based evaluation method built by APCTT (Asia-Pacific Center for Technology Transfer, 1986) and Strategic management based evaluation method (Sharif, 1995) used by World Bank *(UNESCO, 1977a, b; UNESCO, 1984; Fabian Y., 1984; NISTEP).* Namely, these methods can be shortly presented as follows:

a) Science-technology input-output indicators based evaluation method

This method is to evaluate the status of technology level and capabilities through assessment of results gained by enterprises in implementation of production-business activities on basis of existing technologies to turn inputs to outputs. Inputs and outputs under evaluation include: capabilities to train human resources, capabilities to test technical means, capabilities to

absorb and adapt technologies, capabilities to provide and process information. This method is good in easy operation of measurement and implementation. But it cannot provide a direct evaluation of technology level and capabilities and contain a large number of factors, apart technological factors, which cause impacts to effectiveness of production-business activities by enterprises. Then the evaluation outcomes may not reflect well the actual technology level and capabilities of the surveyed enterprises *(UNESCO, 1977a, b; UNESCO, 1984; Fabian Y., 1984).*

b) Technology Atlas based evaluation method

This method was established as result of the Technology Atlas Project which started on the argument that technologies are strategic variables to decide the socio-economic development and acceleration in context of economic globalization and increasing international competition. It was the research project conducted by APCTT (UN-ESCAP) which produces the document "Technology based development principles" for application by the countries in the region since 1986-1988.

According to the Technology Atlas, the manufacturing technologies are divided into 4 groups of basic components: (i) Group of technological machines, equipments, tools and means noted as T (Technoware), (ii) Group of capabilities to absorb technological techniques for manufacturing noted as H (Humanware), (iii) Group of information contained in documents and information data noted as I (Infoware) and (iv) Group of organizational and managerial capabilities of noted as O (Orgaware). The evaluation of manufacturing technology level and capabilities of enterprises and sectors is based on the achievement rate of indicators in these 4 groups *(Ta Ba Hung, 1997; UN-ESCAP, 1989)*. This method is good in its high exactness when giving the direct technological evaluation on basis of main components of technologies. But the method is difficult to be used for SMEs and the method is better used for evaluation of technology level than for evaluation of technology capabilities.

c) Strategic management based method

This method was proposed by Sharif by 1996 under argument that the technology resources and technology capabilities are seen as strong and weak points of enterprises while the technology environment and technology infrastructure are seen as opportunities and challenges, at the same time. On basis of this argument, Sharif had built technological specific indicators which allow to consider, evaluate and issue strategies for technology management *(Sharif M.N., 1986)* which include:

- Technology resources: they are evaluated on basis of consideration of 4 technological components in Technology Atlas;

- Technology capabilities: they are evaluated for 6 components: capabilities to absorb technologies, capabilities to transform, capabilities to sell products, capabilities to repair, capabilities to design and capabilities to create technologies;
- Technology infrastructure: they are evaluated on basis of the method by Ramathan (1993) which include 3 main elements: material support infrastructure, technological activity serving infrastructure and strength of technological activities;
- Technology environment: they are evaluated on basis of the method by Ramathan (1993) which include 4 main elements: information about customers (infor-customers), information about competitors (infor-rivals), information about the own enterprises (infor-owners) and information about activities in the sector (infor-clusters).

This method is advantageous in giving a global view in assessment of technology level and capabilities. But it has some disadvantages while requiring a huge evaluation data for a set of full and detail indicators.

3. Practical background for evaluation works of manufacturing technology level and capabilities

3.1. Experiences from some countries in evaluation of manufacturing technology level and capabilities

a) Experiences from developed countries

➢ For some EU member countries, the evaluation of technology capabilities helps companies realize their manufacturing technology capabilities and then develop a road map for development of their products. For evaluation of technology capabilities, the companies refer to the life time of technologies which is built on the development of technologies. The technologies pass 4 phases: innovative technologies, main technologies, standard technologies and substitution technologies with 7 corresponding R&D stages for development of products. Then, for evaluation of technology capabilities, the companies will make assessment on basis of 4 prototypes set up according to development stages of technologies in their life time *(Pavitt K., 1984; Dahlman, Carl J., Bruce Ross-Larson, and Larry E. Westphal, 1987; Figueiredo, Paulo N., 2002; Gereffi, Gary, John Humphrey, Raphael Kaplinsky, and Timothy Sturgeon, 2001; Gereffi, Gary, John Humphrey and Timothy Sturgeon, 2005).*

Also, some EU member countries developed their own systems to measure and evaluate technology capabilities to meet demands of industrial sectors

with purpose to monitor the accumulation paths and to define parameters leading to competition and growth in the sector. The technology capabilities are defined and get impacted from external factors (competitors, technological changes, government policies and etc.) or internal factors (R&D activities, experiences of on-site working and training of staffs). Technology capabilities are divided into 3 main types: investment capabilities, manufacturing capabilities and networking capabilities. Every type of capabilities uses some mathematical formulas developed for actual measurement.

- For Japan, the evaluation of technology level and capabilities gets added with some analysis on the value chains in the world markets. Researchers and policy makers of Japan had built an adequate analysis framework to fit the requirements of Japan in evaluation of technology level and capabilities which is called the Capability Matrix. The matrix used for evaluation of technology capabilities (shortly called Capability Matrix) is a framework for analysis of technology capabilities in development process. It provides the evaluation of technology capabilities in two directions: width and depth of capabilities. Researchers and managers in Japan define the technology capabilities as resources necessary for creation and administration of technological renovation which includes skills, knowledge, experiences, organizational systems, institutional structure and links. The technology capabilities have a specific nature of the company and are a type of institutional knowledge accumulated during a long period of time in the company *(NISTEP; Fujimoto, Takahiro, 2001; Fujimoto, Takahiro, 2007; Kawakami, Momoko and Timothy Sturgeon eds., 2010).*

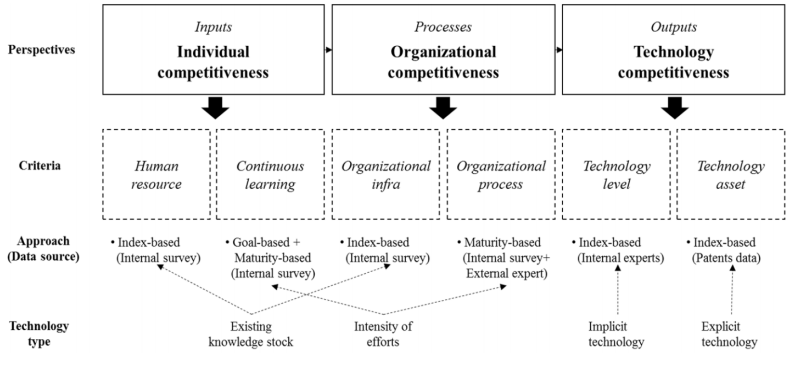
In terms of manufacturing capabilities, the Capability Matrix defines the functions into the corresponding hard and soft aspects related to the two components: manufacturing equipments and production management capabilities. The capabilities related to equipments are defined as operational performance of machines and equipments to process inputs, maintain, design and produce. The capabilities related to production management are defined as the capabilities to arrange effective production activities on basis of indicated targets.

The functional depth of capabilities (ranks of the Capability Matrix) is defined as the depth of capabilities of enterprises. They are divided into capabilities to use existing technologies and capabilities to improve and renovate technologies. The level of use of technologies is the level of capabilities to use existing technologies while the level of improvement and completion of technologies is the level of capabilities to make improvement and completion of existing technologies and to create technological changes.

The level of capabilities of use of existing technologies has two sub-levels: the one is for capabilities of the company to own and to operate existing technologies and the other one is for capabilities of the company to keep operations on and to maintain existing technologies. The level of capabilities to improve and to renovate technologies has also two sub-levels: the one is for capabilities of the company to make light modifications for existing technologies and the other one is for capabilities to make large innovation.

As results, the Capability Matrix applies 4 types of levels of capabilities including: (i) operations, (ii) absorption, (iii) adaptation and (iv) innovation. Every level is defined as follows: the operation level includes capabilities of the company to operate existing technologies; the absorption level includes capabilities of the company to master existing technologies and to maintain the long and stable operation; the adaptation level includes capabilities of the company to make light modifications on basis of existing original technologies; and the innovation level includes capabilities of the company to create new technologies with important changes for existing original technologies.

➢ For Korea, the evaluation of technology capabilities is conducted on basis of the framework of evaluation of technology capabilities which includes 3 main groups of elements: input elements (individual capabilities), procedural elements (organizational capabilities) and output elements (technological outcomes) *(Kim, Linsu, 1997; Kim, Linsu, 2004)*. For a global evaluation, the 3 groups of elements allow to evaluate the technology capabilities of the company.



Source: Kim, Linsu (2004) "The Multifaceted Evolution of Korean Technology capabilities and its Implications for Contemporary Policy" Oxford Development Studies, 32(3), 341-363

Figure 1. Model of evaluation of technology capabilities of Korea

The model of evaluation of technology capabilities is designed for assessment of research capabilities of individuals and organizations, for promotion of technologies outputs and break-through technologies which are divided in groups including: competitive capabilities of individuals, competitive capabilities of organizations and competitive capabilities of technologies.

- For Taiwan, the evaluation of technology capabilities includes the indicators related to R&D activities, training of human resources, granting of patents, financial investment sources for technology innovation, turnovers from new products and technology transfer activities. Through surveys and investigations, the added values are calculated by differences between the values of outputs and the total expenditures for inputs which include costs of raw materials, energy and power *(Kawakami, Momoko and Timothy Sturgeon eds., 2010; Kishimoto, Chikashi, 2004; Sturgeon, Timothy and Ji-Ren Lee, 2005).*

Regarding the evaluation indicators for human resources the labors in enterprises are divided into two groups: high skilled staffs and low trained staffs. The indicators for technology innovation are evaluated through the values of imported equipment lines, technology transfer contracts and financial resources for R&D activities. Regarding the indicators for turnovers from new products sold in markets during 3 years since commercialization of these products.

In summary, we can see in case of developing countries the evaluation of technology level and capabilities is mainly made on the stand of view of strategic management while considering directly technologies in relations with other components in production-business activities of enterprises.

b) Experiences from some developing countries

The evaluation method for technology level and capabilities used mainly in developing countries is the Technology Atlas method where the assessment of technology level and capabilities is made through the evaluation of the 4 basic components (T, H, I, O). Some concrete examples are given under here.

- The evaluation of technology capabilities of light industry sectors in Ethiopia is made for evaluation of capabilities to absorb technologies in light industry sectors. Using the Technology Atlas method, the program of evaluation of technology capabilities of Ethiopia had been conducted with collection, analysis and evaluation of technology capabilities of Ethiopia by 2015. The outcomes gained from the evaluation were used for analysis of

capabilities to absorb technologies (receiving, absorbing, transferring and exploiting) in light industry sectors of Ethiopia.

➢ The evaluation of technology capabilities in main industrial sectors of Iran was made using also the Technology Atlas method. On basis of evaluation works made for 150 enterprises and organizations in industrial sectors of Iran, the evaluation team had built the following graphic of technology capabilities.

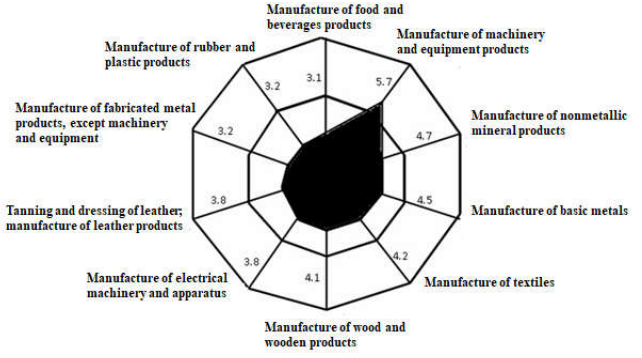


Figure 2. Technology capabilities of industrial sectors of IRAN2

➢ The evaluation of technology capabilities of India was made also by using the Technology Atlas method where the additional work was conducted for fixation of gaps in technology capabilities and analysis for future scenarios. For fixation of gaps in technology capabilities, it is necessary to evaluate the actual level of technology capabilities and the desired level of technology capabilities in future. The actual level of technology capabilities can be measured through 2 main approaches. The first approach is a qualitative method using surveys and interviews by questionnaires. The second one is a quantitative method using collection of data and processing of scores for the desired level. The analysis of scenarios is a tool to illustrate the eventual future and to push decision makers to think in advance before the occurrence of the indicated scenarios. Each scenario gives the ways of interaction between elements in well defined conditions. The analysis of scenario is a useful work when we face uncertainties and high hazards. The scenario analysis method has some limits where the scenario analysis can give good solutions in predicted conditions but uncertain in practice. The scenarios with unknown conditions cannot be useful because the final situation and probability aspects are not drawn out. The scenario analysis method was used largely to study impacts from a single element or a set of elements to the global situation in different environments *(Tran Van Dung, Ha Dang Hien, Hoang Lam et al., 2006).*

Some researches for evaluation of technology capabilities in some concrete sectors are presented in the following table.

Literature	TC Literature				Other references			Capability Matrix
	Lall (1992)	Ariffin and Figueiredo (2004)	Figueiredo (2008)	Kritay alcirana et al. (1989)	Thee (1997)	Hayashi ed. (1986)	Kim (2004)	Yuri Sato (2009)
Country	General	Malaysia/ Brazil	Brazil	Thailand	Indonesia	Japan	Korea	General
Industry	General	Electronics	Electronics/ motocycles	General	Motocycles	General	General	General
Object of observation	Firms	Firms	Firms	Firms	Firms	Industries	Industries	Firms
Level of capabilities	Basic simple routine (experience-based)	Basic operation Level 1	Routine TC: Basic operation Level 1	Aquisitive	Operational	Operations	Acquisition	Operational
		Basic operation Level 2	Basic operation Level 2	Operative	Acquisitive	Maintenance	Assimilation	Assimilative
	Intermediate adaptive duplicative (search-based)	Basic innovative Level 3	Routine TC: Basic innovative Level 3	Adaptive	Adaptive	Repairs and minor modifications	Improvement	Adaptive
		Intermediate innovative Level 4	Intermediate innovative Level 4		Design	Designing and planning		
			High-Intermediate innovation Level 5					
	Advanced innovative risky (research-based)	Advanced innovative Level 5	Advanced innovation Level 6	Innovative	Innovative	Home manufacturing	Generation	Innovative
		Research-based innovative Level 6						

Figure 3. Summary of some researches for evaluation of technology capabilities in some sectors over the world.

The experiences of some countries can show that, for developed countries, the evaluation of technology level and capabilities is mainly conducted by using strategic management principles with a close view to manufacturing process of enterprises while, for developing countries, the evaluation of technology level and capabilities is conducted by using the Technology Atlas method with consideration of technological components. It is the background for the research team to build up an evaluation method which is based on these 2 methods and fits well the actual context and development objectives of Vietnam.

3.2. Recent activities of evaluation of technology level and capabilities of Vietnam

Since 2003, MOST sets up the working team which was introduced into the program of evaluation of technology capabilities of sectors and localities. The objective of the program was to support them to implement evaluation works and then to prepare the kit of standards, methods and procedures for large application over the whole country. Dong Nai Province as the leading local administration in national scale to attract FDI sources was selected by MOST to implement first the project "Survey for evaluation of the status and setting-up of database for S&T capabilities in Dong Nai Province" which lasted from December 2003 to October 2004. On basis of positive outcomes of this project, MOST had assigned Hanoi University of Science-Technology to carry out the national level task "Survey for evaluation of the status, building up of strategic directions and setting-up of database for technology status in Hai Phong City by 2007 *(Tran Van Binh, Pham Minh Tuan, Bui Xuan Hoi et al., 2007)*, assigned Standard-Metrology-Quality Center No. 3 to carry out the national level task "Survey, evaluation and building of database of technology level of industrial sectors in Da Nang City" by 2006 *(Tran Van Dung, Ha Dang Hien, Hoang Lam et al., 2006),* assigned Standard-Metrology-Quality Center No. 1 to carry out the national level task "Survey, evaluation and building of database of technology level of industrial sectors in Quang Ninh Province" *(Nguyen Manh Am, Tran Van Minh, Dang Tuan Hung et al., 2006)*. Quang Binh Province (2016), Binh Duong Province (2004), Binh Dinh Province (2007), Quang Ngai Province (2008), Son La (2010) and Bac Giang (2012) also implemented evaluation activities using local financial sources *(Nguyen Huu Dong, Phan Thanh Nghiem, Phung Thi Hoa et al., 2016).*

Since 2012, Vietnam Center for Science and Technology Evaluation (MOST), coordinated with Hanoi University of Science-Technology to carry out projects of evaluation of technology level of some localities such as "Evaluation of the status of technology level of manufacturing enterprises of driving economic sectors in Lang Son Province" by 2014, "Evaluation of the status of technology level of enterprises of driving economic sectors and technology management in Da Nang City", by 2014, "Evaluation of the status of technology level of manufacturing enterprises of driving economic sectors and technology management in Quang Nam Province, and proposal of road maps for technology innovation for 2016-2025 period, visions to 2030" by 2015, "Evaluation of the status of technology level of manufacturing enterprises of driving economic sectors in Ba Ria-Vung Tau Province" by 2016, "Evaluation of the status of manufacturing technology level of 3 manufacturing sectors (wood

processing, food processing and engineering) in Binh Duong Province" by 2018, "Study and evaluation of the status of manufacturing technology level and solutions for technology management and development of enterprises in Vinh Phuc Province", 2018.

The overview of these surveys and studies shows that the policies of S&T evaluation actually include only guidelines for evaluation works of technology level in Vietnam on basis of Circular No. 04/2014/TT-BKHCN which guides evaluation works of manufacturing technology level. At this scale, the enterprises can do themselves self-evaluation or upgrade on-line information on their own status of technology level and, by this way, identify strengths and weakness of technological elements (T, H, I, O). Also, some documents related to S&T evaluation such as Circular No. 38/2014/TT-BKHCN dated 16th December 2014 by MOST to guide the evaluation of S&T organizations, Joint Circular No. 39/2014/TTLT-BKHCN-BTC dated 17th December 2014 by MOST and Ministry of Finance to guide the evaluation of results of State budgeted works for scientific research, technological development and intellectual assets. These guidelines, however, are of specific nature of evaluation works and they cannot serve the global assessment of S&T activities in Vietnam.

The system of documents to guide the evaluation of technology level and capabilities is shown in the following figure where the Circular to guide the evaluation of technology level and capabilities should be built up on basis of Law on Technology Transfer 2007.

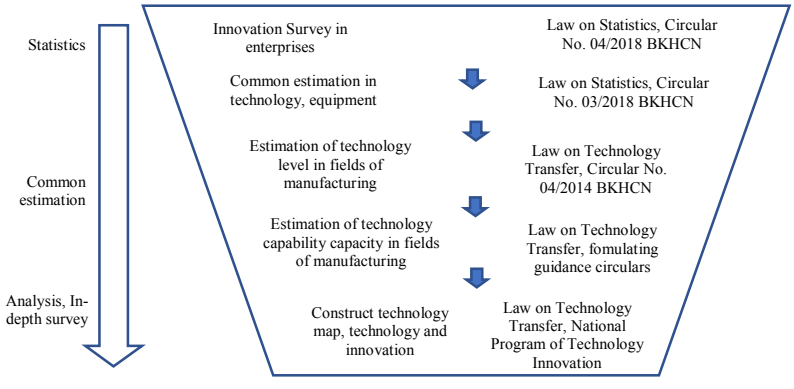


Figure 4. Summary of documents guiding the evaluation of technology capabilities in some sectors in Vietnam

Actually, the evaluation work of technology capabilities does not get the concrete guiding document. Then it is needed to add the guiding document for these activities. The system of technological evaluation of enterprises should include the evaluation of technology capabilities as it is shown well in the following figure.

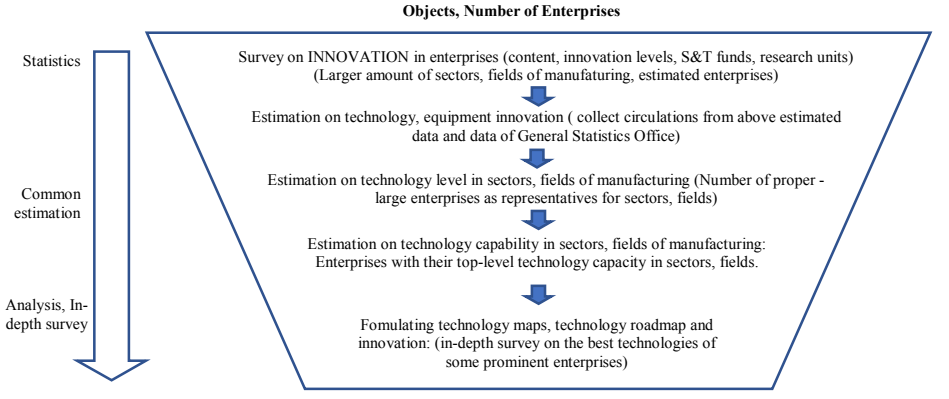


Figure 5. Evaluation of technology capabilities of enterprises and their number

Then, when conducting the evaluation, the depth of technological analysis also depends on the technology level of enterprises as it is shown in the following figure.

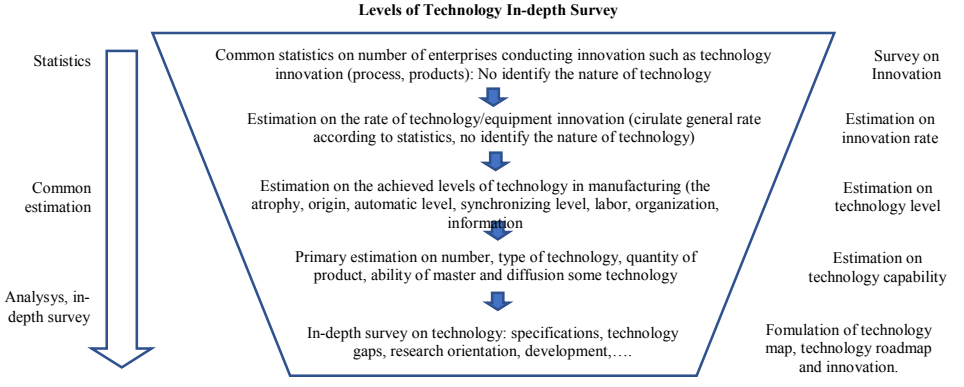


Figure 6. Depth of technological analysis

So, it is possible to state that the evaluation of technology capabilities is a global examination of technology level, enterprise scale and size, and needs of technology innovation in enterprises. The total evaluation work is shown in the following figure.

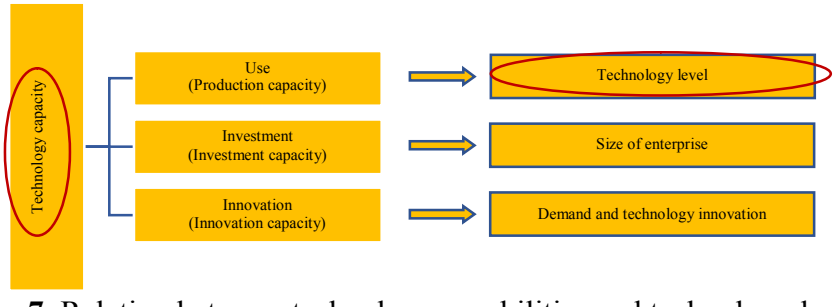


Figure 7. Relation between technology capabilities and technology level

It shows that the technology level and technology capabilities are two aspects relevant and supplementary in evaluation examination. The correlation between them is shown in the following figure.

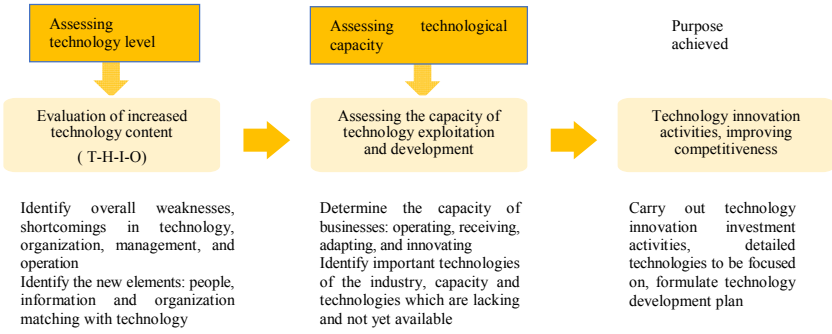


Figure 8. Correlation between technology level and technology capabilities in evaluation

Besides to the documents guiding the technological evaluation, some other guidelines were issued for activities of similar nature, namely:

- Calculation of speed of innovation of technologies and equipments. The evaluation of technology innovation in Vietnam is based on the most popular survey and statistic methodology applied largely in the world which is the OECD Oslo Manual. According to that the evaluation of technology innovation includes 4 aspects: technological products, technological procedures, technological organization and technological market. Then the speed of innovation of technologies and equipments is the ratio between the speed and the average annual growth rate of innovation of technologies and equipments. The level of innovation of technologies and equipments is the index to measure impacts from science-technology to economic development and to measure the efforts of inputs in production-business process. Thanks to technology innovation, the product quality gets enhanced which means the more sustainable position of the enterprise in market. Actually, the method of calculation of the speed of innovation of technologies and equipments applied by localities is based on the guidelines noted in Decision No. 3371/QD-BKHCN dated 24th November 2015 by MOST which governs the issue of temporary procedures and methods for calculation of the speed of innovation of technologies and equipments.
- Technology map for technology evaluation: this method based on the technology map, technology road map and technology innovation is used in various levels: national, sectorial and enterprise. In the actual context of Vietnam, the building of technology map, technology road map and

technology innovation plays important roles to support the set-up of strategies and policies for development of the relevant sectors and also allows to evaluate the effects from the issued strategies, policies and programs in every stage. It also helps State authority agencies identify important technologies to support development of priority products in future and to participate better in R&D contracts for actual sectors (through a better determination of research programs and plans. Acknowledging the importance of this role, the building of the national technology map and the national road map of technology innovation was governed by Decision No. 677/QD-TTg dated 10th May 2011 by the Prime Minister which approved the National Program of Technology Innovation. The technological evaluation by the technology map is the most specific method allowing enterprises, sectors and State authority agencies to understand well the technology status in detail. This method, however, requires a system of qualified experts, extended implementation time and huge resources for this type of in-depth and specific evaluation.

In summary, the authors see that the technological evaluation activities in Vietnam gets improved and completed gradually during recent time. Circular No. 04/2014/TT-BKHCN apart, actually the evaluation of technology capabilities does not have any other official guiding document and is not carried out in practice in Vietnam. Therefore, it is necessary to add some contents required for evaluation of technology capabilities. As it is seen, however, the evaluation of technology capabilities and the evaluation of technology level are relevant and supplementary aspects then their combination in a single method and procedure would make the evaluation work more effective. Regarding the evaluation of technology level and capabilities of enterprises and sectors, the experiences from other countries show that it is necessary to assess the technology level and capabilities under various aspects using separate components of the set of indicators. Vietnam as a developing country with the objective to become a developed country should have a set of indicators which combines reasonably the Technology Atlas method (applied for developing countries) and the Strategic Management method (applied for developed countries). Expectedly the method for evaluation of technology level and capabilities proposed to be built would fit the practical production conditions of enterprises and the strategic development objectives defined by the Party and the State.

4. Proposal of a method for evaluation of manufacturing technology level

4.1. Main points of the proposal

a) Method for evaluation of manufacturing technology level and capabilities of enterprises

On basis of theoretical and practical consideration of activities for evaluation of technology level and capabilities, the authors propose a global approach through analysis of 5 components including: (i) Actual status of manufacturing technologies (called as T Group); (ii) Effects of exploitation of technologies (called as E Group); (iii) Capabilities of organizing and management (called as O Group); (iv) R&D capabilities (called as R Group); and (v) Innovation capabilities (called as I Group). The evaluation set includes 27 indicators. The evaluation of technology level and capabilities uses the common system of 100 scores to make a common platform for evaluation. The total number of gained scores will rank the technology level and capabilities. Data information used to determine the scores of every indicator is inspected and collected on-site in facilities of enterprises. Besides, the synchronous coefficients used to combine technology level and technology capabilities are calculated on basis of gained scores of the groups T, E, O, R, I which would be the background for remarks and conclusions in the Report of evaluation of manufacturing technology level and capabilities. Some indicators depending much on technological properties and characteristics of individual sectors and then varying regularly in results of socio-economic development need to be regulated by comparative considerations at the time of evaluation. Namely the groups of indicators are proposed as follows.

- T Group (maximum 30 scores) includes 8 indicators:

- Indicator 1: Degradation level of technologies and equipments (max. 5 scores) which measures the loss of use values of technologies and equipments along the time;
- Indicator 2: Intensity of capitals of technologies and equipments (max. 3 scores) which measures the use of capitals invested for enterprises;
- Indicator 3: Rate of innovation of equipments (max. 3 scores) which measures the additional investment for substitution and upgrading of equipments of enterprises;
- Indicator 4: Technical standards of technologies and equipments (max. 3 scores) which evaluates the credibility of standards and technical specifications of technologies and equipments of enterprises;
- Indicator 5: Level of automation and smart manufacturing (max. 5 scores) which measures the level of sophistication and digitalization in manufacturing process of enterprises;
- Indicator 6: Rate of energy costs for production activities (max. 4 scores) which measures effectiveness of energy consumption in production activities of enterprises;

- Indicator 7: Rate of material costs for production activities (max. 4 scores) which evaluates effectiveness of use of materials in production activities of enterprises;
- Indicator 8: Products made by production lines (max. 3 scores) which evaluates quality of products made by production lines of enterprises.

➢ E Group (maximum 20 scores) includes 5 indicators:

- Indicator 9: Labor productivity (max. 5 scores) which evaluates effectiveness of use of human resources of enterprises;
- Indicator 10: Effectiveness of application of technical improvement in manufacturing activities (max. 3 scores) which evaluates effectiveness of improvement measures;
- Indicator 11: Capabilities to conduct maintenance and reparation works for production lines and equipments of enterprises (max. 4 scores) which evaluates capabilities of the enterprises themselves to carry out these activities;
- Indicator 12: Capabilities to receive technology transfers (max. 4 scores) which evaluates the capabilities of enterprises to absorb technologies;
- Indicator 13: Quality of human resources (max. 4 scores) which evaluates quality of staffs of enterprises (labors, managers and superior executives).

➢ O Group (max. 20 scores) includes 5 indicators:

- Indicator 14: Rate of expenditures for training works (max. 3 scores) which evaluates the expenditures for formation and training activities for human resources of enterprises;
- Indicator 15: Information for production activities (max. 5 scores) which evaluates the use of information systems to serve production activities of enterprises;
- Indicator 16: Management of global efficiency of equipments (max. 5 scores) which evaluates effectiveness of organizational and managerial activities inside enterprises;
- Indicator 17: Application of production management systems (max. 3 scores) which measures the level of application of management system and tools for enhancement of productivity and quality control of enterprises;
- Indicator 18: Environment protection (max. 4 scores) which evaluates activities for environment monitoring and protection of enterprises.

➢ R Group (maximum 16 scores) includes 5 indicators:

- Indicator 19: Information infrastructure (max. 3 scores) which evaluates the level of IT application of enterprises;
- Indicator 20: Costs for information (max. 3 scores) which evaluates investments for IT application (software, data, information security and etc.) of enterprises;
- Indicator 21: R&D staffs (max. 4 scores) which evaluates the rate (to the total staffs) of human resources used for R&D and training activities;
- Indicator 22: R&D infrastructure (max. 2 scores) which evaluates the level of investments by enterprises for R&D infrastructure;
- Indicator 23: Investment funds and expenditures for R&D activities (max. 4 scores) which evaluate investment efforts by enterprises for R&D activities and product development.

➢ I Group (max. 4 scores) which includes 5 indicators:

- Indicator 24: Results of R&D activities (max. 4 scores) which evaluates research capabilities for improvement, modification and development of new products of enterprises and achieved effects through these activities;
- Indicator 25: Results of technological R&D activities (max. 4 scores) which evaluates results of improvement and modification of existing technologies as well as research for development of new technologies for production activities of enterprises;
- Indicator 26: Capabilities to link and cooperate for R&D activities (max. 2 scores) which evaluates capabilities of enterprises to develop these activities with external partners including enterprises, research institutes, universities and foreign organizations;
- Indicator 27: Capabilities of enterprises in shifting to digital techniques (max. 4 scores) which evaluates capabilities to apply and implement digital platform and integration of smart technologies for optimization of manufacturing modes and procedures.

b) Method for evaluation of manufacturing technology level and capabilities of enterprises

The conducted studies lead to the following proposal for evaluation of technology level and capabilities.

- Step 1: Determination the scores of every indicator and the total scores gained after assessment. The maximal total values are 100 scores.

The technology level and capabilities of enterprises is measured by the total gained scores:

$$\tau = T + E + O + R + I$$

- Synchronous coefficient of technology level and technology capabilities T_{DB} is calculated as:

$$T_{DB} = K_T.\beta_T.K_E .\beta_E.K_O.\beta_O.K_R.\beta_R.K_I.\beta_I$$

with: $K_T = \frac{T}{30}$; $K_E = \frac{E}{20}$; $K_O = \frac{O}{20}$; $K_R = \frac{R}{16}$; $K_I = \frac{I}{14}$

$$\beta_T = 0.30; \beta_E = 0.20; \beta_O = 0.20; \beta_R = 0.16; \beta_I = 0.14$$

where:
- K_T is the coefficient for technology level and capabilities of elements in T Group;
- K_E is the coefficient for technology level and capabilities of elements in E Group;
- K_O is the coefficient for technology level and capabilities of elements in O Group;
- K_R is the coefficient for technology level and capabilities of elements in R Group;
- K_I is the coefficient for technology level and capabilities of elements in I Group;
- βT is the weight of technology level and capabilities of T Group;
- βE is the weight of technology level and capabilities of E Group;
- βO is the weight of technology level and capabilities of O Group;
- βR is the weight of technology level and capabilities of R Group;
- βI is the weight of technology level and capabilities of I Group.

- Step 2: Classification of technology capabilities of enterprises by the total scores of the indicators for technology capabilities;

For out-dated technology level and capabilities: the synchronous coefficient of technology level and technology capabilities < 0.2 and the total scores of technological components < 25 points;

For medium technology level and capabilities: the synchronous coefficient of technology level and technology capabilities is from 0.2 to 0.4 and the total scores of technological components are from 25 points to 50 points;

For high medium technology level and capabilities: the synchronous coefficient of technology level and technology capabilities is from 0.4 to 0.6 and the total scores of technological components are from 50 points to 75 points;

For advanced technology level and capabilities: the synchronous coefficient of technology level and technology capabilities is from 0.6 up and the total scores of technological components are from 75 points up.

c) Method for evaluation of manufacturing technology level and capabilities of sectors

The outcomes of evaluation of technology level and capabilities of enterprises are used for evaluation of technology level and capabilities of sectors through the following steps.

- Step 1: Determination the scores of every indicator and the total scores gained after assessment of the sector.

The scores of groups of technological components of the sectors are calculated as follows:

$$T_N = \frac{\sum_{i=1}^{n} T^i.Q^i}{\sum_{i=1}^{n} Q^i}; \quad E_N = \frac{\sum_{i=1}^{n} E^i.Q^i}{\sum_{i=1}^{n} Q^i}; \quad O_N = \frac{\sum_{i=1}^{n} O^i.Q^i}{\sum_{i=1}^{n} Q^i}; \quad R_N = \frac{\sum_{i=1}^{n} R^i.Q^i}{\sum_{i=1}^{n} Q^i}; \quad I_N = \frac{\sum_{i=1}^{n} I^i.Q^i}{\sum_{i=1}^{n} Q^i}$$

where: - n is the number of the enterprises in the sector under evaluation;

- T^i, E^i, O^i, R^i, I^i are the gained scores of the 5 groups of components T, H, O, R, I of the i-th enterprise;

- Q^i is the added value of products of the i-th enterprise.

The technology level and capabilities of the sector is measured by the total gained scores:

$$\tau(N) = T_N + H_N + O_N + R_N + I_N$$

The synchronous coefficient of technology level and technology capabilities T_{DB} of the sector:

$$T_{DB}(N) = K_T(N).\beta_T.\ K_E(N).\beta_E.\ K_O(N).\beta_O.K_R(N).\beta_R.K_I(N).\beta_I$$

where: $K_T(N) = \frac{T_N}{30}$; $K_E(N) = \frac{E_N}{20}$; $K_O(N) = \frac{O_N}{20}$; $K_R(N) = \frac{R_N}{16}$; $K_I(N) = \frac{I_N}{14}$

The synchronous coefficient of technology level and technology capabilities of a sector can be also calculated by the formula:

$$T_{DB(N)} = \frac{\sum_{i=1}^{n} T_{DB}^i.Q^i}{\sum_{i=1}^{n} Q^i}$$

where: - n is the number of the enterprises in the sector under evaluation;

- T_{DB}^i is the coefficient of contribution of the i-th enterprise;

- Q^i is the added values of products of the i-th enterprise.

- Step 2: Classification of the technology level and capabilities of the sector according to 4 levels on basis of the total scores of manufacturing technology level and capabilities of the components and the synchronous

coefficients of technology level and technology capabilities of the sector, similarly to the case of enterprises.

4.2. Pilot trials for evaluation of manufacturing technology level and capabilities in some enterprises

a) Selection of enterprises for pilot trials of evaluation of manufacturing technology level and capabilities

The enterprises selected for pilot trials of evaluation of manufacturing technology level and capabilities must be from processing and engineering sectors. These enterprises are selected from the both northern and southern regions of Vietnam and they should be different each from other for the check and the adjustment of the set of indicators, namely they have different sizes and types: SMEs and large enterprises, SOEs and JSCs and private companies.

The letters to invite for participation in pilot trials were sent to the targeted enterprises and upon their positive confirmation, the selected enterprises are finally listed as follows:

Table 1. List of the enterprises selected for pilot trials of evaluation of manufacturing technology level and capabilities

No.	Name	Scope of activities
1	AMECC Engineering-Construction JSC.	Engineering-construction products
2	Hoa Mai Automobile Ltd. Co.	Producing automobile parts
3	Van Long Ltd. Co.	Technical plastic products
4	Bach Khoa Electro-Electronic Equipment JSC	Electro-electronic equipment
5	VLC Package Product JSC	PP package products
6	Bui Van Ngo Agriculture Engineering Ltd. Co.	Agriculture-engineering products
7	Viet Nam Food JSC (VNF)	Processing and production of aquatic products (shrimp and fish)
8	INDEFOL Technical Solutions Ltd. Co.	Electric equipment products
9	South Vietnam Engine and Agriculture Machinery Ltd. Co.(SVEAM)	Agriculture-engineering products

b) Outcomes of the pilot trials of evaluation of manufacturing technology level and capabilities

The score results of evaluation of the groups of indicators are as follows:

- T Group

The outcomes of evaluation of T Group of indicators for the 9 enterprises under survey are presented in the following figure.

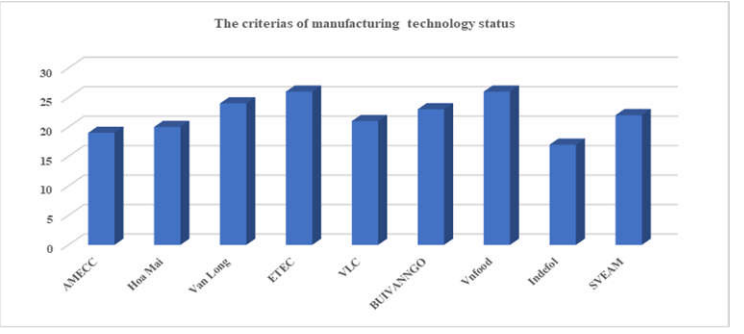


Figure 9. Outcomes of evaluation for T Group

As shown by the outcomes of evaluation, for enterprises in high tech sectors such as plastics, electronics, pharmaceutics, food processing and etc., the increasing demands of the market and the shorter life time of technologies require a more dynamic investment and innovation of machines, equipments and technologies. The longer life time of technologies for enterprises in other sectors (construction, packages, engineering and etc.) leads to slower rhythms of investment and innovation of machines, equipments and technologies. Also in the same sector (e.g. engineering) the enterprises making higher investments for a higher level of machines, equipments and technologies produce products with better quality

- E Group

The outcomes of evaluation of E Group of indicators for the 9 enterprises under survey are presented in the following figure.

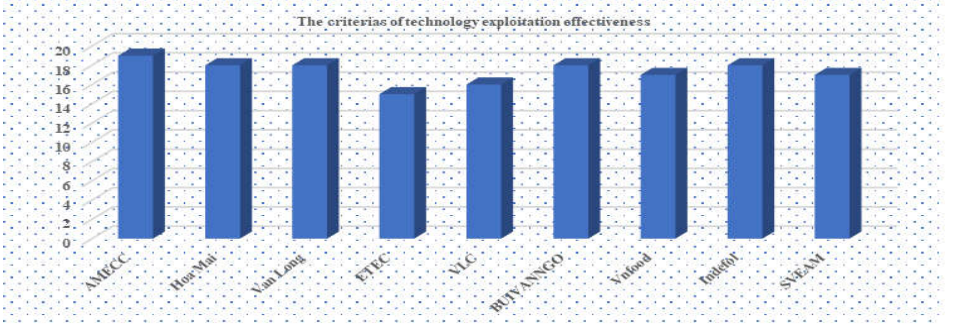


Figure 10. Outcomes of evaluation for E Group

As shown by the outcomes of evaluation, majority of enterprises under evaluation are running well then they have high scores for the item of

exploitation of technologies. Particularly, the technologies owned by private companies or JSCs are exploited maximally making the highest efficiency for production-business activities of the enterprises.

- O Group

The outcomes of evaluation of O Group of indicators for the 9 enterprises under survey are presented in the following figure.

Figure 11. Outcomes of evaluation for O Group

As shown by the outcomes of evaluation, those enterprises (particularly JSCs and private companies) who have both local and overseas markets and international partners have higher scores since they follow the modern management models (ISO 9001, 5S, Kaizen, GPP and etc.). In the meantime, SMEs with their small size, as rules, have a lower level of organizational and managerial structure.

- R Group

The outcomes of evaluation of R Group of indicators for the 9 enterprises under survey are presented in the following figure.

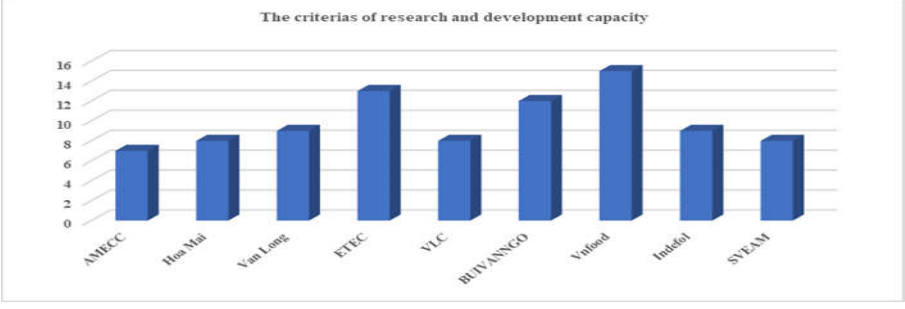


Figure 12. Outcomes of evaluation for R Group

As shown by the outcomes of evaluation, majority of enterprises in high tech sectors (electronics, pharmaceutics, food processing and etc.) and large sized enterprises make investments more focused for research and

development of products then they gain higher scores in this group of indicators. In the meantime, other sectors with lower levels of manufacturing technologies (construction, packaging products, engineering and etc.) face more difficulties in investments and then, as result, have lower R&D capabilities.

- I Group

The outcomes of evaluation of I Group of indicators for the 9 enterprises under survey are presented in the following figure.

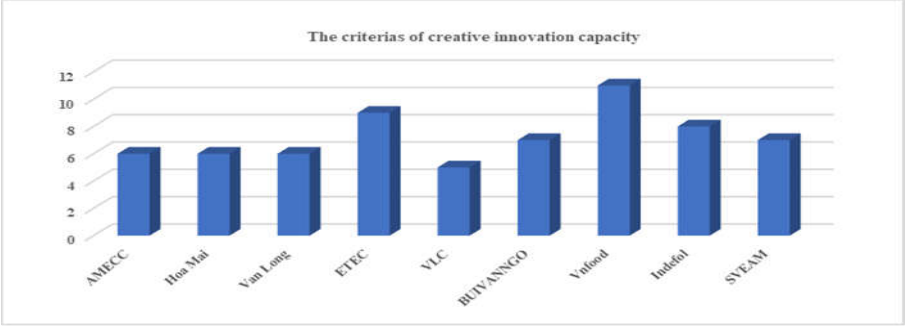


Figure 13. Outcomes of evaluation for I Group

As shown by the outcomes of evaluation, majority of enterprises in high tech sectors (electronics, pharmaceutics, food processing and etc.) and large sized enterprises make investments more focused for innovation then they gain higher scores in this group of indicators. In the meantime, other sectors with lower levels of manufacturing technologies (construction, package, engineering and etc.) face more difficulties in investments and then, as result, have lower innovation capabilities.

In summary, the outcomes of evaluation of manufacturing technology level and capabilities of the enterprises under survey are presented in the following figure.

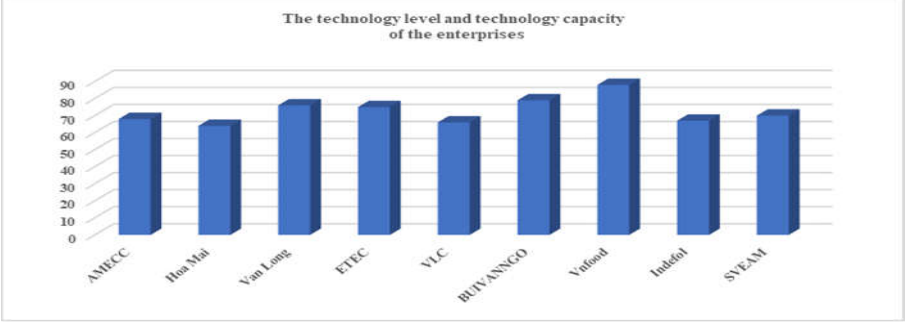


Figure 14. Outcomes of evaluation of technology level and capabilities of enterprises

Globally, the outcomes of evaluation works show the surveyed enterprises have the technology level and capabilities from the high medium level to

the advanced level. Among them, 4 enterprises: Van Long Ltd. Co., Bach Khoa Electro-Electronic Equipment JSC, Bui Van Ngo Agriculture Engineering Ltd. Co. and Vietnam Food JSC (VNF) have the advanced level and the remaining enterprises have the high medium level.

The total scores of evaluation of the synchronous coefficient of technology level and technology capabilities of the 9 surveyed companies are presented in the following figure.

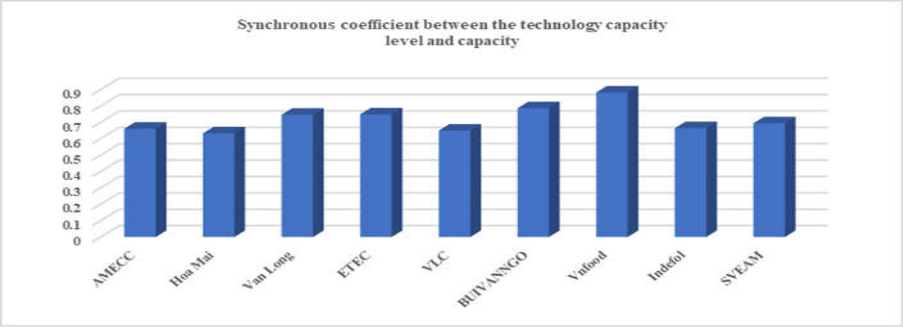


Figure 15. Outcomes of evaluation of the synchronous coefficient of technology level and technology capabilities

As shown by the outcomes of evaluation, the surveyed enterprises have the synchronous coefficients in the range 0.60÷0.85 where the 4 enterprises with advanced level of technology level and capabilities have the high level of synchronization of technology level and technology capabilities. The remaining enterprises have the lower synchronous coefficients.

5. Conclusions

The paper provides analysis of the notions and methods for evaluation of technology level and capabilities for building of the theoretical background, analysis of experiences of the evaluation methods of some countries and the status of technological evaluation activities in Vietnam. They would save as materials for further assessments. On basis of this theoretical and practical platform, the authors propose a method for evaluation of manufacturing technology level and capabilities with a set of 27 indicators. They are divided into 5 groups of elements which combine the evaluation of technology level and technology capabilities in various manufacturing sectors to fit well the actual context of Vietnam. The pilot trials of evaluation in some enterprises serve as tests and allow to adjust and to improve the set of indicators and the method before the recommendation for use in the future Circular to guide the evaluation of manufacturing technology level and capabilities for sectors in Vietnam./.

REFERENCES

In Vietnamese:

1. Ta Ba Hung (Editor-in-Chief) (1997). *Technological Atlas. Volume 1. Technology based development principles*. National Agency for Science-Technology Information.
2. Nguyen Thi Thu Hang (2001). *Teaching curriculum for the unit Technology Management*. Department Industrial Management, Hochiminh City University of Science-Technology.
3. Phan Tu Anh (2006). *Teaching curriculum for the unit Technology Management*. Post-Communication Technology Academy.
4. Nguyen Manh Am, Tran Van Minh, Dang Tuan Hung et al. (2006). *Survey, evaluation and building of database on technology level in Quang Ninh Province*. Ministerial level task. Standard-Metrology-Quality Technical Center No. 1, General Department of Standard-Metrology-Quality.
5. Tran Van Dung, Ha Dang Hien, Hoang Lam, Tran Dinh Giai (2006). *Survey, evaluation and building of database on technology level of industrial sectors in Da Nang City*. National level task. Standard-Metrology-Quality Technical Center No. 3, Ministry of Science-Technology.
6. Tran Van Binh, Pham Minh Tuan, Bui Xuan Hoi et al. (2007). *Survey, evaluation of the status, building strategic directions and database on the technology status in Hai Phong City*. National level task. Hanoi University of Science-Technology.
7. Nguyen Huu Dong, Phan Thanh Nghiem, Phung Thi Hoa et al. (2016). *Survey, evaluation of manufacturing technology level and proposal of solutions for technology innovation in Quang Binh Province*. Provincial level task. Science-Technology Department, Quang Binh Province.

In English:

8. National Institute of Science and Technology Policy (NISTEP), Ministry of Education, Culture, Sports, Science and Technology, JAPAN. "Science and Technology Trends - Quarterly Review Science & Technology Foresight Center".
9. UNESCO (1977). "Guild to the Collection of Statistics on Science and Technology", Paris.
10. UNESCO (1977). "Manual for Surveying National Scientific and Technology Potential", Paris.
11. UNESCO (1984). "Manual on the National Budgeting of Scientific and Technological Activities", Paris UNESCO.
12. Fabian Y. (1984). "The OECD International S&T Indicators System", in *Science and Public Policy* No 11, pp. 4-6.
13. Pavitt K. (1984). R&D Patenting and Innovative Activities: A statistical Exploration, in *Research Policy*, No 11 pp. 33-35.
14. Sharif M.N. (1986). "Management of Technology for National Development", in *Technology Forecasting and Social Change*, No 29, pp. 119-172; et Sharif M.N.

(1995): "Integrating Business and Technology Strategies in Developing Countries, In Technology Forecasting and Social Change, No 45, pp. 195-167.

15. Dahlman, Carl J., Bruce Ross-Larson, and Larry E. Westphal (1987). "Managing Technological Development: Lessons from Newly Industrializing Countries," *World Development*, 15(6): 759-75.
16. UN-ESCAP (1989). "Technology Atlas Project Tokyo Program on Technology for Development in Asia and Pacific", Bangalore, India.
17. Abo, Tesuo ed. (1994). *Hybrid Factory: The Japanese Production System in the United States*, New York and Oxford: Oxford University Press.
18. Bell, Martin, and Keith Pavitt (1995). "The Development of Technology capabilities" in Irfan ul Hague ed., Trade, Technology and International Competitiveness, EDI Development Studies, Washington D.C.: The World Bank.
19. Kim, Linsu (1997). *Imitation to Innovation: The Dynamics of Korea's Technological Learning*. Boston, MA: Harvard Business School Press.
20. Fujimoto, Takahiro (2001). Seisan Manejimento Nyumon (Introduction to Production Management) I, II, Tokyo: Nihon Keizai Shimbun, Inc.
21. Gereffi, Gary, John Humphrey, Raphael Kaplinsky, and Timothy Sturgeon (2001). "Introduction: Globalisation, Value Chains and Development," *IDS Bulletin*, 32(3): 1-8.
22. Figueiredo, Paulo N. (2002). "Does Technological Learning Pay Off? Inter-Firm Differences in Technology capability-Accumulation Paths and Operational Performance Improvement," *Research Policy*, 31: 73-94.
23. Bazan, Luiza and Lizbeth Navas-Aleman (2004). "The Underground Revolution in the Sinos Valley: a Comparison of Upgrading in Global and National Value Chains" in Hubert Schmitz ed.
24. Kim, Linsu (2004). "The Multifaceted Evolution of Korean Technology capabilities and its Implications for Contemporary Policy," *Oxford Development Studies*, 32(3), 341-363.
25. Kishimoto, Chikashi (2004). "Clustering and Upgrading in Global Value Chains: the Taiwanese Personal Computer Industry" in Schmitz ed.
26. Gereffi, Gary, John Humphrey and Timothy Sturgeon (2005). "The Governance of Global Value Chains," *Review of International Political Economy*, 12(1): 78-104.
27. Sturgeon, Timothy and Ji-Ren Lee (2005). "Industry Co-Evolution: A Comparison of Taiwan and North American Contract Manufacturers" in Suzanne Berger and Richard Keith Lester eds. Global Taiwan: building competitive strengths in a new international economy, Armonk: M.E. Sharpe, Inc.
28. Fujimoto, Takahiro (2007). *Competing to Be Really, REALLY Good: The behind-the-scenes drama of capability-building competition in the automobile industry*, Tokyo: International House of Japan.
29. Kawakami, Momoko and Timothy Sturgeon eds. (2010). The Dynamics of Local Learning in Global Value Chains: Experiences from East Asia, Basingstoke, Hampshire: Palgrave Macmillan.