MEASUREMENT SYSTEM FOR SMART TECHNOLOGY CAPABILITY IN INDUSTRIAL FIELDS

CHUI YOUNG YOON

On Kwang Technology Research Center, On Kwang Co. Ltd., South Korea
E-mail: yoon0109@ut.ac.kr

Abstract - With the fourth Industrial revolution, smart technology has been applied through all kinds of industry fields. Most industry has established its smart technology environment appropriate for each industryfields. In this industrial technology environment, the smart technology capability of each industry is very critical for the efficiency of its industrial activity and for the advancement ofits industrial performance. The scientific and objective measurement framework has to be developed for reasonably managing and improvingthe smart technology capability that can efficiently support its industrial fields. The developed measurement framework is verified by reliability analysis and factor analysis based on previous studies. This study provides a 13-item measurement system that can objectivelygauge a smart technology capability for industry fields in a total smart technology perspective.

Index Terms - Smart Technology, Smart Technology Capability, Measurement System, Industrial Field.

I. INTRODUCTION

In the fourth industrial revolution, all kinds of industry has executed many production activities and business tasks in most industry fields with partially and fully utilizing smart device, network, solutions and systems in a smart technology environment [1]-[6]. Most industry have built smart technology environment to raise their industrial productivity and business performance, and to increase their competitiveness in a global industrial environment. Smart technology is utilized for the manufacture, finance, construction, logistics, and service activities to improve their industrial activity performance [2]. It is a critical way to preserve and improve an industrial effectiveness and efficiency in the ever-changing industrial environment [3]. It is not abnormal that each industry has developed its strategy that focalizes on smart technologies as an infrastructure to facilitate the efficient collection and utilization of them. In this industrial environment, smart technology is a core resource for future advanced industrial environment. It is indispensable to widely applysmart technology to all kinds of industrial activities. Systematical construction of smart technology environment is very important to fulfil industrial capability appropriate for each industrial activity and performance. In other words, we have to measure its smart technology capability with a scientific and practical measurement framework in order to reasonably establish and improve a smart technology environment appropriate for the industrial activities and performances. The measurement framework should improve the industrial smart technology capability based on the measurement results of smart technology ability for industry fields. However, previous studies have not researched a scientific and practical measurement scale to gauge an industrial smart technology capability. That is, we need a comprehensive and objective measurement framework that can efficiently examine a smart technology capability for industry fields in terms of its whole smart technology ability.

Therefore, this study provides a practical measurement system that can objectively gauge a smart technology capability of industry fields (STCIF) to efficiently performindustrial activities, and to systematically build and advance its smart technology environment in terms of an entire smart technology capability.

II. RELATED STUDIES

Smart technology has regarded as the critical factor to effectivelyincrease industrial activities and performances, industrial competitiveness, and to prepare for a future industrial environment with advance of smart technology [3]. Smart technology of industry fields can be described as an industrial process that uses the smart technology medium as an expedient to improve industrial activities [3]. The smart technology of industry fields can be defined as an approach to improve the industrial competitiveness by advancing industrial activities and results through utilizing smart technology such as smart devices, networks, solutions, and systems[1]-[6].

Hence, our researchdefinesthe smart technology of industry fields as a technological approach to effectively execute the industrial activities by applying the smart technology and solutions, and smart systems

to all kinds of industrial activities in a smart technology environment. Many studies defined the concepts of information technology capability from the view points of the study researchers [7]-[8]. However, smart technology capability has rarely researched in previous literature. The literature related on smart technology has studied in terms of smart network, smart devices and solutions, and smart phone and platform in a specific technology perspective [1]-[6].

Several research agencies present their research reports in a specific smart technology and solution departments [9]-[12]. Information technology capability is considered as the culmination of the sets of hardware, software, services, management practices, and technologies and management skills related to information technologydepartments [8]. Wecan explain smart technology capability as the ability to integrate other resources of an organization through the disposition and utilization of one's own smart technology resources. Information technology capability is formed by smart technology system convention, smart technology infrastructure, and smart technology human resources and smart technology relationship assets based on these resource-based perspectives[7][8]. It is a kind of technologicalabilityto support to organizational activities and work-flows by the disposition of smart technology resources and integration of other relevant resources [12].

Hence, Smart technology capability is conceptualized as the extent to which an organization is knowledgeable about and effectively utilizes smart technology to manage smart technology data within the organization. The components of smart technology capability representthree co-specialized resources: smart technology objects; smart technology knowledge; and smart technology operations[9]-[14].Smarttechnology objects represent computer-based hardware, software, and support personnel. Smart technology knowledge is summarized as the extent to which an organization possesses a body of technical knowledge about objects such as computer based systems. Smart technology operations are identified as the extent that an organization utilizes smart technology to manage market and customer information [9][10][14]. From a smart technology system perspective, the measurement of the smart technology system level indicates the total capability that includes smart technology vision, smart technology infrastructure, smart technology support, and smart technology application and usage [13]-[20]. The smart technology vision represents a smart technology strategy plan and smart technology project plan of an organization. The smart technology infrastructure includes hardware, networks, system software, and supporting tools. Smart technology support refers to smart technology organization, smart technology direction and institution, and supporting methods for smart technology facilities. Finally, the smart technology application and usage explain the application and utilization that exploit solutions and smart technology for an organization's activities.

From exploring previous literature and our research results, this study defines the smart technology capability of industry fields (STCIF) as the entire smart technology capability that an industry has to retain to efficiently support its industrial activities and performances in a smart technology environment. This research firstly develops the measurement items for STCIF based on the definition of STCIF and previous studies related to smart technology capability.

III. METHODS

A. Research Method

Our research firstly generated 26measurement items for STCIF based on definitions and components of smart technology capability [1]-[20]. The developed measurement items were reviewed and refined by the expert group in our information technology research center: postdoctoral researchers, professors, and information technology developers. Appendix A provides the refined 26measurement items. The construct validity of the developed measurement items is verified to ensure that the measurement items efficiently gaugeSTCIF. This research proved it by providing that the measurement framework was a suitable operational definition of the construct it purported to measure. Literature presented various methods to verify the validation of a model construct [21]-[24]. In general, most studies present two methods of construct validation: (1) correlations between total scores and item scores, and (2) factor analysis [21]-[24]. The former assumes that the total score is valid, and the extent to which the item correlates positively with the total score is indicative of the construct's validity for the items [21][22]. Each item score was subtracted from the total score to exclude spurious part-whole correlation [21][22]: the result was a corrected item- total correlation that was then correlated with the item score. Factor analysis analyzes the underlying structure or components of the framework [23][24]. It helped identify factorally pure items that would facilitate more specific hypothesis tests, and to identify the components that make up the total measure [22]. The factor-analyzed items were selected, since they were closely related to each other.

This research also analyzed a measurementscale of criterion-related validity to identify the measurement items that may not be closely concerned with STCIF. The generalized measurementitem for efficiently analyzing STCIF was used as a criterion measurement

scale. The measure provided a measurementscale of criterion-related validity to the extent that each measurement item was correlated with this. Measurement items should present a favorable or unfavorable attitude toward the object in question [24]. When the measurement item is ambiguous or appears to present a neutral attitude, it should be deleted [24].

Hence, we examined a measurementframework of criterion-related validity to identify measurement items that did not show favorable or unfavorable attitudes. We extracted all of the measurement items in a measurementframework from the domain of a single construct, and responses to these measurement items should be highly inter-correlated. The corrected item-total correlation refers to a measurementframework of this.

In this questionnaire survey, the measurement questionnaire used a five-point Likert-type scale as presented in previous studies; denoting, 1: not at all; 2: a little; 3: moderate; 4: good; and 5: very good. Our research carried out our measurement questionnaire for five industry fields like manufacturing, banking and insurance, construction, logistics, and service. The questionnaire includes three main sections. The first section indicates the backgrounds and objectives, the main contents, and response methods of this questionnaire. The second section asks respondents to provide general information, such as industry fields and position, firm's size and revenue, and business history of their companies. The last section presents the measurementitems for the respondents in industry fields. Wegot questionnaire data from a variety of industries so that the analysis results can be generalized. Our research performed two kinds of survey methods: direct collection and e-mail. The respondents either directly mailed back the completed questionnaires or research assistants collected them two-four weeks later. The collected questionnaires represented 34.7 percent of all the respondents.

B. Sample Characteristics

In this questionnaire survey, we collected 149 responsesform 430 respondents in five industry fields. They indicated a variety of industry fields and position, firm size and revenue, and business history. Our researchruled out four incomplete or ambiguous questionnaires, leaving 145 usable questionnaires for statistical analysis. The respondents of this questionnaire in terms of industry fields were classified as manufacturing (22.8%), construction (19.3%), banking and insurance (20.0%), logistics (16.6%), and service (21.3%). The respondents identified themselves as top manager (4.8%), middle manager (40.7%), and worker (54.5%). Therespondentsinfiveindustryareashadonaverage8.4 years' experience (S.D. =1.09) in their industry fields, their average age was 36.8 years old (S.D.=5.38), and their gender, male (75.2%) and female (24.8%). This research intentionally performed our survey focused on various industries, and managers and workers with various experience within an industry fields. Because, in order to raise the generalization of our research results, we used a diverse sample that thoroughly understands their STCIF, with practical affairs working at their industry areas for more than about 5 years. Namely, the respondents could efficiently present the right responses for our questionnairemeasurement survey.

C. Analysis and Discussion:

In this questionnaire analysis, we extracted the measurement results from the collected questionnaires. The values of measurement items were excluded when their correlation with the corrected item-total correlation was < 0.5 or when their correlation with the criterion scales was < 0.6 [21][22].

The correlations with the corrected item-total correlation and the criterion item were significant at p□0.01and similar to those used by others in previous research [21][22]. This research utilized factor analysis to verify the validity of the developed measurement framework and measurement items. We also used this measurement analysis to identify the underlying factors or components that consist of the STCIF construct.

This researcheliminated inadequate items for the measurement framework based on the measurement results. We contemplated sufficiently high criteria to extract reasonable measurementitems of STCIF. That is, the first 26measurement items resulted in a 15-item scale prior to conducting factor analysis. The sample of 145 responses was examined by using principal components analysis as the extraction technique with the varimax method of rotation. Measurement items with many multiple loadings may be good measurement items forSTCIF, but this blurs the distinction between factors by including these items in the scale [21][22]. The measurement items, having factor loadings greater than 0.3 on other factors, were removed from the measurementframework to improve the distinction between factors [23][24].

In addition, weruled outtwo measurement items, since they got the lowest correlations with a criterion and the lowest factor loadings. These deletions resulted in a 13-item measurement scale to gauge STCIF.

One factor with Eigen value = 8.1 explained as explaining 67% of the variance. Each of the 13measurement items had a factor loading > 0.60. Table 1 indicates the measurement results of the 13

items. As presented in Table 1, each of the 13-measurement items had a corrected item-total correlation > 0.612 and a correlation with the criterion measure of > 0.60. The correlation for each of the 13-measurement items was positive and significant (p□□0.01). This 13-item scale had reliability (Cronbach'salpha) of 0.789 and a criterion-related validity of 0.790. The 13 measurement items present a reliable and valid measurement framework to investigate STCIF.However, we should make an effort to find additional evidencesofthe measurementframework's validity andreliability to develop more scientific and practical measurement items. Many research findings and case studies will be possible to obtain the supplementaryevidences of its validity and reliability. Through considering the measurementresults of many findings and case studies, the developed measurementframework can be became more objective and practical scale in the reasonable application of industry fields.

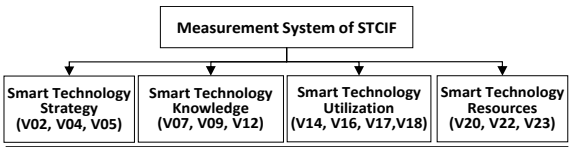
Table 1: Reliability, validity, and factor loading of STCIF construct

Variable	Factor Loading				Corrected Item-Total Correlation	Coefficients Alpha
	Factor 1	Factor 2	Factor 3	Factor 4		
V02	0.783				0.628	
V04	0.809				0.702	0.798
V05	0.804				0.646	
V07		0.763			0.784	
V09		0.736			0.758	0.801
V12		0.799			0.773	
V14			0.811		0.724	
V16			0.802		0.719	
V17			0.721		0.638	0.815
V18			0.639		0.624	
V20				0.759	0.724	
V22				0.798	0.713	0.789
V23				0.618	0.612	

* Significant at P ≤ 0.01

IV. MEASUREMENT SYSTEM

Based on the measurement results, our research extracted the 13measurement items appropriate to gaugeSTCIF. We classified four factor groups based on the factor analysis results for the measurement items. The factor groups signify the potential factors as major components to measureSTCIF. With investigating the measurementitems of each factor group based on previous studies, this study discerned the following four potential factors: factor 1: smart technology strategy; factor 2: smart technology knowledge; factor 3: smart technology utilization; and factor 4: smart technologyresources. The extracted factors comprise the overall measurement content for STCIF from smart technology strategy to smart technologyresources. Smart technology strategy indicates an industry's consistent smart technology policy and plan. It contains consentaneity between smart technology strategy plan and government policy, understanding of smart technology progress trends in future, and implementation program to effectively advance smart technology in industry fields. Smart technology knowledge represents the technical knowledge that an industry has to retain for its activities and performance in a smart technology environment. It consists oftechnology knowledge of smart technology network, solutions, and systems in industry fields, knowledge of artificial intelligence (AI), internet of things (IoT), big data, and cloud systems for industrial activities, and knowledge of smart technology security measures and systems. Smart technology utilization presents an industry's ability to apply smart technology knowledge, smart technology solutions and applications, smart technology systems to industrial activities. It includes utilization of smart B2C, B2B and B2E applications,utilization of smart network, hardware, software, and database, big data and cloud technology, utilization of smart factory, smart construction, smart banking and insurance, smart logistics and service, and utilization of IoT, AI, big data, and cloud systems in industry fields. Smart technology resourcesrefer to smart technology infrastructure for industrial activities. It has infrastructure for smart network, solutions, and systems for industrial activities, building of smart technology education and training program, and possession of intellectual property rights related to smart technologydepartments in industry fields.In general, these findings explain a structural framework that measure STCIF in terms of an entireSTCIF from smart technology strategy to smart technology resources, comprising four measurement factors and 13measurement items.



Smart Technology Strategy
-V02: Consentaneity of smart technology strategy plan and government policy in industry fields?
-V04: Understanding of smart technology progress trends in future?
-V05: Establishment of detailed implementation program for smart technology in industry fields?

Smart Technology Knowledge
-V07: Technology knowledge of smart technology networks, solutions and systems in industry fields?
-V09: Technology knowledge of artificial intelligence(AI), internet of things (IoT), big data and cloud systems for industrial activities?
-V12: Technology knowledge of smart security measures and systems?

Smart Technology Utilization
-V14: Utilization of smart E2C, B2B, and B2E in industrial activities?
-V16: Utilization of smart network, smart hardware, smart software, and smart database in industrial activities?
-V17: Utilization of smart factory, smart marketing and banking, smart construct, smart logistics, and smart services in industry fields?
-V18: Utilization of Internet of Things(IoT), Artificial Intelligence (AI), big data, and cloud systems industrial activities?

Smart Technology Resources
-V20: Infrastructure for smart network, solutions, and systems for industrial activities?
-V22: Building of smart technology education and training programs for smart workers in industry fields?
-V23: Possession of intellectual property rights related to smart technology departments in industry fields?

Fig.1. Framework of the developed measurement system.

The developed system comprises four measurement factors such as smart technology strategy, smart technology knowledge, smart technology utilization, and smart technology resources (Fig.1). Each factor has three or four measurement items. As shown in Table 1 and Fig.1, Smart technology strategy comprises the measurement items, such as V02, V04, and V05. Smart technology knowledge has V07, V09, and V12. Smart technology utilization contains V14, V16, V17, and V18. Smart technology resources include V20, V22, and V23.

These measurement factors affect STCIF that indicates the entireSTCIF of an industry. It is important to manage and improve STCIFbased on measuringof STCIF with using a valid and reliable measurementsystem. We can facilitate efficient advance of a STCIF with reflecting the measurement results for industry fields by this measurement framework. Measuring STCIF is a significant method to understand the real situation for the entire STCIF of an industry, based on its smart technology strategy, knowledge, utilization, and resources. Hence,acquainting the STCIF structure is essential to measure the success of STCIF that denotes the whole STCIF in order to efficiently support its industrial activities. This research can use the structural framework to gaugeSTCIF across different industry fields, and perhaps even as a global measure.

Table 2: Correlation matrix

		(2)	(3)	(4)	(5)
STCIF	(1)	0.41	0.49	0.54	0.39
Smart Technology Strategy	(2)		0.45	0.47	0.43
Smart Technology Knowledge	(3)			0.49	0.42
Smart Technology Utilization	(4)				0.40
Smart Technology Resources	(5)				

Additionally, our research analyzed the correlationbetween the measurement factors, and the correlationbetween each factor and STCIF. Since there are the factors affecting STCIF, understanding their mutual correlation is very critical for the effectiveimprovement ofSTCIF and for the efficient utilization of the developed framework in industry fields. Their mutual correlation is complex and may be affected by other variables. We analyzed how they were correlatedinorder to investigate the correlation between smart technology strategy, knowledge, utilization and resources, and STCIF, as indicated in Table 2.

CONCLUSION

This study provided a comprehensive framework that can measure perceived STCIF from an entiresmart technology perspective. TheSTCIFexplains an industry's total STCIF to effectivelyexecute its industrial activities in a smart technology environment. The measurement framework with 13-item scale is appropriate for research and practical purposes. These results also have some limitations in terms of a specific STCIF. We can solve these problems through performing many comparative and cumulative research findings. The developed measurement system with adequate validity and reliability provides a reasonable method to examine the real situations for STCIF in industry fields.

Therefore, this study presents a structural measurement system that can reasonablygauge the STCIF to effectively carry out industrial activities,and advance their performance and competitiveness in a smart technology environment. Our findings can also support for efficientlyestablishing an industry's smart technology environment appropriatefor its activities and performance advancement. In future research, we will provide the practicality and availability of the developed framework withpresenting the measurement results by applying it to many case studies.

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REFERENCES

[1] Y. F. Chang, C. S. Chen, and H. Zhou, "Smart phone for mobile commerce," Computer Standards & Interfaces, vol. 31, pp. 740-747, 2009.

[2] Y. J. Cho, "The strategy for Smart Factory of Korea in the era of the Industry 4.0,"Communications of the Korean Institute Information Scientists and Engineers, vol. 35, no. 6, pp. 40-48, June 2017.

[3] A. Arvind,"Architecture for Industry 4.0-basedManufacturing Systems", School of Computer ScienceCarnegie Mellon University, July 2016.

[4] H. K. Jang, Change of Paradigm of Firm Business Environment provided by Smart Phone, DigiEco Focus, www.digieco.co.kr, 2010.

[5] E. V. Heck and P. Vervest "Smart business networks: Concepts and empirical evidence," Decision Support Systems, vol. 47, pp. 275-276, 2009.

[6] IBM Research Report, Business Services as a Modeling Approach for Smart Business Networks, www.ibm.com, June 2, 2006.

[7] C. S. Leem, and S. K. Kim, "Introduction to an integrated methodology for development and implementation of enterprise information systems," The Journal of Systems and Software, vol. 60, pp. 249-261,2002.

[8] H. Jiao, C. Chang, and Y. Lu, "The Relationship on Information Technology Capability and Performance: An Empirical Research in the Context of China's YangtzeRiver Delta Region," Proceeding of The IEEE International Conference on Industrial Engineering and Engineering Management, pp. 872-876,2008.

[9] L. M. Hilty, B. Aebischer, and A. Rizzoli, Modeling and evaluating the sustainability of smart solutions, Environmental Modeling & Software, vol. 56, pp. 1-5, 2014.
[10] IT Policy Research Series, Issue and Business Trend Change of Smart Era, www.nia.or.kr, vol, 3, pp. 1-13,2011.
[11] H. J. Lee, "A Study on the Business Strategy of Smart Devices for Multimedia Contents," Journal of Information Processing Systems, vol. 7, pp. 543-548,2011.
[12] M. Gibbert, M. Leibold, and G. Probst, "Five Styles of Customer Knowledge Management, and How Smart Companies Use Them To Create Value," European Management Journal, vol. 20, pp. 459-469, 2002..
[13] B. W. Kim, "The Forth Industrial Revolution: Industrial Internet of Things," Journal of Law & Economic Regulation, Vol. 9, No. 1, pp. 215-232, May 2016.
[14] T. G. Lee, "Smart Manufacturing Execution System and Business Intelligence," Journal of Korea Institute of Information Technology, vol. 9, pp. 35-43,2010.
[15] F. Gabbanini, L. Burzagli, and P. L. Emiliani, "An innovative framework to support multi-model interaction with smart environments," Expert Systems with Applications, vol. 39, pp. 2239-2246, 2012.
[16] D. Zuehlke, "Smart Factory-towards a factory-of-things," Annual Reviews in Control, Elsevier, vol. 34, no. 1, pp.129-138, 2010.
[17] S. H. Lee, H. O. Do, and K. D. Seo, "A Study on Management Plans for Activating of Smart Work," Digital Policy Research, vol. 9, pp. 245-252, 2011.
[18] T. Y. Yoon, "Let's Open a New Era of Domestic Construction Industry through Smartization of Construction Technology," The Magazine of the Korean Society of Civil Ebgineers, vol. 65, no. 7, pp. 6-7, July2017.
[19] C. S. Seo, S. S. Jeong, and S. C. Kim, "Establishment of smart factory to improve enterprise's productivity," The Korean Institute of Communications and Information Sciences, vol. 35, no. 6, pp. 43-49, May2018.
[20] H. M. Choi, "KEPCO's Smart Grid Strategy and Global Energy Crisis," International Management Review, vol. 16, no. 1, pp. 275-293, March 2012.
[21] R. McHancy, R. Hightower, and J. Pearson, "A validation of end-user computing satisfaction instrument in Taiwan," Information &Management, vol. 39, pp. 503-511, 2002.
[22] R. McHancy, R. Hightower, and J. Pearson, "A validation of end-user computing satisfaction instrument in Taiwan," Information &Management, vol. 39, pp. 503-511, 2002.
[23] G. Torkzadeh and J. W. Lee,"Measures of Perceived End-user's Information Skills," Information & Management, vol. 40, pp. 607-615, 2003.
[24] G. Torkzadeh and W. J. Doll, "The Development of a Tool for Measuring the Perceived Impact of Information Technology on Work," Omega, International Journal of Measurement Science, vol. 27, pp. 327-339, 1999.

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