International Refereed Journal of Engineering and Science (IRJES)
ISSN (Online) 2319-183X, (Print) 2319-1821
Volume 8, Issue 4Ser I (April 2019), PP. 23-31

Measurement of Smart Technology Capability for Industry Fields

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ABSTRACT:*In fourth industrial revolution, smart technology has been applied to human life and industry area, such as human living, health, safety, environment, transportation, building, and industry fields. All kinds of industry fields have utilized smart technology to improve their industrial activity and performance in a smart industry environment. It is a core industrial strategy that most industry has built its smart technology environment appropriate for its industrial activity and competitiveness. In this environment, the smart technology capability of industry fields is crucial to efficiently perform industrial activities and effectively advance industrial performance. A reasonable measurement tool is necessary for objectively examining a smart technology ability of industry fields in order to synthetically control and improve its smart technology capability. The developed 15-item framework is confirmed by reliability analysis and factor analysis based on previous studies. This study presents a 15-item measurementmodel that can properly gauge a smart technology capability of industry fields in an entire smart technology perspective. Our findings will contribute to the management and advancement of the smart technology capability of industry fields in a smart industry environment.*

KEYWORDS:*Industry field; Smart technology; Smart technology capability; Measurement model.*

Date of Submission: 10-12-2019 Date of acceptance: 23-12-2019

I. INTRODUCTION

In the 4th industrial revolution, many industries have established smart technology environment to raise their industrial productivity and performance, and to increase their competitiveness in a global industrial environment. They have performed many productive activities and business tasks in industry fields with partially and fully utilizing smart device, network, solutions and systems in a smart technology environment [1]-[4]. It is also applying smart technology to all kinds of industry fields, such as manufacturing, construction, finance, logistics, and services. Smart technology is a core means to preserve and advance an industrial productivity in the ever-changing industrial environment [4]. It is inevitable that each industry has developed its technology strategy that focuses on smart technologies as a resource to facilitate the efficient collection and utilization of them. Smart technology is an important resource for an advanced industrial environment in future. In this environment, industry fieldsare indispensable for generally applying smart technology to all kinds of industrial activities. It is crucial that industry fields systematically build their smart technology environment to upgrade the industrial capability appropriate for each industrial activity and performance. That is, we have to analyze the smart technology capability of industry fields with an objective and practical measurementframework in order to efficiently establish and improve the smart technology capability to properly support the industrial tasks and activities in a smart technology environment. The measurement framework of objective criteria should improve the smart technology capability of industry fields based on the measurement results of smart technology ability for them. However, previous studies have not researched a measurementframework to examine the smart technology capability for industry fields. Namely, we need an objective framework that can efficiently measure a smart technology capability of industry fields in terms of entire smart technology ability.

Therefore, this study presents a structural model that can efficiently measure the smart technology capability ofindustry fields (STCIF) to efficiently perform industrial activities, and generally establish and advancethe smart technology capability in an entire smart technology perspective.

II. RELATED RESEARCH

Smart technology has explained as the core factor to efficiently raise industrial activities and performances, industrial competitiveness, and to prepare for a future industry environment with progress of smart technology [2]. Industry fields have partially or fully built smart technology environment to increase its industrial activities and performance in a global industrial environment [3]. Smart technology for industry fields can be defined as an approach to upgrade the industrial competitiveness by increasing industrial activities and outcomes through utilizing smart technologies, such as smart devices, networks, solutions, and systems[1]-[4].

Smart technology of an industry can be considered as an industrial process that uses the smart technology medium as a conduit to execute industrial tasks and activities in a smart industry environment.

Hence, this research can define the industrial smart technology as a technological approach to efficiently perform the industry fields by applying the smart technology and solutions, and systems to all kinds of industry fields in a smart technology environment. In previous literature, many studies defined the concepts of information technology capability from the viewpoints of the study researchers [5]-[11]. . Several research agencies present their research reports in a specific information technology and solution departments [9]-[11]. However, smart technology capability has not researched in previous studies. In previous literature, 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 technology departments. This research can present an information technology capability as the ability to integrate other resources of an organization through the disposition and utilization of one's own information technology resources. Information technology capability is formed by information technology system convention, information technology infrastructure, and information technology human resources and information technology relationship assets based on these resource-based perspectives [12]. We explain that a kind of information technological ability is to support for organizational activities and workflows by the disposition of information technology resources and integration of other relevant resources. Information technology capability is conceptualized as the extent to which an organization is knowledgeable about and effectively utilizes information technology to manage information technology data within the organization [13]. The components of information technology capability represent three co-specialized resources: information technology objects; information technology knowledge; and information technology operations. Information technology objects represent computer-based hardware, software, and support personnel. Information technology knowledge is summarized as the extent to which an organization possesses a body of technical knowledge about objects such as computer based systems. Information technology operations are identified as the extent that an organization utilizes smart technology to manage market and customer information. From an information technology system perspective, the measurement of the information technology system level indicates the total capability that includes information technology vision, information technology infrastructure, information technology support, and information technology application and usage [14]. The information technology vision represents an information technology strategy plan and information technology project plan of an organization. The information technology infrastructure includes hardware, networks, system software, and supporting tools. Information technology support refers to information technology organization, information technology direction and institution, and supporting methods for information technology facilities. Finally, the information technology application and usage explain the application and utilization that exploit solutions and information technology for an organization's activities. In this research, we can convert an information technology capability to a smart technology capability in a smart technology perspective.

Hence, with examining previous literature and our research results, this study defines the smart technology capability of industry fields (STCIF) as the total smart technology capability that industry fields have to possess for efficiently supporting its industrial activities and performances in a smart technology environment. Our research develops the first measurement items for STCIF based on the definition of STCIF and previous studies related to the smart technology for industry fields.

III. METHODS

1.1 Research method

This research firstly developed a list of 28measurement items for STCIF based on definitions and components of information technology capability and smart technology [1]-[21]. We analyzed the construct validity of the developed measurement items to ensure that the developed items properly analyze STCIF. This research proved it by providing that the measurement framework was a suitable operational definition of the construct it purported to analyze. Many literatures presented various methods to verify the validation of a model construct [22]-[26]. Generally, most studies present two methods of construct validation: correlations between total scores and item scores, and factor analysis. 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 [22]-[24]. Each item score was subtracted from the total score to exclude spurious part-whole correlation: the result was a corrected item- total correlation that was then correlated with the item score. The latter, factor analysis, analyzes the underlying structure or components of the framework [25][26]. It helped identify factorally pure items that would facilitate more specific hypothesis tests, and to identify the components that make up the total measure [25]. We selected the factor-analyzed items, since they were closely related to each other. This research also investigated anmeasurement scale of criterion-related validity to identify measurement items that may not be closely concerned with STCIF. This research uses the generalized item for efficiently gauging STCIF as a criterion measurement scale. The developed scale provided a measurementframework of criterion-related validity to the extent that each measurement item was correlated with this. Measurement items should indicate a favorable or unfavorable attitude toward the object in question. When the measurement item is ambiguous or appears to indicate a neutral attitude, it should be deleted [26]. Hence, we examined ameasurement scale of criterion-related validity to identify measurement items that did not show favorable or unfavorable attitudes. Our research selected all of the measurement items in anmeasurement scale 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 measurement framework 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. We performed our measurement questionnaire for five industry fields like manufacturing, finance, construction, logistics, and service. The questionnaire includes three main sections. The first section explains the backgrounds and objectives, the main contents, and response methods of this questionnaire. The second section requires respondents to provide general information, such as industry fields and position, firm's size and revenue, and business history of their enterprises. The last section provides the measurement items for the respondents in industrial fields. This research collected questionnaire data from a variety of industries in order to generalize the measurement results. We 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 32.3percent of all target respondents.

1.2Sample characteristics

In this questionnaire survey, this research collected 129 responses form 400 target respondents in five industry fields. They represented a variety of industry fields and position, firm size and revenue, and business history. We excluded three incomplete or ambiguous questionnaires, leaving 126 usable questionnaires for statistical analysis. The respondent distribution in each industry field is as follows: manufacturing (28.5%), construction (13.5%), finance (16.7%), logistics (27.0%), and service (14.3%). The respondents identified themselves as senior manager (4.8%), middle manager (33.3%), and worker (61.9%). The respondents in five industry fields had on average 7.6 years' experience (S.D. =1.13) in their industry fields, their average age was 36.9 years old (S.D.=5.75), and their gender, male (69.8%) and female (30.2%). We carried out our survey focused on various industries, and managers and workers with ample experience within an industry fields. Table 1 shows the distribution of respondents in terms of degree, industry, business department, and business position in our questionnaire survey.

Table 1 Distribution of respondents

Division	Total	Percentage
Degree		
Humanities & Social Sciences	21	16.7
Management & Economics	28	22.2
Engineering	55	43.6
Science	22	17.5
Total	126	100
Industry		
Manufacturing	36	28.5
Construction	17	13.5
Finance	21	16.7
Logistics	34	27.0
Services	18	14.3
Total	126	100
Business Department		
Strategic Planning	24	19.0
Development & Maintenance	27	21.4
Business Application	47	37.3
Administrative Support	28	22.3
Total	126	100
Business Position		
Senior Manager	6	4.8
Middle Manager	42	33.3
Worker	78	61.9
Total	126	100

Our research used a diverse sample that thoroughly understands their STCIF, with practical affairs working at their industry fields for more than about 3 years in order to increase the generalization of our research results. That is, the respondents could properly present the reasonable responses for our questionnaire survey.

1.3Analysis and discussion

This research extracted the analysis results from the collected questionnaires. The 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 [22]-[24]. The correlations with the corrected item-total correlation and the criterion item were significant at $p \leq 0.01$ and similar to those used by others in previous research [25][26]. We used factor analysis to verify the validity of the developed measurement tool and items. Our research also used this analysis to distinguish the underlying factors or components that include the STCIF construct

This study deleted inadequate items for the measurement framework based on the analysis results. We considered sufficiently high criteria to select reasonable measurement items of STCIF. Hence, the first 28 measurement items resulted in an17-item scale prior to conducting factor analysis. The sample of 126 responses was investigated 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 of STCIF, but this blurs the distinction between factors by including these items in the scale [25]. The measurement items, having factor loadings greater than 0.3 on other factors, were deleted from the measurement instrument to improve the distinction between factors [26].

Table 2Factor loading, reliability, and validity of STCIF construct

Item description		Corrected item-total correlation	Correlation with Criterion	Factor loading
V01	Utilization of artificial intelligence (AI), internet of things (IoT), big data, and cloud systems in industry fields?	0.91	0.78*	0.90
V02	Knowledge of smart technology network, solutions, and systems for industry fields?	0.87	0.81*	0.84
V03	Utilization of smart network, smart hardware, smart software, and smart database for industry fields?	0.84	0.80*	0.85
V04	Consentaneity of smart technology strategy plan and government policy for industry fields?	0.82	0.74*	0.83
V05	Utilization of smart B2C, B2B, and B2E for industrial activities?	0.80	0.78*	0.80
V06	Knowledge of AI, IoT, Big data, and cloud systems for industry fields?	0.79	0.72*	0.77
V07	Knowledge related to smart hardware, software, network, and databases?	0.77	0.79*	0.81
V08	Infrastructure for smart network, solutions, and systems for industrial activities?	0.74	0.81*	0.73
V09	Consentaneity of smart technology strategy and industrial strategy?	0.72	0.71*	0.80
V10	Knowledge related to smart security solutions and systems for industry fields?	0.68	0.74*	0.74
V11	Establishment of detailed implementation program to effectively advance smart technology for industry fields?	0.67	0.69*	0.69
V12	Possession of smart technology education and training program for industry fields?	0.65	0.68*	0.79
V13	Possession of intellectual property rights related to smart technology for industry fields?	0.63	0.72*	0.69
V14	Utilization of smart security measures and systems for industry fields?	0.61	0.74*	0.64
V15	Possession of smart security measures and systems for industry fields?	0.60	0.62*	0.61

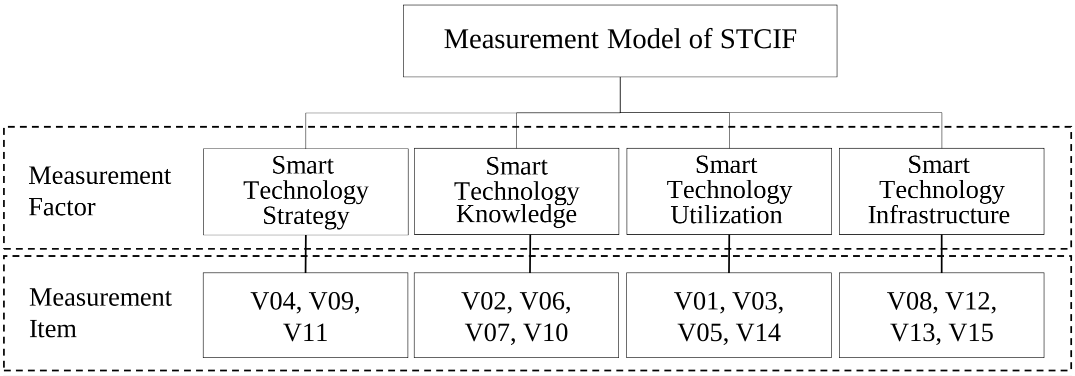
From this analysis process, this research deleted two items, since they had the lowest correlations with a criterion and the lowest factor loadings. These eliminations resulted in a 15-item scale to measure STCIF. One factor with Eigen value = 8.2 explained as explaining 68% of the variance. Each of the 15 measurement items had a factor loading > 0.60. Table 2 indicates the analysis results of the 15 items. As shown in Table 2, each of the 15 measurement items had a corrected item-total correlation > 0.60 and a correlation with the criterion measure of > 0.60. The correlation for each of the 15 measurement items was positive and significant ($p \leq 0.01$). This 15-item framework had reliability (Cronbach's alpha) of 0.86 and a criterion-related validity of 0.81. Table 3 shows the correlation matrix, means, and standard deviations for the 15-item scale. These correlations are significant ($p \leq 0.01$). In general, the 15 measurement items present a reliable and valid measurement framework to examine STCIF.However, we should endeavor to find additional proofs of the validity and reliability of the measurementframework to advance an objective and practical measurement items. Through many research findings and case studies, we will possible to obtain the additional evidences of its validity and reliability. With reflecting the analysis results of many findings and case studies, the developed measurementmodel can be became more objective and practical scale in its application to industry fields.

Table 3Correlation matrix of STCIF measurement items

V02	0.53														
V03	0.51	0.49													
V04	0.30	0.36	0.25												
V05	0.31	0.33	0.29	0.51											
V06	0.30	0.32	0.31	0.47	0.50										
V07	0.29	0.31	0.24	0.51	0.52	0.54									
V08	0.31	0.33	0.31	0.28	0.23	0.32	0.31								
V09	0.33	0.32	0.35	0.31	0.28	0.33	0.30	0.44							
V10	0.29	0.30	0.31	0.33	0.31	0.35	0.25	0.51	0.52						
V11	0.29	0.27	0.30	0.28	0.31	0.30	0.24	0.49	0.53	0.50					
V12	0.29	0.28	0.31	0.35	0.31	0.30	0.33	0.36	0.31	0.28	0.29				
V13	0.31	0.35	0.28	0.31	0.30	0.33	0.36	0.35	0.33	0.29	0.30	0.49			
V14	0.29	0.33	0.31	0.32	0.28	0.30	0.27	0.34	0.26	0.30	0.29	0.50	0.55		
V15	0.31	0.29	0.28	0.35	0.30	0.32	0.34	0.27	0.32	0.30	0.28	0.52	0.50	0.51	
	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15
Mean	3.12	2.96	2.50	3.34	3.32	2.88	2.79	3.12	2.95	3.05	2.68	2.65	3.04	2.87	3.06
S.D.	1.50	1.41	1.28	1.34	1.37	1.36	1.38	1.25	1.38	1.39	1.34	1.29	1.33	1.36	1.34

IV. MEASUREMENT MODEL

Our research developed the 15measurement items appropriate for gauging STCIF. We identified four factor groups from our factor analysis results on the 15-measurement items. The factor groups present the potential factors as the core components to gauge STCIF. Through investigating the measurement items of each factor group based on previous studies, our research identified the following four factors: factor 1: smart technology strategy; factor 2: smart technology knowledge; factor 3: smart technology utilization; and factor 4: smart technology infrastructure. The identified factors include the overall measurement content for STCIF from smart technology strategy to smart technology infrastructure. Smart technology strategy represents the consistent smart technology policy and plan of industry fields. It includes smart technology strategy, such as consentaneity of smart technology strategy plan and government policy, consentaneity of smart technology strategy and industrial strategy, and establishment of detailed implementation program to effectively advance smart technology for industry fields. Smart technology knowledge indicates the technical knowledge that industry fields have to preserve for their activities and performances in a smart technology environment. It contains knowledge of smart technology network, solutions, and systems for industry fields, knowledge of AI, IoT, Big data and cloud systems, knowledge related to smart hardware, software, network, and database, and smart security solutions and systems for industry fields. Smart technology utilization presents the ability of industry fields to apply smart technology knowledge, smart technology solutions and applications, smart systems to industrial fields. It has utilization of AI, IoT, Big data, and cloud systems, utilization of smart network, hardware, software, and database, utilization of B2C, B2B, and B2E, and smart security measures and systems for industry fields. Smart technology infrastructure refers to smart technology resources to utilize for industry fields. It comprises infrastructure of smart network, solutions, and systems, possession of smart technology education and training program, intellectual property right related to smart technology, and smart security measures and systems for industry fields. Generally, they present a structural framework that can measure STCIF in terms of an entire STCIF from smart technology strategy to smart technology infrastructure, including 4 measurement factors and 15measurement items.



Smart Technology Strategy (STS)

-V04: Consentaneity of smart technology strategy plan and government policy for industry fields?
-V09: Consentaneity of smart technology strategy and industrial strategy?
-V11: Establishment of detailed implementation program to effectively advance smart technology for industry fields?

Smart Technology Knowledge (STK)

-V02: Knowledge of smart technology network, solutions, and systems for industry fields?
-V06: Knowledge of smart solutions related to AI, IoT, Big data, and cloud systems for industry fields?
-V07: Knowledge related to smart hardware, software, network, and database for industrial activities?
-V10: Knowledge related to smart security solutions and systems for industry fields?

Smart Technology Utilization (SKU)

-V01: Utilization of artificial intelligence (AI), internet of things (IoT), big data, and cloud systems for industry fields?
-V03: Utilization of smart network, smart hardware, smart software, and smart database for industry fields?
-V05: Utilization of smart B2C, B2B, and B2E for industrial activities?
-V14: Utilization of smart security measures and systems for industry fields?

Smart Technology Infrastructure (STI)

-V08: Infrastructure for smart network, solutions, and systems for industrial activities?
-V12: Possession of smart technology education and training program for industry fields?
-V13: Possession of intellectual property rights related to smart technology for industry fields?
-V15: Possession of smart security measures and systems for industry fields?

Fig. 1.Framework of the developed measurement Model

Hence, the developed modelconsists of four measurement factors such as smart technology strategy, smart technology knowledge, smart technology utilization, and smart technology infrastructure (Fig. 1). Each factor consists of three or four measurement items. As shown in Table 2 and Fig. 1, Smart technology strategy includes the measurement items, such as V04, V09, and V11. Smart technology knowledge has the measurement items, such as V02, V06, V07, and V10. Smart technology utilization contains the measurement items, such as V01, V03, V05, and V14. Smart technology infrastructure comprises the measurement items, such as V08, V12, V13, and V15.These measurement factors affect STCIF that presents the smart technology capability of industry fields. It is very importantto control and advance STCIF by gauging STCIF through utilizing a valid and reliable measurement framework. Our research can facilitate efficient advance of the smart technology capability of industry fields with reflecting the measurement results for industry fields by this measurementmodel. Gauging STCIF is a crucial method to grasp the real situation for the smart technology ability of industry fields, based on the smart technology strategy, knowledge, utilization, and infrastructure. Therefore, grasping the STCIF structure is essential to measure the success of STCIF that denotes the entire smart technology ability in order to efficiently support industry fields. We can use the structural model to measure STCIF in industry fields, and perhaps even as a global measure.

In addition, this research analyzed the correlation between the measurement factors, and the correlation between each factor and STCIF. Since there are the factors affecting STCIF, examining their correlations is essential for reasonably improving STCIF and effectively utilizing the developed measurement model for industrial fields. Their correlation is complex and may be affected by other variables.

Table 4Correlation matrix between measurement factors and STCIF

Division		(2)	(3)	(4)	(5)
STCIF	(1)	0.41	0.48	0.50	0.39
Smart Technology Strategy	(2)		0.42	0.45	0.43
Smart Technology Knowledge	(3)			0.49	0.44
Smart Technology Utilization	(4)				0.42
Smart Technology Infrastructure	(5)				

Our research analyzed how they were correlated in order to analyze the correlation between smart technology strategy, smart technology knowledge, smart technology utilization and smart technology infrastructure, and STCIF, as shown in Table 4.As shown in Table 4, the measurement factor of smart technology utilization has the most influence for STCIF. It means that we have to firstly consider the smart technology utilization for efficiently improving STCIF. In correlation between the measurement factors, the correlation of smart technology knowledge and utilization has higher than the others. This explains high interrelationship between the smart technology utilization and knowledge.

V. CONCLUSION

In the 4^{th} industrial revolution, smart technology is a core issue in human life and industrial area. Smart technology has been utilized all kinds of industry fields, such as manufacturing, construction, finance, logistics, and service, etc. The smart technology ability of industry fields is crucial to effectively support its industrial activities and reasonably raise the competitiveness in a global industry environment. This research presented a comprehensive model that can measure perceived STCIF in a smart technology perspective. STCIFmeans the smart technology capability of industry fields to efficiently perform its industrial activities and improve performances in a smart technology environment. The developed measurementmodel with adequate validity and reliability provides a reasonable method for grasping the real situations for STCIF in industrial fields.

Therefore, this study presents a structural model that can efficiently measure the STCIF to perform the industrial tasks and activities, and improve their performance in industry fields. This research can also support for effectively establishingthe smart technology environment appropriate for its efficient industrial activities and competitiveness reinforcement in industry fields. Our findings provide a new direction and foundation for the development of the efficient measurementmodel for STCIF that has never researched in previous literature.

In future research, we will present the utilization of this measurementmodelthrough providing the measurement results by applying it to many case studies in industry fields.

ACKNOWLEDGMENT

This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology (NO: 2017R1D1A1B03036086).

APPENDIX A: MEASUREMENT ITEMS OF SMART TECHNOLOGY CAPABILITYFOR INDUSTRY FIELDS

1. Preparation and consistency of a smart technology strategy and vision?
2. Consentaneity of smart technology strategy plan and government policyfor industry fields?
3. Consentaneity of smart technology strategy and industrial strategy?
4. Understanding of smart technology progress trends in future?
5. Establishment of smart technology strategy and plan to improve smart technology environment for industry fields?

6. Establishment of detailed implementation program to effectively advance smart technology for industry fields?
7. Knowledge of smart technology network, solutions, and systems for industry fields?
8. Knowledge related to smart ERP, SCM, CRM, and KMS etc.?
9. Knowledge of artificial intelligence (AI), internet of things (IoT), big data, and cloud systems for industrial activities?
10. Knowledge related to smart hardware, software, network, and databases?
11. Knowledge for the development and implementation of smart systems and smart resources?
12. Knowledge related to smart security measures and systems for industry fields?
13. Knowledge of institution and regulation for smart operation systems?
14. Utilization of smart B2C, B2B, and B2E for industrial activities?
15. Utilization of smart solutions such as smart ERP, SCM, CRM, and KMS etc.?
16. Utilization of smart network, smart hardware, smart software, and smart database for industry fields?
17. Utilization of smart manufacturing, smart finance, smart construction, smart logistics, and smart service in industry fields?
18. Utilization of artificial intelligence (AI), internet of things (IoT), big data, and cloud systems for industry fields?
19. Utilization of smart security measures and systems for industry fields?
20. Infrastructure for smart network, solutions, and systems for industrial activities?
21. Implementation of smart database management system and data warehouse?
22. Possession of smart technology education and training program for smart workers for industry fields?
23. Possession of intellectual property rights related to smart technology departments for industry fields
24. Possession of smart systems appropriate to management activities?
25. Possession of smart security measures and systems for industry fields?
26. Possession of human resources appropriate for smart industry environment?
27. Possession of smart B2C, B2B, and B2E applications?
28. Possession of institution and regulation for smart operation systems?

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Chui Young Yoon, "Measurement of Smart Technology Capability for Industry Fields" International Refereed Journal of Engineering and Science (IRJES), vol. 08, no. 04, 2019, pp 23-31