

An assessment framework for smart manufacturing

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Abstract — This paper proposes an assessment framework for smart manufacturing in terms of the extent of Information & Communication Technologies (ICT) adoption to manufacturing process. For an assessment framework, this paper establishes assessment principles and identifies activities of manufacturing process to be assessed. In addition, maturity levels of smart manufacturing are defined in this paper. Each level has different characteristics and different extent of ICT adoption in manufacturing process.

Based on an assessment reference model, this paper gives a way of creating assessment indicators for each activities per each maturity levels. With answers to questionnaires/indicators, smart manufacturing can be assessed and expressed as a maturity level.

Keywords — Assessment, smart manufacturing, smart factory, digital manufacturing, automation enterprise, automation system

I. INTRODUCTION

Smart manufacturing is a broad category of manufacturing with the goal of optimizing concept generation, production, and product transaction. While manufacturing can be defined as the multi-phase process of creating a product out of raw materials, smart manufacturing is a subset that employs computer control and high levels of adaptability. Smart manufacturing aims to take advantage of advanced information and manufacturing technologies to enable flexibility in physical processes to address a dynamic and global market. There is increased workforce training for such flexibility and use of the technology rather than specific tasks as is customary in traditional manufacturing [1].

From technical point of view, smart manufacturing is understood to apply advanced information and communication technology (ICT) to traditional industrial production to promote development of industry towards high value-added direction through wide application of ICT and reformation of traditional industry.

With the rapid development and the wide range of use of ICT, the application of ICT to traditional manufacturing has promoted the development of advanced ways of production and promoted resource allocation that is more comprehensive and dynamic as well as optimal. Therefore, it is important for industry enterprises to assess the extent of their application of ICT to manufacturing, to improve manufacturing capability.

This paper proposes a framework to assess a level of maturity how traditional manufacturing adopts ICT and improvement of manufacturing capability is achieved.

For this objective, this paper defines assessment principles and identifies activities of manufacturing process to be assessed. In addition, maturity levels of smart manufacturing are defined in this paper. Based on assessment reference model and activities to be assessed, this paper gives a way of creating assessment indicator as a form of questionnaires for each activities per each maturity levels, and the way of decision on maturity level of smart manufacturing.

II. FUNCTIONAL HIERARCHY OF MANUFACTURING FOR ASSESSMENT

Figure 1 depicts the different levels of a functional hierarchy model of manufacturing function [2].

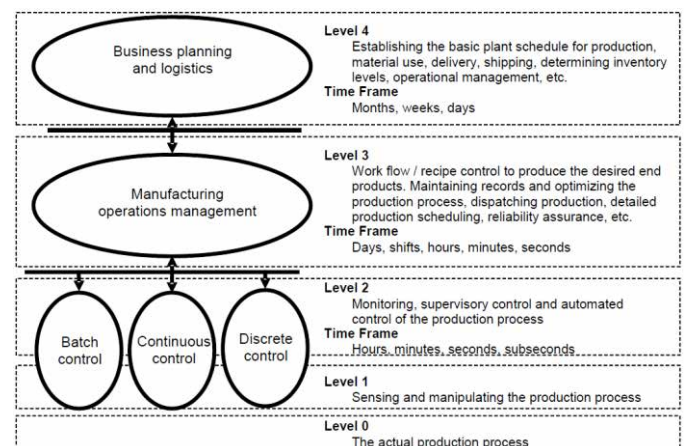


Figure 1. Functional hierarchy (IEC 62264-1)

[2] explains the level of functional hierarchy and its characteristics as follows in Table 1:

Table 1. Characteristics of functional hierarchy

Level of Functional Hierarchy	Characteristics
Level 0	defines the actual physical processes.
Level 1	defines the activities involved in sensing and manipulating the physical

	processes. Level 1 typically operates on time frames of seconds and faster.
Level 2	defines the activities of monitoring and controlling the physical processes. Level 2 typically operates on time frames of hours, minutes, seconds and sub-seconds.
Level 3	defines the activities of the work flow to produce the desired products. It includes the activities of maintaining records and coordinating the processes. Level 3 typically operates on time frames of days, shifts, hours, minutes and seconds.
Level 4	defines the business-related activities needed to manage a manufacturing organization. Manufacturing-related activities include establishing the basic plant schedule (such as material use, delivery and shipping), determining inventory levels and making sure that materials are delivered on time to the right place for production. Level 3 information is critical to Level 4 activities. Level 4 typically operates on time frames of months, weeks and days.

Assessment framework proposed in this paper focuses on the functions in Level 3 and Level 4.

III. ASSESSMENT REFERENCE MODEL

A. Assessment Principles and Activities of Manufacturing Process

Regarding Level 3 and Level 4 explained in Figure 1 and Table 1, this paper defines assessment principles to classify activities of manufacturing process.

1) Level of department of the enterprise: Application of ICT in a single business link at the level of department of the enterprises.

Level of department of the enterprise includes product design, process design, process control, material management, quality management, sales management, financial management, security management, maintenance management, human resource management, document management, and environment, safety and health (EHS).

2) Vertical and Horizontal integration of the manufacturing functions: Business merging, integration and collaboration of the internal department and the cross-enterprises.

Vertical integration of the manufacturing functions includes integration of production management and process control, integration of production and supply and sales.

B. Definition of Maturity Level

Based on the assessment principles considering Level 3 and Level 4 of manufacturing functional hierarchy, Table 2

defines the maturity levels of smart manufacturing and its characteristics.

Table 2. Maturity levels of smart manufacturing

Maturity level	Name	Characteristics
0	No assessment	– Non ICT-applied to manufacturing functions
1	Identified	– Item-level identification of materials (raw materials, work-in-process (WIP), module, final product, etc.) – Tracking and tracing of materials
2	Measured	– Real-time data acquisition of materials, machinery, process and human, and data integration
3	Analysed	– Data analysis and optimized decision making
4	Optimized	– Real-time optimized decision making and control for principal processes
5	Customized	– Flexible process control by configuration – Customization by entire processes optimization

IV. ESTABLISHMENT OF ASSESSMENT INDICATORS AND DECISION OF MATURITY LEVEL

A. Assessment Indicators

To assess manufacturing functions from the extent of ICT adoption point of view, this paper proposes to define assessment indicators as a questionnaire form for each activity defined in clause III. These questionnaires shall be answered as Yes or No.

However, this paper does not define the detailed questions as assessment indicators but shows a way of establishing assessment framework with questionnaires for the maturity levels as assessment indicators.

Table 3 shows an assessment indicator form.

Table 3. Assessment indicator form for each maturity level and activities

Maturity Level	Activities of Manufacturing Process	Indicators
Level 0	– product design – process design	N/A
Level 1	– process control – material management	Questionnaires for Level 1 – Level 5 of each activities considering the characteristics of maturity level given in
Level 2	– quality management – sales management	
Level 3	– financial management – security management	

Level 4	– maintenance management – human resource management	Table 2.
Level 5	– document management – environment, safety and health (EHS)	

B. Decision of Maturity Level

Figure 2 shows an example of the decision level of maturity level. Decision of maturity level of smart manufacturing is dependent on the answers to the assessment indicators given in Table 3.

Condition of going to the next level is dependent to the status (the number of Yes or No) of the answer and the condition can be configured by the way of creating assessment indicators.

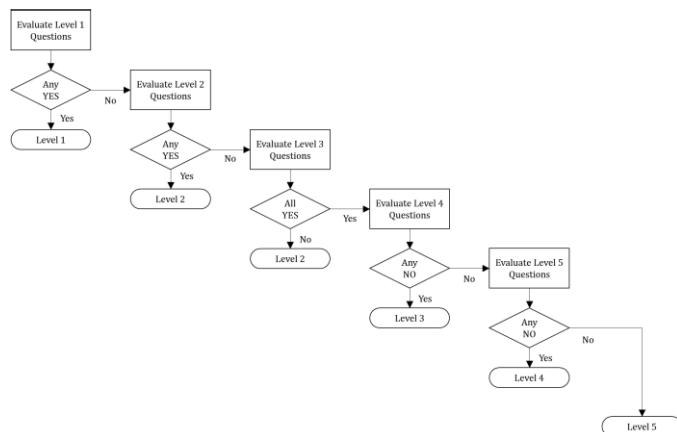


Figure 2. An Example of Method for Decision of Maturity level

C. Assessment Analysis

There might be multiple methods to assess the maturity of smart manufacturing of an industry. For example, in an assessment of production, a table which can brief the maturity level per each principle or activities of manufacturing process given in clause III for could be constructed. As another example, the use of spider chart is a good tool of analysis to show the relative maturity and visual representation.

V. CONCLUSIONS AND FUTURE WORKS

This paper gives an assessment framework of smart manufacturing including maturity levels and its characteristics, and assessment indicators for the decision of maturity level.

With this assessment, an industry enterprise can analyse the current level of maturity of smart manufacturing and can arrange the plan to enhance the level of maturity. For future work, the questionnaire as assessment indicators shown in Table 3 shall be defined in detail.

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Sangkeun Yoo received the M.S degrees from Chungnam National University, Korea in 1999. He developed micro payment systems in start-up from 1999 to 2000. Since 2001, he has worked for ETRI in areas of information security, RFID, sensor networks and IoT, recently smart factory. He has been a Convenor of ISO/IEC JTC 1/WG 10 (Working Group on Internet of Things) since 2014. His current research interests include IoT, smart factory and digital manufacturing.



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