SMKL (Smart Manufacturing Kaizen Level) for Smart Manufacturing Transformation

Nicole Shonan Otoki
Mitsubishi Electric Corporation

Yasuo Onodera
Mitsubishi Electric Corporation

Mitsushiro Fujishima
Mitsubishi Electric Corporation

1. Introduction

The trend toward digital transformation has been gaining momentum in recent years, and smart factories implemented by the Industrial Internet of Things (IIoT) are attracting attention for their importance to digital transformation in the manufacturing industry.

Using various kinds of information in digital form enables smart factories to make the interconnections among manufacturing processes smarter and optimize the value chain. Although many companies are aware of the enormous value that smart factories can create, surprisingly few are making steady progress toward smarter factories.

However, there are many challenges in the path toward smart factories, including advanced automation, software-based management, and the establishment of platform-based ecosystems. It is thus necessary to deploy IIoT technologies to appropriate places in manufacturing and coordinate them to ensure a reasonable return on investment (ROI) while achieving continuous improvement.

Given that situation, companies are seeking methods for evaluating current ongoing IIoT initiatives and methods for continuous optimization based on Plan Do Check Action (PDCA) and return on investment (ROI). We also believe that it is essential for companies to understand the maturity level of IIoT.

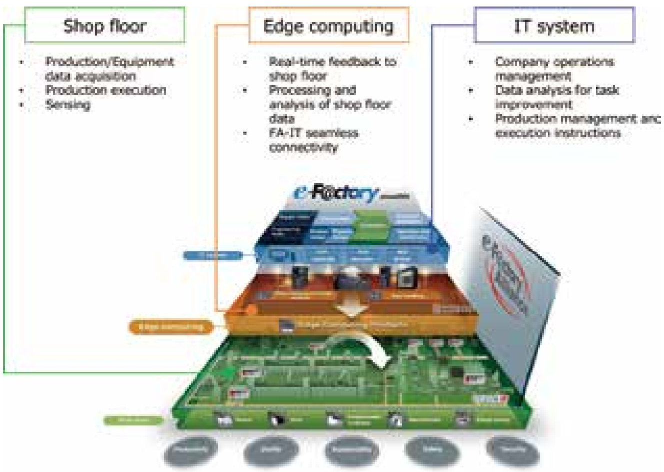
To address those issues, we position maturity assessment as an important approach for companies in the promotion of IIoT and define a path to establishing smart factories using maturity assessment.

2. Maximal use of digitalization in smart factories

IIoT will have application in all aspects of the manufacturing world opened up by digital technology. The move towards smart factories has begun; big data collected from shop floors is being used to improve the productivity and quality of facilities and work, and digital technology is being used to link supply and engineering chains.

To cope with such changes, the e-F@ctory (Figure 1) provides an integrated factory automation (FA) solution that supports total cost reduction across the supply chain and engineering chain and improving its corporate value by handling flexible manufacturing through coordination of workers, machines, and IT toward the objectives of implementing and optimizing smart factories, beginning with the shop floor. The e-F@ctory provides a product lineup for linking the shop floor and the IT system to enable seamless networking from the FA side to the IT side and promote optimization based on the level of maturity of the shop floor and analysis of big data.

Figure 1: The e-F@ctory Integrated FA solution



3. Smart factory that enables continuous optimization

The smart factories based on the e-F@ctory solution that we have seen so far are multidimensional, comprising a combination of many IIoT technologies. For example, bringing together multiple innovative technologies, such as big data analysis, artificial intelligence, and robotics, provides the perfect means of optimizing the value chain.

While a smart factory is a very complex endeavor, it is a prime motivator of business success by creating new value. Here, companies need to answer "what," "when," "how cost effectively," and "to what level" questions as they move forward in their smart factory journey. Companies also need to visualize the maturity level of IIoT adoption and use that as a basis for determining ROI.

SMKL (Smart Manufacturing Kaizen Level) evaluates the level of maturity of IIoT using Key Performance Indicators (KPI) specified by the ISO 22400 international standard and identifies problems and plans for optimization for individual companies. It also indicates the ROI of improvement proposals and goes into means of promoting step-by-step progress toward smart factories to achieve continuous optimization.

3.1 Definition of SMKL

SMKL (Smart Manufacturing Kaizen Level) is a simple assessment of IIoT maturity based on a matrix of five levels of maturity and four levels of management (Figure 2). The maturity levels are data collection, visualization, analysis, optimization, and prediction (Table 1). The management levels for discrete manufacturing are defined as installation and workers, workshop, factory, and supply chain (Figure 3).

Figure 2: Definition of SMKL

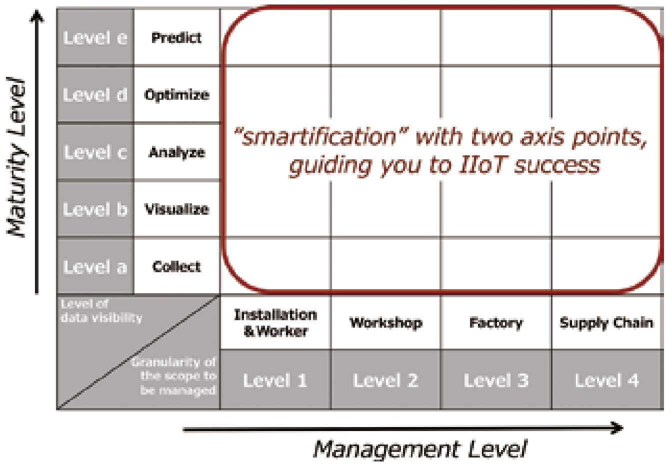
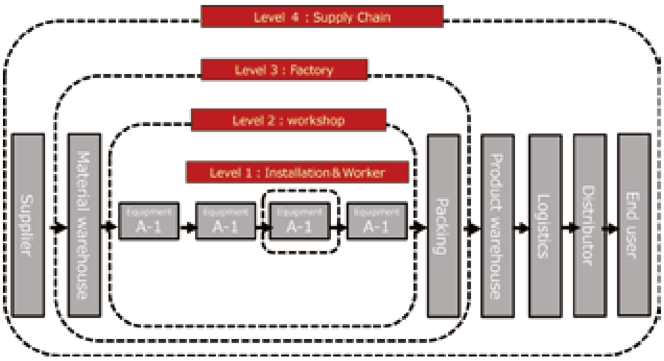


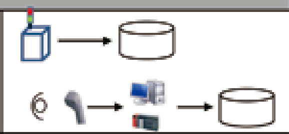
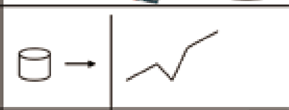
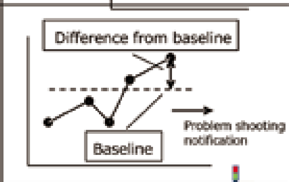
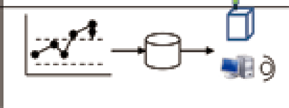
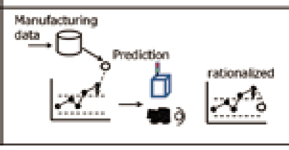
Figure 3: Management levels



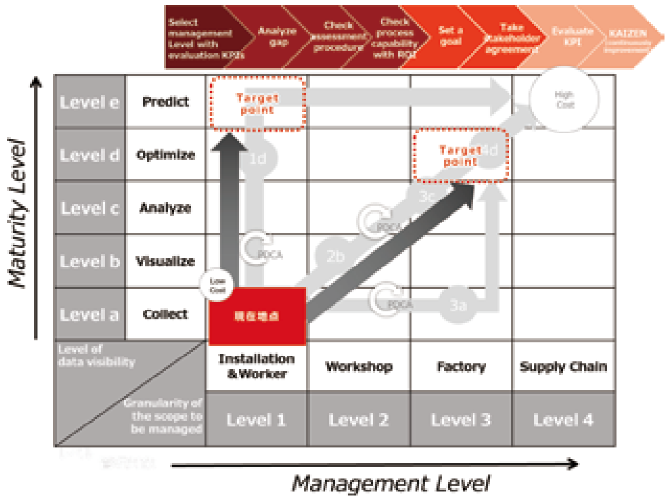
3.2 Application of SMKL

The steps of using SMKL are illustrated in Figure 4. In the first step, the KPIs are selected according to the management targets which are set by the SMKL users (managers, production managers, workers, etc.). Then, the KPIs are used to determine the current SMKL ("current point" in Figure 4) and the differences between the current values and the target values in the SMKL matrix are denoted. Possible implementation procedures for achieving the targets are also confirmed. Next, ROI is used to determine the feasibility of each implementation, and appropriate targets and implementation procedures are set (Figure 4). Afterwards, the details of the implementation procedures are checked by the stakeholders (such as factory

Table 1: Maturity levels

Maturity Level	Description		Example
Level a Collect	Manufacturing data, installation or work status are collected and stored in an electrical way automatically or manually with simple input action.		･Database ･CSV file
Level b Visualize	Charts or tables are automatically generated based on collected and/or stored manufacturing data along with management objective.		･List description ･Graph description (histogram, trend etc.)
Level c Analyze	Charts and tables describing the comparison of a target performance with as-is status with variance are automatically generated according to the maturity level. For example, manually analytics at worker can be exempted.	 	･Manufacturing operation management ･Trouble handling
Level d Optimize	KAIZEN instrument is automatically feedback to management objectives to solve the performance difference that specified in maturity level.		･AI powered KAIZEN
Level e Predict	Manufacturing data is automatically categorized with analytics that make predictions about future outcomes. Based on the prediction, management objective can be integrated and rationalized overall.	 	･Equipment predictive maintenance ･Manufacturing operation simulation based on equipment allocation ratio

■ Figure 4: SMKL application



managers, production managers, etc.) and a consensus decision is reached. In the final step, the SMKL target levels ("target points" in Figure 4) are achieved by continuous optimization based on SMKL assessment.

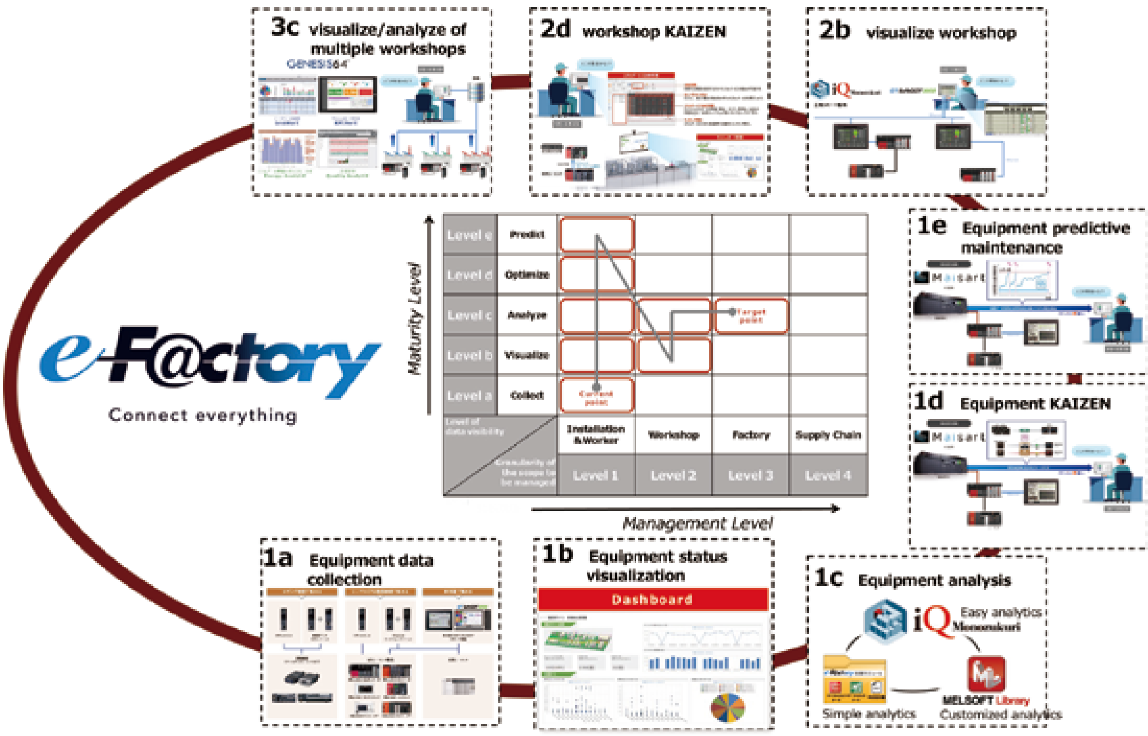
SMKL can be used to promote adoption of IIoT by individual companies and assess the direction of adoption to enable continuous investment decisions. Doing so will enable implementation of the right IIoT products at the right time, promising faster and more effective optimization compared to conventional approaches.

4. Case study

The effort towards carbon neutrality in manufacturing has become increasingly important in recent years. The 2021 White Paper on Manufacturing raises an urgent need for a transition to green manufacturing by introducing digital technology. As a means of promoting energy conservation by improvements in operations, achieving energy efficiency and efficiency in the optimization cycle through energy management and use of IIoT, and integrated control technologies for production management and energy management have been attracting attention. However, a problem for the executives of many manufacturing companies is the difficulty in making investment decisions for lack of knowledge of their current level of energy management and what solutions are appropriate for improvement. Here, we provide an example of applying e-F@ctory for energy management and describe how optimization using SMKL achieves energy conservation.

As a means of promoting energy conservation by operational optimization using IIoT, we are taking a step forward in the evolution from conventional optimization of individual facilities in a factory toward overall optimization of the entire factory as an integrated system of linked facilities. Accordingly, the

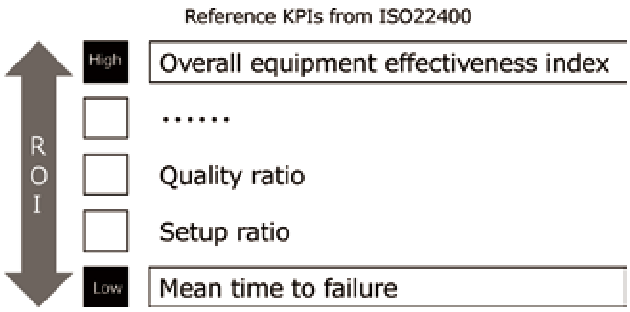
■ Figure 5: SMKL example application: Assessment of energy conservation (specific energy consumption)



assessment example of using SMKL shown in Figure 5 targets three management levels: Installation & Worker, Workshop, and Factory. Each management level is assessed for all maturity levels from Collection (Level a) to Prediction (Level e). After completing the Level e assessment for Installation & Worker, the visualization and analysis steps for a Workshop and Factory are easily accomplished. The assessment criteria and examples of the related IIoT technology for each SMKL in this case study are listed in Table 2.

Specific energy intensity is a widely used KPI for energy conservation. The machine availability rate is also an important assessment point. Differences in cost effectiveness associated with choice of KPI related to specific energy are presented in Figure 6. Factory managers can begin with KPI that have high

■ Figure 6: SMKL example application: KPI used in assessment of specific energy consumption



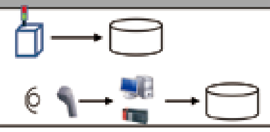
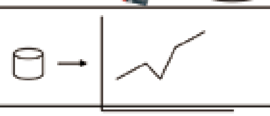
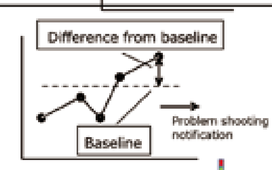
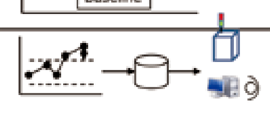
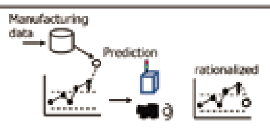
cost effectiveness with the objective of achieving a future energy-efficient smart factory through adoption of IIoT and stepwise improvement of SMKL. Machine designers can refer to the selected KPI to determine the current SMKL. The upgrading criteria indicated by SMKL can also be considered in decisions on improving existing facilities and introducing new facilities. Production managers can use the defined managed items and management target levels in the execution of PDCA (Plan-Do-Check-Act) cycles to achieve their goals.

5. Conclusion

IIoT initiatives that are appropriately tailored to the business of the individual company are essential to achieving a smart factory. Data-driven IIoT requires collection of various types of data from the shop floor, and digital transformation of the entire supply chain and engineering chain requires a high level of investment and time before optimization is actually achieved. Nevertheless, the SMKL described in this paper can be used to guide the promotion of IIoT in companies, so acceleration in achieving smart factories can be expected.

To further invigorate the future IIoT market, we will also work on openness and international standardization at the IAF (Industrial Automation Forum) and promote development of products and solutions that can be mapped to the SMKL matrix with the objective of contributing to the digital transformation of the customer's organization and global development of the IIoT market.

■ Table 2: SMKL example application: Criteria used in assessment of specific energy consumption

Maturity Level	Description		Example
Level a Collect	Manufacturing data, installation or work status are collected and stored in an electrical way automatically or manually with simple input action.		·Database ·CSV file
Level b Visualize	Charts or tables are automatically generated based on collected and/or stored manufacturing data along with management objective.		·List description ·Graph description (histogram, trend etc.)
Level c Analyze	Charts and tables describing the comparison of a target performance with as-is status with variance are automatically generated according to the maturity level. For example, manually analytics at worker can be exempted.		·Manufacturing operation management ·Trouble handling
Level d Optimize	KAIZEN instrument is automatically feedback to management objectives to solve the performance difference that specified in maturity level.		·AI powered KAIZEN
Level e Predict	Manufacturing data is automatically categorized with analytics that make predictions about future outcomes. Based on the prediction, management objective can be integrated and rationalized overall.		·Equipment predictive maintenance ·Manufacturing operation simulation based on equipment allocation ratio