Smart Manufacturing Continuous Improvement Maturity Model

ARC White Paper
March 2020

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Executive Overview

When the management at manufacturing companies express the goal to apply smart manufacturing or Industrie 4.0; or if a line or a maintenance manager suggest using Industrial IoT to introduce predictive maintenance, there's likely to be at least some misunderstanding between the different parties involved. This applies to the technologies, implications, objectives and motives.

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Mitsubishi Electric experienced this when implementing smart manufacturing in one of its own sites. To help facilitate discussions, the R&D department created a simple matrix to map both the current degree of usage of smart solutions through the company and the relative maturity of those solutions. The higher the combined scores, the higher the total impact on the company.

The tool, dubbed Smart Manufacturing Kaizen Level, or SMKL, traces the continuous improvement in implementing smart manufacturing solutions across manufacturing operations to provide value in a variety of situations, including:

- in early discussions to create a common understanding
- for strategic and investment planning,
- during feasibility studies and risk analyses
- for technology mapping
- for operational planning and project management, and
- as a tool to manage the progress of implementation programs

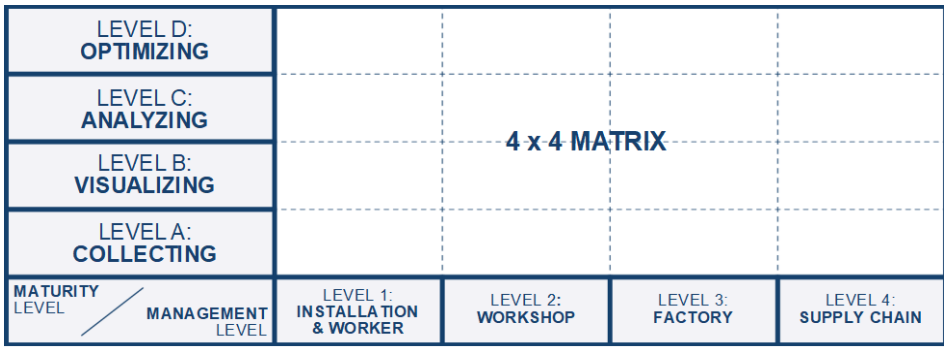
This white paper explains the concept of SMKL, the range of different ways to use it, the associated benefits, and the beginning of the journey to file the model as international standard.

Measuring the Impact of Smart Manufacturing

Today, we're seeing a confusing array of different names used to characterize the modernization of manufacturing industries. Initiatives such as the Industrial Internet Consortium, target the financial and economic health of industrial companies. Initiatives such at the German Industrie 4.0 add sustainability and social improvement goals, such as helping protect the environment and improve employment. Many other countries, large and small, all have their own "flavors" of such a program, including Connected Industries in Japan.

More general terminology, such as "digital transformation" applies across most of those initiatives and standardization initiatives have emerged to attempt to make sure private and public initiatives alike remain interoperable. FIWARE, the Industrie Platform 4.0, or the Open Process Automation Forum (a forum of The Open Group) are examples. Sometimes the technology aspect is emphasized as in Industrial IoT. All these smart manufacturing-related initiatives intersect with similar initiatives such as smart cities, smart transportation, smart agriculture, etc. Smart manufacturing and related initiatives encompass technologies, appropriate standards, strategies and business processes, risk management and compliance, interactions with humans and society, environmental footprint, and more.

As Mitsubishi Electric discovered in its Nagoya Works when implementing smart manufacturing, the understanding and interpretation of the terms introduced above may vary among different roles in industrial companies, such as management, technical experts and workers.



"Smart Manufacturing Kaizen Level" Matrix Tool (Source: Mitsubishi Electric)

In response, the company developed a matrix that maps both the degree of penetration of smart manufacturing and the degree of effectiveness. The degree of penetration measures how far a smart manufacturing solution covers the enterprise on a

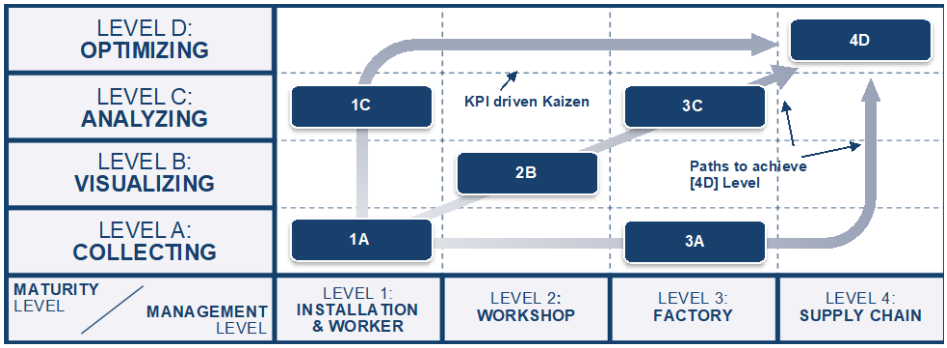
scale ranging from the worker or installation (level 1), a workshop (level 2), a factory (level 3), or across the full supply chain (level 4).

The effectiveness is measured by the "maturity level," which indicates the intelligence and the impact of the solution. This ranges from data collecting (level A), visualization (level B), analysis (level C), and finally, optimization (level D). This axis helps personnel understand that, before anything else, equipment and people need to start producing electronically accessible data of good quality, with context information such that the data can be understood and interpreted by all actors in the organization. This can be quite an undertaking, especially if equipment is decades old and lacks smart instrumentation and controls that can communicate electronically and, ideally, have compute and/or health self-assessment capabilities. This concept is in line with "foundational or threshold digital maturity" defined in this article, that the author believes to be needed for the success of any substantial digital transformation.

Mitsubishi dubbed the matrix the Smart Manufacturing Kaizen Level (SMKL). Kaizen originates from the Japanese concept in Lean Manufacturing of continuous improvement that has spread through the world since the 1980s. Kaizen Level refers to the level of impact or effectiveness on the enterprise. The latter, an obvious management concept, is very useful to emphasize. This is because many companies get so focused on experimenting with smart technologies that they can get sidetracked, delaying rollout of successful experiments across the business to create bottom-line impact.

A Range of Possible Applications and Benefits

SMKL can be used throughout the smart manufacturing program lifecycle. First, it can help facilitate conversations among stakeholders who need to agree on terminology, how to sequence project work packages, and the level of impact and penetration to target. Of course, teams will need additional tools, such as technical feasibility studies, risk and failure mode analysis, financial analysis or business



SMKL Used to Map Improvement Trajectories (Source: Mitsubishi Electric)

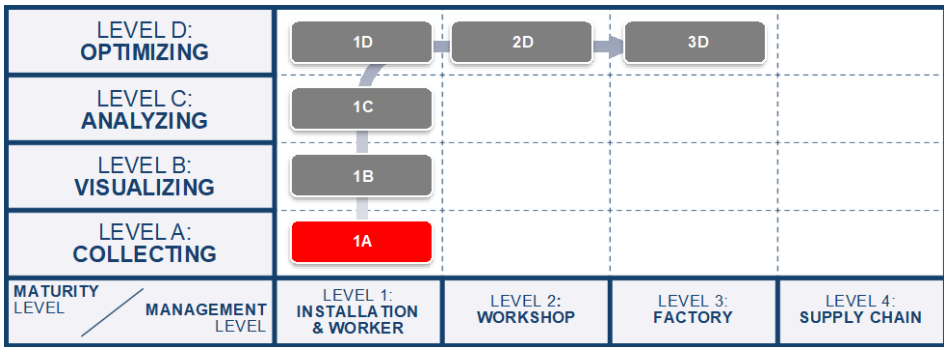
case, and more. SMKL will serve as the highest-level framework and can also function as a map for the project team as well as a dashboard to visualize progress versus plans. Teams could map benefits, risks, costs, other impacts or all of them together in the matrix or choose to use representative key performance indicators (KPIs) for those impacts or easy-to-interpret color codes.

A Journey of Discoveries

The figure also suggests that the project team could evaluate different paths to reach an end target. Risk/benefit analyses or resource availability can help deciding which path would be more favorable or contain less risk.

The final target could, but does not necessarily have to, be the largest penetration at the highest maturity level (4D in the figure). This depends on the strategy and objectives of the company, business unit or plant, and the additional benefits that additional maturity would bring. It could also be that, for a given solution, a higher level of maturity could bring more significant added value in one business unit or type of manufacturing operation than in another.

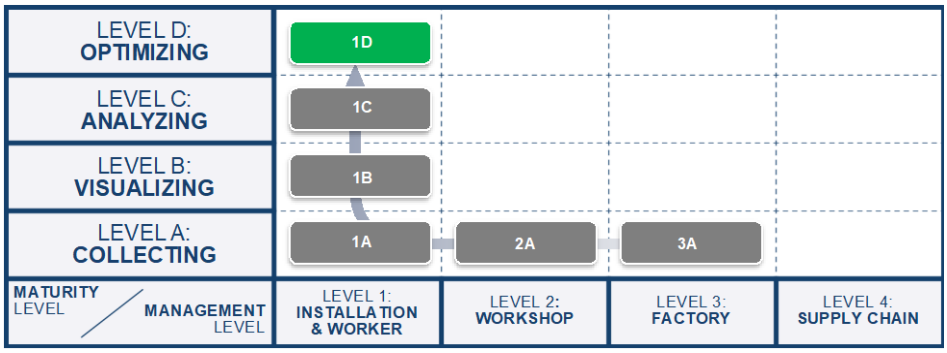
It might be that the strategy for improvement and the chosen path progress from bottom-left, a low level of maturity at the worker or machine level, to top-right, a high level of optimization at the value chain level. This is likely to be the case for manufacturing or assembly lines. Investment would increase along the same path and the progression would provide an opportunity to review if the investment has sufficient ROI before scaling up.



SMKL Used to Map Production Improvement Trajectories (Source: Mitsubishi Electric)

Another example could be energy management. Often, utility consumption data are available at an aggregated level, for example a site or a factory, but not at the line or as machine data. It might be useful to create dashboards and analyze consumption of sites with high utility consumption and then invest at the more granular line or machine level to get more understanding

of and control over the energy consumption of individual machines. In this case, the path of improvement would start at 3A and increase granularity of the information via 2A down to 1A. Would investment in metering at machine level be necessary? Maybe, but a calculation approximating power based on uptime and nominal power consumption could be sufficiently accurate as a KPI. In any case, in getting more sophisticated in managing energy consumption of individual machines, the improvement path would go up from 1A toward 1D.



SMKL Used to Map Energy Management Improvement Trajectories (Source: Mitsubishi Electric)

A discovery mindset is optimal in this stage. Thinking scenarios through and drawing conclusions based on the findings gives the best chances to find improvement potential. This also implies that project teams should make cost/benefit analyses to determine the useful degree of maturity for their context. Of course, if a solution can benefit a single work activity or equipment instance, it is very likely to be benefit all similar activities or equipment. This also makes it beneficial to roll-out across workshops and factories.

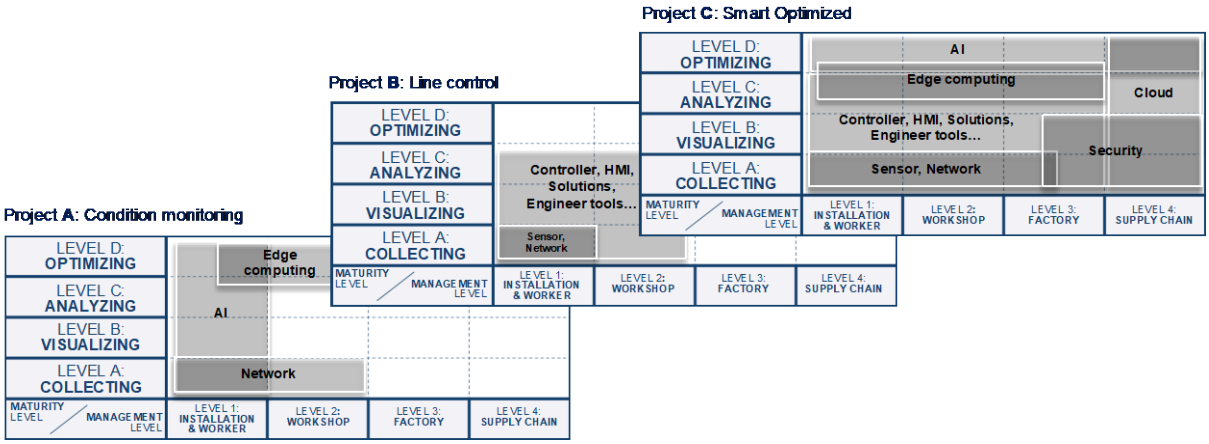
Using SMKL as a Strategic Planning Tool

A company or team could create several versions of the graph, comparing the impact of technologies or solutions and their impact with increasing penetration or map the increasingly complex interplay of multiple solutions along the maturity and penetration axes. The SMKL then becomes a strategic planning tool.

ARC recommends investigating by business process. Knowing the value associated with the business process (for example through value stream mapping) could help prioritizing. Another approach could be to prioritize by the cost of issues associated with the business process, such as defects, poor quality or plant stops. It could also be important to look at social or environmental metrics, such as absenteeism, conflict, toxic waste or water

consumption; while continuing to identify and keep things that work well, teams are proud of, and the company wants to retain.

Once the "bad actors" are known, process improvement approaches should be used to reduce cost or increase value produced. Technology may be part of the solution, but it is likely that the improvement will also include changes in the work process, information process, and probably human aspects such as training and coaching. Companies may be knowledgeable and experienced in applying automation and IT technologies, but far less so in applying data science and machine learning. To be able to use the largest possible palette of technologies and imagine a solution based on all these possibilities, companies may first want to invest in acquiring knowledge of training people, for example by creating a small center of expertise with representations of many disciplines.



SMKL Used to Map Technologies and Plan Competence Development (Source: Mitsubishi Electric)

Only then will teams be ready to select technologies, run scenarios, compare business cases, do some experiments, get feedback from key users, and make a balanced set of recommendations based on these inputs. They may map their findings and recommendations for technology implementations on maps as shown in the figure. When experiments are promising, a company would want to do a pilot at limited industrial scale to confirm the returns from the solution before deciding upon a company-wide or supply chain-wide roll-out. In summary, the tool supports collaborative project resource and investment planning at strategic and operational levels.

A Benchmarking Tool

Ideally, a maturity model should represent proven levels of performance. SMKL could be the basis for a benchmarking approach. To do so, companies must go beyond the business case and measure benefits when a solution is implemented. They could also measure the synergies of different solutions, or additional benefits when increasing the management range. These are benchmarks that can be used as benefit estimates for new implementations of the same kind. They could be compared with actual benefits obtained by new implementations to check and reinforce the statistical significance of the benchmark.

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Standardization Adds Significance and Credibility

After a few years of using SMKL internally with good results, Mitsubishi Electric decided to share the concept and experience of SMKL with the manufacturing community. To this end, it proposed that the Industrial Automation Forum (IAF), an organization for industrial standard-based manufacturing innovation promotion in Japan, prepare to introduce SMKL as an international standard. The IAF has taken on to prepare ISO and/or IEC standards of SMKL. The peer reviews necessary in this process will further increase the value and the credibility of the maturity model. IAF is working on extensions of SMKL, in particular establishing standardized KPIs that can be used in conjunction with the maturity model.

Recommendations

Manufacturing companies that aim to make an impact on strategic or operational objectives should consider SMKL as a tool to investigate which improvements in manufacturing could make impact on those objectives, guide them in comparing and planning investments and projects, and executing and managing programs to transform them into actual impact. This applies to classical financial bottom-line-related objectives, more specific objectives such as related to supply chains, collaboration, innovation, quality or client-satisfaction; or more broad societal, or environmental objectives.

Those companies should also become familiar with other maturity and digital readiness models that could help add non-technical aspects to smart manufacturing implementation programs and further enrich their approaches.

Further Reading

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Acronym Reference:

IAF	Industrial Automation Forum
IEC	The International Electrotechnical Commission
ISO	International Standardization Organization
IoT	Internet of Things
IIoT	Industrial Internet of Things
IT	Information Technology
KPI	Key Performance Indicator
OPAF	Open Process Automation Forum
R&D	Research & Development
ROI	Return on Investment
SMKL	Smart Manufacturing Kaizen Level

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