~Research on manufacturing in the IoT / AI era (Industry 4.0) and responding to changes in human roles — —Π-Type abilities and to promote "manufacturing DX"— Japan Machinery Federation: Specialized Subcommittee for Manufacturing Human Resources Survey in IoT / AI Era

1. First of all

1-1. Recognition of the times

It has been nine years since the German Industry 4.0 came out in 2011. The wave of digital transformation (DX) of manufacturing (Industry 4.0) has begun around the world, including the advanced manufacturing and industrial IoT in the United States, and the era of the fourth industrial revolution has arrived (Figure 1). The Japan Machinery Federation has traced these overseas trends over the years since 2014. Industry 4.0 has now shifted from the discussion stage to the implementation stage. In the discussion that follows, instead of calling it the "IoT / AI era," we have decided to call it the era of utilizing IoT / AI.



Figure 1: Digital transformation(DX)of manufacturing in the world. Source:Nippon Steel Research Institute (NSRI)

1-2. Examination of manufacturing environment

In recent years, with the increase in geopolitical risks represented by the US-China conflict, skepticism about globalization has emerged. In addition, the threat of natural disasters is increasing day by day, and the demographics in Japan are also declining more than estimated. These kind of uncertainties are considered to increase year by year.

Considering the business environment surrounding the manufacturing industry, the wave of vertical integration by IT companies such as GAFA is spreading to the

manufacturing industry. The wave of the fourth industrial revolution is affecting not only manufacturing companies in the developed world, but also those in the developing world. China, which has declared that it wants to become a world power in manufacturing, is also putting a lot of effort into promoting digitalization, and with some fields coming out ahead of Japan, the leapfrog phenomenon is becoming a reality there.

1-3. Industry 4.0, DX and Manufacturing DX

The concept of Industry 4.0 has had a huge impact around the world, and similar efforts have been extended to fields other than manufacturing. For example, logistics 4.0, small and medium-sized enterprises 4.0, "Mittelstand" 4.0, transportation 4.0, health and safety 4.0, labor and work 4.0, education 4.0, vocational training 4.0, continuous learning 4.0, and many other 4.0s are advocated in each field. Thus, in various fields, utilization of digital technology is progressing, which is called Digital Transformation (DX).

The Specialized Subcommittee has discussed and considered the path to proceed with DX, taking into account the Japanese characteristics and history of the country. However, since this Specialized Subcommittee is a gathering of machine industry companies, it has a strong commitment to MONOZUKRI or Japan-specific "manufacturing", we decided to call it "Monozukuri DX" or "Manufacturing DX.

1-4. Only leaders can grow

According to the report of World Economic Forum, "Forth Industrial Revolution Beacons of Technology and Innovation in Manufacturing", it compares three groups, companies adopting AI before others, their followers, and those who do nothing, and concluded that only leading companies can grow and dominate the market (Figure 2). The success or failure of the promotion of DX depends on whether you start to begin DX before you discuss it. It is important to recognize that we are on the brink of whether or not to address DX.



Figure 2 Changes in the index of the cumulative Cash Flow of the pioneering AI adopters

Source: WE F : White Paper January 2019 In collaboration with McKinsey & Company Fourth Industrial Revolution Beacons of Technology and Innovation in Manufacturing¹

Examples of DX include collecting data using IoT and starting predictive maintenance using AI. These all correspond to the partial digital technology implementation stages in the individual manufacturing processes. However, you need to be aware that if you are satisfied with these steps, you will sooner or later lose competitiveness.

Rather than staying within the existing network, it is necessary to build a larger network by connecting and expanding these networks one after another. In other words, not only do we need to connect the various trading chains we already have with digital tools, but we also need to expand more beyond traditional trading chains. On top of that, it is necessary to establish a solid competitiveness and growth potential by networking as much as possible chains (constructing an ecosystem).

2. The stance of this Specialized Subcommittee

2-1. A common sense of crisis in this Specialized Subcommittee

The Specialized Subcommittee has been working on DX issues for six years since the previous committee. As a result, we began to feel a sense of crisis that if we did nothing, the various strengths unique to Japan that the postwar Japanese machinery industry had built up would be eroded under the forth industrial revolution.

One of the great features of digital is its incredible speed. In other words, not only do electronic devices carry information at high speed, but also the speed of business must be adjusted to that speed. It is important to be able to cope with this change.

2-2. Why "Monozukuri DX " or "Manufacturing DX"

The most important thing in manufacturing DX is how to adapt to the digital concept and the speed of digital, while at the same time making it compatible with the basics of manufacturing. Is it possible to smoothly respond and adapt to the difficulty of balancing this? It's an unprecedented challenge. At the same time, the challenge of manufacturing DX is to enhance international competitiveness by incorporating technologies that make full use of the characteristics of digital technology.

2-3. Digital characteristics that should be utilized

Digitalization is characterized by its overwhelming speed. It not only shortens processing time, but also contributes to cost reduction. This is supported by the "hollowing-out effect" that connects the "source of data" and the "use of data" and also by the advancement of software technology. Behind this are the following characteristics of digital: That is, (1) it can be shared and analyzed immediately, (2) it can be copied and moved instantaneously,

(3) it has high reproducibility (restorability), (4) the moving cost is almost zero, (4) deterioration due to transmission and copying is extremely small, ⁽⁶⁾Easy data storage, ⁽⁷⁾ Low storage costs, ⁽⁸⁾Easy cooperation between companies.

3. What is Monozukuri DX?

3-1. Concept of Monozukuri DX

Let's consider "Monozukuri DX". Here we take the production process of the manufacturing industry as an example.

The point is that the purpose of promoting DX is not to "introduce DX", but to discover and solve the real problems in the production process. The problem to be discovered lies in the gap between AS IS (as is) and TO BE (as it should be) (Figure 3). Once the problem is clarified, digital tools as a means of solving it are almost already in the world.

With dramatic technological progress, various simulations can be tried by making full use of software in cyber space. As a result, for example, it is possible to try even "a case that could not be conceived in a test of a real machine".

In the conventional method, it took a lot of time to make a real machine in the real world. However, in the world of manufacturing DX, it is possible to make a prototype that is as close to completion as possible, in a very short time efficiently by utilizing simulations based on "DT(Digital Twin). This is the concept of CPS (Fig. 3) in case of production process. By utilizing digital technologies such as IoT, BD, AI, and "DT", manufacturing can be done quickly and efficiently. Furthermore, by utilizing the technology of AM (additive manufacturing), the manufacture of three-dimensional shapes that was impossible with conventional processing technology became possible.



Figure 3 From AS IS to TO BE (by building CPS that makes full use of IoT, BD. AI) Source:Nippon Steel Research Institute (NSRI)

3–2. The image of Monozukuri DX

The age of Monozukuri DX is an age of IoT / AI utilization. It is an era where you can benefit from technological innovation represented by IoT / AI. An era where various evolving digital technologies can be used both vertically and horizontally. To win the competition with the world, the thorough DX and gaining the agility of digital technology will be the key to the game in both corporate management and manufacturing. In other words, the era of competing on how to promote the DX to incorporate the speed of digital technology into the management and production of the manufacturing industry has come. That is the most important point of the manufacturing paradigm shift of the manufacturing industries.

Various networks are created by the Monozukuri DX. It spreads to the engineering chain, and further to the supply chain (SC) and products and services. In this way, smart factories, smart SCs, and smart connected products and services are generated. This connection extends from headquarters staff to internal factories as well as domestic and overseas factories, local suppliers, universities, research institutes, even rivals and users.

A world of networks will be created one after another as so-called Connected Industries (Fig. 4). Once connected to the network , you can get the information you need when you need it. It allows sharing of the visualized information. You can make decisions for overall optimization. You can create new business through new digital networks. When this functions organically, it becomes an ecosystem, and its spread and overlap lead to the world of Society 5.0.



Figure 4: DX: A world in which related parties are connected under a circle of information Source:Nippon Steel Research Institute (NSRI)

The dominant forms of thinking in the traditional manufacturing industry include analytical Cartesian thinking that delves into various problems at the site in a "closed" environment and deepens tacit knowledge related to the site. On the other hand, in the manufacturing industry in the new era, in a world that is open and connected, emphasis is placed on system thinking, design thinking, and the like that try to capture the whole, rather than being captured by parts. In addition, emphasis is placed on Breakthrough Thinking and speed in challenging the use of digital tools, creating new value, and searching for knowledge.

3-3. Direction for Manufacturing DX

Assuming a manufacturing environment in which only uncertainty can be reliably foreseen, the most important strategy for corporate management is how to strengthen the ability to respond to fluctuations. The concrete measures are hard to imagine other than how to promote "Monozukuri DX" quickly. Speed is key. This is the true nature of the "Paradigm Shift of manufacturing industry ".

What we have assumed in the discussions of this subcommittee is neither "demanufacturing" nor "business model theory". Nor is it in a position to improve the manufacturing industry as it is. By advocating " Monozukuri DX", we aim to become an "attractive manufacturing industry" for next-generation human resources.

The manufacturing industry at present includes, for example, problems such as "cold treatment of non-managers such as professionals and technicians" or "consensus creation by "Nemawashi" inside the organization". On the other hand, the "attractive manufacturing industry" can provide instantaneous visualization and decision-making support through "information sharing between remote areas" by means of Monozukuri DX. Moreover it makes it possible to try out new business that can emphasize the aspect of "I can challenge" and to have entrepreneurship.

The new manufacturing industry that we should aim for must be able to shift to an industry that can attract young and talented male and female students in inter-industry competition with IT companies and others. Whether the existing manufacturing industry can be transformed or not depends on the success of "manufacturing DX" promotion.

Monozukuri DX needs to be based on the commitment to manufacturing as a machine industry that reflects the national character and history of Japan. At the same time, we need to gain the speed of both business and works through digital transformation. Such efforts will also transform the Japanese manufacturing industry in a way that appeals to students seeking employment.

4. Key points in promoting Monozukuri DX

4-1. Discovery and expansion of cooperative areas and construction of Π -type capabilities

The Subcommittee focuses its discussions on the production process. This is because it is considered to be a theme that is easier to take on the common playing field than the issues of production and services. Based on that, we considered the role of human resources who can promote Monozukuri DX, the necessary abilities, and the image of human resources.

The promotion of Monozukuri DX is to shift from a traditional, independent, closed, competitive world to an open and connected world(Figure 5). In order to discover and expand the area of cooperation, it is necessary to build a new network called "ecosystem" that is "connected" by digitalization. The question is how quickly we can switch to a new world.



Figure 5: Image of Monozukuri DX (Digitalization of Manufacturing, Paradigm Shift) Source:Nippon Steel Research Institute (NSRI)

In order to realize Manufacturing DX, it is necessary to cultivate Π -type skills that can be used in both Manufacturing and Digital. However, Π -type abilities cannot be obtained overnight. Therefore, a team of Π -type is formed by both experts, aiming to acquire not as individuals but as a team (group). This is the task at hand. On the other hand, developing and supporting human resources aiming for Π -type skills (Π -type human resources) is a long-term issue.

4-2. "Type 2.0" aiming to build Π-type capability

Based on TAKUMI 4.0 advocated by the specialized subcommittee before the current one, we focused on the acquisition of Π -type abilities in order to identify how manufacturing professionals, such as modern artisans, can acquire knowledge and knowhow for using digital tools. The conventional word of " Π -type" was a name that represented two specialized fields. An area that requires both mechanical and electrical specialties is called mechatronics. This is an example of the conventional Π -type. In this "Monozukuri DX", we decided to describe it as " Π -type 2.0 "(Figure 6). This 2.0 means the following extensions of Π -type: That is, the entire flow of expansion from Π -type team $\rightarrow \Pi$ -type learning $\rightarrow \Pi$ -type ability $\rightarrow \Pi$ -type human resources is called Π -type 2.0.



Figure 6: Traditional Π-type, Π-type extension, Π-type 2.0 Source:Nippon Steel Research Institute (NSRI)

4-3. The wall (gap) to overcome

In order for the manufacturing industry to utilize digital technology, the conditions (walls, gaps) for promoting Monozukuri DX must be overtaken. The Special Subcommittee indicates the following four conditions (hereinafter referred to as "gap"), standardization gap, lean gap, mind gap, and skill gap. To fill the standardization gap, it is necessary to standardize work and knowledge and create textbooks that are common in the industry. To fill the lean gap, it is necessary to thoroughly introduce the lean production method(TOYOTA Production Method). To fill the mind gap, you must embrace the digital mind. To fill the skills gap, you must acquire digital skills. In order to promote Monozukuri DX, it is necessary to make efforts to bridge the four gaps.

4-4. From a traditional control management type to a flat Π -type organization

RTB (Run the Business) which is traditional organization firmly supports the profit base of conventional manufacturing. On the other hand, CTB (Change the Business) paves the way to the next era, while taking charge of the planning and promotion of Monozukuri DX(Figure 7).



Figure 7: Division of roles between CTB and RTB

Source:Nippon Steel Research Institute (NSRI)

The CTB team gathers not only experts in various fields of manufacturing but also various experts from the digital field. This team will be an autonomous decentralized organization that requires bold team management, such as repeated trial and error. It is necessary to bring together each specialty in line with the team goal of promoting Monozukuri DX.

Therefore, It will be a flat Π -type team instead of the traditional management and control-type team. Its goal is achieved by bringing together the power of the team / group members.



Figure 8:Image of a flat Π -type organization

Source:Nippon Steel Research Institute (NSRI)

4-5. Producer-type and support-type leader indispensable to the new organization

Producer-type and support-type leaders are suitable for CTB team leaders. Such leaders are required to be of a type that is different from the types screened by conventional personnel evaluation systems. The CTB team in charge of promoting manufacturing DX has members who have their own specialties and it is necessary to fully utilize the talents of each member. The leader of the CTB team is required to build and create the team and its

images so as to realize the goal of the CTB team, and is also to support the team member with a sense of "like" to back up.

That is why the team itself should be a flat Π -type organization, not conventional pyramid type.

5. What is required for Π -type ability

5-1. Digital mind, unlearning, and continuous organizational learning

Digital mind and digital literacy are the another Π -type abilities, other than Monozukuri literacy, required to promote Monozukuri DX. Digital mind is a kind of strategic thinking such as customer-oriented, idea-oriented, flexible and quick response to fluctuations, early implementation while quickly repeating experimental verification, and minimal rework. It is also the attitude and mindset to intentionally use such thoughts.

In order to acquire a digital mind, it is necessary to learn not only system thinking but also design thinking, lean startup thinking, agile development thinking, and module thinking. To organize and operate a Π -type team, it is difficult to extrapolate from conventional ideas, experience and know-how. Therefore, it is necessary to once throw away the inertia and practices bound by traditional knowledge (unlearning) and relearn new ideas unique to digital (digital mind).

Unlearning is the elimination of stereotypes and beliefs, or the destruction of what we have learned. Technological innovation in the digital field is progressing rapidly. It is a world where changes which are so-called exponential functions, are taken for granted. Unlearning as well as continuous learning ability as an organization is required.

5-2. Building of Π -type abilities and Securing and training Π -type human resources based on the essentials of manufacturing

The development of human resources for Monozukuri DX depends on the construction of Π -type ability that has both literacy of manufacturing and digital literacy. Therefore, it is desirable to continue to secure the "requirements of manufacturing" and make the most of the digital characteristics without compromising the features of the conventional manufacturing industry. In other words, it would be ideal to be able to freely use digital technologies such as IoT and AI, VR / AR / MR, AM, and robotics as well as literacy in manufacturing. From the long-term point of view in the Monozukuri DX, Π -type human resources who wear "analog" as well as "digital" will play a leading role.

In the future, it will be the Π -types who will drive the manufacturing industry through Monozukuri DX. They are digital natives and "excellent students", oriented to science and mathematics. The future of manufacturing depends on the transformation into a "dreamy and attractive manufacturing industry" that can fascinate such young people. We have to be able to compete with other industries. "Monozukuri DX" will penetrate into various fields of the manufacturing industry and forces us to shed from the traditional shell. It all comes down to the success of "Monozukuri DX".

6. Challenges required for Monozukuri DX

6–1. Creation of professional qualification in Π -type abilities

The acquisition of Π -type abilities is a difficult task. Therefore, it is desirable to visualize and systematize the levels of Π -type competence by classifying them into beginner/intermediate/advanced/TAKUMI4.0.

Level-specific qualifications in Π -type competence can be a learning goal for those seeking to acquire Π -type competence. As a result, it is expected that the number of learners who aim to acquire Π -type abilities will increase.



Figure 9: Image of acquisition of Π-type abilities of manufacturing human resources Source:Nippon Steel Research Institute (NSRI)

6-2. Education to face the Fourth Industrial Revolution

Historically, the Industrial Revolution required new education, and education has changed its content in a corresponding way (Figure 10). From the 1st Industrial Revolution to the 3rd one, it required a skilled worker and an engineer. Each industrial revolution has been supported by human resources with expertise in "machinery," "electricity," and "information and electronics. The Fourth Industrial Revolution is a digital world and requires Π -type combinations. The problems discussed most in the special sub committee are about how traditional experts in each field can acquire "digital", and to master Π -type



Figure 10:Education, literacy and skill gap corresponding to each industrial revolution Source: Nippon Steel Research Institute (NSRI)

It is necessary to consider and build the new education system in response to the 4th Industrial Revolution. Companies should work together to build a continuing education system. On the other hand, educational institutions must further focus on science and mathematics education and informatics education in order to face the Fourth Industrial Revolution. For human resource development to acquire Π -type abilities, it is desirable to combine industry-academia collaborative education, which is a combination of classroom lectures and practical training.

7. At the end \sim Promotion of manufacturing DX

The Monozukuri DX that is required in Japan today is not merely a "reform of the current business" or a level of aiming for the partial optimization "Kaizen" that Japanese companies have been good at so far. It is to review the current situation from the bottom of it and to reorganize it into a new digital process that can achieve total optimization. Furthermore, it is necessary to step into a radical change in the current business model. It is to tackle "real reform" and "destruction and creation". This effort is a reform itself to survive the era of speed competition without missing out on the paradigm shift. Already, Germany's "2030 Vision for Industrie 4.0" (March 29, 2019) states that Industry 4.0 has fundamentally "changed" its production mechanism.

This subcommittee focuses on the importance of "Monozukuri DX". In order to promote "Monozukuri DX", it is necessary to build Π -type ability quickly and steadily. Therefore, we proposed " Π -type 2.0", which is an extension of the conventional Π -type concept. This is a concept that encompasses the entire flow from Π -type teams to Π -type learning, Π -type abilities, and Π -type human resources. Our aim is not to aim for DX itself, but to freely use various digital tools based on the awareness of problems in the machine industry. That's why we call it Monozukuri DX, not just DX.

What is the new way of learning that is required to develop the human resources in the new era?

Continued learning in accordance with Π - type 2.0 is required for already employed people. The next generation needs an opportunity to experience the wonders of manufacturing. In addition, it is necessary to reform the system of the school toward the direction that places more emphasis on Π -type learning and practical education. On the other hand, one of Japan's new strengths in the era of Monozukuri DX will be the creation of a system that enables the conversion of advanced tacit knowledge generated by "Takumi (Master craftsman)" into formal knowledge. This "Takumi" needs to be regarded as "a person who can always think about value" and is also a symbol of Japan's strength. In the long run, such commitment to Monozukuri and the promotion of Π - type 2.0 will create the dream and charm of the manufacturing industry.

What is most needed now is to spread the understanding of "unlearning" in order to acquire Π -type abilities in various fields. "Unlearning" is to relearn digital once you have wiped out the experiences and ideas you have been accustomed to. For example, in order to further expand the areas in which each organization should work together through Monozukuri DX, each stakeholder must be prepared to make a significant change in their management attitude. Industry-wide common textbooks need to be developed so that students can learn Π -type abilities.

However, in order to do so, it is necessary to deepen mutual understanding among stakeholders and to engage in industry-academia-government collaboration. The environment surrounding employment is diversifying, including the increase in the number of "overseas human resources", and it is necessary to improve the management environment through the development of appropriate laws. This requires discussion not only at industry associations but also at the national government level. To fill the standardization gap, lean gap, mind gap, and skills gap, it is necessary to share awareness and take measures through industry-academia-government collaboration. In all cases, "unlearning" is essential.

Science and mathematics students who should support the manufacturing industry are said to be moving away from the industry. How to appeal to the wonderfulness of the manufacturing industry to them. This is a major issue that companies should work together on.

In order for the manufacturing industry to achieve sustainable growth and development, it is essential to transform into a dreaming and attractive manufacturing industry. "Manufacturing DX" may be the last valuable opportunity left for that. The industry must tackle reform for Monozukuri DX quickly.