Review

Promotion of Digital Transformation of Nippon Steel Corporation

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Abstract

Nippon Steel Corporation is working on the enhancement of business competitiveness and digital transformation by using digital technology and data. We are promoting various measures with "Strength in connecting" and "Strength in maneuvering" as keywords to realize the three effects—"location-free," "data-driven," and "empowerment"—generated by digital technology. In this paper, we discuss the concept and outline of the approach.

1. Introduction

Nippon Steel Corporation set up the Digital Innovation Division in April 2020 in order to further enhance its business competitiveness by utilizing data and digital technologies actively. This division's main roles are as follows: 1) Forming medium-to-long-term strategies for business and production process innovation using digital technologies and planning and promoting company-wide tasks, 2) improving company-wide resource input management for digital investment and making such management more efficient, 3) evaluating digital technologies to be applied to investment projects and coordinating matters between implementing departments, and 4) researching the latest digital technologies, considering, and promoting their application to actual machines. Through these tasks, the division has been working to address company-wide issues related to manufacturing/maintenance sites, sales/production plans, and profit management in a centralized manner and to accelerate the business and production process innovation by improving data management because it serves as a base to address those issues.

This paper outlines Nippon Steel's steel business process innovation.

2. Nippon Steel's Digital Transformation Promotion Strategies

Nippon Steel's digital transformation (DX) promotion does not refer to merely applying new digital technologies. We are working to innovate our business and production processes as "business innovation and DX promotion." Nippon Steel believes it is important to utilize digital technologies to enhance its ability to continue innovation, that is, the ability to change, without being affected by traditional constraints. This is because digital technologies help to form a cycle in which current operations and production processes are efficiently standardized and automated, and the knowledge and resources acquired in the standardization and automation process are then used to start new innovation activities, thus being able to produce high values. In addition, when judgments are made, they tend to be optimal only for some departments/workers; however, we intend to make optimal decisions from a broader perspective beyond organizational barriers and hierarchies by reviewing our business and production processes with data as the core.

Even in the coming era of digital innovation, it is still humans that propose and carry out innovation. Accordingly, it is important for humans to have a higher sense of mission and draw a course for future-oriented innovation. In addition, we think it is extremely important to utilize digital technologies as a means to turn the cycle of innovation. Specifically, by displaying the three effects of digital technologies—"location-free," "data-driven," and "empowerment"—we will reform traditional workstyles and are striving to significantly increase our productivity, accelerate our decision-making, and improve our problem-solving capabilities (**Fig. 1**).

Nippon Steel will enhance its strengths in connecting and in maneuvering: As strength in connecting, valuable data assets that only one department or one factory has are organically connected using advanced information technologies and the latest digital technologies; as enhanced strength in maneuvering, the enabling of high-level utilization of data and formidable process control and automation (**Fig. 2**). As our vision that will be realized by strength in connecting and in maneuvering, while combining our technologies/expertise with digital technologies, we have been working on the following projects for: 1) smarter manufacturing, 2) enhancement of the optimal supply system, and 3) establishment of common platforms and technologies that implement Nippon Steel's DX measures (**Fig. 3**).

3. Smarter Manufacturing

Nippon Steel has been proactively adopting ICT since the 1960s

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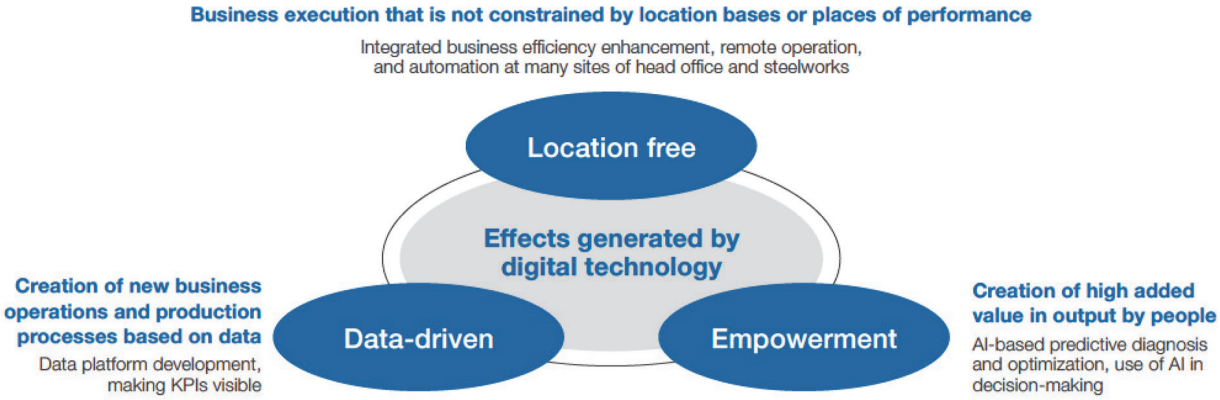

Fig. 1 Three types of values that are generated by Nippon Steel's DX strategies

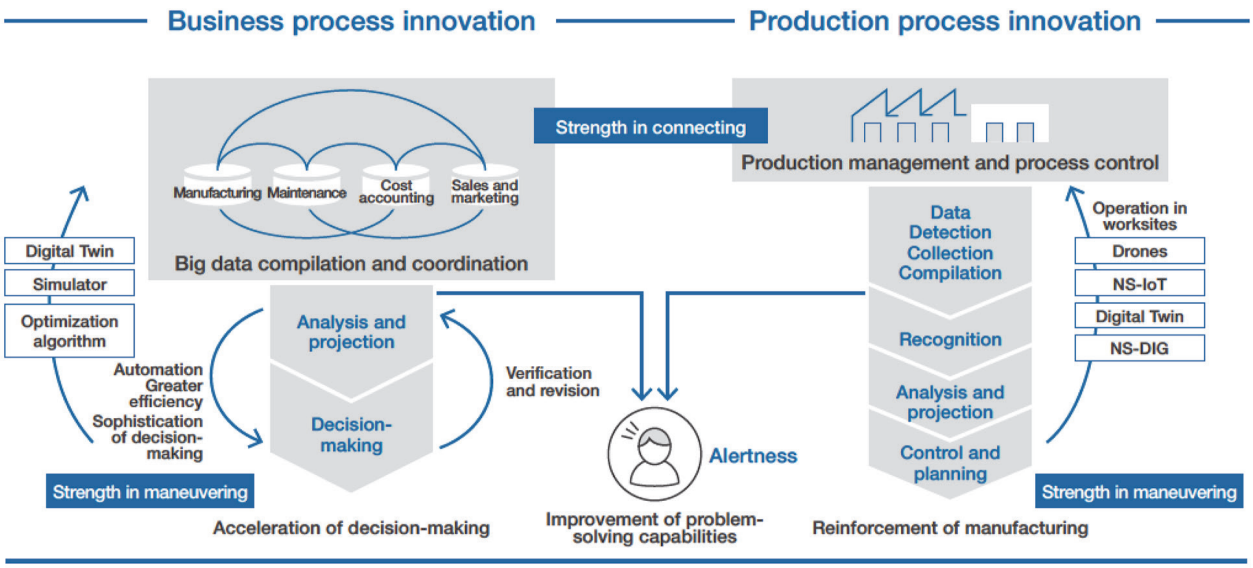

Fig. 2 Business and production process innovations through the "Strength in connecting" and "Strength in maneuvering"

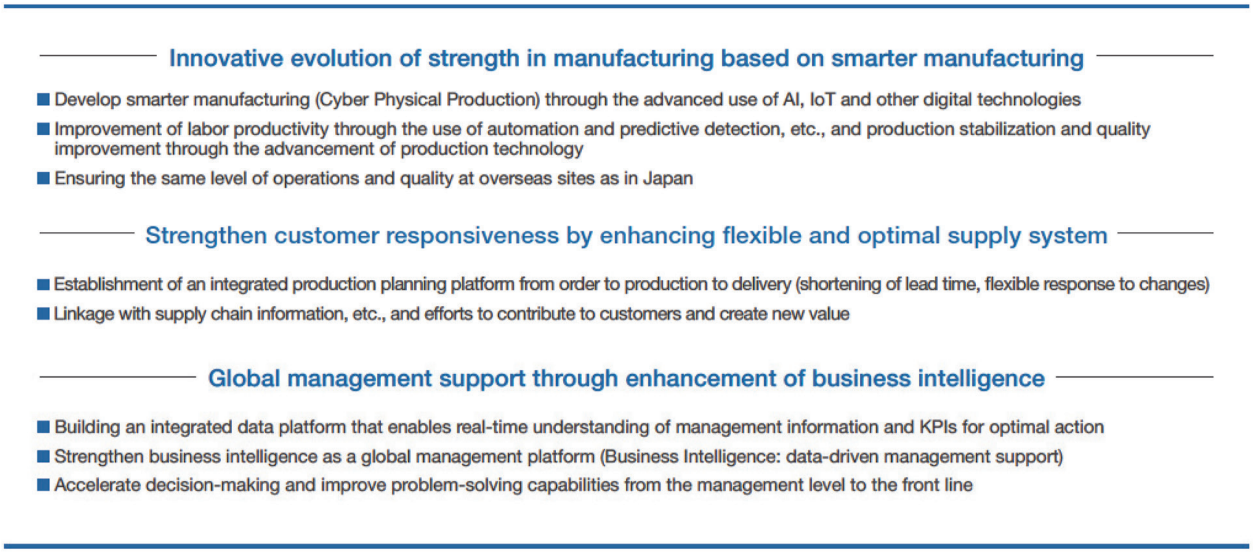

Fig. 3 Future vision of Nippon Steel's DX promotion strategies

in a variety of fields, including production, sales, logistics, maintenance, purchasing, and profit management. One of its major strengths is the large number of business systems it has developed and the vast amount of high-quality data stored in such business systems. We will enhance our strength in maneuvering, which will enable higher-level utilization of data and formidable process control and automation, by making advanced use of our strength in connecting, which will entail organically linking valuable data assets that are dispersed in individual departments and factories by utilizing advanced information technologies and the latest digital technologies. As tasks in the medium-to-long-term business plan starting in FY2021, we determined to accelerate our decision-making and enhance our problem-solving capabilities through DX promotion and have been working to utilize digital technologies, such as AI and IoT, in our production processes. Specific cases are outlined below (the measures will be described in detail in the later technical reports).

1) Establishment of NS-IoT—a platform using wireless sensors (**Fig. 4**)

Each steel works' manufacturing site collects, stores, and analyzes sensor data and utilizes it for production management (e.g., detection of irregular points) based on the knowledge that it acquired. Introducing NS-IoT—a platform using wireless IoT sensors—has made it possible to manage data that was obtained from sensors introduced to each steelworks' manufacturing site in a centralized manner and to utilize big data (data collected from many sites and integrated) to detect errors in equipment and monitor trends. This has led to improvement of the level of data analysis, establishing data-driven production processes. In addition, NS-IoT enables the same engineer to monitor multiple sites, in place of monitoring at each site, thus also contributing to improving the labor productivity. Through this project, we aim to turn technologies including tacit knowledge (e.g., expertise) into explicit knowledge and standardize more of such technologies; we also aim to stabilize our production and further improve the quality by improving our production technologies through utilization of automation, and predictive detection, etc.

2) Cyber Physical Production

We are working on Cyber Physical Production (CPP) to improve the level of our manufacturing by combining Digital Twin that will simulate production/equipment conditions at manufacturing sites in a digital space with real-time analysis of big data collected via the aforementioned platforms and other techniques (**Fig. 5**). Through CPP, we are enhancing our strength in maneuvering—quick detection of changes in operations that are difficult to standardize and turn into explicit knowledge and prediction of aged deterioration of equipment—and promoting smarter manufacturing.

4. Enhancement of the Optimal Supply System

In recent years, the business environment including energy/resource prices and steel demand has been remarkably and greatly changing due to the COVID-19 disaster, Russia's invasion of Ukraine, global price increases, and monetary tightening as a result of the price rise. To quickly cope with such changes in the business environment and optimize the entire supply system for the processes of raw material procurement, manufacturing, shipment, and logistics, it is necessary to minimize the lead time from order receiving to product shipment and to establish business processes that can be quickly turned and timely executed.

The lead time from order receiving to product shipment in the

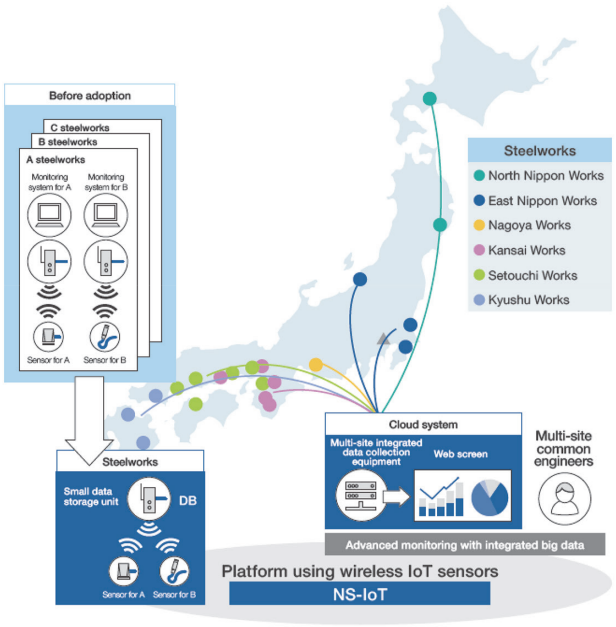

Fig. 4 NS-IoT

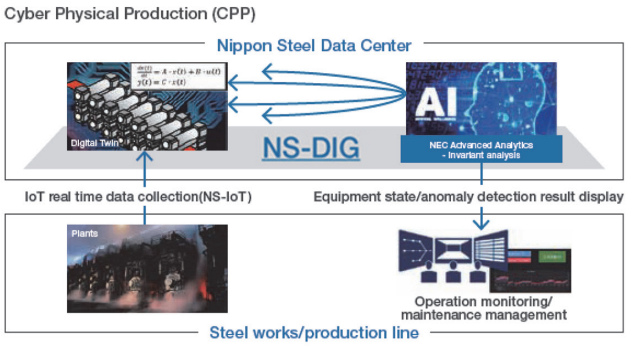

Fig. 5 Cyber Physical Production

manufacturing industry can be divided into two stages, in general: Formation of procurement/production/shipment plans and flow of actual goods (from raw material procurement and manufacturing to shipment and logistics). Procurement/production/shipment plans are determined from the downstream side of the supply chain to the upstream side considering the delivery schedules and other conditions. On the other hand, because actual goods are moved from the upstream side to the downstream side, manufacturing can be started only after the plans up to the upstream side (raw material procurement) have been determined. Accordingly, the lead time tends to be longer for the time required for planning up to the upstream side (**Fig. 6**). Therefore, in order to reduce the lead time, it is important to reduce the time required for actual goods' flow and also the time required to formulate plans.

To organically link information on various conditions, such as delivery schedules and material quality, and to form optimal plans in the planning stage, conventional deliberation by people and use of a bucket brigade to transmit information take enormous amounts of labor and time and require skills of experienced workers. As one generation is giving way to another due to the retirement of experts and other reasons, it has become practically impossible to form

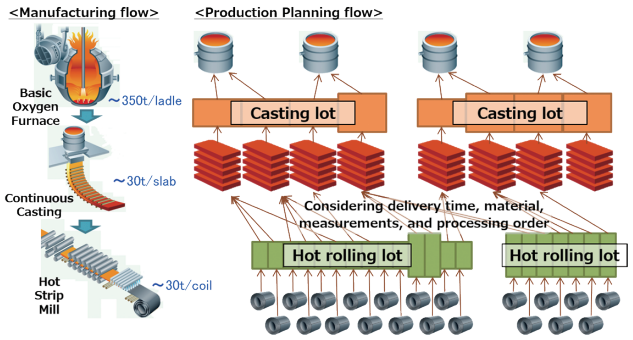

Fig. 6 Manufacturing and production planning flow of Nippon Steel

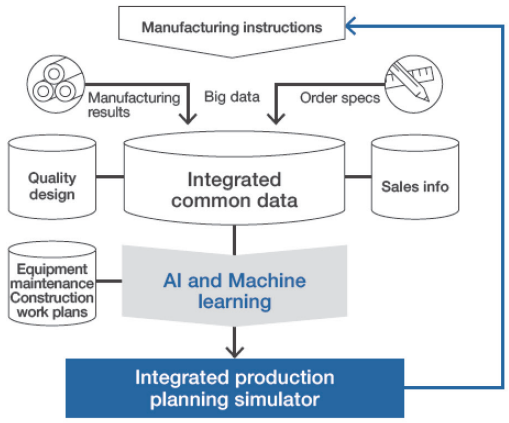

Fig. 7 The concept of integrated production planning platform

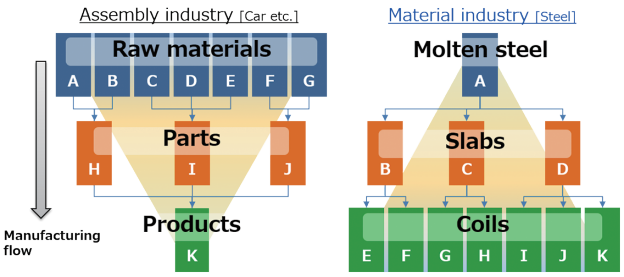

Fig. 8 The difference between the assembly industry and material industry [steel]

plans in a timely manner so as to match the latest business environment. Under such circumstances, to enhance company-wide optimal procurement/production control and greatly reduce the time required to form plans, we have been promoting business process innovation by establishing an integrated production planning platform (production planning DX) and developing a raw material combination simulator and engine for allocating raw materials to ships (raw material procurement DX).

For the integrated production planning platform, information on actual manufacturing efficiency of the manufacturing processes and detailed order specifications that each steelworks accumulated are integrated to obtain consolidated company-wide information. We also developed an integrated production planning simulator that enables us to accurately address customer order details and appropriately cope with changes in raw material procurement environments (**Fig. 7**). In the steel industry, multiple end products are manufactured from one intermediate product, which characterizes production planning in our industry (**Fig. 8**). In the assembly industry, one end product is linked to one intermediate product (part). Meanwhile, because a combination of multiple end products determines a necessary intermediate product in the steel industry, the production plan needs to be formed also considering the delivery schedules, and material quality, etc. of the other products. We have been carrying out this development considering the uniqueness of the steel industry. We started prototype development in FY2020 and utilize the agile development method (in which system development processes are executed in short cycles for individual functions) and container technology (technology to put together environments necessary for applications and required to execute them into one unit and it can make it easier and quicker to establish an environment) to accelerate the development toward release. In addition, we use cloud services that can perform high-speed computation of big data, realizing upward elasticity of the mathematical competence and expansion of functions.

For raw material procurement DX, we have been developing the following two tools while linking information also with the integrated production planning platform: Raw material combination simulator for calculating necessary amounts of raw materials (iron ore and coal) for the entire company based on information on the production plans; and an engine for allocating raw materials to ships that optimizes ship allocation for raw material procurement and transportation based on the necessary amounts of raw materials. With regard to ship allocation, in particular, because raw materials loaded onto one ship will be transported to multiple steelworks and Nippon Steel has many steelworks, the problem of combination—to which steelworks the ships will be sent and in what order—considering the production status and raw materials in stock is very complicated. Formerly, this planning was manually performed by skilled workers. This time, an optimization technique was introduced into ship allocation planning to reform the business process; that has made plans appropriate in a level equal to or higher than that of conventional plans formed by workers and that achieved remarkable reduction of the business and cycle time and operational loads.

Information on production plans and raw material procurement will be linked with financial information and other data in the future will be mutually fed back so as to optimize Nippon Steel's steel business processes.

5. Establishment of Common Platforms and Technologies to Implement Nippon Steel's DX Measures

We outlined the projects for smarter manufacturing and enhancing the optimal supply system so far. In promoting innovation with strength in connecting and in maneuvering as keywords, establishing platforms to realize those is essential. Nippon Steel has NS-Lib as a platform for strength in connecting and NS-DIG™ and AIRON-EDGE™ as platforms for strength in maneuvering. We have been promoting and improving activities for developing DX human resources so as to manage and fully use the aforementioned platforms and also activities for data governance and information security so as to utilize data correctly and securely.

Nippon Steel and NS Solutions Corporation established an integrated data management platform (DATAOPTERYX™) by combining Talend (data management function), and Snowflake (data storage and linkage function), etc. NS-Lib is a platform based on DATAOPTERYX and its operation began in April 2022 (**Fig. 9**). For example, data on orders, production plans/instructions, manu-

facturing, and other factors used to be separately accumulated at each steelworks; NS-Lib registers the meaning of data and its database address (cataloging) to integrate and put together the data. Via NS-Lib, we aim to allow the management and employees including workers at the front line to use the same data and information to make high-level decisions more quickly and resolve problems.

Furthermore, we will accelerate various DX measures by making it easier to analyze data at high levels and to develop and implement AI models, for accumulated data in NS-Lib, by the integrated AI data analysis platform NS-DIG and the edge computing platform AIRON-EDGE (**Fig. 10**). NS-DIG that is a platform commonly used throughout the entire company and that can perform data preparation, analysis, AI development, and evaluation in a seamless way enables large-scale, efficient AI development. AIRON-EDGE refers to an edge computing platform that works based on predefined AI execution environment utilization requirements and standard platform configuration. This platform has been made available to the entire company to incorporate AI models into each steelworks smoothly and enhance the agility of platform establishment.

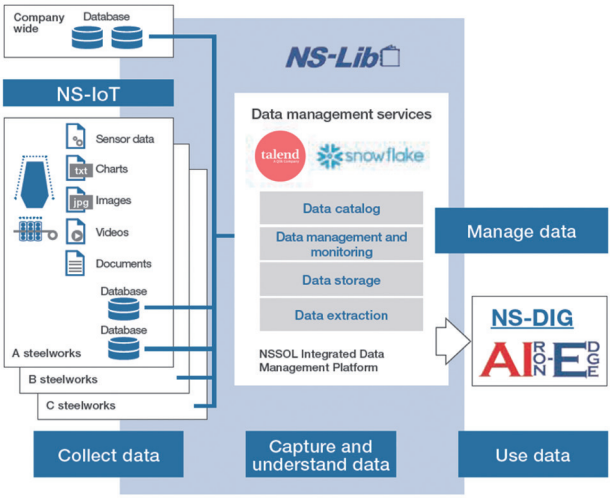

Fig. 9 The concept of NS-Lib

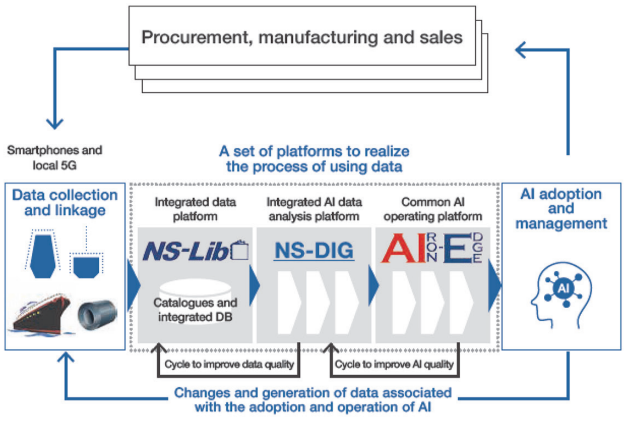

Fig. 10 The concept of new digital technology and data methods

Moreover, to generate innovation from these platforms, developing human resources who will manage these platforms is also important. Nippon Steel defines DX human resources as human resources who can extract business issues with data as the core and resolve such issues. We are developing such human resources by providing data science training to allow the employees to acquire more knowledge and skills on the data science and providing digital/management training to teach mindset and literacy to the management who will take the lead in carrying out the DX measures at each office/worksite.

To promote data utilization, managing data appropriately and securing its quality and safety are also important. Nippon Steel formed rules for management methods related to data creation, storage, utilization, disclosure, and disposal and improved the existing basic rules related to information management in order to enhance the data governance on which we have been continuously working. In addition, in February 2022, we determined AI development and management guidelines by summarizing various points to note when using and creating AI. We aim, via rules and human resource development, to create a corporate culture where the employees work for digital innovation on their own and work to continuously improve their levels.

Regarding information security, in addition to conventional information security measures, we are introducing the latest security measures involving the concept of zero trust (security of all communications is checked for important data). In addition, security training via e-learning and training against attack-type emails are provided as continuous measures to enhance the IT literacy (enhance the sensitivity for information security) of each employee as a system user. Group-wide security is also important and we have an organization called NSG-CSIRT consisting of Nippon Steel group companies to respond to computer incidents. The number of NSG-CSIRT member companies has been steadily increasing and it reached 20 as of June 2022. In addition to the group companies in Japan, we are improving the security measures also at the overseas group companies and enhancing the IT literacy of their employees via training and practice, thus aiming to be a highly-secure company group.

6. Conclusion

Nippon Steel aims to be an advanced digital company in the steel industry and will work to innovate its production and business processes while fully utilizing data and digital technologies. We will also strongly promote activities that contribute to accelerating our decision-making and enhancing our problem-solving capabilities. This special issue introduces specific DX measures that we are promoting regarding the three major projects for 1) smarter manufacturing, 2) enhancement of the optimal supply system, and 3) establishment of common platforms and technologies that implement Nippon Steel's DX measures along with the progress of the projects (**Fig. 11**).

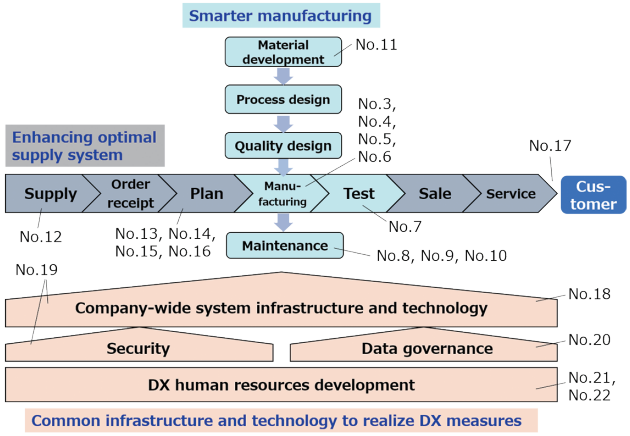

Fig. 11 The DX measures of Nippon Steel

Smarter manufacturing

No.3 Digital Twin of Steel-making Process Control in Nippon Steel Corporation
No.4 Application of Data-driven Models for Process Control and Operational Action Recommendations
No.5 Factory Smartification: Automated and Remote Manufacturing Operations
No.6 Applications of Computer Vision in Steel Production Processes
No.7 Development of Automatic Steel Surface Inspection System toward Digital Transformation
No.8 Radio Technology for Integrated Platform for Facilities Monitoring
No.9 Integrated Platform for Facility Monitoring for Anomaly Detection
No.10 Unsupervised Anomaly Detection in Mixed Processes Using Clusters
No.11 Microstructure Formation and Data Science

Enhancing optimal supply system

No.12 Business Reform and DX in Raw Material Procurement
No.13 Summary and Prospects of Digital Transformation for Production Management
No.14 Genetic Scheduler Development Systems and their Application
No.15 An Application Study of Quantum Computers to Optimization of Production Planning
No.16 Digital Twins for Logistics in Steel Manufacturing Process
No.17 Expectations for DX Progress in the Field of Building and Infrastructure

Common infrastructure and technology to realize DX measures

No.18 Platforms to Realize Nippon Steel's DX
No.19 Natural Language Processing for Business Process Innovation
No.20 Data Governance and AI Principles for Development and Operation in Nippon Steel Corporation
No.21 DX Human Resources Development of Nippon Steel Corporation
No.22 A Framework for Implementing Data-Driven Business Operations

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