ICT-based Monozukuri Innovation Activities and Practice of Human-Machine Harmonized Production

● Akira Goudo

Shimane Fujitsu Limited is the largest production site in the Fujitsu Group for ubiquitous client devices such as laptop PCs (LIFEBOOK Series) and tablets (ARROWS Tab Series). It has made Monozukuri (Japanese way of manufacturing) smart by combining production engineering and information and communications technology (ICT) including the Internet of Things (IoT). Thus, the site is capable of single-unit-based customization in production. With Fujitsu Production System (FJPS), based on the Toyota Production System (TPS), at the core, we at Shimane Fujitsu pursue our unique Monozukuri innovation activities. They facilitate significant enhancements in quality, cost, and delivery (QCD), through a system of design assistance using simulation technology, robot-based automation, and ICT, in addition to the ongoing field-centric efforts for making improvements in production lines. These results have been recognized, and this initiative won the Ministry of Economy, Trade and Industry (METI) award in the 6th Monozukuri Nippon Grand Award. This paper presents Shimane Fujitsu's Monozukuri innovation activities in terms of human-machine harmonized production, product and factory simulation, and ICT deployment in production lines.

1. Introduction

The market for PCs has become highly commodified in recent years, and competition with global vendors is intensifying. In order to deliver made-in-Japan products with a competitive edge, it is indispensable to stay ahead of the game, not only in terms of quality, cost, and delivery, but also with regards to product appeal. To avoid falling into a mere price war, our mission is to develop a factory that employs next-generation Monozukuri (Japanese way of manufacturing), with highly value-added offerings to flexibly cater to diverse customer needs, such as industry-specific models, ultra-thin and lightweight devices, and high-security-embedded products.

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This paper describes the Monozukuri innovation at Shimane Fujitsu, in terms of the human-machine harmonized production, product/factory simulation, and ICT deployment in production lines.

2. Monozukuri innovation activities

Shimane Fujitsu has two main lines: a printed circuit board (PCB) production line and an assembly line of laptop PCs and tablets (**Figure 1**). The Monozukuri innovation activities started in 2003, largely based on

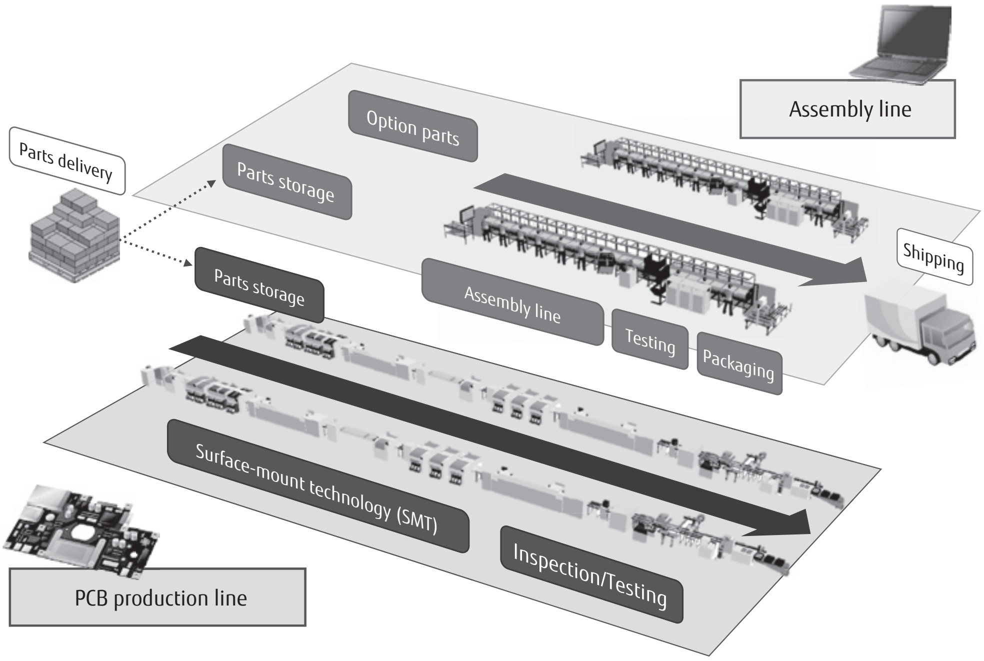


Figure 1
Production line overview.

two major principles, just-in-time (JIT) manufacturing and automation. Initially, the activities revolved around eliminating wasteful use of resources based on the 2S concept (*seiri seiton*: tidy and orderly environment). In 2005, the Toyota Production System (TPS) was introduced across the plant, and the scope of the activities was extended in 2009, to include not only the production sites but also the entire supply chain from parts procurement to the logistics following shipments. We describe in this section our efforts for having streamlining, production leveling, and a mixed production system through the Monozukuri activities.

1) Streamlining

The production site in 2005 was formed of several flows of parts and products, diverting and merging several times. Practicing the push-type production system while needing to improve the facility uptime efficiency, the plant was accumulating material/product inventory between processes. We streamlined the flow of materials and products into a single traffic line, and adopted the back-process pull-system production, which realized JIT manufacturing. This production system enabled us to minimize the inter-process inventory, thereby helping to significantly reduce production lead time (**Figure 2**).

2) Production leveling

Previously, the volume of daily orders directly influenced the production plans and plant operation, which was prone to fluctuations in person-hours and which was making it difficult to smooth out the operational workload. We introduced a leveled operation system, in which confirmed orders may be brought forward to level out the daily production volume. This initiative made it possible to minimize the plant uptime loss. This production leveling has now been extended to include the Logistics Division, and we plan production in terms of the regions that the products are to be delivered to, so that the production coincides with shipment dispatches, and this leads to enhanced efficiency.

3) Mixed production system

At Shimane Fujitsu, we have developed production lines so that individually tailored machines can be produced in a single line. This mixed production system is capable of manufacturing different models requiring different person-hours in the same production line. It enhances the productivity with shorter cycle times compared to lot-based production. This system further improves productivity by allowing us to manufacture two to three types of products in a single line at any given time, as opposed to having separate production

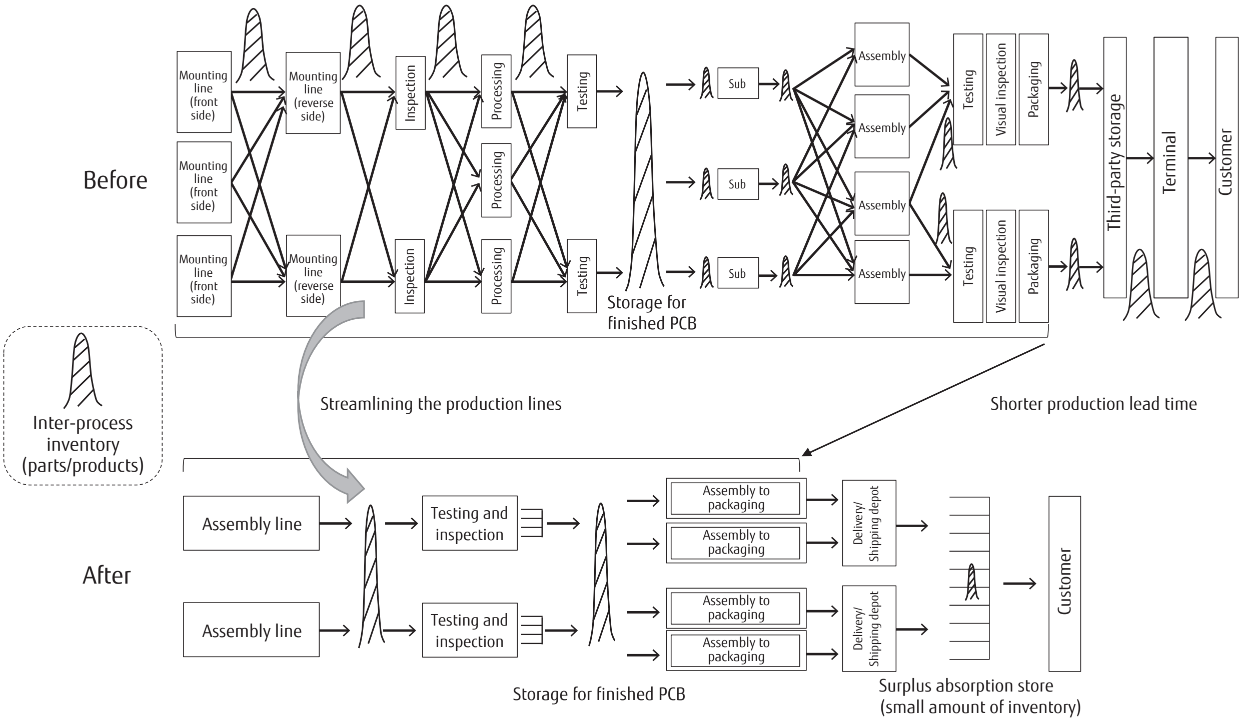


Figure 2
Streamlining of the production line.

lines for different product models.

3. Automation and human-machine harmonized production

Automation through the employment of multi-purpose robots, and human-machine harmonized production, entail the reassignment of repetitive tasks to robots or such like, while human labor can be directed toward more highly value-added processes, thereby improving the QCD aspects. In this section, we describe this initiative of automation and human-machine harmonized production.

1) Automation

PCB production is completely automated from the surface mounting process to processing and inspection/sorting, with no need for human intervention. Automation is proactively incorporated to enhance both quality and efficiency, in that, for example, facility data and carrier rails are automatically reconfigured according to the specific workpiece on the line. While the robots are of a multi-purpose build, our in-house engineers undertake integration and movement programming to suit the needs of our production facilities. In this way, we can develop the flexibility to accommodate improvement requests regarding products, while enabling us to accumulate know-how in robot control.

Human intervention is reduced in the processes of screen printing, parts mounting, reflow soldering, and visual inspection by introducing robots into these processes, and this enhances the productivity. Other tasks are also automated using robots, which mount and unmount test CPUs or memory, conduct performance tests with a test operating system, set PCBs onto PCB separators, retrieve the separated PCBs onto trays after processing, and transport them.

2) Human-machine harmonized production

The assembly lines make it possible to have collaboration between humans and machines to ensure zero mistakes and enhance efficiency in operation when handling different products each with different specifications (assembly person-hours).

For example, a selective compliance assembly robot arm (SCARA) is employed for the task of screwing the bottom panels of some products at a right angle, which is a repetitive process. As a result, the number of products that are defective due to incorrect positioning of the screws has been dramatically reduced, and the cycle time has been shortened.

Gantry robots, meanwhile, can automatically select and apply product labels for built-to-order machines according to respective order information. Automation here also helps to reduce erroneous label application such as any displacement and deformation of labels.

3) Automatic assembly of port replicators

We have developed an automated assembly robot arm for port replicators (auxiliary unit with interface ports for laptop PCs). This successfully automated the processes of molding, PCB placement and tightening screws. A robot hand equipped with a force sensor can detect any displacement of workpieces, and re-execute the task as well as correct the workpiece positions.

4) Automated keystroke testing

We have developed an automatic keystroke tester with cylindrical jigs. The robot automatically detects the velocity of a belt conveyor and piecework model, and determines the keystroke speed, height of the jig and keystroke patterns to realize optimal testing.

5) Automated label/keyboard verification

Previously, labels and prints on the keyboard were visually examined by human inspectors, and there was always the risk of errors going unnoticed. This has been improved by introducing an image recognition technology for improved accuracy in inspection.

4. Simulation technologies

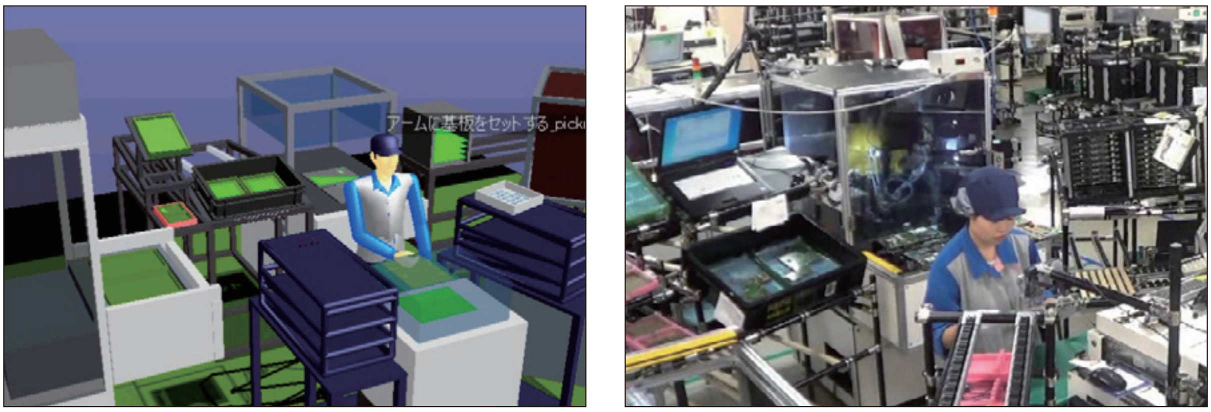
At Shimane Fujitsu, we are working to achieve a virtual factory by introducing concurrent process engineering and simulation. This virtual Monozukuri process enables us to pursue productivity assessment and post-event fault analysis during the product development and design stage, helping to improve product quality and productivity. In this section, we describe the concurrent process engineering and product simulation.

1) Concurrent process engineering

We have adopted the concurrent engineering method in our product development, in which product design, production planning, and evaluation are conducted simultaneously, to improve efficiency. The old method of product development revolved around actual models, where one process must conclude before we can move on to the next. Prototypes were necessary in order to carry out tests and evaluations, which in turn prolonged the lead time for product development and increased the cost. We are leveraging simulation technology, productivity assessment and measures to enhance product quality concurrently with product development. In this way, the lead time to market is reduced while productivity is enhanced.

2) Product simulation using Virtual Product Simulator

We deploy FUJITSU Manufacturing Industry Solution VPS (Virtual Product Simulator)[1] for product simulation. It can synchronize with computer-aided design (CAD) data for product design to assess the process executability at various stages. By incorporating a number of requests and ideas for improvement from the perspective of production into product design, it potentially helps to reduce the risks of having to rework



Simulation result

Actual production line based on the simulation

Figure 3
Simulation of pre-installation floor layout using GP4.

the models and incurring modification costs. The VPS can be also used to create moving images to show line workers assembly procedures, and this is more useful in helping them to understand the tasks than conventional paper-based instructions, contributing to a reduction in the time required for training.

3) Factory simulation using GP4

The virtual process planning and production line simulator, FUJITSU Manufacturing Industry Solution GP4 (Global Protocol for Manufacturing)[2] helps to represent production line layouts, personnel/equipment positions, and flow lines, and thus can optimize the production site. For example, we adopt a process in which the machine time cycles and floor layouts with human-machine harmonized production configurations are rendered on the simulator for deliberation, and the system is introduced to the actual production site, where it will be further improved through operation. **Figure 3** depicts an example where introduction of new equipment was considered using the simulation tool. It was also applied to the process of parts picking. The flow lines of pickers and parts locations were simulated for analysis, and rearranged so that the distance that pickers moved was minimized, and the simulated operations were then successfully achieved.

5. Quality and productivity enhancement through ICT deployment

We deploy an ICT-enhanced system in our production line to bolster product quality and productivity, which is described in this section.

1) System to ensure there are no untightened screws

In the screwing line, a system is in place that connects a screwdriver with a counter to ensure there are no untightened screws. The predetermined torque signal for tightening screws sent from the screwdriver is counted to detect any untightened screws for each product, and the system automatically stops the production line with an alarm if it detects any errors.

2) Assistance system

We have developed a system that enables workers to use the 3D data of the VPS on a tablet and in this way assists the production work. Unlike old-fashioned printed instruction manuals, it is easier for workers to understand the order of assemblage and spatial arrangement of each part by video. Another advantage is that the manual can be updated easily, which is useful in training line workers.

3) Store picking system

We have developed a picking system involving tablets, radio frequency identifiers (RFIDs), and wearable devices, to achieve accurate and efficient parts picking for complex parts configurations. The store picking cart system is illustrated in **Figure 4**. Picking

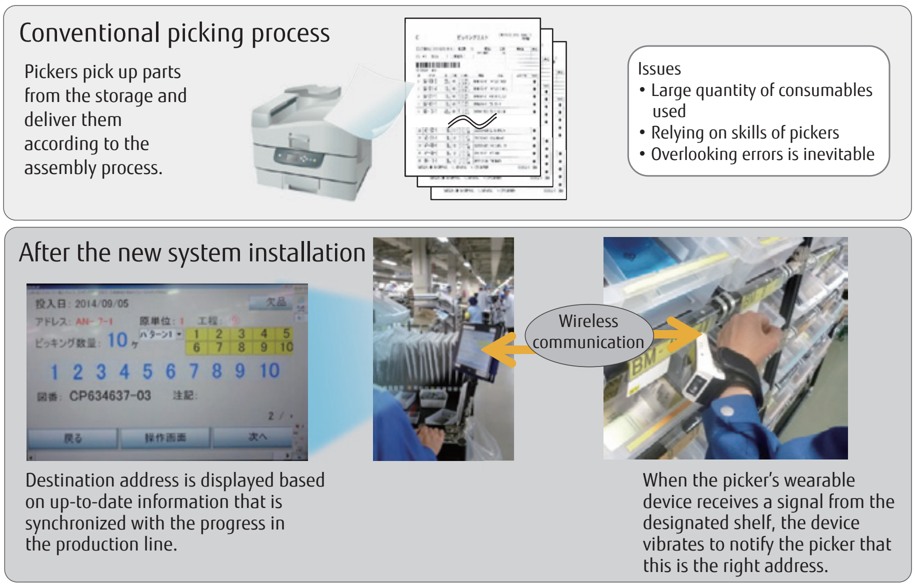


Figure 4
System of store picking cart.

orders sent by the system via a wireless network are displayed on a tablet installed on a trolley. When the RFID receiver of the picker's wearable device receives the signal of the address from the designated shelf's RFID, the device vibrates to notify the picker that it is the right shelf. After picking the right parts from the shelf, the next order appears on the tablet. The system thus helps to reduce human errors in the picking process. It also contributes to saving consumables such as paper and toner as compared to conventional printed instruction manuals.

4) Equipment maintenance system

We have developed an equipment maintenance system using augmented reality (AR) technology. Maintenance personnel in the PCB production line read the markers installed in the line equipment to find out the timing for parts replacement and to detect signs of malfunction without delay. The data are fed into the system via a tablet, and centrally managed on a server in real time. This helps to reduce the person-hours for equipment management and maintenance.

6. IoT-leveraged solution

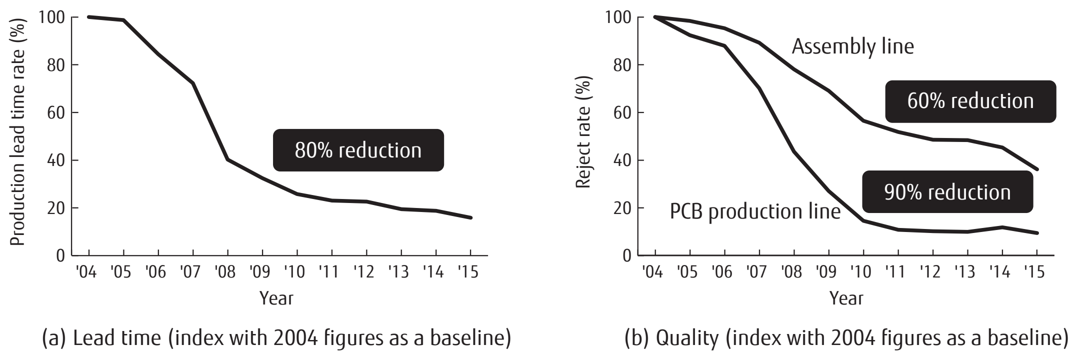
At Shimane Fujitsu, we have started an experiment to create a solution that leverages IoT.[3) The objective is to improve quality by analyzing the relationship between post-shipment field information and sensor data of various products. As the initial step, we are working to visualize the repair process for rejected products in a pre-shipping inspection. Using real-time positional data and shipment urgency levels, the system allows us to follow the progress made in the repair process and reduce the person-hours needed by the extra processes before delivery.

Future challenges include having image analysis of line workers and equipment in the testing process, and conducting relational analysis of these data with test log data, to use the results for further lowering the reject rate of finished products. Additionally, we will work toward minimizing indirect costs, and aim to extend the visualization initiative throughout the supply chain as well as between other factories.

7. Outcomes of Monozukuri innovation activities

Over the past decade, we have pursued the Monozukuri innovation activities to achieve high productivity, high quality and short lead time to market, as well as the versatile and responsive human-machine harmonized production system. **Figure 5** illustrates some of the outcomes of these activities. Production lead time has been cut by 80%, while visualization and ICT-based defect elimination have helped to reduce defects by 90% in PCB production, and 60% in assembly lines. The production cost has also been halved thanks to the enhanced productivity achieved by leveraging simulation technology.

These improvements together have helped to reduce the production area by 30% as well as the inventory. This has created some secondary benefits—for example, third-party storage space may be reduced, and redundant space in the factory may be put to use for service businesses.



(a) Lead time (index with 2004 figures as a baseline)　(b) Quality (index with 2004 figures as a baseline)

Figure 5
Outcomes of Monozukuri innovation activities.

8. Conclusion

This paper described the Monozukuri innovation activities at Shimane Fujitsu Limited, in terms of the human-machine harmonized production and ICT deployment in production lines.

We are continuing our efforts to further develop these activities. We will strive to elevate Monozukuri to a new level and to realize a system with flexibility and versatility in customization, capable of catering to ever-changing customer needs. We are also heading toward a smart factory based on the IoT and robotic technologies.

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