# Automation Techniques Supporting Smartphone *Monozukuri*

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**"Shortening the development period" and "reducing costs" have become key issues in today's mobile-phone market dominated by smartphones. Resolving these issues requires "vertical product launch" technology to support short-term manufacturing and automation techniques to cope with model changes. Fujitsu Peripherals Limited (FPE) has a history of developing ubiquitous products such as mobile phones and tablet computers and has accumulated a variety of mechatronics technologies such as large-scale system printing and facility automation to support *monozukuri* (Japanese-style manufacturing and production). By using automation techniques that apply these technologies and promoting generality in automation processes, FPE has been expanding *monozukuri* as part of the "Made in Japan" heritage. These techniques feature a platform consisting of different types of robots (parallel link robots, multi-joint robots, and direct-acting robots) and original customization of robot-hand sections and peripheral sections, such as for linked testing, to achieve automated systems matching the functional program element requirements. This paper discusses current issues in the development and manufacturing of smartphones and introduces automation techniques supporting "Made in Japan" *monozukuri* centered about solutions using FPE technologies.**

## 1. Introduction

Up until 2010, the most popular type of mobile phone in Japan was the clamshell, or folding, feature phone boasting a wide variety of features and functions such as a thin/water-resistant enclosure and mobile wallet. Yet, compared with the world market, Japan's mobile-phone market had become a somewhat unique, Galapagos-type environment ("Galapagos" describes the phenomenon of a product or a society evolving in isolation from globalization; it refers to a similar phenomenon observed in the Galápagos Islands where plants and animals evolved in isolation from other locations). This isolated environment became a barrier to entry for overseas mobile-phone makers. Now, however, as the mobile-phone market makes a transition to smartphones, even overseas makers are ramping up their support for multi-function phones. Thus, in today's market, Japanese makers find themselves in an environment in which they much compete with overseas makers, which makes shortening the development period and reducing costs prime issues.

In this paper, we introduce automation techniques for achieving high-quality products and lowering costs in smartphone *monozukuri* (Japanese-style manufacturing and production) while presenting application examples.

## 2. Problems in existing *monozukuri*

In mobile-phone *monozukuri*, the objective has been to develop mobile phones with functions that meet the needs of a wide range of customers, and to this end, many models have been targeted for development with shape, appearance, and functions differing from one model to another and each model having a very short manufacturing period, typically just a few months. As a consequence, improvements in *monozukuri* have been limited to those made on the basis of industrial engineering (IE), and the manufacturing process has come to be "people-based *monozukuri*." Manufacturing costs, meanwhile, have been high compared to process costs when using cheap labor outside of Japan, and the number of Japanese makers moving their manufacturing bases overseas has been gradually increasing as a result.

On the other hand, domestic manufacturing (within Japan) has its own advantages. Because of their proximity to the market, makers can deliver products at just the right time and can make production changes as needed. The problem here is how to lower the process costs of domestic manufacturing, which are high compared to overseas labor costs, while taking advantage of shorter development periods and shorter total lead times. The development period and total lead time can be shortened by transforming the conventional series-type development process into a parallel-type one (**Figure 1**) that exploits the benefits of design and manufacturing bases inside the country.

In short, it has become difficult to achieve competitive costs by using conventional *monozukuri* techniques, and the need has grown for a dramatic jump in efficiency through new innovation in *monozukuri*.

## 3. Automating the line

Automation from the commencement of mass production is essential to the manufacturing of mobile phones having short development and manufacturing periods. However, given that mobile phones feature a large number of models with shape, appearance, and functions differing from one product to another, the biggest problem facing the automation of mobile phones is "generality" in the automation process.

At Fujitsu Peripherals Limited (FPE), we have been developing automated machinery by extracting the tasks common to diverse models. Before we decide which tasks to automate, we consider the effects of automation, the generality of the automation process, and how long the automated machinery will be usable.

The first task that we undertook to automate was screw tightening. Since current mobile phones have a water-resistant function, poor screw tightening can be directly associated with a defective product. With this in mind, we prioritized the automation of screw tightening and by extension the improvement of product quality and set out to develop an automated machine for this purpose.

Key features of this automated machine (**Figure 2**) are support for small M1.0 screws, defect-detection functions such as for screw float and spinning, and

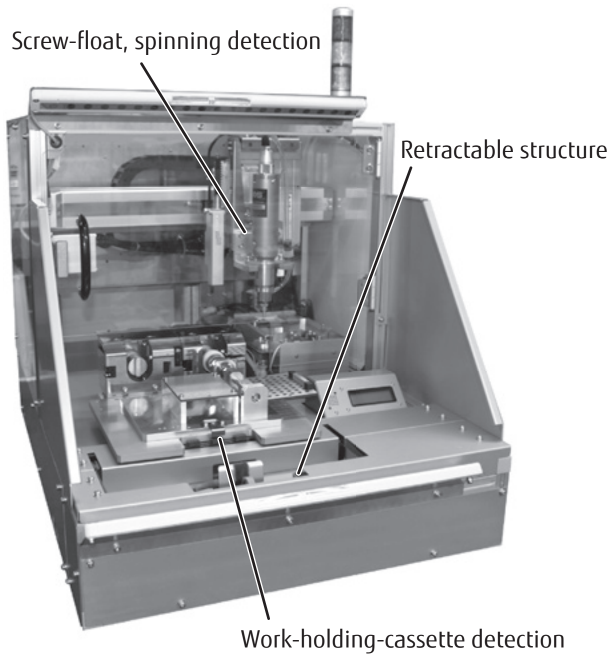


**Figure 2**
**Automatic screw-tightening machine.**

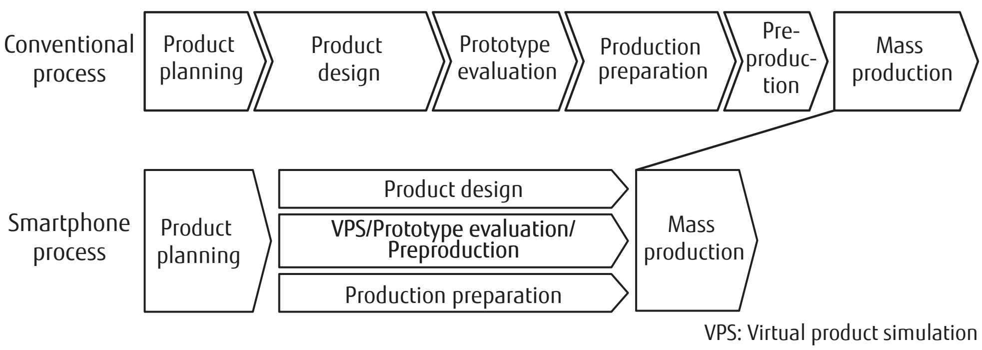


**Figure 1**
**Device development processes.**

significant shortening of model-switching time by providing a retractable structure and automatically detecting the work-holding cassette unique to each model. This automated machine, which will optimize screw-tightening conditions, is currently being rolled out for all models.

Our next target for automation was the secondary assembly process for printed circuit boards (PCBs), which consists of tasks like attaching shield plates and pasting tape. The shape and specifications of target parts, though different for each model, had some commonality, and we investigated the automation of common parts-handling work.

Taking into account the complex motion of the manual operations associated with these tasks and the need for high-speed operation, we selected parallel link robots as a basis for achieving our automation objectives. Automation of an assembly process requires "automation of target operations," "automation of parts feeding," and "automation of work handling." When setting out to automate this process, we reviewed the configuration of the present manufacturing line (work procedure, configuration of line personnel, line layout) and investigated automation specifications on the basis of our image of the final automated line and decided to introduce parallel link robots in stand-alone form (**Figure 3**). In addition, we developed and deployed automated line machinery to automatically do the work of attaching parts after it receives a work order

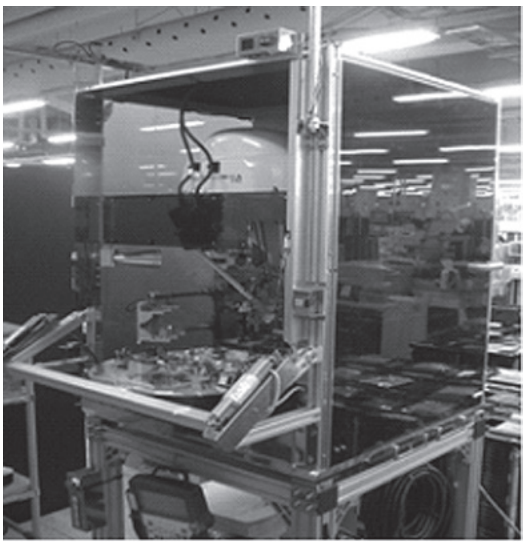

**Figure 3**
**Parallel link robot.**

from an operator received from an operator.

We reduced the set-up change time by providing a hand-tool switching function and automating this function at multiple line locations. We deployed automated machinery in this new manufacturing line to link with and transport PCBs to the stand-alone parallel link robots. We also added a manufacturing-label pasting machine, a camera for product recognition, and new automated machinery for handling PCBs delivered to the PCB separator, i.e., an arm robot an arm robot. In this way, we constructed a uniformly automated line linking the automated assembly machines (**Figure 4**). This line, which requires only one operator to run, is now in operation. All of the automated machines introduced here can be extended to other models or next-generation models through a set-up change.

The most important issue in moving ahead with automation is the establishment of elemental automation technologies since they have a great effect on resolving other key issues such as reducing the development time of automated machinery and achieving generality in the automation process. For this reason, we will be focusing more research on elemental automation technologies to support the production of next-generation smartphones.

## 4. Automation techniques

At FPE, we are enhancing *monozukuri* as part of the "Made in Japan" heritage while making extensive use of automation techniques and promoting generality in the automation process. The short manufacturing life of mobile phones and the rapid transition to smartphones has underscored the need for rationalization through "vertical product launches" (i.e., quick and effective product launches) achieved by introducing automated machinery and processes.

In this section, we describe techniques for achieving short-term development/manufacturing of automated machinery (modular design) and parameter design and short-term evaluation techniques for improving the quality of automated machinery (quality engineering).

### 4.1 Modular design

1) Objectives

FPE uses modular design for the five objectives listed below. It prioritizes, in particular, modular design

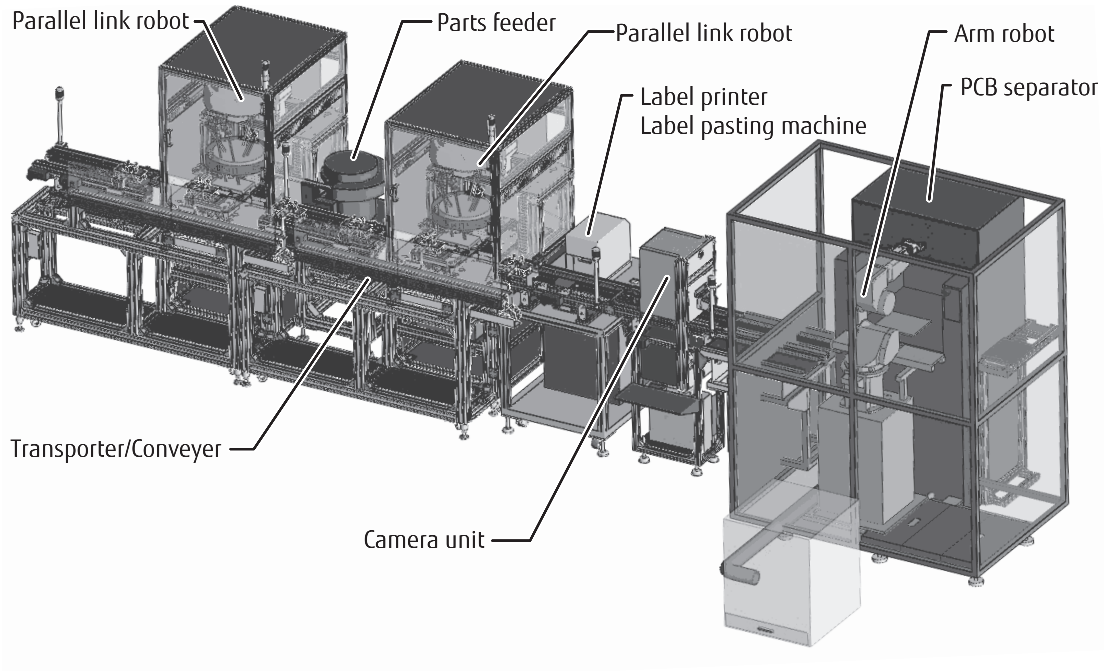


**Figure 4**
**Configuration of automated machinery for secondary assembly of printed boards.**

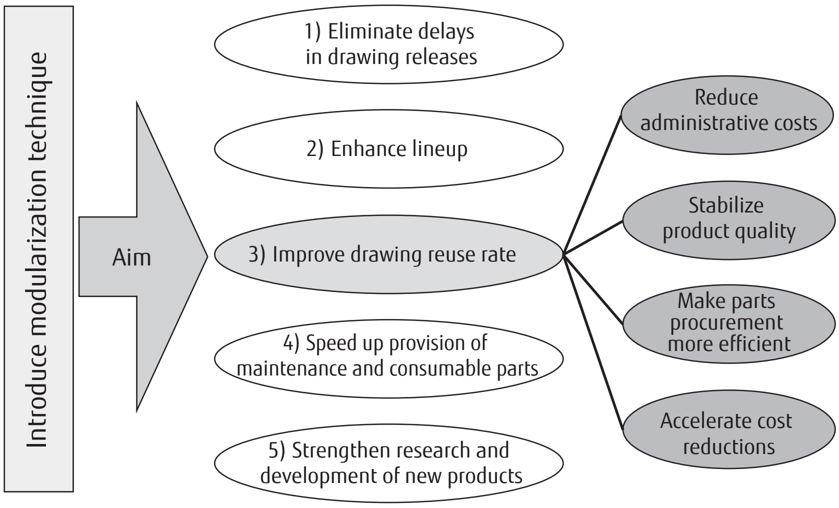


**Figure 5**
**Modularization technique.**

for making the selection and use of design drawings more efficient since doing so has a direct effect on shortening the development period and reducing costs (**Figure 5**).

- Shorten lead time and prevent production mix-ups by eliminating delays in the release of design drawings
- Facilitate the provision of options and variations and enhance the product lineup to meet customer needs
- Make use and reuse of design drawings more efficient
- Speed up provision of maintenance and consumable parts by clarifying product configuration

- Strengthen research and development of new products by effectively shifting resources.

2) Support of diversification

Modularization refers to the process of dividing the parts making up a product into functional units, combining those functional units into a basic section, and combining that section with a custom section corresponding to particular needs.

Increasing the variation of such combinations makes it possible to meet short-term quality, cost, and delivery (QCD) requirements with respect to diversification (variation) of product specifications.

3) Administrative issues

Having to create drawings for each product in accordance with customer specifications, rather than using modular drawings, means that completely new drawings have to be prepared for each product. As a result, the reuse rate of drawings at the equipment level is zero, resulting in very inefficient design in the development of automated machines having a small production run.

4) Means of resolving issues

Here we present our approach to setting up a modular design system. To reduce the amount of labor required for custom designs, "module" itself must be defined, and a mechanism for providing and managing variation through the use of modules must be established.

Specifying modules can provide uniformity in design philosophy when sharing and reusing drawings. It can also help to raise the drawing reuse rate and reduce labor hours as well as improve design and manufacturing quality by reusing drawings having a proven track record. This module-based mindset can also help to make downstream processes such as manufacturing and quality assurance more efficient (**Figure 6**).

5) Effects

The effects shown in Figure 6 with respect to product QCD have been obtained by modularization. There have also been indirect effects, such as the ability to visualize sales proposals and to mitigate the problem of "bottleneck" parts.

FPE's application of its technologies to a modularized product matrix have led to tangible, quantifiable results, and the period from intra-group technology proposal and estimation to detailed design has been significantly shortened. The introduction of module-based development has shortened the development period by 50%, enabling the customized section of a product to be designed within a week. This has had a substantial effect on profit. In addition, modularization is now being applied to all work areas including sales, production arrangement, and manufacturing, and the prospect of reducing the total lead time from order to delivery from the current three months to two is promising. The modularized design of the robot-platform section and options-platform section in the Fujitsu technology matrix has been completed. Combining these two platforms has enabled us to provide automated machinery that meets customer needs in a short period of time (**Figure 7**).

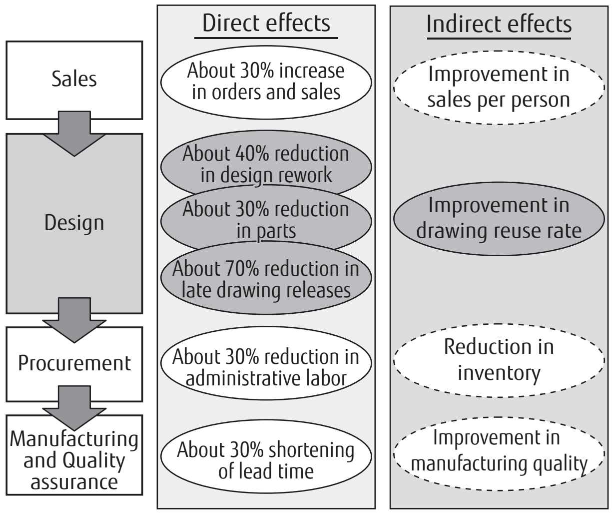


**Figure 6**
**Effects of modularization.**

## 4.2 Introduction of quality engineering[note)]

1) Aim

The application of quality engineering methods enables short-term development and deployment of automated machinery with optimally designed parameters, that is, with high robustness to external disturbances. This, in turn, enables early design of product functions and measures for ensuring their stability while making it possible to quickly perform

note) Quality engineering is based on methods for efficiently developing technologies and new products. They are also called "Taguchi methods" after Genichi Taguchi, the engineer and statistician who developed them.

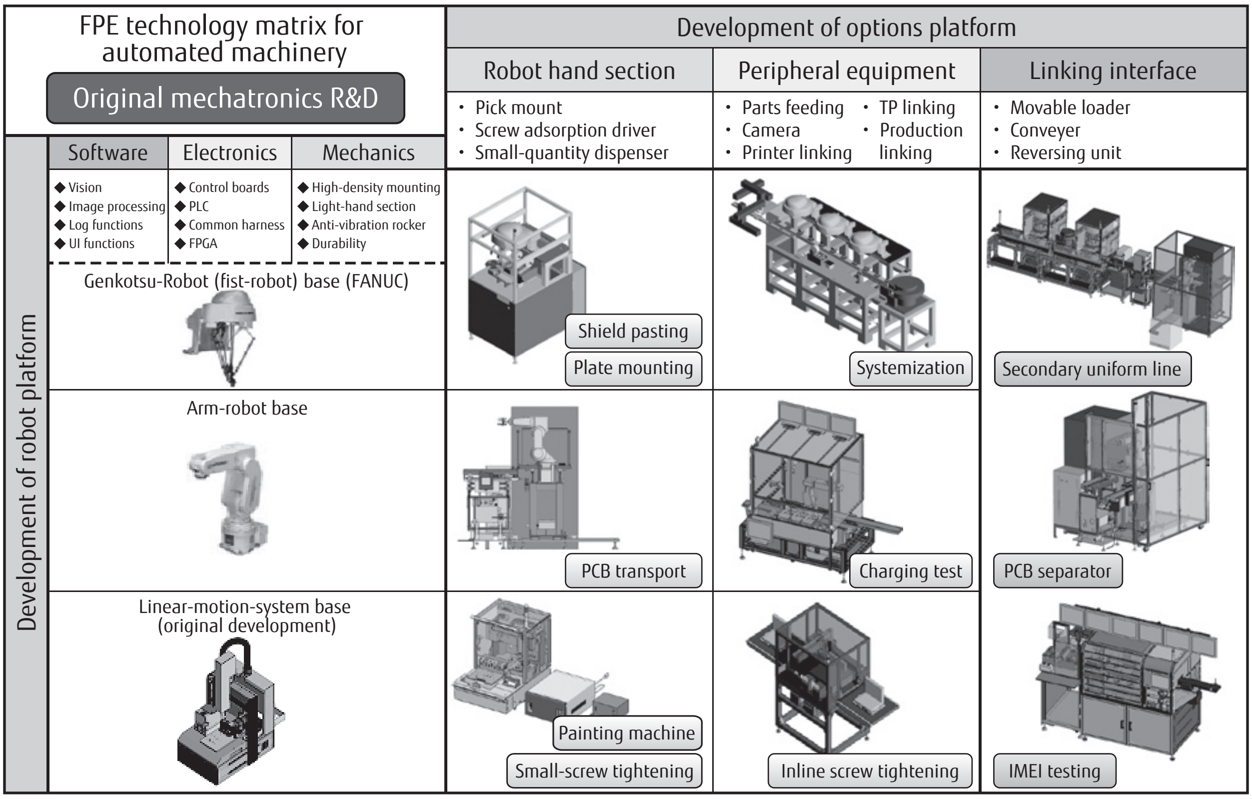


**Figure 7**
**FPE technology matrix for automated machinery.**

simulations to find the causes of quality problems even after product deployment. Quality engineering addresses the following issues:

- Technical issues resulting from the need for short-term parameter design
- Technical issues that are difficult to solve
- Technical issues predicted to be difficult to solve

Addressing the above issues is essential in the design of automated machinery needed for urgent vertical product launches.[1)]

2) Expected effects

Three benefits can be obtained by evaluating and improving functionality through quality engineering.

- Early to market—Shortening of development period

Since the merits of the technologies to be used in the product and the limitations of those technologies can be evaluated in a shorter period prior to product planning, development efficiency can be greatly improved, and the development period can be significantly shortened.

- Generality—Applicability to similar products

Since the fundamental strength of applied technologies can be improved by implementing quality engineering, support can be provided without problem to the development of similar products using the same technologies and even to a new series of products.

- Reproducibility—Reliability of experimental results

The result of confirming in the development stage that a technology is inherently strong against deterioration and changes in usage scenarios and environmental conditions enables the prevention of problems during manufacturing or after the product enters the market, which can significantly reduce claim expenses (Taguchi loss function).[1)]

3) Application example: small-screw-tightening machine

To optimize the screw-tightening function, we devised an experiment. We established and set control factors, including the driver's rise-and-fall speed, pressing force, and rotating speed, and performed experiments on the basis of an orthogonal array that takes the offset of the driver bit to be an error factor. Next, we measured quality from a cause-and-effect analysis diagram prepared from experiment results (output) and derived optimal conditions by appropriately selecting the level of those factors with a high signal-to-noise ratio (S/N) and high sensitivity.[2)]

4) Expanding application of quality engineering—From design verification to quality-assurance testing

In this sub-section, we introduced an example of applying quality engineering in the design stage. Quality engineering enables us to obtain a variety of statistical data such as the standard deviation of set values as well as a cause-and-effect analysis diagram.

Use of quality engineering is not restricted to the design department—it is a concept that should also be applied to *monozukuri* on the whole. For this reason, we are in the process of expanding the range of its application. We not only apply all aspects of quality engineering in each case but also it as an optimized evaluation tool on a project-by-project basis such as to judge quality and reliability by applying statistical techniques to data obtained from an orthogonal array of design elements.[3)]

### 4.3 Elemental automation technologies

It is no exaggeration to say that automation is the last stronghold of the "Made in Japan" heritage. The automation activities described above are being expanded across *monozukuri* (horizontal development), and the plan is to establish new automation technologies in parallel. For example, in sensory tests classified as part of a testing process, the feel of clicking, the judgment of voice quality, and the noticing of small painting defects depend on the human senses of touch, hearing, and sight, respectively, and once these have been quantified, it will be necessary to develop sensing technologies that can be incorporated in automated machinery. At FPE, we are working on the development of such technologies in collaboration with Fujitsu Laboratories Limited and other parties.

## 5. Conclusion

This paper introduced automation techniques used to support smartphone *monozukuri* while presenting specific examples. FPE makes the most of having both development and manufacturing departments promote *monozukuri* that satisfies the needs of Fujitsu customers. Looking to the future, we plan to contribute to the further evolution of "Made in Japan" *monozukuri* and to the expanded use of ubiquitous products in society.

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