Innovation of Automobile Manufacturing Fundamentals Employing New JIT: Developing Advanced Toyota Production System

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Abstract
This paper introduces the Advanced Toyota Production System (ATPS) that contributes to the innovation of automobile manufacturing fundamentals employing New JIT surpassing JIT. In order to realize this, the author has constructed the ATPS utilizing new three core models: New Global Partnering Production Model (NGP-PM), Upgrading Intelligence of Production: High-cycle Model (UIP-HM), and New Japan Global Production Model (NJ-GPM). The author has developed these models at Toyota Manufacturing USA and others, and has verified the effectiveness of the Advanced Toyota Production System.

Keywords: Advanced Toyota Production System (ATPS), New JIT, Automobile manufacturing fundamentals, Toyota Manufacturing USA

Introduction
The top priority of the industrial field today is the new deployment of global marketing in order to survive the era of global quality competition (Amasaka, 2009a). All over the world, including Japan, advanced companies are shifting to global production to realize worldwide uniform quality and production at optimum locations to enable survival in fierce competition. From this point of view, the reform of Japanese-style management technology is desired once again. In this need for improvements, Toyota is no exception (Goto, 1999: Amasaka, 2000ab).

The aim of this study is to reassess the way management technology was carried out in the automobile manufacturing industry and establish “New JIT, new management technology principle” surpassing JIT (Just in Time) for innovation of automobile manufacturing fundamentals (Amasaka, 2002, 2014a). In order to realize this, the author has created the “Advanced Toyota Production System (ATPS)” employing New JIT to contribute to worldwide uniform quality and production at optimal locations as a strategic deployment of global production through high quality assurance manufacturing (Amasaa, 2007ab, 2009b).

As a concrete development, the author has constructed the ATPS by utilizing three core models: “New Global Partnering Production Model (NGP-PM)” for bringing overseas manufacturing up to Japanese standards, “Upgrading Intelligence of Production: High-cycle Model (UIP-HM)” for the advanced production business process, and “New Japan Global Production Model (NJ-GPM)” for the simultaneous achievement of quality, cost, and delivery (QCD) requirements, and has developed these models at Toyota Manufacturing USA and others (Ebioka et al., 2007: Amasaka and Sakai, 2008, 2011).
The significance of New JIT strategy, surpassing JIT

Today, Toyota's JIT has already been developed as an internationally shared system, known as a Lean System, and is no longer an exclusive technology of Toyota in Japan (Ohno, 1977). As a result, the superiority in quality of Japanese products assured has been gradually undermined in recent years (Amasaka, 2002; Taylor and Brunt, 2001). To realize manufacturing that places top priority on customers with a good QCD and in a rapidly changing technical environment, it is important to develop a new production technology principle and establish new process management principles.

Furthermore, a new quality management technology principle linked with overall activities for higher work process quality in all divisions is necessary for an enterprise to survive (Burke and Trahan, 2000). The creation of attractive products requires each of the sales, engineering/design, and production departments to be able to carry out management that forms linkages throughout the whole organization (Seuring, et al., 2003). Having said the above, it is the author’s conjecture that it is clearly impossible to lead the next-generation by merely maintaining the two Toyota management technology principles, Toyota Production System and TQM.

To overcome this issue, it is essential to renovate not only TPS, which is the core principle of the production process, but also to establish core principles for marketing, design and development, production, and other departments (Amasaka, 2002). The next-generation management technology model, New JIT, which the author has established through theoretical and systematic analyses, as shown in Figure 1, is the JIT system for not only manufacturing, but also customer relations, marketing, product planning, R&D, design, production engineering, logistics, procurement, administration and management, for enhancing business process innovation and introduction of new concepts and procedures (Amasaka, 2002, 2014ab).

New JIT contains hardware and software systems as the next-generation technical principles for accelerating the optimization (high-linkage) of business process cycles of all divisions. The first item, the hardware system, consists of the Total Development System (TDS), Total Production System (TPS), and Total Marketing System (TMS), which are the three core elements required for establishing new management technology.

![Figure 1 — New JIT, New Management Technology Principle](image-url)
principles. For the second item, the strategic quality management system, the author has established “new principle of quality management, TQM-S (Total Quality Management by utilizing Science SQC) called Science TQM, in Toyota as a software system for improving the business process quality of the 13 departments (Amasaka, 2002, 2004ab).

**Creation of Advanced Toyota Production System employing New JIT**

*Demand for achieving global production*

Dramatic changes are occurring in today’s manufacturing industry are truly severe. It is vital for Japanese manufacturing not to fall behind in the advancement of management technologies. In order for a manufacturer to succeed in the future world market, it needs to continue to create products that will leave a strong impression on customers and to offer them in a timely fashion (Amasaka, 2000ab, 2002).

Recent years have seen significant changes in manufacturing, including the evolution of digital engineering, the shortening of product lead time, and simultaneous global start-up. In order to prevent a lag in the transformation of production sites, the most critical issue has become creating superior products based on the customer-first policy of QCD (Amasaka, 2004b, 2008).

However, it has been observed that, despite the fact that overseas plants have the relevant production systems, facilities, and materials equivalent to those that have made Japan the world leader in manufacturing, the building up of quality—assuring of process capability (Cp), and machine capability (Cm) has not reached a sufficient level due to the lack of skills of the production operators at the manufacturing sites.

In this context, many studies are being carried out abroad on globalization and TQM (Amasaka, 2004a: Lagrosen, 2004: Ljungström, 2005: Hoogervorst et al., 2005). As a countermeasure to this problem, and in order not to lag behind the evolution of digital engineering—the transition to advanced production systems at production plants, Japanese manufacturers expect the production plants in Japan to serve as mother plants. They would welcome overseas production operators to these plants, and promote a local production program—transplanting the know-how of Japanese manufacturing (Amasaka, 2007bc; Amasaka and Sakai, 2010).

It is by no means easy to transfer the know-how of Japanese manufacturing directly to overseas production bases as mentioned above. In other words, there is always an obstacle to overcome—a suitable production system for each production base, due to the difference in ability (level of skill) or national characteristics between the local production site and Japan. Therefore, to cope with this situation, an environment in which the creation of labor values—Employee Satisfaction (ES), advanced skills, a sense of achievement, and self development—can be realized must be urgently considered (Amasaka, 2007b, 2008: Yamaji et al., 2007).

In order to accomplish this, the author surmises that it is necessary to develop a type of manufacturing that fits the local circumstances of various overseas production bases and to advance from Japanese mother plants to global mother plants.

*Advanced Toyota Production System for evolution of manufacturing fundamentals*

In order to offer customers high value-added products and prevail in the worldwide
quality competition, it is necessary to establish an advanced production system that can intellectualize the production technology and production management system. This will in turn produce high performance and highly functional new products. Therefore, the author (Amasaka, 2007ab) has created the Advanced Toyota Production System so-called New Japan Production Model (NJ-PM), as introduced in Figure 2, in order to enable the strategic deployment of evolution of manufacturing fundamentals.

The mission of Advanced Toyota Production System is to contribute to worldwide uniform quality and production at optimal locations as a strategic deployment of global production and to realize CS, ES, and SS through high quality assurance manufacturing. With a concrete target, this model is the systemization of a new, next-generation Japanese production management system and this involves the high-cyclization of the production process for realizing the simultaneous achievement of QCD requirements.

In order to make this system into a reality it will be necessary to (i) adapt it to handle digitalized production and (ii) reform it to realize an advanced production management system. Other prerequisites for realizing this include the need (iii) to create an attractive workplace environment that (iv) accommodates the increasing number of older and female workers at the production sites and to cultivate intelligent production operators. These four measures need to be organically combined and spiraled up in order to make the simultaneous achievement of QCD possible.

One of the technical elements necessary for fulfilling these requirements is the reinforcement of maintenance and improvement of process capabilities by establishing an intelligent quality control system. Second, a highly reliable production system needs to be established for high quality assurance. Third, reform is needed for the creation of a next-generation working environment system that enhances intelligent productivity. Fourth, intelligent production operators need to be cultivated who are capable of handling the advanced production system and an intelligent production operating
development system needs to be established.

Through strategic management of these elements, worldwide uniform quality and simultaneous launch (production at optimal locations) will be possible (Amasaka, 2009; Sakai and Amasaka, 2008a). The author believes that what determines the success of global production strategies is the advancement of technologies and skills that are capable of fully utilizing the above mentioned advanced production system in order to realize reliable manufacturing at the production sites (Amasaka and Sakai, 2010, 2011).

**New Global Partnering Production Model for expanding overseas manufacturing strategy**

For advanced Japanese companies in the process of developing global production, the most important issue is how to “bring overseas manufacturing to Japan standards” at overseas plants. The author therefore has constructed in Figure 3, the New Global Partnering Production Model (NGP-PM) which generates a synergetic effect that organically connects and promotes continual evolution of the production plants in Japan and overseas, as well as greater cooperation among production operators (Amasaka, 2007b, 2009; Ebioka et al., 2007).

The mission of NGP-PM is the simultaneous achievement of QCD in order to realize high quality assurance. The essential strategic policies include the following three items: first of all, (A) the establishment of a foundation for global production, “realization of global mother plants - advancement of Japanese production sites”; second, (B) achieving the “independence of local production sites” through the incorporation of the unique characteristics (production systems, facilities, and materials) of both developing countries (Asia) and industrialized countries (US, Europe); and third, (C) the necessity of structuring of a Global Network System for Developing Production Operators (DNS-DPO) to promote knowledge sharing among the production operators in Japan and overseas as well as for the promotion of higher skills and enhanced intelligence.

In order to realize this, with ATPS as the foundation, it is essential to create a spiraling increase in the four core elements by increasing their comprehensiveness and high cycle-ization. Specifically, in “realizing global mother plants” if Japanese and overseas manufacturing sites are to share knowledge from their respective viewpoints, the core elements must be advanced. To achieve this, a necessary measure is to design separate approaches suited to developing and industrialize countries.

First, in developing countries “Asia”, the most important issue is increasing the autonomy of local manufacturing sites. At these sites, “training for highly skilled operators (focus on manual laborers)” that is suited to the manual-labor-based manufacturing sites is the key to simultaneous achievement of QCD. Similarly, in industrialized countries, where manufacturing sites are based on automatization and increasingly high-precision equipment, “training of intelligence operators” resulting in “realizing highly reliable production control systems and ensuring high efficiency” is the key to simultaneous achievement of QCD.
Furthermore, production operators trained at “global mother plants” (3) can cooperate with operators at overseas production bases, and in order to generate the synergistic results, can work to “localize global mother plants” in a way that is suited to overseas production bases.

Developing Advanced Toyota Production System at Toyota Manufacturing USA

Upgrading Intelligence of Production: High-Cycle Model for the advanced production business process

Considering the points mentioned above, the author has recognized the need to upgrade the intelligence of the production sites in order to successfully carry out the strategic deployment of the new manufacturing system. Therefore, the author has established a “Upgrading Intelligence of Production: High-cycle system (UIP-HS)” for the advanced production business process for expanding overseas manufacturing strategy as a top runner at Toyota Manufacturing USA (Amasaka, 2007b: Amasaka and Sakai, 2008).

The objective of this system employing ATPS is effective management in order to improve the intelligent productivity of production operators and to consolidate the information about highly cultivated skills and operating skills for advanced facilities into a commonly shared system. In this way, the production operators can upgrade their simple labor work to intelligent production operation. To realize this, the four key technologies depicted in Figure 4 (I-IV) are to reform for intelligent operation of the production sites:

(I) The “Intelligent Quality Control System” aims to achieve high quality assurance through digital engineering, reinforcement of quality incorporation focusing on intelligent control charts, and ensuring the process capability (Cp) and machine capability (Cm) through innovation of the operating and maintenance systems of production facilities.

(II) The “Highly Reliable Production System” that enhances intelligent productivity with highly skilled workers, aims to construct a global production network system
through incorporation of the latest technologies, such as CAE, CAD, robots, and the use of CG (computer graphics).

(III) The “Renovated Work Environment Model” aims to improve the value of labor and bring about a comfortable workplace environment that can accommodate the increasing number of older and female workers in the labor force.

(IV) The “Intelligent Operators Development System” aims to realize the early cultivation of highly skilled workers through utilization of visual manuals supported by the latest IT and virtual technology.

**Figure 4—Upgrading Intelligence of Production: High-cycle Model (UIP-HM)**

**Application: Strategic development of New Japan Global Production Model**

Global production must be deployed in order to establish the kind of manufacturing that is required to gain the trust of customers around the world by achieving a high level of quality assurance and efficiency and shortening lead times to reinforce the simultaneous achievement of QCD requirements. The vital key to achieving this is the introduction of a production system that incorporates production machinery automated with robots, skilled and experienced workers (production operators) to operate the machinery, and production information to organically combine them.

Thus, having recognized the need for a new production system suitable for global production, Amasaka and Sakai (2011) have created a New Japan Global Production Model (NJ-GPM), as shown in Figure 5 to realize the strategic deployment of the Advanced Toyota Production System. The purpose of this model is to eradicate ambiguities at each stage of the production process from production planning and preparation through production itself and process production system for global production that will improve the reliability of manufacturing through the clarification and complete coordination of these processes.

More specifically, this model is intended to (i) employ numeric simulation (CAE) and CG
right from the production planning stage to resolve technical issues before they occur, (ii) reinforce production operators’ high-tech machine operating skills and manufacturing capabilities, and (iii) visualize the above using IT in order to reform production information systems to create a global network of production sites around the world. The six core technologies that constitute this model and their characteristics are described below.

(I) Reform of production planning: TPS Layout Analysis System (TPS-LAS) is a production optimization system intended to realize a highly reliable production by optimizing the layout of both the production site as a whole and each production process with regard to production lines, robots, and production operators through the use of numeric simulation (Sakai and Amasaka, 2006b). TPS-LAS is made up of four subsystems: Digital Factory CAE System (LAS-DFS), Robot Control CAE System (LAS-RCS), Workability Investigation CAE System management (LAS-WIS), and Logistic Investigation CAE System (LAS-LIS) as shown in Figure 6.

![Figure 5—New Japan Global Production Model (NJ-GPM)](image-url)
(2) Reform of production preparation: Human Intelligence—Production Operating System (HI-POS) is an intelligent operator development system intended to enable the establishment of a new people-oriented production system whereby training is conducted to ensure that operators develop the required skills to a uniform level, and diagnosis is then carried out to ensure that the right people are assigned to the right jobs (Sakai and Amasaka, 2006a). HI-POS contains two sub-systems: the Human Intelligence Diagnosis System (HID), and Human Integrated Assist System (HIA) (Sakai and Amasaka, 2007c, 2008b) as shown in Figure 7.
(3) Reform of the working environment: Intelligent Production Operating System (IPOS) is intended to lead to a fundamental reform of the work involved in production operations by raising the technical skills level of production operators and further improving the reliability of their skills for operating advanced production equipment within an optimized working environment. IPOS is made up of three sub-systems: the Virtual-Intelligent Operator System (V-IOS) (Sakai and Amasaka, 2003), Aging & Work Comfortable Operating System (AWD-COS) (Amasaka, 2007c), and Robot Reliability Design-Improvement Method (RRD-IM) (Sakai and Amasaka, 2007a). As an example of V-IOS for assembly work, Figure 8 illustrates the a) training processes, b) work training systems, and standard work sheet.

(4) Reform of process management: TPS Quality Assurance System (TPS-QAS) is an integrated quality control system intended to ensure that quality is built into production processes through scientific process management that employs statistical science to secure Cp and Cm (Amasaka and Sakai, 2009). TPS-QAS is made up of two sub-systems: Quality Control Information System (QCIS) and Availability & Reliability Information Monitor System (ARIM) (Amasaka and Sakai, 1998) as shown in Figure 9 and Figure 10.
(5) Visualization of production processes: The Human Digital Pipeline System (HDP) ensures that top priority is given to customers through manufacturing with a high level of quality assurance (Sakai and Amasaka, 2007b). This involves the visualization of intelligent production information throughout product design, production planning and preparation, and production processes, thereby facilitating the complete coordination of these processes as shown in Figure 11.

![Figure 11—Human Digital Pipeline (HDP) System](image)

(6) Globalization of production information: The Virtual-Maintenance Innovated Computer System (V-MICS) is a global network system for the systemization of production management technology necessary to realize a highly reliable production system, which is required to achieve worldwide uniform quality and production at optimal locations (Sakai and Amasaka, 2005) as shown in Figure 12. Production operators are able to browse information using DB and CG whenever necessary from the client computers at each maintenance station via the network, and can also input any special items as necessary.

![Figure 12—Virtual - Maintenance Innovated Computer System (V-MICS)](image)
For example, the software allows authors to execute the manual creation program by registering (i) procedures and descriptions and (ii) a display screen to convert the maintenance manual into a visual manual that can be read via the Internet as shown in Figure 13. Below is an example for installing assembly lines in a new overseas plant. The example shown here is a robot maintenance manual where CG depicting the disassembled structures and motor replacement is presented to elucidate its effectiveness.

**Figure 13—Example of a Visual Manual using Internet (Robot)**

Development ATPS at Toyota Manufacturing USA and others
Concretely, the author has verified the effectiveness of developing these models at Toyota Motor Manufacturing, Texas, Inc. (TMMTX) \(^{40-42}\), and other countries (in such cases as Thailand, Turkey, Malaysia, China, and Vietnam) \(^{26,43-46}\). As the first example, Figure 14 shows an application of skill training for newly employed production operators displaying a trimming process.

**Figure 14—Skill Training Curriculum for New Overseas Production Operators**
As the second example, Figure 15 shows an application case of shortened training for new overseas production operators. After conducting the aptitude test, skill training utilizing the visual manual and intelligent IT system was repeatedly carried out until the standard set out in the evaluation sheet was met. The deployment of APS reduced the conventional training period by more than half, from two weeks to five days, leading the full-scale production to a good start.

The development of NG-PM, UIP-HM, and NJ-GPM are innovation of automobile manufacturing fundamentals of ATPS at Toyota manufacturing USA. The author has verified the effectiveness of developing these models at Toyota Motor Manufacturing, Texas, Inc. (TMMTX: Fikes, Li, and Sakai, 2016), and others (Ebioka et al., 2007; Yeap et al., 2010; Shan et al., 2011; Amasaka, 2013; Miyashita and Amasaka, 2014).

**Conclusion**

To realize manufacturing that places top priority on customers, the author has created the ATPS employing New JIT, new management technology principle surpassing JIT. As a concrete development, the author has constructed the ATPS consisting of new three models as follows; NG-PM, UIP-HM, and NJ-GPM, and has developed these models at Toyota Manufacturing USA and others. In the future, ATPS employing New JIT will be contributed as “new principle of next-generation manufacturing” of worldwide production management technology strategy.

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