MANUFACTURING IN JAPAN AND FROM JAPAN

K. Takahashi, K. Morikawa, K. Nagasawa
Division of Electrical, Systems and Mathematical Engineering, Faculty of Engineering, Hiroshima University 1-4-1, Kagamiyama, Higashi-Hiroshima 739-8527, Japan

Abstract
In Japan, companies have continuously improved the performance of quality, cost, delivery, environment, safety, and morale of Japanese Manufacturing Systems (JMS) by using unique management approaches, total quality management (TQM), Toyota production system (TPS), and total productive maintenance (TPM). After the introduction, they are implemented by many companies and organizations not only in Japan but also all over the world. Also, in modern Japan, Industry 4.0, IoT, and AI are considered, and various activities are promoted. In this paper, the literature on the research topics and methodologies related to TQM, TPS, and TPM are reviewed. Also, by referring the empirical studies on TQM, TPS, and TPM in overseas companies, the findings and issues to transfer them are discussed. Also, the current situation on the recent practical activities and academic research are reviewed.

Keywords:
TQM, TPS, TPM, Industry 4.0, IoT, technology transfer.

1 INTRODUCTION
Previously, “Made in Japan” was a word to show low price and low-quality products. However, it has been changed to a reasonable price and high quality. For the change, in Japan, not only specific some companies but also many or all companies have continuously improved the performance of quality, cost, delivery, environment, safety, and morale. One reason is that Japan was in economic development, but the other is that Japanese manufacturing system (JMS) and Japanese management system are established and promoted in Japan. In this paper, in JMS with three management approaches, TQM, TPS, and TPM are considered, and the influence upon Japanese manufacturing and the manufacturing all over the world are considered. Also, by reviewing the recent activities in Japan, the remaining issues in the future of Japanese manufacturing are summarized.

In the activities of improving the performance, total quality management (TQM), Toyota production system (TPS), and total productive maintenance (TPM) can be pointed out as management approaches developed in Japan. After introducing the approaches, they are applied to many companies and organizations not only in Japan but also all over the world. For promoting the management approaches, various research topics and methodologies, such as quality function deployment (QFD), Just-in-Time (JIT), Kanban system, U-shape line are developed and implemented. In this paper, the literature on the research topics and methodologies related to TQM, TPS, and TPM are reviewed, and future directions are shown.

Furthermore, the markets, suppliers, and manufacturing sites of Japanese companies spread not only in Japan but also all over the world, and global supply chains that include global suppliers, manufacturing sites, and distributions become popular. Then, the optimization and management of global supply chain are requested. For the purpose, JMS and the management approaches, such as TQM, TPS, and TPM, should be deployed to all the global sites. The success of the deployment significantly depends on the technology transfer, and by reviewing the literature on technology transfer of TQM, TPS, and TPM, the research topics and academic research are discussed in this paper.

Also, in recent Japan, Industry 4.0, IoT, and AI are considered, and various activities are promoted. Recent activities are mainly initiated by governments and companies in Japan, and only a few academic research on these topics has been considered. This paper reviews the current situation of the practical activities and academic research and shows remaining research issues on these topics.

2 JAPANESE MANUFACTURING SYSTEMS (JMS)
Many JMSs utilize management approaches, TQM, TPS, and TPM. In this section, the overview and research on the three management approaches are explained.

2.1 Total Quality Management

Overview of TQM
TQM is one of management approaches related to quality control (QC). QC is a process by which entities review the quality of all factors involved in the production. However, in Japan, the management approach related to QC is developed and revolutionized.

At first, in 1950, statistical quality control (SQC) is introduced to Japan by Deming, and total quality control (TQC) popularized by Feigenbaum is introduced. TQC stresses involvement of all departments in addition to production (e.g., accounting, design, finance, human resources, marketing, purchasing, sales). Then, the introduced TQC is modified into Japanese TQC or Company-Wide QC (CWQC) and then to TQM by defining concepts, tools, and principles and integrating bottom-up approach such as QC circle activities.

Research on TQM
Including some methodologies, TQM as a management approach is developed and implemented by many Japanese companies. Also, the academic issues have attracted interest and attention from researchers. Empirical research on TQM surveyed literature or companies to clarify the effects on company’s performance and the critical factors [1][2][3][4][5]. For example, Porter and Parker [1] picked up the following eight factors from a literature survey and discussed the effects of the materials of TQM awards winning companies.

• The role of management leadership and quality policy.
• The role of the quality department.
• Training of employees.
• Product/service design.
• Supplier quality management.
• Process management.
• Quality data and recording.
• Employee relations.

Also, some papers reviewed the literature and found critical factors in TQM (for example, [2][3]).

In the various methodologies and techniques in TQM, Policy Deployment, Ishikawa Diagram, quality function deployment (QFD), and QC circle were developed in Japan.

Hoshin Kanri, or Hoshin Management, was developed by Yokogawa Hewlett-Packard in Japan in the early 1970s, and Jolayemi reviewed the literature on the Hoshin Kanri [6] and the two best practices models [7].

QFD is also a method developed in Japan in 1966 to help transform voice of customer (VOC) into engineering characteristics for a product, and it has been applied successfully by many Japanese, American, and European companies for their product development. The concepts and methods were reviewed by Chan and Wu [8]. For utilizing QFD effectively, a method for rating the importance of customer needs was proposed. Also, QFD was utilized for various problems, and the biggest problems of QFD are evaluated from an empirical survey of UK companies [9].

Ishikawa cause and effect (CE) diagram developed by Ishikawa is a popular tool to investigate and identify numerous different causes of the problem. For Ishikawa CE diagram, not so much literature has been published. Only a method for analytically estimating the causes of the problem and building CE diagrams was proposed [10], and CE diagram was applied to practical plants with Pareto diagram for reducing quality defects [11].

QC Circle is an activity in TQM and a driver of TQM to promote TQM to companies in Japan as shown above. The value of QC circle in TQM was studied by Sherwood et al. [12]. Also, QC circle is valuable for knowledge creation and organizational learning, and the value of QC circle was evaluated by Seo et al. [13].

The methods developed by Japanese, Policy Deployment, Ishikawa Diagram, quality function deployment (QFD), and QC circle, are all for clarifying the complicated relationship between policy and tactics, cause and effects, or enhancing the motivation of workers, and they show the characteristics of TQM activities.

2.2 Toyota Production System

Overview of TPS

TPS is one of Japanese management approaches and an integrated socio-technical system developed by Toyota Motor Corp. (TMC). TPS comprises its management philosophy and practices, and it is explained as a production system which is steered in the philosophy of "the complete elimination of all waste" imbuing all aspects of production in pursuit of the most efficient methods. TPS was established based on two concepts: "jidoka" and "Just-in-Time." The two concepts of TPS are realized by some technologies, means, and activities, including continuous improvement activities by small groups.

After introducing TPS, many companies and academic researchers not only in Japan but also all over the world were interested in TPS, and MIT started a big project on TPS. However, the topic of the project was not TPS but lean manufacturing (LM) in 1990.

Research on TPS

Not only many companies but also many researchers were interested in TPS, and many research papers on TPS or LM were published. TPS is developed and implemented as a management approach for companies. Academic issues have been considered, and the effectiveness of the developed methodologies have been evaluated. Then, many papers for empirical studies for companies and literature reviews are published. Recently, Jasti and Kodali [14] reviewed the literature on lean manufacturing and introduced an increase in the empirical study. Empirical studies were conducted for evaluating the effectiveness of TPS or LM. Matsui [15] analyzed the effectiveness of JIT in Japanese companies, and Thun et al. [16] evaluated TPS principles in utilizing Kanban system empirically. Also, as TPS includes many methodologies, researchers were tried to find the main ideas and methods, and Spear and Bowen [17] and Towill [18] clarified the DNA of TPS.

As it has many interesting contents, TPS has been researched from various viewpoints. Many papers were published, and they were categorized [19] and reviewed in each category, such as JIT principles or philosophy [20], Kanban system [21][22][23], U-shape line [24] and production smoothing [25].

JIT in TPS is a principle in accomplishing TPS and improving the performance. However, JIT and especially Kanban system has been considered as an interesting topic and great impacts on researchers. Kanban system is considered as a research topic for analyzing, comparing, improving the performance, and applying to other manufacturing and non-manufacturing systems. Also, determining the number of Kanbans is considered as an interesting topic. For U-shape line, line-balancing were considered as an interesting research topic [24]. U-shape line and multi-skilled worker lead to more flexible line such as bucket brigades. Also, production smoothing is for reducing the fluctuations of production quantity [25].

The effects of TPS on US manufacturing, inventory increased or decreased, were investigated [26].

2.3 Total Productive Maintenance

Overview of TPM

TPM is a production management approach which has been developed in Japan in 1971. TPM was considered as activities for improving the productivity of equipment in production departments. Recently, it is considered as activities of overall companies including design, technology, and indirect operations departments.

TPM seeks to improve the productivity of equipment extremely, however, at the same time, TPM creates a corporate culture which constantly strives to eliminate loss by changing the way of thinking of employees through overlapping small group activities within sites to achieve the Three Z’s, Zero Breakdown, Zero Defects and Zero Accidents. The main activities in TPM are improvement activities for equipment and facilities by small groups.

Research on TPM

Unlike TQM and TPS, TPM has no original methodology that has been developed and attracted attention from researchers, especially Japanese. Most of the researches on TPM are for evaluating the effects and factors of TPM. TPM has been introduced into many companies, and the reported cases show the effectiveness to improve the performance of introduced companies. Also, many research papers reported the effectiveness and factors of success. McKone at al. [27][28] surveyed plants where TPM is implemented and analyzed what kind of plants had
utilized TPM and the impacts of utilizing TPM. They were clarified that managerial factors such as JIT, TQM, and Employee Involvement are more important to the execution of TPM programs than environmental and organizational variables, such as country, industry, equipment age, equipment type, company size, plant age, and unionization. Wang [29] and Jeon et al. [30] proposed to use Data Envelopment Analysis (DEA) to evaluate the efficiency to implement TPM. Also, Attri et al. [31] proposed a graph theoetric approach to evaluating the intensity of barriers in implementing TPM.

In TPM, for increasing equipment efficiency extremely, improvements activities and maintenance activities are implemented into all over the plant. The necessary education and training are prepared, and 5S for the primary activities are prepared and implemented as organizational culture. All of those are practically meaningful. However, they are not so academically interesting. As a result, compared with the literature on TQM and TPS, not so much literature on developing methodologies related to TPM has been published.

3 TECHNOLOGY TRANSFER OF JMS

Now, many Japanese manufacturing companies produce products not only in Japan but also over the sea, and TQM, TPS, and TPM are transferred into the overseas sites for improving the performance of the sites. Also, JMS developed in Japan and is directly transferred to overseas companies with TQM, TPS, and TPM. In the direct transfer, first JMS can be transferred to some companies in some countries without modification. However, it cannot be transferred to the others. In this case, some kinds of modifications should be considered for utilizing JMS to improve the performance.

Ebrahtmpour and Schonberger [32] studied the transfer of JIT in TPS and TQM to developing countries and mentioned multi-skilled workers as a critical issue. Also, Takahashi et al. [33] surveyed Japanese companies in Indonesia and analyzed the current status of business, progress of technology transfer, and the four kinds of factors. As a result, it was clarified that improving not only education for workers and staffs but also improving the systems for enhancing the motivation of workers and staffs lead to an increase of the average score and current status of business.

Based on this results, it can be understood that JMS can be transferred to other countries. However, the transfer needs careful consideration of the difference of conditions and the idea to overcome the difference. The following sub-sections show technology transfer of each of JMS, the issues, and the countermeasures.

3.1 TT of TQM

After introducing Japanese high-quality products and TQM, many overseas companies, especially in developing countries, have been interested in TQM. Since the 1990s, overseas winners of Deming Prize, the most famous prize of TQM, have increased, and it can be understood that TQM has been promoted as before, but its main region has shifted from Japan to overseas.

ISO9001 was enacted in 1987, and ISO9001 certification is used for certificating the organizations that have implemented Quality Management System. Then, this certification has been a powerful driver to promote TQM to all over the world. Furthermore, many companies not in Japan but in overseas, especially in Thailand, China, and India have applied Deming Prize. Also, as one of important activities to improve employees’ satisfaction and performance of organizations, QC circle activities have been transferred into all over the world. Since 1976, International Convention on QC Circle have taken place every year, and many presentations and delegates have come from India, Malaysia, Thailand, and Korea. Original QC circle in Japan was suitable for Japan where all of Japanese sought to improve their life including the works in companies, and QC circle activities by the group are appropriate for Japanese culture to do not by an individual but by the team. The promotion of QC circle in Asia and Africa shows similar situation or culture in the countries.

Many papers for evaluating the effects of TQM have been published. In the papers, the effects of TQM were evaluated based on the surveyed results for companies that implemented TQM and the critical factors to implement TQM successfully and improve the performance of companies were identified. The papers [4][5] for the literature review were also published. In the literature, papers for empirically study on TQM implementations in specific countries are included.

Figure 1 shows that TQM has direct and indirect effects on performance, and organization learning or company non-financial performance is a mediator of the indirect effects.

<table>
<thead>
<tr>
<th>Factors of TQM:</th>
<th>Mediator between TQM &amp; Performance:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Culture: [36] Spain, [38] Iran</td>
<td>Organization learning: [35] Turkey, [37] Taiwan</td>
</tr>
<tr>
<td>Barriers: [41] India</td>
<td>Company Non-Financial Performance: [41] India, [43] Turkey</td>
</tr>
</tbody>
</table>

The countries for the empirical studies are in Asia except for Spain. As a result, it can be claimed that TQM is attracting interests from overseas, especially Asian companies, and TQM has effects on the performance of the companies mainly in Asia, that is, developing countries where improving quality is one important issue. However, for achieving fruitful results of TQM, avoiding barriers and constructing appropriate culture such as organizational learning and trying to improve non-financial performance should be considered. As remaining issues, TQM and its methodologies not for developing countries like in Asia but for developed countries where the level of quality has already been improved, and the importance of innovation is high, can be pointed out. The current TQM and the methodologies are mainly not for innovating but for improving the level, and it is not certain whether they are valuable for managing innovation or not.

3.2 TT of TPS

As of the end of Dec. 2016, TMC conducts its business worldwide with 53 overseas manufacturing companies in 28 countries and regions. All of the manufacturing companies and many of their suppliers, and other overseas companies have introduced TPS, and TPS has been transferred into many overseas companies all over the world. Especially, similar concept and system of TPS called lean production are introduced and practiced mainly...
in the USA and other countries. Although there is no organization to promote TPS, the activity or performance of TMC itself is a strong driving force of TPS.

Figure 2 shows that TPS does not always have positive effects on the performance but negative ones in some cases. Also, as factors, external and internal factors were identified, and people development and process development were identified as critical factors for implementing TPS. Negrão et al. [48] identified that the causes of high variability, in China without better management practice, with soon after introducing Kaizen, show negative effects.

Figure 2. Results of empirical studies on the factors and effects of TPS.

Japanese people like rule or discipline and eager to avoid uncertainty. The characteristic of Japanese people can be considered as a DNA of TPS [17][18], and it may not be easy to implement TPS to people who is not like Japanese people. Also, as TPS reduces uncertain factors and wastes as much as possible, it may not be easy to implement TPS to countries and regions with some or many uncertain factors. Reducing or suppressing uncertain factors is one key point to implement TPS to the countries and regions. Also, TPS has bottom-up approaches with small group improving activities and some activities to stimulating improvements, such as Kanban system and production smoothing. However, it does not have a top-down approach to improving the total performance. For the purpose, introducing any top-down approach or utilizing not only TPS but also TQM may be better for achieving fruitful results.

3.3 TT of TPM

TT of TPM to overseas can be understood from companies that applied and won TPM Excellent Awards. TPM prepares eight pillars of activities and tools like multiple small group activities, and TPM Excellent Awards evaluate the degree of intensity to promote activities for reducing breakdown, defects, and accidents that reduce overall equipment efficiency. They are necessary for implementing TPM successfully and achieving fruitful results. Konecný and Thun [49] identified that human relations such as employee satisfaction, cross-functional employee integration, and multi-skill development, are driving forces for TQM, but the both implementation of TQM and TPM do not show positive effects because of limited human resources for the implementation. However, Sethi and Tripathi [50] identified that the both implementations of TQM and TPM show positive effects because not only quality but also maintenance is important in India.

Figure 3. Results of empirical studies on the factors and effects of TPM.

4 FOR NEXT GENERATION OF JMS

For improving JMS, many activities and research have been conducted, and this section shows those activities and discusses issues for further developments. TQM, TPS, and TPM are still implemented and practiced in Japan, and the research on them is still ongoing. However, recent topics in Japanese manufacturing industries are IoT, Industry 4.0, and Cyber-Physical. By using them, issues to renovate JMS and TQM, TPM, and TPS are discussed in this section.

4.1 Recent Activities of JMS

As recent activities and Initiatives in Japan for Industry 4.0, IoT, Cyber Physical System, the following three activities can be pointed out. That is, Robot Revolution Initiative (RRI) [53], the IoT Acceleration Consortium (IAC) [54], and the Industrial Value Chain Initiative (IVI) [55]. Through the activities and initiatives, Japanese industries, especially manufacturing industries, are trying to revise JMS. By using IoT, AI, and other ICT technologies, Japanese companies developed tools and devices for improving JMS, and some of excellent examples are introduced. Hitachi Corp. developed AI technology for identifying standard motions in operations for avoiding abnormal operations and identifying correlation between manufacturing data and KPI for controlling factors of KPI for improving productivity. Omron visualized the flow of operations in production lines for improving productivity by detecting defects or unusual operations. Also, Omron developed an analysis tool of process data and test results for identifying the causes of defects. Mitsubishi Electric promoted activities for e-Factory and developed a system for directing operations in cell production systems and a system for visualizing, analyzing, and improving operations in SMT lines. Besides the companies, various Japanese companies, such as Fujitsu, NEC, Panasonic, Oki Digital Imaging, YKK, Yamazaki Mazak, Komatsu, Kubota, etc., are trying to develop and use IoT, AI, and other ICT technologies for visualizing and integrating the process, plants, and products and for improving performance and offering value added services.
4.2 Further Development based on Recent Activities
Companies that initiate RRI, IAC and IVI, are developing and applying the devices, platforms, and systems for collecting, communicating and visualizing data for JMS. Some academic papers have already published such as [56][57][58], however, as Liao et al. clarified [59], only a few papers from Japan, and about 13.8% from Asia. More academic research is expected for improving the developed systems and improving the performance of JMS.

Now in the stage to seek the possibility to utilize IoT, and academic research is expected in the future. In the academic research, renovating previous TQM, TPS, and TPM is requested. For example, for TQM, defects and the causes should be identified and analysed the relationship for supporting small group activities including QC circles. For TPS, demand and supply fluctuations should be identified and responded without losses or wastes for improving the efficiency. Also, for TPM, defectives and machine breakdowns should be identified predictively. The issues are expected for the JMS in next generations.

5 CONCLUSION
In this paper, three management approaches developed in Japan, TQM, TPS, and TPM, are explained with the literature review. Also, the technology transfer of TQM, TPS, and TQM and recent activities in Japan for next generation are explained for identifying the new issues on JMS.

JMS has shown satisfactory results by TQM, TPS, and TPM. Also, they give practical and academic impacts not only on Japan but also on many countries. Japanese companies have already achieved sufficient or saturated level. However, it can be expected that the recent trend on IoT, Industry 4.0 and others stimulates Japanese companies and academia to achieve one more high-level manufacturing. Also, it is expected to develop JMS and new TQM, TPS, and TPM or other new management approaches for next generation.

REFERENCES


