STUDIES ON NEW MANUFACTURING THEORY

Kakuro Amasaka

Aoyama Gakuin University

ABSTRACT: This study introduces the New Manufacturing Theory (NMT) that contributes to the transformation of Japanese corporate management. NMT is the innovation of manufacturing fundamentals surpasses JIT. The foundation of NMT consists of the Total Development System (TDS), Total Production System (TPS) and Total Marketing System (TMS) for product design, production and sales marketing respectively. To realize the NMT, concretely, the author has created the New Japan Manufacturing Model (NJ-MM) using the three core models: the New Japan Development Management Model (NJ-DMM), the New Japan Production Management Model (NJ-PMM) and the New Japan Marketing Management Model (NJ-MMM). The effectiveness of NMT employing NJ-MM was verified through the actual applications to automobile manufacturing in Toyota.

Keywords: New Manufacturing Theory, Japanese Corporate Management Strategy, Toyota.

1. INTRODUCTION

The Japanese management technology that made the biggest impact on the world in the latter half of the 20th century was the Toyota Production System. It is often also referred to as to Just-in-Time (JIT) or Total Quality Management (TQM) [1-5]. As TPS became practiced as Lean System around the world and was further developed, it lost its status as a Japanese production system. In recent years, the superior quality of Japanese products has rapidly lost ground [3, 6-10]. To be successful in the near future, a global marketer must develop an excellent management technology that can impress customers and continuously provide high value products in a timely manner.

To transforming Japanese corporate management strategy, the author has created the New Manufacturing Theory (NMT) using the three core systems: The Total Development System (TDS), Total Production System (TPS) and Total Marketing System (TMS) as a high-linkage business process of product design, production and sales marketing [11-13]. To realize NMT surpassing JIT, the author has created the New Japan Manufacturing Model (NJ-MM) using the three core models: The New Japan Development Management Model (NJ-DMM), New Japan Production Management Model (NJ-PMM) and New Japan Marketing Management Model (NJ-MMM). NMT employing NJ-MM has proved to be effective in actual implementations at Toyota.

2. BACKGROUND-INNOVATION OF MANUFACTURING FUNDAMENTALS

The increasing sophistication and diversification of customers’ needs have made the development of global production, which acts in concert with the overseas deployment of production bases, a pressing management issue. In order to succeed in global production, achieving worldwide uniform quality and simultaneous launch (production at optimal locations) is an urgent task. The simultaneous achievement of QCD requirements that reinforce the product appeal is required to realize this global production system [4, 5, 14, 15].

The author posed a question, therefore, “What are some of the issues that need to be addressed in order to prevail in the 21st century?” to 154 respondents chosen from the top management and researchers of the 15 companies and 4 universities who participated in “Amasaka Forum,” which is a study group of the ideal situation the quality management of manufacturing industry at Union Japanese Scientists and Engineers (JUSE) (hosted by Amasaka New JIT Laboratory from May 2004 to March 2006). The survey revealed the interests of the top management and manager classes. Figure 1 is an example of the summary...
and analysis results. As shown here, their interests center on technological development, human resources development, globalization, product differentiation, quality, safety, organization, and management [4, 5, 16, 17].

Consolidating all of these items, the management technology issue that they commonly think important is the establishment of a global production system that can achieve worldwide uniform quality and simultaneous launch at optimal locations. Among other things, what they give top priority to is the realization of manufacturing with high quality assurance. This is achieved through high cycle-ization of the business method (or business process) related to manufacturing at overseas production plants in industrialized nations in the West or developing nations, not to mention in Japan.

In particular, they are concerned about the current situation in which the production sites are undergoing drastic changes due to the use of digital engineering and IT. The survey results confirmed that the pressing management technology issue is to overcome concerns such as, “Is Japanese manufacturing reliable?,” “Is it possible to carry out an overseas product launch similar to in Japan?,” and “Can the same products be manufactured overseas as in Japan.” Furthermore, it was seen as critical to realize the intellectualization of the production sites so that they do not lag behind the advancements being made in technology and skills.

3. NECESSITY FOR TRANSFORMING CORPOTATE MANAGEMENT STRATEGY

At Japanese manufacturers that are experiencing a drastic transition in on-site manufacturing due to digital engineering, launches of new products at domestic bases have been promoted through a concurrent system. In the concurrent system, each production-related department conducts its own preparations based on their experience, while also taking into consideration a large number of design changes. However, the experience, intuition and know-how of the Japanese production staff are not conveyed to the local staff in each process, such as procurement, production preparation and manufacturing. Therefore, the practical problems are often not solved. One countermeasure currently being taken is to launch at a production site in Japan first, solving various problems one by one, and then to transfer the production as it is to an overseas site. If this current practice is continued for a worldwide simultaneous launch, a large number of the Japanese production members will need to be dispatched to each overseas production bases [17].

Figure 2 shows conceptually what is stated above. The upper half of Figure 2 depicts the status of production launch in Japan, while the lower half shows the status at overseas sites. In a normal production launch in Japan, planning, development, prototyping, equipment and material procurement, and production preparation overlap with one another, and the project is promoted through trial and error. The quality problems that occur after the production gradually decrease as the designing and manufacturing staff take the necessary measures to solve them. A widely observed case is for the transfer of manufacturing to an overseas production base to be carried out after these quality problems have been solved. On the other hand, in the case of a launch at an overseas plant from the start, equipment and material procurement as well as production preparation do not overlap with each other; rather, they are often executed in sequence. For this reason, the production start is usually three to six months later than Japan. Even though the production begins after the quality problems have been solved in Japan, once production starts overseas, additional unexpected quality problems often occur that stem from causes peculiar to local factors. Such additional quality problems are handled as needed on a trial and error basis similarly to Japan, and often such troubles gradually diminish [4, 5].

4. NEW MANUFACTURING THEORY SURPASSING JIT

4.1 Renovation of the Japanese Manufacturing Management

In the rapidly changing environment of management technology, Japanese manufacturers need to actively and courageously endeavor to offer highly reliable products of the latest model that will enhance the customer value ahead of their competitors. However, the technological capability of Japanese manufacturers has become diffused due to the transfer of production to overseas bases in recent years [3, 11, 18].

The U.S. government has implemented the “21st century manufacturing vision: New Wheel-Type Manufacturing Model” as a revival strategy for the manufacturing sector, and it has achieved a remarkable improvement in the quality level, which can be seen in recent U.S. made cars [19] In contrast, the hallmark of Japanese manufacturing, namely, the utilization of process control charts, has been dying out
and the process capability (Cp) or machine capability (Cm) needed for incorporating quality according to the design drawing has been losing its distinctive effect [20].

In the environment where highly precise quality control is being demanded, it is obvious that the Japanese manufacturers (1) are bearing market claim expenses that cannot be easily solved with conventional process control, and (2) have been pushed into a situation of no return, where single wrong step can lead to a recall problem and considerably damage customers’ trust in the corporation [21]. Therefore, it can be said that the urgent task now is innovation of the Japanese production system (typified by Toyota Production System) and to not cling to past successes or the conventional production systems [11, 18, 22, 23].

4.2. Foundation of New Manufacturing Theory (NMT) With Three Core Systems

It is the author’s conjecture that it is clearly impossible to lead the next-generation by merely maintaining the Japan Production System (JPS) named traditional Toyota Production System. To overcome this issue, it is essential to renovate not only production process, but also to establish three core systems for high-linkage business process of development and design, production and marketing as well as other departments [24].

In the next-generation management technology strategy, the “New Manufacturing Theory” (NMT), which the author has created through theoretical and systematic analyses, is the JIT system for not only manufacturing, but also customer relations, sales and marketing, product planning, product design, production engineering, production, logistics, procurement etc., for enhancing business process innovation and introduction of new concepts and procedures. NMT contains hardware and software systems as the next generation technical principles for accelerating the high-linkage and optimization of business process cycles of all the divisions as shown in Figure 3 [3, 12, 13].

NMT called “New JIT, new management technology principle” consists of the “Total Development System” (TDS), “Total Production System” (TPS) and “Total Marketing System” (TMS), which are the three core elements required for sales and marketing product design and production, among others.

The expectations and role of the first core element “TDS” are the systemization of design management method which is capable of clarifying the following: (a) Information-based design: Collection and analysis of updated internal and external information that emphasizes the importance of design philosophy, (b) Management-based design: Development design process employing review-planning-design cycle, (c) Technology-based design: Design method that incorporates enhanced design technology for obtaining general solutions, and (d) Designer’s decision-based design: Design guideline for designer development.

The expectations and new role of the second core element “TPS” comprise the following: (a) Production based on information - Customer-oriented production control systems that place the priority on internal and external quality information, (b) Production based on management - Creation and management of a rational production process organization, (c) Production based on engineering - QCD activities using advanced production technology, and (d) Production based on workshop formation - Creation of active workshop capable of implementing partnership.

The expectations and role of the third core element “TMS” include the following: (a) Market creative activities - Market creation through the gathering and use of customer information, (b) Product value improvement - Improvement of product value by understanding the elements essential to raising merchandize value, (c) Building ties with customer - Establishment of hardware and software marketing system through forming the ties with customers, and (d) Customer value improvement - Realization on the necessary elements for adopting a corporate attitude (behavioral norm) of enhancing customer value and developing customer satisfaction (CS), customer delight (CD) customer retention (CR), customer loyalty (CL) and networks based on the customer focus.

5. NEW JAPAN DEVELOPMENT MANAGEMENT MODEL (NJ-DMM)

Currently, to continuously offer attractive, it is important to establish the “new development design model” that predicts customer needs [4, 11, 14, 16, 25-27]. In order to do so, manufacturing is a battle against irregularities, and it is imperative to renovate the business process in the development design system and to create a technology so that serious market quality problems can be prevented in advance by means of accurate prediction control.

Furthermore, it is a requisite for leading manufacturing corporations to balance high quality development design with lower cost and shorter development time by incorporating the latest numerical
simulation and statistical science. Therefore, the author has created the “New Japan Development Management Model” (NJ-DMM) called “Advanced TDS” for the high quality assurance and simultaneous achievement of QCD as the key of strategic development of NMT as described in Figure 4.

NJ-DMM is to contribute to the same quality worldwide and development at optimal locations. In Figure 4, technical issues that must be resolved by development design departments include digitized development and design, product design process reform, super-short–time process system reform, high accuracy of the prediction and control, and optimization of product design specifications. In terms of a methodology for resolving these issues, the author has created four core elements: The “Intelligence Product Design Management System” (IPDMS), “High Reliability Development Design System” (HRDDM), “Intelligence Numerical Simulation System” (INSS) which employs Computer Aided Engineering (CAE), and “Intellectual Technology Integrated System” (ITIS) which enables sharing of knowledge and the latest technical information possessed by all related divisions.

The organically integrated and intelligent application of these four core elements is essential. An overview of each is given below. Figure 5 shows the transitions in the automotive development and design process in Japan. For model changes in the past (development time of production: approx. 4 years), after completing the designing process, problem detection and improvement were repeated mainly through the process of prototyping, testing, and evaluation. In some current automotive development, vehicle prototypes are not manufactured in the early stage of development due to the utilization of CAE and Simultaneous Engineering (SE), resulting in a substantially shorter development period [25, 26, 28, 29].

Focusing on management technology for development and production process, it is clear that there has been excessive repetition of prototyping, testing, and evaluation for the purpose of preventing the “scale-up effect” in the bridging stage between design and development and mass production. This has resulted in unstable built-in quality assurance in the design and development stage, and an increase in the development period and cost. Therefore, it is now vital to reform conventional design and development processes through the effective use of the intelligent numerical simulation (CAE) [14, 30].

For strategic product development, it is important to explore consumer values, which are the basis for creating “wants,” through the collection/analysis of customer information, and to reflect as well as exteriorize such values in product development. Against this background, the “Customer Information Analysis and Navigation System” (CS-CIANS) was constructed as shown in Figure 6 [4, 31]. As indicated therein, this system enables the networking (1) the Merchandise Planning Div. which explores customer values and (2) each division of Product Planning and Design to regularly receive Customer Data from (3) domestic and overseas dealers which are exposed to the front line of the customer desires through their marketing/sales/service activities. Similarly, the collection of Customer Data is also possible through (4) Consulting Spaces, namely, the showrooms promoting the company’s own products or public facilities for discussions and consultations from the customers. Moreover, (5) Marketing Research Companies via (6) an exclusive company WEB.

All these sections are connected through on-line networking for building (7) a Data Base (DB) via a server of the company’s own information system division. Into this system utilizing statistical science approach - “Science SQC” (8), actually, the core system of SQC integration network system - “Total SQC Technical Intelligence System” (TTIS) including four core elements: the “Total SQC Intelligence System” (TSIS), “Total TQM Promotional Original SQC Soft” (TPOS), “Total SQC Manual Library” (TSML) and “Total Technical Information System” (TIRS). These are accessible for search and utilization from (9) Analytical case data base (DB). Particularly, cooperation requests for analysis can be submitted to (10) a special SQC adviser in Quality Assurance division.

CS-CIANS is designed in such a way that the collection of analytical results created by total linkage of the merchandise planning, product design, sales marketing and service for the successive development of analytical technology [4, 14, 31, 32].

6. NEW JAPAN PRODUCTION MANAGEMENT MODEL (NJ-PMM)

As digital engineering transforms manufacturing in workshops, a reduction in the engineering capability of members is often a result. This weakens the scientific production control that ensures that quality is incorporated in processes. Therefore, despite conventional success from the viewpoint of global production, it is an urgent task to strategically advance Toyota Production System [11]. The author has created the “New Japan Production Management Model” (NJ-PMM) called “Advanced TPS and New Japan Production Model” as described in Figure 7 as the key of strategic development of NMT [4, 11, 13, 18, 23, 33, 34]. The mission of NJ-PMM is to contribute to same quality worldwide and production at
optimal locations for global production strategy and to attain CS, Employee Satisfaction (ES), and Social Satisfaction (SS) through manufacturing with a high level of quality assurance.

This model is the systemization of a new, next-generation Japanese production management system for simultaneously achieving QCD requirements. In Figure 7, first, one of the four core elements necessary for fulfilling these requirements is enhanced maintenance and improvement of process capabilities by establishing the “Highly Reliable Production System” (HRPS) for realizing digitized production. Second, “Intelligent Quality Control System” (IQCS) needs to be established for renewal of production management. Third, “Renovated Work Environment System” (RWES) needs to be reformed to enhance intelligent productivity by creating attractive workshop environment. Fourth, intelligent production operators need to be cultivated who are capable of handling the advanced production system and the “Intelligent Operating Development System” (IODS) needs to also be established in the environment of increasing older and female workers.

As well as NJ-DMM, the organically integrated and intelligent application of these four systems is essential. An overview of each is given below. For example, the author has recognized the necessity of upgrading the intelligence of the production sites for global production in order for the strategic deployment of the NJ-PMM to be carried out successfully. Therefore, the author has created the “High-cycle system for the automobile production business process” as shown in Figure 8 [4, 5, 16-18]. This system is effective management of the advanced production process 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 commonly shared systems (I-IV), as follows.

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

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

(III) The Renovated Work Environment System (RWES) aims to improve the value of labor by bringing 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 (IODS) aims to realize the early cultivation of highly skilled workers through utilization of visual manuals supported by the latest IT and virtual technology.

7. NEW JAPAN MARKETING MANAGEMENT MODEL (NJ-MMM)

When the author views recent changes in the marketing environment, what is needed now is to develop the innovative business and sales activities that are unconventional and correctly grasp the characteristics and changes of customers’ tastes. Contact with customers has never called for more careful attention and practice.

To offer an appealing and customer-oriented marketing strategy, it is important to evolve current market creation activities [3, 35-37]. Therefore, the author has created the “New Japan Marketing Management Model” (NJ-MMM) called “Advanced TMS” as described in Figure 9 as the key of the strategic development of NMT [4, 11, 23, 38]. NJ-MMMM is the implementation of a successful global marketing strategy by developing the same quality worldwide and marketing at optimum locations.

In Figure 9, NJ-MMMM aims to achieve the “high cycle rate for market creation activities” and is composed of four core elements: the “New sales office pmage” (NSOI), the “Intelligent Customer Information Network System” (ISINS), the Rational Advertisement Promotion System (RAPS) and the “Intelligent Sales Marketing System” (ISMS). By these elements, NJ-MMMM innovates for bonding with the customer and reforms office-shop appearance and operation. At a certain implementation stage of NSOI, for example, it is more important to construct and develop the ISINS, RAPS and ISMS that systematically improve customer information software application know-how about users. This information network turns customer management and service into a science by utilizing TMS according to customers’ involvement in daily life. As well as NJ-DMM and NJ-PMM, the organically integrated and intelligent application of these four systems is essential. An overview of each is given below.

Concretely, one vital point of the strategic marketing structure is its definition; Sales marketing activities should be defined from closed marketing activities that are limited to the business and sales divisions to open marketing activities that can be performed through steady linkage with all other divisions in a company-wide framework. The aim is for an evolution of market creation by utilizing the
scientific approach of NJ-MMM. So, the author has created the “Scientific Customer Creative Model” (SCCM) which takes the form of strategic marketing as shown in Figure 10 [4, 16].

In Figure 10, the entire structure consists of three domains; (1) Marketing Strategy, (2) Manufacturing Process and (3) Market and Customers. In each domain, the key marketing items are linked by paths to show how they are associated with integrated four core elements. The outline of SACCM is shown in the following. First of all, in the (1) Marketing Strategy, the key point is how the market segment and the target market are determined. In general, the target market is determined based on the company’s core competencies, competition strategy, and resource strategy over the medium and long term basis. By introducing a scientific analysis approach that uses IT, it clarifies a potential target market from the changing market or the customer structure analysis.

Secondly, in the (2) Manufacturing Process, the key point is to collect/analyze customers’ demands and expectations precisely. At this time, it is important to consider what value the customer’s want. When implementing information collection/analysis, customer value is described in numerical form from many different viewpoints, and a new product which is aimed at enhancing customer value is implemented through the flow of planning, development, and production.

Thirdly, in the (3) Market and Customer, the key point is to learn the structure of the customer’s motivation to buy products. Concretely, it is important to develop an analysis tool for close examination of the marketing structure and a marketing structure analysis system that will support marketing activities in three domains stated above from a strategic market viewpoint.

8. APPLICATION EXAMPLE 1: AUTOMOBILE PRODUCT DESIGN FOR BOTTLENECK SOLUTION USING NJ-DMM

In general, experienced development design staff and CAE engineers understand the mechanism that is causing the bottleneck technical problem as implicit knowledge [39]. While many examples of calculation based on CAE analysis have been reported, the accuracy of estimation has not to be improved for satisfactory vehicle development [27, 40]. Therefore, the author has created the “Intelligence CAE Management Approach System” in an effort to help solve the bottleneck technical problem that had become a global technological issue as shown in Figure 11 [26, 29]. To accomplish this, as the first stage, it was important to (A) the “Visualization - Visualize the dynamic behavior of the problem” by using “Actual vehicles and equipment” and carrying out testing. At this point the expertise of specialists from both inside and outside the company was brought together through the “Partnering” activities. As the second stage, it was vital to deduce the (B) fault mechanism using various “Techniques.”

In order to carry out the precise fault analysis and factor analysis, new seven tools (N7), statistical quality control (SQC), reliability engineering (RE) multivariate analysis (MA) and design of experiment (DE) were combined and utilized to search out and identify previously unknown or overlooked latent causes. In this way a logical thinking process was used to carry out a logical investigation into the cause of fault mechanism for the “Modelling.” Furthermore, all of this knowledge and information was then unified through (C) the creation of “CAE Navigation Software” that employs computer graphics (CG) to reproduce the visualization of the actual vehicle and testing data so that it can be made consistent to a “Qualitative model.” At this stage, where CAE Navigation Software is being created, it was important to carry out actual vehicle and testing work so that a model (Qualitative model) could be made for the cause and effect relationships of the unknown mechanism. It would then become extremely important to use this model to reduce the divergence (gap) between the results from the actual vehicle testing and CAE to develop the “absolute value evaluation.”

As the third stage, in addition, at the stage of developing the (D) “Numeric value simulation,” exhaustive actual vehicle testing was carried out in order to convert the leak mechanism from implicit knowledge into precise explicit knowledge. The information gained from these work processes would then be unified and a “highly credible numerical simulation (Quantitative model)” would be carried out to make absolute value prediction and control possible. In the final stage (E), the CAE analysis results are then verified by comparing them to the actual vehicle testing results. In the case of a decentralized organization and business process (such as shown in Figure 11), it is essential that the specialists in the fields of design, testing, CAE analysis, CAE software design, and SQC carry out cooperative team activities, “partnering” (© Main, ⊚ Sub, △ Support) at each stage of the work process (A to E).

By using the Intelligence CAE Management Approach System described above, the author has solved current technological problems in automotive product design [4, 14, 41]. As an actual case study, firstly, the bottleneck problem in the world is an unknown mechanism causing an oil seal leakage on the surface of the drive shaft during high-speed rotation [42]. The author discusses the
application of “Optimal CAE Design Model” for drive train oil seal leaks through a partnership between Toyota Motor Corp. and NOK Corp. as examples where the mechanism of technical problems is unknown [28-30]. As shown in Figure 12, the author has created the “Highly Accurate CAE Analysis Approach Model” to prevent automobile oil seal leaks, incorporating SQC technical methods [41].

The author has contributed to solving a problem of drive train oil seal leaks, which was a bottleneck technological problem for automotive manufacturers worldwide. This was achieved through an analysis process involving problem clarification, visualization experiments, theoretical conceptualization, CAE analysis and optimal design. First, the authors have begun by developing a device for visualizing the ascertained phenomena in order to estimate the unknown mechanisms involved in the leaks. This made it possible to estimate the mechanism of the oil seal leaks by visualizing the dynamic behavior involved in the process whereby metal particles (foreign matter) from gear rotation wear, found around the rotating and sliding portions of the oil seal lip, become mechanically fused and accumulate. Next, the findings obtained were used to formulate the following design countermeasures as follows.

(i) Strengthen gear surfaces to prevent occurrence of foreign matter even after 100,000 km (Improve quality of materials and heat treatments).

(ii) Formulate a design plan to scientifically ensure optimum lubrication of the surface layer of the oil seal lip (uneven portions of the sliding surface) where it rotates in contact with the drive shaft.

These design technology elements were incorporated into the “Highly Accurate CAE Analysis Approach Model for the Oil Seal Simulator” to create highly-reliable CAE analysis software capable of accurately reproducing the oil seal leak phenomena, enabling them to be identified and controlled as describe in Figure 13 [4, 14, 30]. The following methods were proposed: (i) Identifying the problems: Simulation of variously converging physicochemical phenomena (methodology: (1) to (3)), (ii) Modeling: Building of problem-solving models (methodology: (1) to (3)), (iii) Algorithms: Useful and practical algorithms (methodology: (1) to (2)), (iv) Rational theories: Creation of the suitable theoretical equations (methodology: ((1) to (3)) and (v) Calculators: Innovations enabling calculations to be made accurately within a realistic period of time (methodology: (1) to (3)).

As a result, it is now possible to implement highly-reliable numerical simulation (CAE analysis, 2D and 3D), enabling the realization of the quality assurance CAE analysis. The CAE analysis shown in the figure is an example of numerical simulation for pump flow volume (flow of lubricant: air side [atmosphere] – oil side [gears]) around the oil seal. Oil seal leaks (market claims) have now been reduced to less than 1/20 due to the implementation of design improvements (design of shape and materials). As the application examples to similar problem-solving, the author was able to apply the NJ-DMM to critical development design technology for automotive production, including predicting and controlling the special characteristics of urethane foam molding of seat pads, aerodynamics of body lifting power, seat pads, anti-vibration design of door mirrors, loosening bolt-nut tightening and others [4, 16, 26, 28, 29, 32, 43, 44]. In each of these cases as well, discrepancy was 3–5% versus prototype testing. Based on the achieved results, this model is now being used as an intelligent support model for optimizing product design.

9. APPLICATION EXAMPLE 2: AUTOMOBILE HIGHLY RELIABLE PRODUCTION FOR GLOBAL MANUFACTURING USING NJ-PMM

Strengthening of the automobile highly reliable production becomes the most important of the strategic development of NJ-PPM. Thus, having recognized the need for a new production system suitable for global manufacturing, the “Human Digital Pipeline System” (HDPS) shown in Figure 14 has the following features [4, 34].

(i) HDPS creates and supplies, in advance, “Standard Work Sheets” on which production operators have recorded each task in the correct order for jobs such as assembly work, by using design data for new products and facilities prepared from design through to production technology, even if there are no production prototypes.

(ii) Next, HDPS enables visualization training for machining processes step-by-step in the order that parts are built up, even if the actual product does not yet exist.

Actually, HDPS is proving to be very effective in raising the level of proficiency for processes requiring skills and capabilities at the production preparation stage, as follows.

(1) This system enables a real-time, total linkage of “Data print service (DPS) data” related to techniques and skills, from designing to manufacturing through a digital pipeline for the operators in both domestic and overseas production plants. By this means, the training for highly intelligent work with intellectual productivity can be realized before long.
(2) Furthermore, this system promotes the leveling of the workload of the operators in each process and then completes the building up of the production line even before launching it.

Concretely, the hardware configuring HDPS is depicted in Figure 15. The conventional work procedure manuals in which hand-written letters and drawings were used are to be done away with. Instead, intelligent, user-friendly operation manuals are prepared, which clearly present the items listed and instructed in an easily understandable manner, and offered to production operators. The CAD data as well as CAE data used from development to production engineering are stored in (1) Production D/B through the digital pipeline. Next, (2) Production Information D/B, containing the production management information, such as production scale and volume as well as the parts arrangement information regarding procurement status and locally procured parts is connected to (3) Work Procedure D/B, which accumulates typical examples of past work procedures, completing a total linkage.

In such a procedure, a work procedure manual is prepared from work data and parts data in advance and offered to production operators. Also, at the same time, based on this work procedure manual, the routes which can be taken by the operators when moving in the production line are prepared. Then, from among these routes, the optimal combination of production operations is selected and arranged by utilizing simulation algorithm [4, 5]. As a result, the process setup which rearranges the work processes to correspond to multi-model production will be verified before the start of mass production. In addition, the workload of each process is totaled for comparison, so that an uneven distribution of the workload (uneven distribution of the work amount among differing vehicle models on the production line) is leveled out. The workload as well as the work posture of the operators are confirmed beforehand, which then is subjected to evaluation and fault finding.

The software configuring HDPS is depicted in Figure 15. The work procedure manual mentioned above is prepared using the (1) “Work Procedure Manual System.” This system contains a wide range of information, such as the work data consisting of work names, times, locations, the specification data consisting of the specification, number, and quantity of parts, in addition to quality, work posture, instruments, safety, intuitive knacks and know-how, etc. Based on all this, the work procedure manual mentioned above is prepared. Next, the visual data of parts is generated by using the (2) “Parts Ledger System.” In concrete terms, target parts are extracted using the (1) “Work Procedure Manual System.” In concrete terms, target parts are extracted using the information about their number, name, model, or quantity, and the associated 3-D shape data (CAD data) or verification data (CAE data) are searched.

Based on the above systems of (1) and (2), the linkage between work and parts is made, and the elemental instruction sheet is prepared for each of the parts in the order of the steps in which the parts are being assembled. For the types of work operations that cannot be fully instructed through explanations and photographs, video images are added to the visual manual to describe the acquired knacks and know-how. This is to ensure more accurate work operations by instructing the procedure to be followed and the things not to be performed by providing animation. As the application case, an example of the accumulated work operations for each process is shown in Figure 16 (left). The work hours are accumulated for each assembling location, specification, and priority, and are colored for easy distinction.

The walking time is automatically calculated from the traces connecting each part of a vehicle, and it is confirmed whether each operation is completed within the given takt time. In addition, an example of comprehending and confirming the network ratio and the walking time is shown in Figure 16 (left). By sorting out the working time and walking time from the accumulated time results, the uneven distribution of the networking time and the non-working time, such as time spent walking, are stratified to serve as a guideline for reviewing the process layout. Figure 16 (right) shows the re-calculation of the work accumulation after reshuffling the basic work operations between processes. Such changes can be easily made on the accumulative simulation screen by dragging and dropping with the mouse, immediately confirming the work points of previous and subsequent operations while automatically adjusting the walking time involved. Moreover, the author has developed the NJ-PMM to strengthen above “High-cycle system for the automobile production business process” through the concrete examples as follows;

In (1) Highly Reliable Production System as the reform of production planning and Preparation: The author has created the (i) “Virtual-Maintenance Innovated Computer System” (V-MICS) for the globalization of production information, (ii) “TPS Layout Analysis System” (TPS-LAS) for the production optimization CAE system with the investigation of digital factory, robot control, workability, logistics and vehicle body auto fitting, and (iii)

“Human Intelligence Production Operating System” (HI-POS) for the intelligent operator development [4, 5, 34].
In (II) Intelligence Quality Control System as the reform of production process management: The author created the (iv) “TPS Quality Assurance System” (TPS-QAS) utilizing “Quality Control Information System” (QCIS) with quality control charts of abnormal diagnosis, and “Availability & Reliability Information Monitor System” (ARIM) with Weibull analysis of equipment failures in real-time. Thus, TPS-QAS enabled the development of manufacturing by integrated the high-precision quality management systems suitable for global production [4, 5, 34, 45].

In (III) Renovated Work Environment System as the reform of work and labor: The author has created the (v) Aging & Work Development - Comfortable Operating System (AWD-COS) named “Aging & Work Development 6 Programs Project” (AWD6P/J). AWD6P/J contains the P/J-I (boost morale of worker), P/J-II (study work standards to reduce fatigue), P/J-III (build up physical strength for work), P/J-IV (alleviate heavy work by employing easy-to-use tools and equipment), P/J-V (thermal conditions suited to work characteristics), and P/J-VI (reinforce preventive measures against illness and injury) [43, 46].

In (IV) Intelligent Operators Development System as the reform of technical skills level of production operators and further improving the reliability of their skills: The author created the (vi) “TPS-Intelligent Production Operating System” (TPS-IPOS) to lead to a fundamental development of the work. TPS-IPOS is made up of two sub-systems: The “Virtual-Intelligent Operator System” (V-IOS), and “Robot Reliability Design-Improvement Method” (RRD-IM) [4, 5, 34].

Recently, for expanding overseas manufacturing, the authors have established the “New Global Partnering Production Model” (NGP-PM) employing NJ-PMM [47]. At present, the validity of the strategic development of NGP-PM in the advanced country (: US. and Europe) and the developing country (: Asia) is verified [4]. Concretely, the author has developed the “Advanced Toyota USA Manufacturing System,” “New Turkish Production System,” “New Malaysia Production Model” and “New Vietnam Production Model” [4, 5, 33].

10. APPLICATION EXAMPLE 3: CHANGE IN AUTOMOBILE MARKETING FOR IMPROVING BUSINESS and SALES USING NJ-MMM

As the automobile market creative activities, the commanding of CS and CL in the Market and Customer domain is a criterion for the strategic development of above SCCM. As the prior research, the authors know of no studies that have been done on auto sales from a multidisciplinary perspective [22, 48].

In above three domains of the Marketing Strategy, Manufacturing Process and Market and Customer, CL is the concept that will become increasingly critical in the future. It requires that dealerships work to boost satisfaction among their core customers by continuing to offer the products and services that these loyal customers want to take advantage of and purchase.

This research uses the statistics approach for focusing on CS as a way of boosting marketing effectiveness, clarifying the key factors that comprise CL [49]. At a stage of execution, the key factors comprising CS and CL among core customers at the six target dealerships, each of whom represent major automakers in japan—four Japanese (Toyota, Nissan, Honda and Mitsubishi) and two foreign (Mercedes-Benz and Volkswagen) were identified in order to determine the level of impact each carries.

The authors collected and analyzed sales information from core customers to identify the four key factors of CS and CL among them using covariance structure analysis by employing above ICINS named CS-CIANS as the intelligent customer information network system as shown in Table 1. In Table 1, these included 17 product factors, 3 employee factors, 6 dealership factors, and 3 corporate factors as an example of Toyota. The 29 factors were rated on a seven-point scale along with CS and CL to identify the kinds of things that customers were looking for. In an example of Toyota, Table 1 shows the results of covariance structure analysis on each individual factor by using the data of the persons (: 226 in total 138 male and 88 female) who came to four typical auto-shops (affiliated dealerships).

Under product, for example, the analysis results indicate that if auto manufacturers are to prioritize CS and CL during their sales and marketing activities, they need to enhance product development so that it focuses on performance quality (engine displacement, fuel efficiency, straight-line stability, body shaking and cornering, etc.), design quality (exterior design, seats comfort and interior design etc.) including body shape and paint color and others. At the same time, affiliated dealerships need to work to enhance customer handling during emergencies measure as well as mandatory inspection services. Under topic of employees, similarly, polite, prompt customer service was found to have the greatest impact on CL.

In addition, it can be inferred that because corporate image, advertisements (Television commercials (TV-CM) and Pamphlet-website) also have the powerful effect on customers. Vehicles are an important
factor in generating trust towards a company. These results point to a customer mindset whereby those looking to replace an existing vehicle have a desire to go back to the dealership where they purchased their old car because they have a lasting impression of the courteous manner with which a salesperson treated them before. Furthermore, the author carried out the market survey and analysis of other five automakers in the same way, and acquired effective knowledge toward management strategy and manufacturing process innovation.

As the automobile sales activities, useful advertisement methods in the Market Strategy domain is a fundamental for the strategic development of SCCM. According to automotive dealers’ empirical knowledge, number one in rank for major mass effect is TV-CM. But as far as the author knows, there are no studies on the quantitative effects of TV-CM, etc. as the strategic advertisement methods [10, 45, 50, 51]. The author is interested in quantitatively turning the purchasing behavior of customers, who visit dealers with intentions to buy after watching TV-CM etc., into explicit knowledge. Moreover, the visiting ratio of customers will rise, and the effect of marketing and sales activities will be drastically enhanced due to an improved understanding of the effects of TV-CM and the media-mix of newspaper ads, radio, flyers, magazine, direct mail (DM), direct hand (DH), poster, train car ad., internet and others.

Figure 17(i) shows the “Customer Purchasing Behavioral Model—Advertisement Effects” (CPBM-AE) by employing above RAPS named “Scientific Mixed Media Model” (SMMM) at the time of introduction of new small-size vehicles “Japanese names: Funcargo/Platz” with the help in Toyota and Amasaka New JIT laboratory in Aoyama Gakuin University [45, 51, 52]. As background for the influential factors, the author established the following CPBM-AE: starting with recognition of the vehicle name (R)→interest in the vehicle (I)→desire to visit a dealer to see the vehicle (D-1)→consideration of purchasing (C-1)→visiting a dealer for purchasing contract (P-1). This was influenced by TV-CM, newspaper ad, radio, flyer, DM/DH, or presence/business talk over approximately 2 months. Moreover, the authors realized that the CPBM-AE exists, starting from considering purchasing the vehicle (C-2)→desire to visit a dealer (D-2)→impression from actually seeing the vehicle at the dealer (I-2)→purchasing contract (P-2).

For example, supposing that customers have their purchasing desire aroused by watching TV-CM for a newly released car. What percentage of customers would visit their dealers? It is important for future marketing strategies to conduct a dynamic survey of customers’ purchasing behavior. First, Figure 17(ii) (the lower line graph of figure) shows the results of analysis that applied the CPBM-AE. As the verification results of the investigation analysis of TV-CM alone at the time of introduction of the new car, Fancargo. In Figure 17(ii), the total mean curve indicates that 1/3 (34.6%) of customers recognize the new car name (R) from TV-CM alone. The number of customers drops by half (18.4%) at the interest stage (I), dropping by a further a half (8.1%) at the desire to visit a dealer stage (D-1). At the considering purchase stage (C-1), the figure drops to 9.6% at best, even with the addition of D-2→I-2, as stated above. Moreover, at the visiting stage in the figure, the ratio of customers that visited a dealer fails to reach 1.7%. This implies the need to establish an effective media mix model in the future. It has been verified that this analysis has a similar dynamic trend for the Platz and does not vary for gender of purchasers, age or area.

Next, the author shows the most effective mix-media model for increasing the rate of dealer visits as shown in Figure 17(ii) (the upper line graph in the middle of the figure). Compared to the effect of TV-CM alone, the media mix effect of TV-CM, newspaper ads, and radio improved vehicle name recognition (R) to 72.5%. Similarly, use of flyers and posters increased interest in the vehicle (I) to 42.8%. DM/DH increased the desire to visit the dealer, and also vehicle purchase consideration (D-2, C-2, I-2) to 38.2%. The cumulative effect produced an end result where the rate of dealer visits (P-2) increased greatly to 7.3%. To strengthen the CPBM-AE employing RPAS, the author proceeds with the qualitative improvement studies such as TV-CM, fliers, DM/DH, poster/pamphlet, motion picture and video for internet, catalog, train car ads. and mix-media effects of mid-size vehicle [52-55]. The author has established above ISMS, NSOI, RAPS and ICINS, named the “Toyota Sales Marketing System” (TSMS) to strengthen three domains linkage at Toyota, as a way to aid sales marketing through innovative bonding with the customer as shown in Figure 18 [36-38]. As the CR investigation to enhance the validity of TSMS, the author dealt with the subject of improving the sales rate for replacement Toyota vehicles, which involves setting up Netz dealers in a model case [14, 16].

Concretely, “Categorical Automatic Interaction Detector” (CAID) and “Cramer’s analysis” is used to identify characteristics and variations in customer orientation through the analysis of user questionnaire data. Accordingly, specific models are developed for customers of high replacement probability [4, 37]. The knowledge thus obtained is used to generate specific measures for increasing sales through CR based on customer type, enabling the construction of the TSMS, an intelligent customer information network
system. TSMS employing the above CPBM-AE combines IT and statistical science to make practical use of customer data in order to increase the rate of CR, and acquire new customers.

In order to increase the rate of dealer visits and vehicle purchases by current loyal users, they are stratified into high-probability customers (HPCs), medium-probability customers (MPCs) and low-probability customers (LPCs), and then a sample is taken of the marketing, sales, and service items that the customers demanded, and CS is taken as follows.

1) The CR activities based on customer type are adopted by classifying HPCs and MPCs into those who visit the shop and those who must be visited by our staff, taking characteristics at new vehicle purchase into account. A system is established so that the shop manager directly receives MPCs when they visit to the shop without fail in order to promote visits to the shop by HPCs. Thus, the frequency of contact with customers is increased. Further, sales and service activities focus on telephone calls for customers who visit the shop, and telephone calls and home visits for those who require visits by our staff.

2) As for LPCs, who have less contact with the sales staff, a telephone call center is established within the dealer, to accumulate know-how related to the effective use of customer information software. The two-step approach is adopted as the practical sales policy where telephone calls are used to follow up on the effect of advertisements, catalogs, fliers and DM/DH. As expected, excellent results have been reported at Netz Chiba, Netz Ehime and other Toyota dealers who applied the TSMS described here.

This system can also be made use of when visiting customers, and to help acquire new customers at the time they visit a dealer. Due to the application of TSMS, which involves the CPBM-AE, TSMS operation has recently contributed to an increase in the sales share of vehicles at Toyota in Japan (40% / 1998 to 46% / 2007) [35, 56].

11. CONCLUSION

The author has created the NMT (New Manufacturing Theory) to transforming Japanese corporate management strategy for the innovating business process associated with product design, production and sales marketing. To realize NMT toward the expanding overseas manufacturing strategy, the author has created the NJ-MM (New Japan Manufacturing Model) using three core models: NJ-DMM, NJ-PMM and NJ-MMM. Actually, NMT has been verified its effectiveness through the applications to Toyota automobile manufacturer.

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Note: The number of four key factors (: product, dealership, employee and corporate) in the table shows standardizing coefficient.

Table 1. An example of covariance structure analysis (Ex. Toyota Motor Corp.)

<table>
<thead>
<tr>
<th>Product</th>
<th>CS</th>
<th>CL</th>
</tr>
</thead>
<tbody>
<tr>
<td>exterior</td>
<td>612</td>
<td>470</td>
</tr>
<tr>
<td>interior</td>
<td>198</td>
<td>217</td>
</tr>
<tr>
<td>Safety device</td>
<td>024</td>
<td>109</td>
</tr>
<tr>
<td>Handling</td>
<td>087</td>
<td>026</td>
</tr>
<tr>
<td>Comering</td>
<td>190</td>
<td>149</td>
</tr>
<tr>
<td>Straight-line stability</td>
<td>207</td>
<td>213</td>
</tr>
<tr>
<td>High-speed stability</td>
<td>106</td>
<td>077</td>
</tr>
<tr>
<td>Durability</td>
<td>-045</td>
<td>-064</td>
</tr>
<tr>
<td>pedal</td>
<td>-458</td>
<td>-257</td>
</tr>
<tr>
<td>seat</td>
<td>519</td>
<td>694</td>
</tr>
<tr>
<td>Engine displacement</td>
<td>600</td>
<td>343</td>
</tr>
<tr>
<td>fuel efficiency</td>
<td>475</td>
<td>270</td>
</tr>
<tr>
<td>Interior noise</td>
<td>136</td>
<td>188</td>
</tr>
<tr>
<td>Body shalving</td>
<td>284</td>
<td>508</td>
</tr>
<tr>
<td>Car navigation system</td>
<td>-045</td>
<td>-120</td>
</tr>
<tr>
<td>audio</td>
<td>181</td>
<td>069</td>
</tr>
<tr>
<td>price</td>
<td>-024</td>
<td>119</td>
</tr>
</tbody>
</table>

Dealership

| Appearance               | .115| -.041|
| Opening Hours            | .024| -.048|
| Location                 | -.068| 169|
| mandatory inspection services | .203| 086|
| Emergency measure        | .659| .559|
| Periodic contact         | -.264| .278|

Employee

| point                   | .291| .562|
| knowledge               | .154| .316|

Corporate

| Promt customer service   | .464| .077|
| pamphlet / Website       | .205| .057|
| TV commercials           | .128| .502|
| corporate image          | .778| .511|

Source: (Author)

Figure 1. What is the important issue which should be tackled?

Source: (Author)

Figure 2. Production launches of new products

Source: (Author)
Figure 3. Foundation of New Manufacturing Theory (NMT)

High-linkage cycle for Renovation the Business Process

**New Manufacturing Theory**

Total Development System (TDS)

(a) Information-based design

(b) Management-based design

(c) Technology-based design

(d) Designer’s decision-based design

Total Development System (TDS)

Source: (Author)

Figure 4. New Japan Development Management Model (NJ-DMM)

Global Development Design Strategy - Same Quality Worldwide and Development at Optimum Locations -

High Quality Assurance

Development Design System Reform

High Reliability Development Design System

Super-short-term Process System Reform

Intelligence Numerical Simulation System

High Accuracy of the Prediction & Control

The key of the strategic development of NMT

Source: (Author)
Figure 5. Transitions in the automotive development and design processes in Japan

Source: (Author)

Figure 6. CS-CIANS, Networking of Customer Science Application System

Source: (Author)

Figure 7. New Japan Production Management Model (NJ-PMM)

Source: (Author)
Figure 8. High-cycle system for the automobile production business process

Source: (Author)

Figure 9. New Japan Marketing Management Model (NJ-MMM)

Source: (Author)
Figure 10. Scientific Customer Creative Model (SCCM)

Source: (Author)

Figure 11. Intelligence CAE Management Approach System

Source: (Author)

Figure 12. Highly Accurate CAE Analysis Approach Model to Prevent Automobile Oil Seal Leaks

Source: (Author)
Figure 13. Oil Seal Simulator using Highly Reliable CAE Analysis Technology Component Model

Source: (Author)

Figure 14. Outline of Human Digital Pipeline System (HDPS)

Source: (Author)

Figure 15. Hardware and software configuration of “HDPS”

Source: (Author)
Figure 16. An example of accumulated work operations

Source: (Author)

Figure 17. Customer Purchasing Behavior Model of advertisement effect (CPBM-AE)

(i) Scientific Mixed Media Model (SMMM)
(ii) Reality of SMMM of customer actions

Source: (Author)

Figure 18. Schematic drawing of Toyota Sales Marketing System (TSMS)

Source: (Author)