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New Japan Automobile Global Manufacturing Model Using Advanced TDS, TPS, TMS, TIS & TJS

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Abstract

This study mentions the New Japan Automobile Global Manufacturing Model (NJ-AGMM) for the strengthening of Japan automobile corporate management in advanced companies that surpasses traditional Toyota Production System. Specifically, to evolution of Japan automobile manufacturing foundation, NJ-AGMM consists of a structured "Integrated 5 hold-core system - Advanced TDS, TPS, TMS, TIS & TJS" for expanding "uniform quality worldwide and production at optimum locations". The validity of NJ-AGMM has been verified through the actual applications based on the author's Research studies in Toyota.

Keywords: *New Japan Automobile Global Manufacturing Model, Advanced TDS, TPS, TMS, TIS & TJS, Toyota*.

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1. Introduction

At present, leading automobile companies are promoting global production strategies to realize "same quality standards and simultaneous production startup worldwide". Advanced companies in particular are eagerly looking for a new quality management method to supply new attractive product models ahead of their competitors to ensure their survival in the worldwide market. A future successful global marketer must develop an advanced manufacturing model that impresses users and continuously provides excellent products of high quality in a timely manner through corporate management. To realize global manufacturing that places top priority on customers with a good QCD (Quality, Cost and Delivery) in a rapidly changing manufacturing technical environment, it is essential to create the new core principles that are capable of changing the work process quality of all divisions in order to reform super-short-term development production.

Therefore, for the strengthening of Japan automobile corporate management, this study focuses on the New Japan Automobile Global Manufacturing Model (NJ-AGMM) for expanding "same quality worldwide and production at optimum locations". Specifically, to evolution of automobile manufacturing foundation, NJ-AGMM consists of a structured "Integrated 5 hold-core system - Advanced TDS, TPS, TMS, TIS & TJS (TDS is the Total Development System, TPS is the Total Production System, TMS is the Total Marketing System, TIS is Total Management System, and TJS is Total Job Quality Management System) in advanced companies that utilize the author's research principles: the New Japan Model (NJM), new corporate management principle employing New JIT, Science TQM and New Manufacturing Theory in the world (Amasaka, 2002, 2007a,b, 2008a, 2014, 2019a; Amasaka Ed., 2007a).

The aim of NJ-AGMM is *the traditional Just in Time (JIT)* system for not only manufacturing, but also for customer relations, business and sales, merchandise planning and engineering design, product development design, product engineering, administration, and management for enhancing business process innovation. The validity of NJ-AGMM surpassing JIT has been verified through actual applications based on author's researches in Toyota (Amasaka Ed., 2012; Amasaka, 2015, 2017a, 2018a, 2019a,b, 2020a,b).

2. Demand for achieving Japanese automobile global manufacturing

Today's Japanese global manufacturing issues

For manufacturers to be successful in the future global market, they need to develop products that give strong impressions to consumers and supply such items in a timely fashion through effective corporate management. In recent years however, the Toyota Production System representing Japanese manufacturing has been adopted as a called Just-in-Time and Lean System (Ohno, 1977; Amasaka, 1988; Taylor and Brunt, 2001), and further developed in various systems shared internationally. Therefore, it is no longer Japanese (or Toyota's) exclusive technology. In the United States and European countries also, the importance of quality control has been increasingly recognized through studies of Japanese TQM (Total Quality Management). However, a close look at recent Japanese corporate management activities reveals various situations where an advanced manufacturer, which is leading the industry, is having difficulty due to unexpected quality related problems. Some companies have slowed down their production engineering development and are thus facing a crisis of their own survival as a manufacturer.

Against this background, improvement of the Japanese administrative management technology is sorely needed at this time (Goto, 1999: Amasaka, 1999: Nihon Keizai Shinbun, 1999, 2000, 2006: Asahi Shinbun, 2005). To be successful in the future Japanese global marketer must develop an excellent quality management system that can impress consumers and continuously provide excellent quality products in a timely manner through corporate management for manufacturing in the 21st century. Given the above, the author has conducted an awareness survey of general management personnel and executives (a total of 72 people) from 12 advanced companies belonging to the Toyota Group (Amasaka Ed., 2007a). Similarly, based on another awareness survey of the companies (Fuji Xerox and Daikin among others, with a total of 153 participants) participating in the "Study Group for Manufacturing Quality Management (aka "The Amasaka Forum")", management technology issues have been investigated from the standpoint of corporate management.

The result of analysis by incorporating Quantification Class III, it can be confirmed that managers responsible for development give the highest priority to "suggestion-based new merchandise and product development" as a global merchandise strategy, whereas production managers put efforts into establishing the "next generation manufacturing principle" in view of global production. Sales managers, on the other hand, prioritize the "development of new marketing methods" in order to be successful in global marketing. Moreover, the issue common to all was how to respond to globalization (Refer to Amasaka (2007b, 2015, 2019b) in detail).

Needs for the new Japanese automobile global management technology

At present, automobile advanced companies in the world, including Japan are shifting to "global manufacturing" to realize "uniform quality worldwide and production at optimum locations" for survival in fierce competition (Amasaka, 2007a,b). To attain successful global manufacturing, technical administration, production control, purchasing control, sales administration, information system and other administrative departments should maintain close cooperation with clerical and indirect departments while establishing strategic cooperative and creative business linkages with individual development, production and sales departments, as well as with outside manufacturers.

For a manufacturer to accurately grasp customer intentions in order to proceed with production that satisfies the demand of the times, it is important that all the departments play the leading role in company management with an advanced view of the world (Amasaka, 2008a,b, 2014). Because realizing "manufacturing at optimum locations with the same quality worldwide" ahead of competitors is the key to successful global manufacturing, it is not too much to say that strategic partnering between development design, engineering, production and sales operations as well as suppliers is essential (Amasaka, 2007a, 2008b). Specifically, in order to overcome these management issues, it will be necessary to reform the organization and system and innovate the human resources cultivation system through intelligent sharing of information and to create a new management technology for closer ties among the company's divisions.

The above awareness surveys and analysis clarified the core technologies necessary for the next generation management technology principle, the basis for the new management technologies, and the technological elements required for linking these core technologies. Consequently, what will be important in the future is the creation of a new Japanese automobile global management technology equipped with a new concept. That enables a total linkage of QCD research conducted by each of aforementioned divisions from the standpoint of strategic corporate management will be deemed possible (Amasaka, 2008b). Moreover, to promote excellent quality management capable of contributing to global manufacturing, the quality of the business processes of all divisions needs to be enhanced through clear-cut, rational JIT activities (Amasaka, 2010, 2011, 2014).

3. New Japan Automobile Global Manufacturing Model (NJ-AGMM)

Establishment of New Japan Model, new corporate management principle

The aim of corporate management activity in global manufacturing is to offer attractive products. To realize this goal, it is vital for all departments to share the same values toward work and improve the business quality of their work through internal and external cooperation in the world. This means because the existing corporate management activities are based on past successes brought about by each person's particular experience or skills, and it is not enough to encompass such diversified technologies. To create customer-oriented furthermore, attractive products which can truly satisfy the customer's demands, a core technology needs to be established.

Specifically, the author has established the "New Japan Model (NJM), new corporate management principle" employing "New JIT, new management technology principle" and "Science TQM, new quality management principle" as the "global transforming management technology strategy" in the world as shown in Figure 1 (Amasaka, 2004a, 2008a, 2014; Amasaka Ed., 2007a). NJM would allow, technological development designing, production engineering / manufacturing, the advertisement / promotion and sales related departments, which are organically linked together by the management department, and office personnel / indirect department having the role of utilizing human resources in all departments and thus activating the organization, to improve the quality of their work. It is imperative that all these are linked with one another systematically and organizationally.

This model rationalizes the high-linkage cycle for the improvement of business process of each department in a continuous circular ring employing information technology (IT) and statistical science named "Science SQC, new quality control principle" (Amasaka, 2004b). Grasping the mission of each department involved in management technology, this new model is composed of a structured "Integrated five core elements", namely: the Total Development System (TDS), Total Production System (TPS), Total Marketing System (TMS), Total Business Intelligence Management System (TIS) and Total Job Quality Management, System (TJS) as shown in Figure 2, so that each department is equipped with the core technology and linked with one another cooperatively. Each of TDS, TPS, TMS, TIS and TJS consists of organized "four sub-core elements (a)-(d)", as follows;

The significance of TDS as is to create the optimum product design based on the common knowledge by shared use of information. TDS is to systematize the development design methodologies through (a) design based on the on internal and external information with stress laid on design philosophy, (b) development-design management aimed at a reasonable design process, (c) creating general solutions based on the most advanced design technologies, and (d) clarifying the design behavior based on the design policy of a development designer (: theory – action-decision making).

Figure 2: Outline of New Japan Model (NJM) using integrated "five core elements"

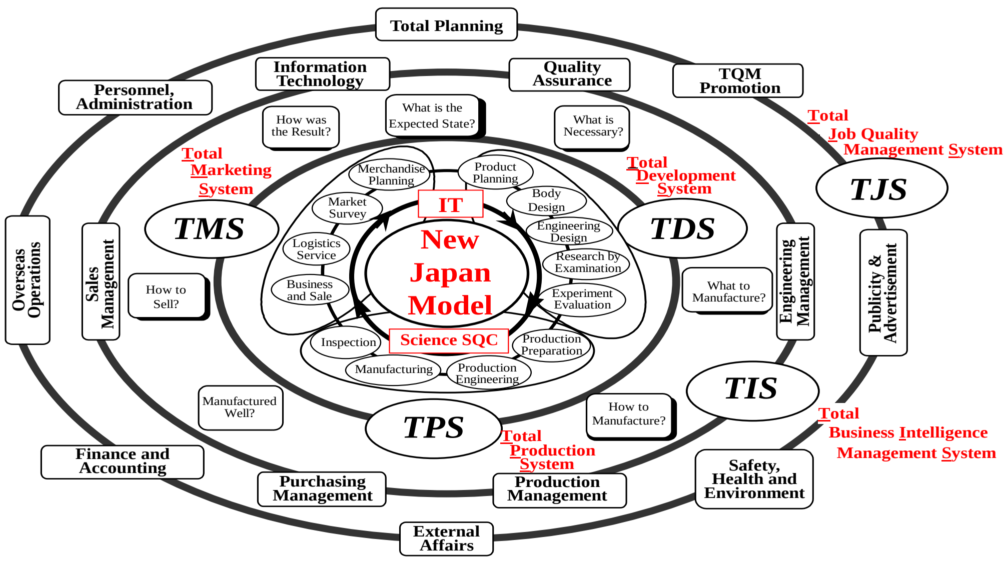
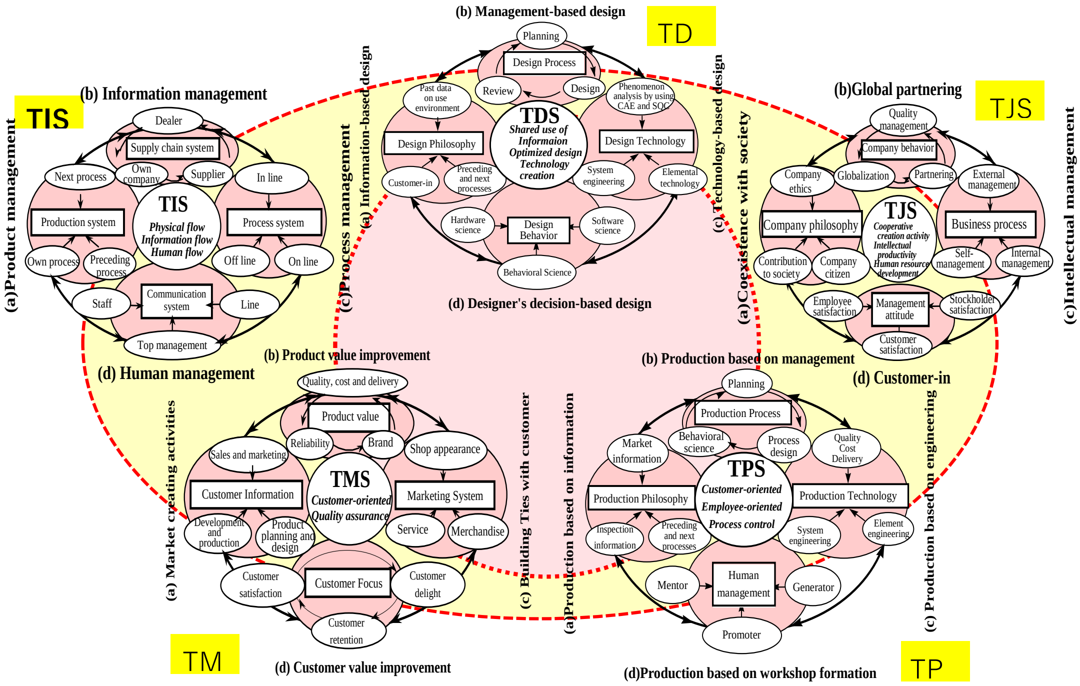


Figure 1: Schematic drawing of New Japan Model (NJM), new corporate management principle

Evolution of the Corporate Management Technology using
high-linkage cycle for the improvement of business process



The main objective of TPS is process management laying stress on customers and employees to realize working environment leading to skill improvement. To improve the reliability of the entire production process, TPS is composed of indispensable sub-core elements: (a) production based on information, (b) production based on management, (c) production based on engineering, and (d) production based on workshop formation.

Similarly, TMS is to develop quality management to be relied on by customers through scientific marketing and sales not sticking to conventional concept. To realize quality assurance with an emphasis on the customer, TMS is composed of strategic sub-core elements: (a) market creating activities, (b) product value improvement, (c) building ties with customer, and (d) customer value improvement.

The aim of TIS has a function of new management technology system for the development design, production and sales departments in the inner circle by linkage with the indirect office department in the outer circle. TIS is composed of organized sub-core elements: (a) product management, (b) information management, (c) process management, and (d) human management based on the integrated cooperative activities.

Similarly, TJS as has a function for improving intellectual productivity by employee training and internal/external partnering to strengthen global marketing. TJS is composed of intellectual sub-elements (a) coexistence with society, (b) global partnering, (c) intellectual management through human resource development, and (d) customer-in management activity, to grasp the importance of cooperative creation activity.

The development and validity of NJM are detailed to the references of Amasaka Ed. (2007a, 2012) and Amasaka (2008a).

Creation of New Japan Automobile Global Manufacturing Model (NJ-AGMM) using "Advanced TDS, TPS, TMS, TIS & TJS"

A future successful global marketer must develop an advanced management system that impresses users and continuously provides excellent products of high quality in a timely manner. In this sub-section, the author creates the New Japan Automobile Global Manufacturing Model

(NJ-AGMM) using a structured "Integrated 5 hold-core system, Advanced TDS, TPS, TMS, TIS & TJS" as shown in Figure 3. The mission of NJ-AGMM in the automobile global deployment of NJM is aimed at the simultaneous achievement of QCD by high quality manufacturing which is essential to realize CS (Customer Satisfaction), ES (Employee Satisfaction), and SS (Social Satisfaction) (Amasaka Ed., 2007, 2012; Amasaka, 2007b, 2008a, 2015, 2019b).

Advanced TDS, Strategic Development Design Model

In the automobile business process from development design to production, the development cost is high and time period is prolonged due to the "scale-up effect" between the stages of experiments (tests and prototypes) and mass production. Against this background, it is vital not to stick to the conventional product development method, but to expedite the next generation development design business process in response to a movement toward digitizing design method. In Figure 3-1, to tackle this issue, the author has created the Advanced TDS, Strategic Development Design Model using "organized four sub-core elements (i)-(iv)" for the strategic application of automobile product design of further updates TDS, a core element of NJM (Amasaka, 2007a,b; Amasaka Ed., 2007a).

In realizing global development strategy employing Advanced TDS, for same quality worldwide and production at optimal locations, customers' orientation (subjective implicit information) must be scientifically interpreted by means of Customer Science Principle, namely, converting the implicit information to explicit information by objectifying the subjective information using Science SQC (Amasaka, 2002, 2004b). Specifically, the author has created the (i) Intelligence Product Design Management System so as to (ii) create the High Reliable Development Design System, thereby (iii) eliminating prototypes with accurate prediction and control by means of Intelligence Numerical Simulation. To this end, it is important to (iv) introduce the Intellectual Technology Integrated System which enables a sharing of knowledge and the latest technical information possessed by all related divisions (Amasaka, 2007c, 2012).

Advanced TPS, Strategic Production Management Model

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. In Figure 3-2, to solve this issue, the author has clarified the "Advanced TPS, Strategic Production Management Model" using organized "four sub-core elements (i)-(iv)" for the strategic application of automobile production of further updates TPS, a core element of NJM (Amasaka, 2007a,b, 2010, 2018). In developing global production strategy employing Advanced TPS, for same quality worldwide and production at optimal locations, the fundamental requirements are the "renewal of production management systems" to accommodate "digitized production" and the "creation of attractive workshop environments" tailored to the "increasing number of older and female workers".

In more definite terms, what is needed is to (i) strengthen process capability maintenance and improvement by establishing Intelligent Quality Control System, (ii) establish the Highly Reliable Production System for high quality assurance, (iii) realize the Renovating Work Environment System in order to enhancement intelligent productivity, and (iv) develop the Bringing up Intelligent Operators through the establishing Intelligent Production Operating System.

Particularly, accomplishing these objectives will achieve the higher-cycled business processes through the joint efforts of production technology, production preparation, manufacture and

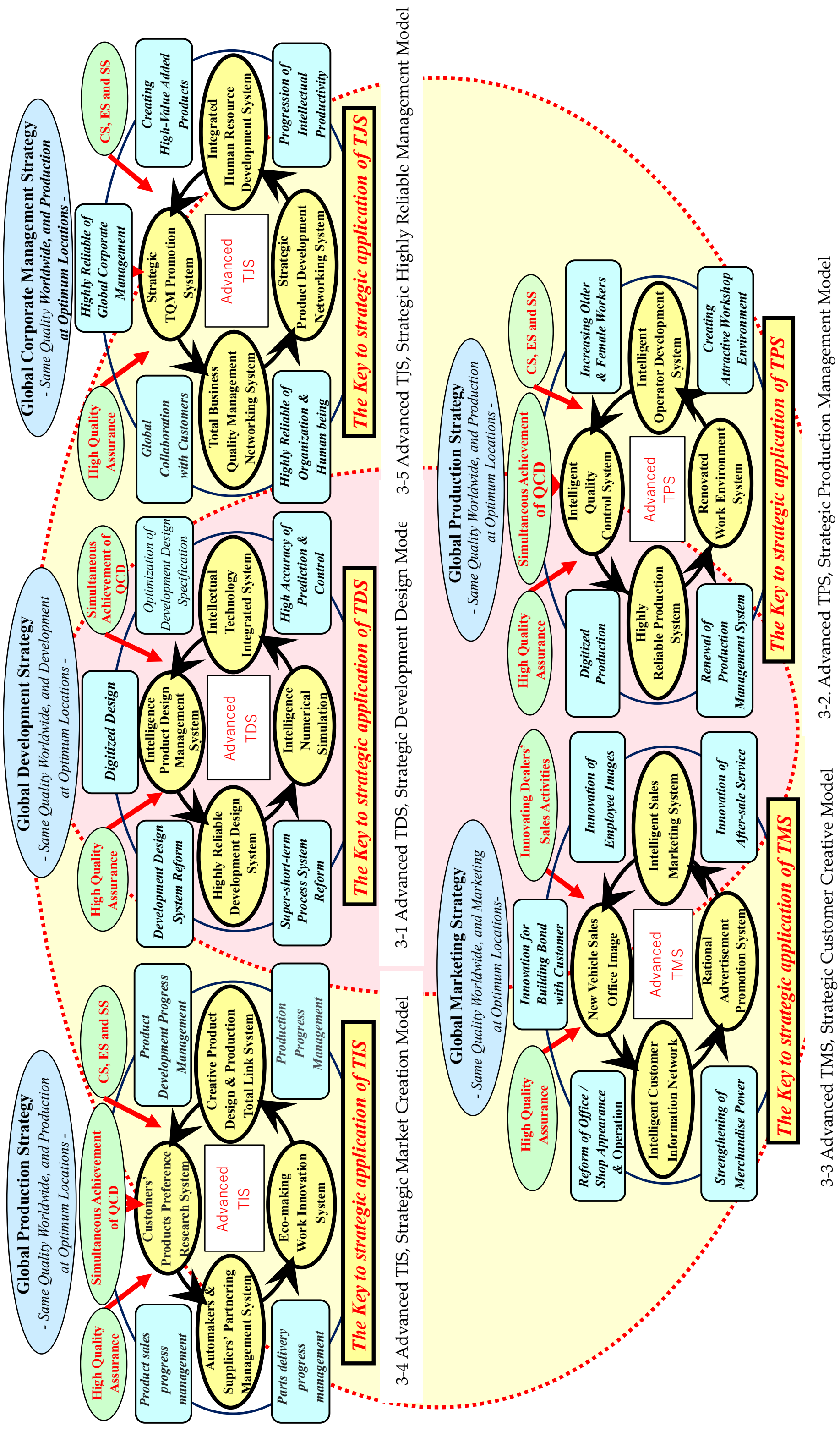


Figure 3: Outline of New Japan Automobile Global Manufacturing Model (NJ-AGMM) using integrated "five core elements"

others (Amasaka et al., 2008; Amasaka and Sakai, 2011; Amasaka, 2018, 2020a,b; Amasaka Ed., 2019)

Advanced TMS, Strategic Customer Creation Model

When the author views recent changes in the marketing environment, what is needed now is to develop "Innovative business and sales activities" that are unconventional and correctly grasp the characteristics and changes of customers' tastes (Amasaka 2007b). In Figure 3-3, therefore, the author has established the "Advanced TMS, Strategic Customer Creation Model" using organized "four sub-core elements (i)-(iv)" for the strategic application of automobile production of further updates TMS, a core element of NJM (Amasaka, 2007b,d, 2011; Yamaji and Amasaka, 2009a). In developing global Marketing strategy, for same quality worldwide and production at optimal locations, Advanced TMS aims to achieve the customer-oriented marketing strategy "Contact with customers" (Amasaka, 2007d) as follows; Sub-core element (i), the New Vehicle Sales Office Image to achieve a high cycle rate for market creation activities by, "innovation for bond building with the customer" and "reform of shop appearance and operation", is particularly important. These constitute the basis for the development of "strengthening of merchandise power", "innovation of after sale service", and "innovation of the employee image". At a certain stage of execution, for example, it is more important to construct and develop (ii) the Intelligent Customer Information Network, (iii) "Rational Advertisement Promotion System" and (iv) "Intelligent Sales Marketing System" that systematically improves "Customer information software application know-how" (Amasaka Ed., 2007a, 2012; Amasaka, 2015, 2019b) .

Advanced TIS, Strategic Market Creation Model

The management departments of "quality assurance, engineering, production, purchasing, sales, and information technology" are the core of corporate activity so as to strengthen and enrich both internal and external management with the general administration department, and cooperate with the on-site departments, such as development designing, manufacturing and sales, as well as with business partners. In Figure 3-4, to tackle this issue, the author has created the Advanced TIS, Strategic Market Creation Model using "organized four sub-core elements (i)-(iv)" for the strategic application of further updates TIS, a core element of NJM (Amasaka Ed., 2007a, 2012; Amasaka, 2004a, 2008a,b).

In developing global production strategy, Advanced TIS aim to achieve the "simultaneous achievement of QCD" as follows; (i) Customers' Products Preference Research System for the development of "product sales progress management", (ii) Creative Product Design and Production Total Link System for the strengthening of "product development progress management", (iii) Eco-making Work Innovation System for the realization of "production progress management", and (iv) Automakers and Suppliers' Partnering Management System for the development of "parts delivery progress management". Particularly, these objectives achieve the strategic development of JIT involving "human resources, technical and product information and SCM" (; Amasaka, 2007e, 2015, 2017a, 2019b ; Yamaji et al., 2008; Okihara et al., 2014).

Advanced TJS, Strategic Highly Reliable Corporate Management Model

It is increasingly important for the general administration-related department to advance corporate management by grasping the changing domestic and overseas environment surrounding the industry so as to strengthen internal and external management. In Figure 3-5, to enhance the "cooperative creation activity, intellectual productivity and human resource development", the author has created the Advanced TJS, Strategic Highly Reliable Corporate Management Model using "organized four sub-core elements (i)-(iv)" for the strategic application of further updates TJS, a core element of NJM (Amasaka Ed., 2007a, 2012; Amasaka, 2004b, 2007d, 2009a,b; Yamaji and Amasaka, 2007, 2009b).

In developing global corporate management strategy, for same quality worldwide and production at optimal locations, Advanced TJS aims to enhance the corporate reliability" as follows; (i) Strategic TQM Promotion System for the realization of highly reliable of global corporate management, (ii) Integrated Human Resource Development System for the strengthening of creating high-value added products, (iii) Strategic Product Development Networking System for the progression of intellectual productivity, and (iv) Total Business Quality Management Networking System for the development of highly reliable of organization and human being and global collaboration with customers.

Particularly, to solve pressing problems inside and outside companies, this is done through cooperation with the development designing, production, customer and sales, and management-related departments (Amasaka, 2015, 2017, 2019b; Amasaka Ed., 2019).

4. Application examples

In this section, the author illustrates typical research examples of Toyota's pioneering manufacturing foundation as the NJ-AGMM application employing Integrated Advanced TDS, TPS, TMS, TIS & TJS. NJ-AGMM is contributing to the evolution of automobile global manufacturing management at Toyota and suppliers, and is proving to be effective both in Japan and overseas (Amasaka, 2015, 2017, 2019a,b, 2020a,b).

Automobile Global Manufacturing Model for the simultaneous QCD fulfilment utilizing Advanced TDS, TPS, TMS, TIS & TJS: Key to the customer value creation

To realize manufacturing that places top priority on customers with a good QCD and in a rapidly changing technical environment, it is essential to create a new global quality management technology linked with overall activities for higher work process quality in all divisions is necessary for an enterprise to survive (Burke and Trahant, 2000; Amasaka, 2007a, 2008b; Amasaka Ed., 2007a). To actualize the key to the customer value creation, the author has created an Automobile Global Manufacturing Model (AGMM) called Toyota's Global Intelligent Partnering Model for Corporate Strategy (GIPM-CS) for the strategic productivity improvement of White-Collar utilizing Advanced TDS, TPS, TMS, TIS & TJS as shown in Figure 4 (Yamaji and Amasaka, 2007a, 2009b; Amasaka, 2009a).

In Figure 4, the function of the (i) Quality Assurance (QA) and TQM promotion as corporate environment factors for succeeding in "global production are (1) CS, ES, and SS, (2) High Quality Assurance, (3) simultaneously achievement of QCD, (4) success in global partnering, and (5) evolution of quality management and intellectual productivity. More specifically, the (i) QA division needs to promote manufacturing of high reliable manufacturing, and cooperative activity across the organization is indispensable to achieve that. In the (ii) TQM promotion division, it is important to cultivate human resources that have even higher skills, knowledge, and creativity. Therefore, the value of intelligent human resources must be promoted in an effort to improve the productivity of White-Collar.

To realize AGMM, global partnering which enables a strategic cooperation among divisions, such as designing, production, marketing and administration as well as the entire company, affiliated and non-affiliated companies, and overseas corporations, must be achieved. Specifically, to increase the effectiveness of AGMM, the author has established the Intelligence High-cycle System of Assembly Maker Production Process (HIS-AMPP) and Total Quality Assurance Networking Model (TQA-NM) for Toyota's new defect prevention in Toyota (Amasaka and Sakai, 2010; Kojima and Amasaka, 2011).

Then, the author illustrates the typical case studies of AGMM deployment below

Figure 4: Outline of Automobile Global Manufacturing Model (AGMM)

Automobile development and design for the bottleneck technology solution

In general, experienced development and design staff and CAE engineers understand the mechanism that is causing the bottleneck technical problem (BTP) as the implicit knowledge (a rule of thumb or empirical rules). 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 (Amasaka Ed., 2007b). Therefore, as the development of "Optimal CAE Design Model", the author has created the "Intelligence CAE Management Approach System" in an effort to help solve the BTP that had become the global technological issue as shown in Figure 5 (Amasaka, 2007c, 2008c, 2017b).

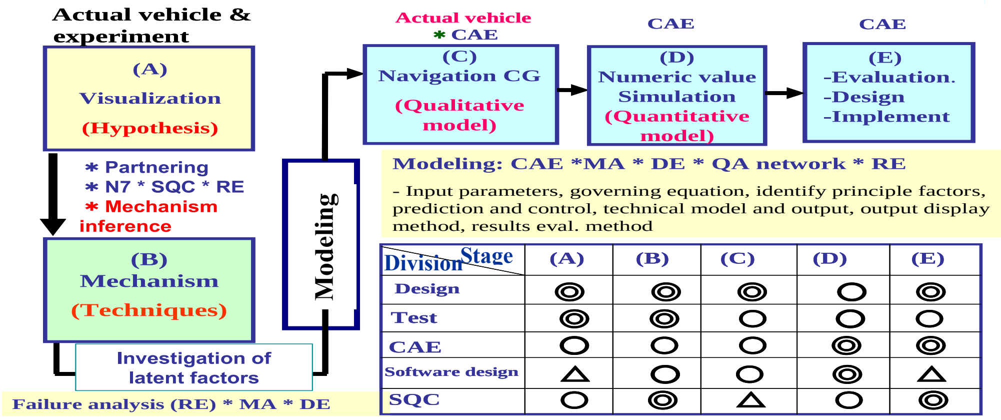


Figure 5: Intelligence CAE Management Approach System
for the bottleneck technology solution

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 using Strategic Stratified Task Team Model (Amasaka, 2004a, 2017b). As the second stage, it was vital to deduce the (B) fault mechanism using various "Techniques". 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 (BTP) mechanism for the "Modelling".
Moreover, 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 (QM)". At this stage, where CAE Navigation Software is being created, it was important to carry out actual vehicle and testing work so that a QM 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, at the stage of developing the (D) "Numeric value simulation", exhaustive actual vehicle testing was carried out in order to convert the mechanism of BTP from implicit knowledge into precise explicit knowledge. The information gained from these work processes would then be unified and a "highly credible numerical simulation for the realization of QM" 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, 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, the author has solved current technological problems in automotive product design (Amasaka, 2010, 2012, 2015; Amasaka et al., 2012).

As an actual case study, the BTP in the world is an unknown mechanism causing an oil seal leakage on the surface of the drive shaft during high-speed rotation (Lopez et al., 1997). 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 (Amasaka, 2008b,c, 2010). As shown in Figure 6, the author has created the "Highly Accurate CAE Analysis Approach Model" to prevent automobile oil seal leaks, incorporating SQC technical methods (Amasaka et al., 2012). The author has contributed to solving a problem of drive train oil seal leaks, which was the BTP 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 the estimate the unknown mechanisms involved in the leaks. This made it possible to

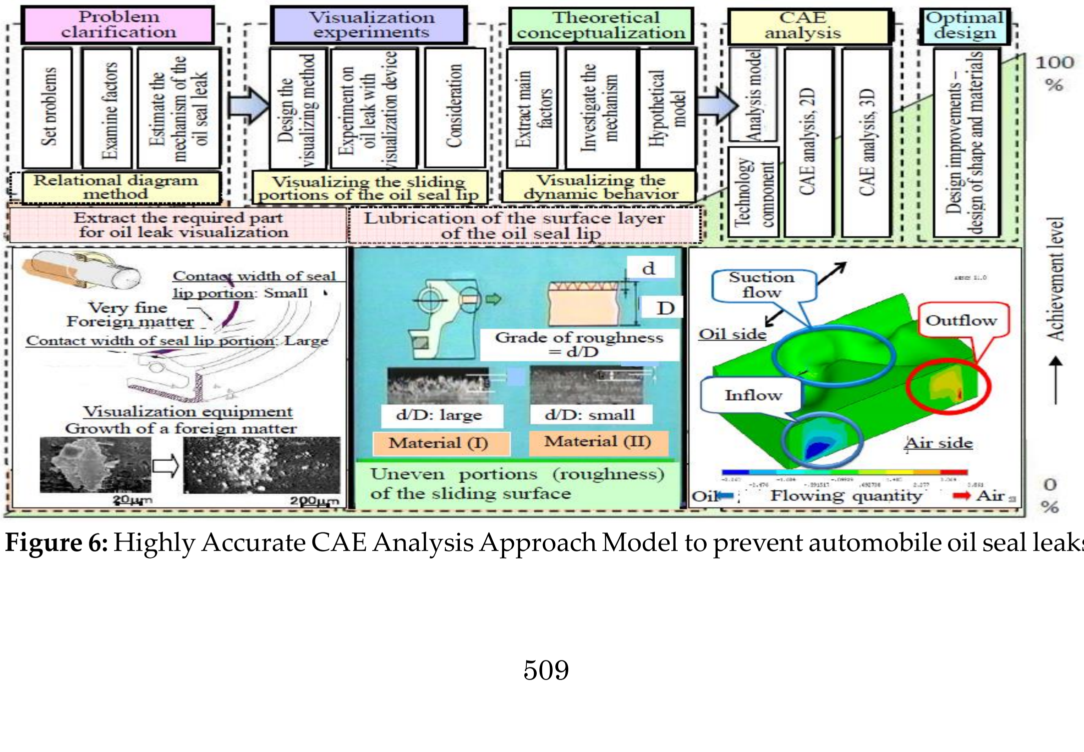


Figure 6: Highly Accurate CAE Analysis Approach Model to prevent automobile oil seal leaks

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 "Oil Seal Simulator using Highly Reliable CAE Analysis Technology Component Model" 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 7 (Amasaka, 2010, 2012).

The following methods were proposed: (i) Identifying the problems: Simulation of variously converging physiochemical phenomena (methodology: (1) to (3)), (ii) Modeling: Building of problem-solving models ((1) to (3)), (iii) Algorithms: Useful and practical algorithms ((1) to (2)), (iv) Rational theories: Creation of the suitable theoretical equations ((1) to (3)) and (v) Calculators: Innovations enabling calculations to be made accurately within a realistic period of time ((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 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 product design improvements (design of shape and materials).

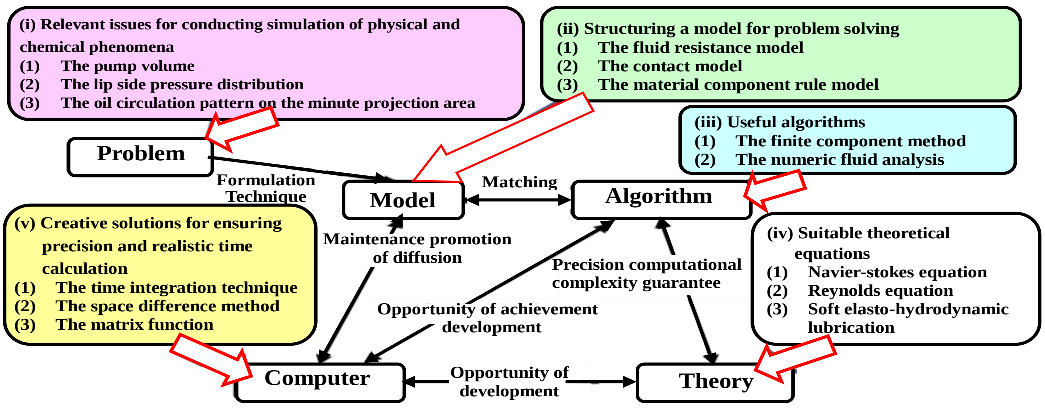


Figure 7. Oil Seal Simulator using Highly Reliable CAE Analysis Technology Component Model

As the application examples to similar problem-solving, the author was able to apply the Intelligence CAE Management Approach System to critical development design technology for the automotive high-quality production. This approach system includes the 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 (Amasaka, 2007c, 2008b,c,d, 2010, 2012, 2019c; Amasaka Ed. 2007b; Sakai et al., 2011; Amasaka et al., 2012). 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.

These examples of AGMM development are detailed to Amasaka (2015, 2019b).

Automobile highly reliable production for global manufacturing

Strengthening of the automobile highly reliable production becomes the most important of the strategic development of global manufacturing engineering employing Dual Global Engineering Model (DGEM) possessing the NJ-GPM and NJ-GMM (Amasaka and Sakai, 1998, 2009, 2011; Amasaka, 2009d, 2015, 2017a, 2018, 2019b, 2020a,b).

Specifically, the author has established the Human Digital Pipeline System (HDPS) as the new production system suitable for the Total linkage of planning, preparation and production as shown in Figure 8 (Sakai and Amasaka, 2007a, 2013).

(i) HDPS creates, 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 product design data for new products and facilities prepared from product 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) Moreover, this system promotes the leveling of operators' workload 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 8 (Sakai and Amasaka, 2007a). 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 Product D/B through the digital pipeline. Next, ② Production Information D/B, containing the production management information, such as production scale and volume as

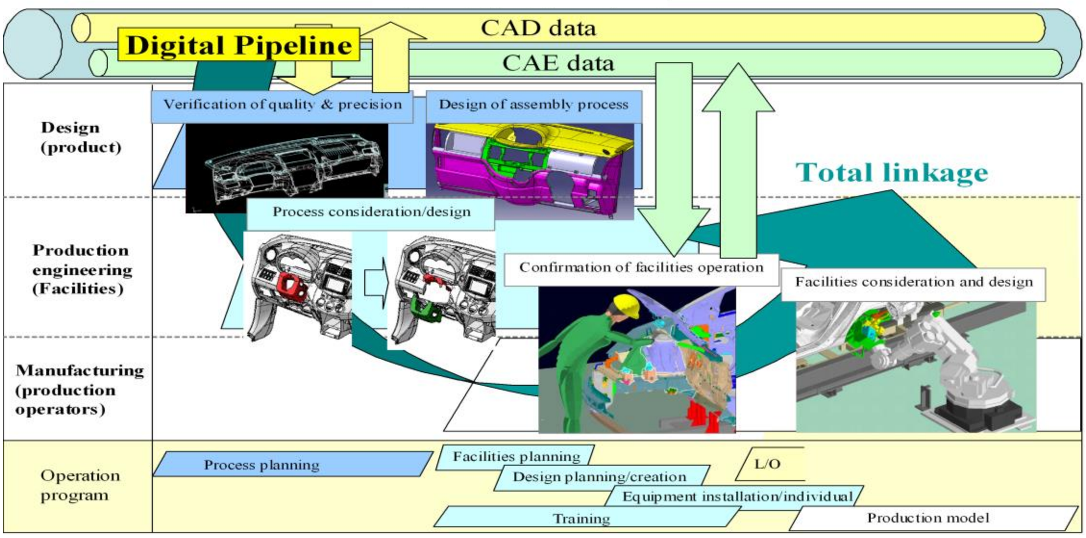


Figure 8: Outline of Human Digital Pipeline System (HDPS)

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. 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 9. 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 information about their number, name, model, or quantity, and the associated 3-D shape data (CAD data) or verification data (CAE data) are searched.

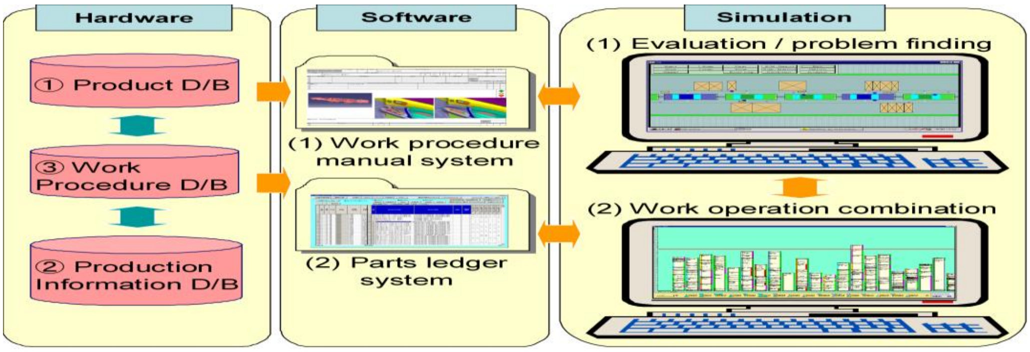


Figure 9: Hardware and software configuration of "HDPS"

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 10. 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.

An example of comprehending and confirming the network ratio and the walking time is shown in Figure 10 (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

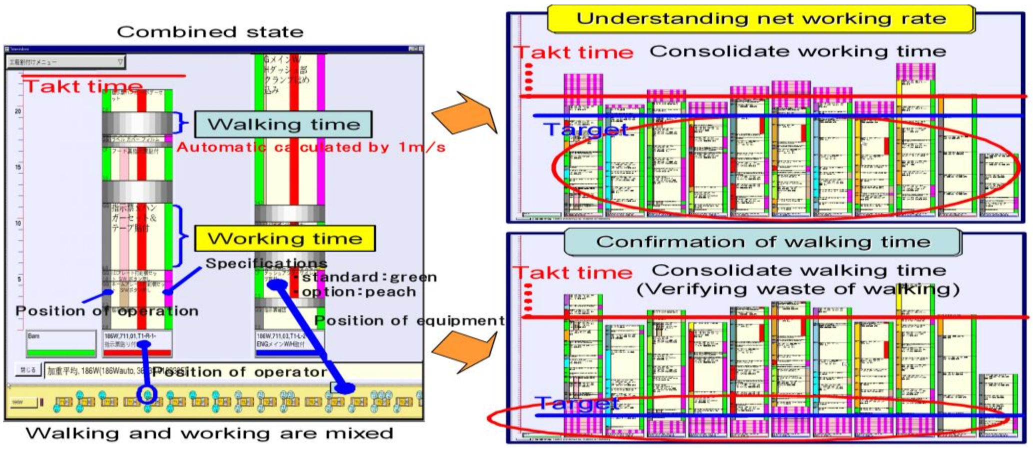


Figure 10: HDPS example of accumulated work operations

spent walking, are stratified to serve as a guideline for reviewing the process layout. Figure 10 (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.

Furthermore, the author has developed the DGEM possessing the typical core systems for the simultaneous QCD fulfillment through the concrete examples as follows;

(1) In Highly Reliable Production System (HRPS) 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) using Human Intelligence Diagnosis System (HID) and Human Integrated Assist System (HIA) for the intelligent work development (Sakai and Amasaka, 2011, 2013).

(2) In Intelligence Quality Control System (IQCS) as the reform of production process management: The author created the (iv) TPS Quality Assurance System (TPS-QAS) using 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 (Amasaka and Sakai, 1998, 2009).

(3) In Renovated Work Environment System (RWES) 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). (Amasaka et al., 2000; Amasaka, 2007e). 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), 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).

(4) In Intelligent Operators Development System (IODS) as the reform of technical skills level of production operators and further improving the reliability of their skills: The author has 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) (Sakai and Amasaka, 2003, 2007c).

(5) In Accelerated Technical Training System (ATTS) for the highly skilled operators: The author has realized the shortened training of highly skilled operators in auto-assembly line employing

Intellectual Working Value Improvement Management Model (IWV-IMM), Working Value Evaluation Model (WVEM), and Inexperienced Machine Workers' Training Model (IWPM) for strengthening of manufacturing technology and making of "Creative workplace" (Yamaji et al., 2007b; Tsunoi et al., 2010; Uchida et al., 2012; Yanagisawa et al., 2013; Kawahara et al., 2016).
Recently, for expanding overseas manufacturing using DGEM, the author has created the New Global Partnering Production Model (NGP-PM) (Ebioka et al., 2007) employing AGMM. Concretely, the author has developed the New Turkish Production System (NTPS), New Malaysia Production Model (NMPS), New Vietnam Production Model (NVPM) and Advanced Toyota USA Manufacturing System by developing Partnering Performance Measurement to strengthen corporate management of Japanese automobile assembly makers and suppliers (PPM-AS) and TQM Promotion Diagnosis Model (TQM-PDM) (Shan, et al., 2007; Yamaji et al., 2008; Yeap, et al., 2010; Shan et al., 2011; Kozaki et al., 2012; Miyashita and Amasaka, 2014; Amasaka, 2016; Kozaki et al., 2012).
These studies of AGMM development are detailed to Amasaka (2015, 2017a, 2019b).

Change in automobile marketing for developing customer creation

One vital point of the strategic marketing structure is its definition; Sales marketing activities for developing 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. Then, the author has created the Scientific Customer Creative Model (SCCM) which takes the form of strategic marketing as shown in Figure 11 (Amasaka Ed., 2007a, 2012). 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.
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 that uses IT, it clarifies a potential target market from the changing market or the customer structure analysis.

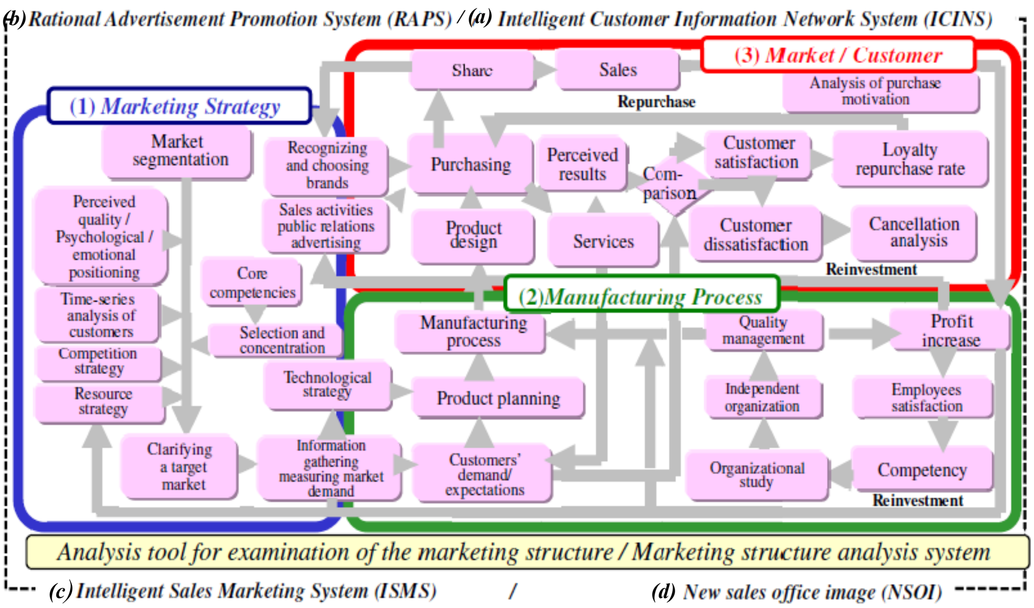


Figure 11: Outline of Scientific Customer Creative Model (SCCM)

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.

In Figure 11, for realization of strategic employment of SCCM, the author has created the total linkage by four elements with (A) Intelligent Customer Information Network System (ICINS), (B) Rational Advertisement Promotion System (RAPS), (C) Intelligent Sales Marketing System (ISMS) and (D) New Sales Office Image (NSOI) as follows. To accomplish SCCM, as the first application of automobile market creative activities, the commanding of CS and CL (Customer Loyalty) in the (3) *Market and Customer domain* is a criterion for the strategic development of SCCM. As the prior research**,** the authors know of no studies that have been done on auto sales from a multidisciplinary perspective (Mikawa, 2008). 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.

Specifically, by employing the (a) Intelligent Customer Information Network System (ICINS), this research uses the statistics approach for focusing on CS as a way of boosting marketing effectiveness, clarifying the key factors that comprise CL (Ishikawa et al., 2011; Iida et al., 2013; Okutomi and Amasaka, 2013). 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 author collected and analyzed sales information from core customers to identify the four key factors of CS and CL among them using covariance structure analysis 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

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

Product	CS	CL
exterior	.612	.470
interior	.198	.217
Safety device	-.034	-.109
Handling	.087	.026
Cornering	.190	.149
Straight-line stability	.207	.213
High-speed stability	.106	-.077
Durability	-.045	-.064
pedal	-.458	-.257
seat	.519	.694
Engine displacement	.600	.343
fuel efficiency	.475	.270
Interior noise	.136	.188
Body shaking	.254	.506
Car navigation system	-.045	-.120
audio	.181	-.099
price	-.024	.119

Dealership	CS	CL
Appearance	.115	-.041
Opening Hours	.024	-.048
location	-.098	.169
mandatory inspection services	.203	.086
Emergency measure	.659	.559
Periodic contact	-.294	.278
Employee	**CS**	**CL**
polite	.291	.552
knowledge	.154	.316
Prompt customer service	.464	.077
Corporate	**CS**	**CL**
pamphlet・Website	.205	.057
TV commercials	.128	.502
corporate image	.776	.511

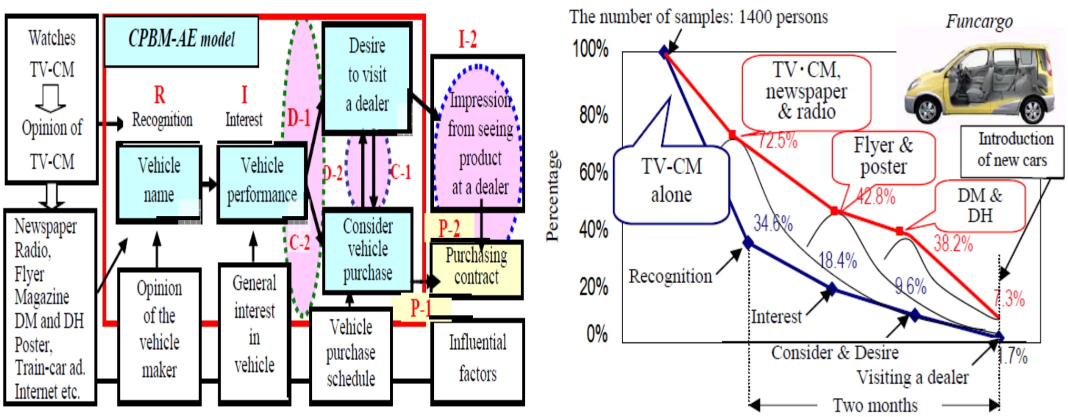
Note: The number of four key factors (: product, dealership, employee and corporate) in the table shows standardizing coefficient.

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.

As the second application based on the above-mentioned knowledge, by employing the RAPS, ISMS and NSOI in order to strengthen automobile sales activities, usuful advertisement methods in the (1) *Market Strategy* domain is a fundamental for the strategic development of SCCM. Then, 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 (Niiya and Matsuoka, Eds., 2001; Amasaka, 2003, 2009d).

Specifically, the author has developed the Customer Purchasing Behavior Model of advertisement effect (CPBM-AE) employing Scientific Mixed Media Model (SMMM) as shown in Figure 12 (Amasaka, 2011; Amasaka, Ed., 2012; Amasaka, et al., 2013). Here, the author has borne interest 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 12(i) shows a 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. As background for the influential factors, the author has 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



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

Figure 12: Customer Purchasing Behavior Model of advertisement effect (CPBM-AE)

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 12(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 19(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, 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 (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, 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 (Ishiguro and Amasaka, 2012; Ogura et al., 2014; Koizumi et al., 2014).

As the third application, furthermore, 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 13 (Amasaka, 2007d, 2011).

As the CR investigation to enhance the validity of TSMS, the author dealt with the subject of

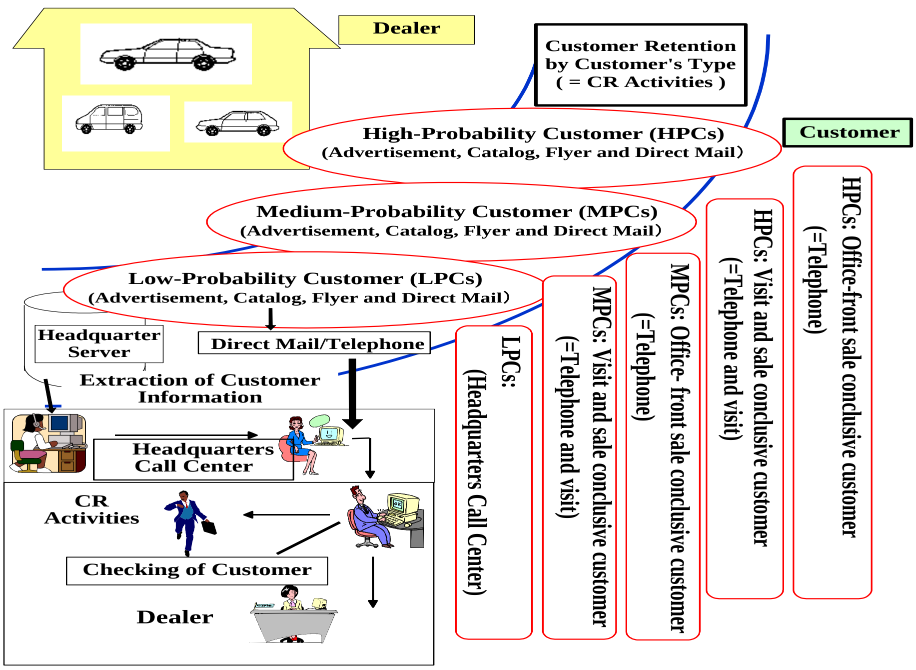


Figure 13: Schematic drawing of Toyota Sales Marketing System (TSMS)

improving the sales rate for replacement Toyota vehicles, which involves setting up Netz dealers in a model case (Yamaji et al., 2010; Amasaka, Ed., 2007b, 2012)

Concretely, the Categorical Automatic Interaction Detector (CAID) and Cramer's Analysis are 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 (Amasaka, 2011, 2015, 2019b). 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 (i) increase the rate of CR, and (ii) acquire new customers.

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 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.

SCCM operation using TSMS has recently contributed to an increase in the sales share of vehicles at Toyota in Japan (40%/1998 to 46%/2007) (Nikkei Business.1999; Toyota, 2013). Furthermore, as the typical case studies, SCCM can also be made use of when visiting customers, and to help acquire new customers at the time they visit a dealer through the raising capability of the employee of the car dealer, and developing long-term eco-friendly car in the logistics industry (Toyoda et al., 2015; Okihara et al., 2015).

5. Conclusion

In this study, the author has created the NJ-AGMM (New Japan Automobile Global Manufacturing Model) for expanding "same quality worldwide and production at optimum locations". Specifically, to evolution of automobile manufacturing foundation, NJ-AGMM consists of a structured "Integrated 5 hold-core system - Advanced TDS, Advanced TPS, Advanced TMS, Advanced TIS and Advanced TJS in Toyota and advanced companies. The validity of NJ-AGMM surpassing JIT has been verified through the actual applications based on the author's researches in Toyota and others.

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