Journal of Economics and Technology Research
ISSN 2690-3695 (Print) ISSN 2690-3709 (Online)
Vol. 5, No. 2, 2024
www.scholink.org/ojs/index.php/jetr

Original Paper

Creation of a New Automobile Customer Value Creation Model: The Strategic Development of Customer Science Principle

Kakuro Amasaka[1*]

[1] College of Science and Engineering, Aoyama Gakuin University, Tokyo, Japan

[*] Kakuro Amasaka, College of Science and Engineering, Aoyama Gakuin University, Tokyo, Japan

Received: July 11, 2024 Accepted: July 28, 2024 Online Published: August 16, 2024

doi:10.22158/jetr.v5n2p132 URL: http://dx.doi.org/10.22158/jetr.v5n2p132

Abstract

This study describes a "New Automobile Customer Value Creation Model" (NA-CVCM) employing the strategic development of "Customer Science principle" (CSp) for realizing attractive cars creation based on the "Science TQM, new quality control management principle" with "Science SQC, new quality control principle". Specifically, to strengthen "auto-corporate management", The foundation of NA-CVCM develops a "Dual Affective Engineering", and contains both of the "exterior design engineering strategy and driving performance design engineering strategy" through 3 domains of the "designing, manufacturing and sales marketing" employing "Strategic Stratified Task Team Model" (SSTTM) for excellent QCD activities. Concretely, by developing "Intelligent Customer Information Marketing Model" (ICIMM), the foundation of NA-CVCM consists of the "Automobile Exterior Design Model with 3 Core Methods (AECD-3CM), Automobile Optimal Product Development Design Model (AOP-DDM) and CSp-Customer Information Analysis and Navigation System (CSp-CIANS)". The validity of NA-CVCM is then verified through the actual applications in Toyota and others.

Keywords

New Automobile Customer Value Creation Model, Customer Science principle, a dual affective engineering strategy, exterior design engineering, driving performance design engineering, Toyota

1. Introduction

Lately, global automotive industry proceeds with the strategic development of "automobile corporate management strategy in the world" to win the quality competition through realizing "customer value creation activities through simultaneous achievement QCD (quality, cost and delivery)" (Amasaka, Ed., 2007a, 2007b, 2012, 2019; Amasaka, 2015a, 2017a, 2017b, 2022a, 2022b, 2023a, 2024).

Recently, the increasing sophistication and diversification of "customers' wants" are needed for the development of global production, which acts in concert with the overseas deployment of production bases, a pressing management issue (Amasaka, 2002, 2005). Nowadays, customers have been selecting products that fit their lifestyles and their set of personal values. For this reason, manufacturers' success or failure in global marketing will depend on whether or not they are able to precisely grasp the "customers' preferences", and are then able to advance their manufacturing to adequately respond to the demands of the times (Amasaka, 2014, 2018, 2019a, 2021, 2023b, 2024).

Above all, looking closely at the quality management issues "Unpopularity of appearance design quality and recalls of driving performance" facing Japanese advanced automotive manufacturing industry both domestically and overseas, it has become clear that a "new corporate management technology" by focusing "Product plan and development design" strategy is being strongly sought after (Matsuoka and Harada, 1997; JD Power and Associate, 1998; Nihon Keizai Shinbun, 1999, 2000, 2006, 2012; Amasaka, 2002, 2007a, 2007b, 2008a, 2010a; Lockman, 2010).

For that accomplishment, integrative strengthening of the "excellent designing, production and sales marketing" becomes indispensable for realization of the "super short-term product development design process and high-quality manufacturing in optimal locations" (Amaska, 2017a, 2007b, 2022a, 2022b, 2023a, 2024). There, in this study, then, the author creates a "New Automobile Customer Value Creation Model" (NA-CVCM) employing the strategic development of "Customer Science principle" (CSp) strategy for realizing attractive cars creation based on the development of "Science TQM, new quality control management principle" with "Science SQC, new quality control principle" (Amasaka, 2004a, 2004b, 2005, 2010a; Amasaka, Ed., 2012).

Specifically, to strengthen "auto-corporate management", NA-CVCM develops a "Dual Affective Engineering" named "Kansei Engineering" in Japan, and contains both of the "exterior design engineering strategy and driving performance design engineering strategy" through 3 domains of the "designing, manufacturing and marketing" employing "Strategic Stratified Task Team Model" (SSTTM) for excellent QCD activities (Amasaka, 2004a, 2008b, 2017a, 2023c).

Concretely, by developing "Intelligent Customer Information Marketing Model" (ICIMM), the foundation of NA-CVCM consists of the "Automobile Exterior Design Model with 3 Core Methods" (AECD-3CM) using "psychographics", "Automobile Optimal Product Development Design Model (AOP-DDM) using experiment and simulation" and "CSp-Customer Information Analysis and Navigation System (CSp-CIANS) visualizing customers' demand" (Amasaka, 2005, 2018, 2023c).

The validity of NA-CVCM is then verified through the actual applications to product development design, production engineering, manufacturing and marketing in Toyota and others (Amasaka, 2018, 2019a, 2019b, 2021, 2023c, 2024).

.

2. Automotive Management Technology Issues in Shifting to Global Production

Today, the mission of auto-manufacturers (automakers) in this rapidly changing management technology environment is to be fully prepared for "worldwide quality competition" so as not to be pushed out of the market, and also to establish a "new auto-management technology model" that enables them to offer highly value products of the latest design that are capable of enhancing "customer value" (Amasaka, 2006, 2007c, 2007d, 2010b, 2011, 2012a, 2012b, 2014, 2018, 2021, 2023b; Amasaka et al., 2012; Okutomi & Amasaka, 2013; Toyoda et al., 2015).

There, advanced companies in the world including Japan are shifting to global production to realize the "uniform quality worldwide and production at optimum locations" for survival in fierce competition (Amasaka, 2015a, 2017a, 2017b, 2022a, 2007b, 2023a, 2024a; Amasaka, Ed., 2012, 2019). Today, consumers have quick access to the latest information in the worldwide market thanks to the development of Information Technology (IT), and strategic organizational management of the production control department has become increasingly important. Therefore, "simultaneous attainment of QCD requirements for customer value creation" is the most important mission for developing highly reliable new products ahead of competitors (Amasaka, 2004a, 2006, 2008c, 2008d, 2010a, Amasaka, Ed., 2012).

This requires the urgent establishment of an innovative production control system for the next generation. With a view to assuring that future management technology is a new leap forward for "Japanese manufacturing", the "progress of production control of plants in the manufacturing industry" made so far by the manufacturing industry is summarized in Figure 1 (Amasaka, 2004a, 2009a; Amasaka, Ed., 2019). In Figure 1, the basis of the major production control methodologies, such as Industrial Engineering (IE), operations research, quality control, management of administration, marketing research, production control, and IT, are plotted along the vertical axis. Along the horizontal axis, some of the key elemental technologies, management methods, scientific methodologies, and so on are mapped out in a time series.

Since the beginning of this century, the operation of manufactures has shifted from domestic production in Japan to overseas production bases, and management technology has become increasingly complicated as depicted in Figure 1.. Actually, "key to success in global production" is modeling of "strategic Supply Chain Management (SCM) for domestic and overseas suppliers with a systematization of its management methods". In the implementation stage, deep-plowing studies of the "typical Toyota Production System" (TPS) called Just in Time (JIT), Total Quality Management (TQM), partnering, and digital engineering" will be needed in the future (Amasaka, 2000b, 2006, 2008a, 2008e, 2009a, 2014; Amasaka, Ed., 2007a).

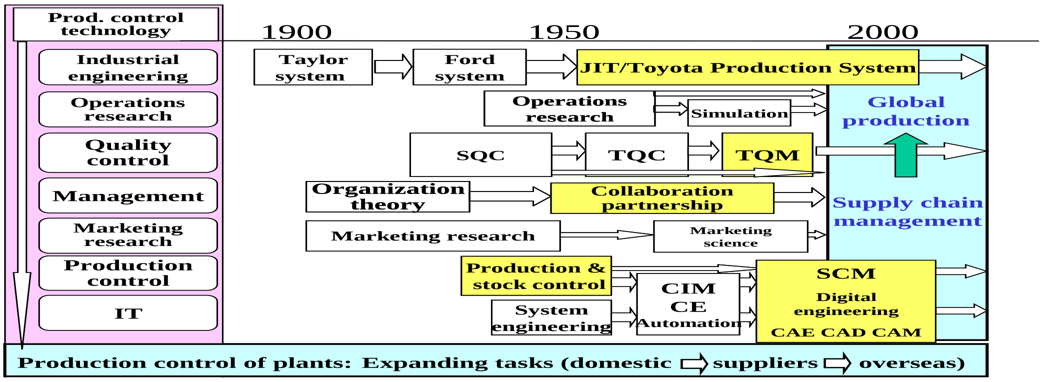


Figure 1. Progress of Management Technology in the Manufacturing Industry

3. Developing Customer Science Principle for Customer Value Creation

3.1 Customer Science Principle (CSp) Aiming Customers' Demand Scientific Analysis

When it is watched closely in the automotive industry which Japan represents, it is important the "reinforcement of the corporate management function for realizing customers' wants". The mission of auto-manufacturer is to offer products the consumers (customers) are pleased with, as the basis for sustainable growth. Entering into a new century of product creation based on the management of global marketing, it is necessary to create the kind of products which further enhance the "life stages and lifestyles of customers", as well as customer value.

To develop and offer attractive, customer-oriented products, it is vital to urgently and seriously consider "customer needs" and to establish strategic product development methods which are ahead of the times (Amasaka, 2002, 2004b, 2005). To directly confront the management environment, today's companies are surrounded by and to implement the necessary measures to respond to it, it is indispensable to establish a "scientific approach toward customer orientation". A reasonable business approach is needed which can be utilized for product planning and technical development through the digitalization of the hidden desires of customers, so that subjective information (about the customers) and objective information (objectified by technology) can be mutually and compatibly exchanged.

Generally speaking, though customers have both favorable and unfavorable evaluations about current products in the market, they usually do not have a clear image of what types of products they want in the future. The customers express their demands in spoken words, and therefore the product designers (planning and designing staff) need to accurately interpret such expressions and convert them into corresponding design drawings. For this reason, the sales and service staff who are closest to the customers need to express the product image that the customers have to the planners, (research engineers/designers who think objectively in numerical terms) who engage in product development, in a scientific, common language rather than rely on an implicit, vague language (Amasaka, 2002, 2005).

In connection with the creation of future products, it is particularly important to “offer precisely and quickly what the customers want before they realize they want it”. To do this, it is vital to clearly grasp the hazy, ambiguous feelings of customers.

The product development technological method—“Customer Science principle” (CSp) shown in Figure 2 is what gives concrete shape to such customer wants (Amasaka, 2004b, 2005). It is intended to present a mode of (an approach to) a new business process for creating “wants” which is indispensable for manufacturing attractive products.

As depicted in the Figure. 2, called objectification of subjectivity wherein the image of customers' words (implicit knowledge) is expressed in a common language (lingual knowledge) and then, by incorporating technical words (design drawings etc.) as well as correlation techniques, it is further interpreted appropriately (into explicit knowledge).

This refers to the CSp that converts subjective information (y) and objective information ($\hat{y}$) reasonably to two-way through application of correlation technology. When using CSp for approaching various customer-related situations, such as why the customers are satisfied or dissatisfied with a particular product, what is the underlying feeling behind a certain expression, what kind of products then need to be offered, or in what specific situation a recall case occurs, the situations can then be

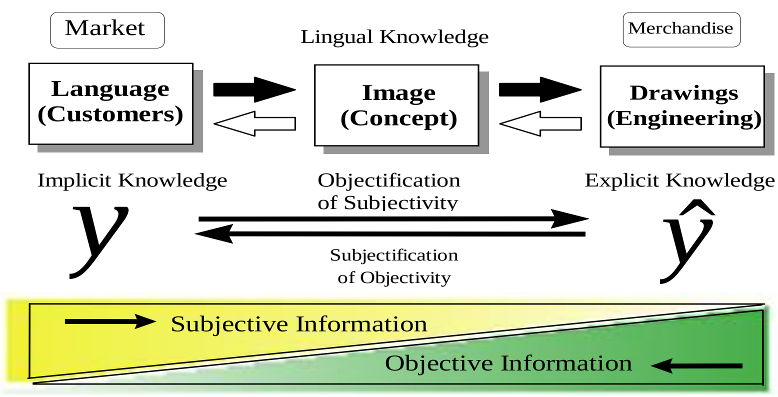


Figure 2. Schematic Drawing of Customer Science Principle (CSp)

interpreted into a common language, and further converted into the language of technology.

Then the staff of the research & development or designing departments can digitize such situations by means of correlation techniques utilizing statistical science, simulate them in the laboratory or experiment facility, and confirm the conditions in which such situations are most likely to occur. Finally, it is necessary to check whether what is represented on a drawing specifically reflects what “customers' actually wants” and thereby confirm the accuracy of the work being performed, thus subjectifying the objectivity using correlation techniques (Amasaka et al., 1999; Amasaka & Nagaya, 2002; Amasaka, 2002, 2004b, 2005, 2008a; Amasaka, Ed., 2000, 2007a).

By conducting "total marketing", that is, an approach focusing on "quality management that gives customers top priority" incorporating CSp, the implicit business process, consisting of promotion/sales, product planning, designing, development designing, and production, which has been a major concern for the management class, can be clarified further.

By means of the scientific knowledge obtained from the cycle of these business processes, "accumulation of successes" or "correction of failures" can be carried out more accurately than ever, and therefore highly reliable quality management, "scientific Total Quality Management (TQM)" named "Science TQM, new quality management principle" can definitely be realized in Toyota and others (Amasaka, 2008a, 2013, 2014; Amasaka, Ed., 2012).

It is observed that well-performing manufacturers both inside and outside Japan today have maintained an attitude which prompts them to humbly repeat the process of clarifying implicit knowledge to grasp the customers feelings to the greatest extent possible, and then feed it back to check whether what is reflected in their product design drawings truly represents the objectified demands of customers. Such an attitude constitutes the basis of their manufacturing activities (Amasaka, 2007a, 2008a, 2008b, 2009a).

3.2 CSp Strategy Employing Science SQC Approach Based on the Science TQM Activity

To realize CSp strategy, then, to strengthen of "automobile management technology", the author has employed the "Science SQC, new quality control principle" approach as the "integrated scientific methodology" based on the Science TQM activity (Amasaka, 2002, 2993, 2004a, 2004b; Amasaka, Ed., 2000, 2007, 2012). Specifically, Science SQC was developed under a new concept using a new methodology that applied the 4 core principles that enabled jobs to be scientifically performed based on a new quality principle that is the secret of success for next-generation manufacturing as shown in Figure 3. As determined from figure, the four core principles are incorporated into a "New SQC application system" where they are closely linked to each other (Amasaka, 1988a, 1988b, 2024c).

The 1st core principle of "Scientific SQC" refers to scientific approaches at every stage of the process ranging from determination of problem to accomplishment of objectives. The 2nd core principle of "SQC Technical Methods", which use the "New Seven Tools" (N7) for TQM, Multivariate Analysis (MA), Design of Experiment (DE), Reliability Analysis (RA) and others, refers to the "mountain-climbing methodology for solving problems. The 3rd core principle of "Integrated SQC Network "TTIS" (named Toyota SQC Technical Intelligence System)", represents the networking of SQC software application by using the sub-core principles. It can turn proprietary data inheritance and development into science.

The 4th core principle of "Management SQC" is to support prompt solution of deep-rooted problems.

Particularly in the practical application, the gaps between principles and rules have to be clarified scientifically as engineering problems, and general solutions have to be approached by clarifying the gaps that exist in theory, testing, calculation, and actual application (Amasaka, 1998a, 1998b, 2000a, 2003, 2004b). Science SQC is vital to deploy this advancement of manufacturing in a systematic and organizational manner by deploying the personal "empirical knowledge" as "organizationally shared knowledge" at Toyota (Amasaka, 2000a, 2004a, 2004b, Amasaka, Ed., 2012).

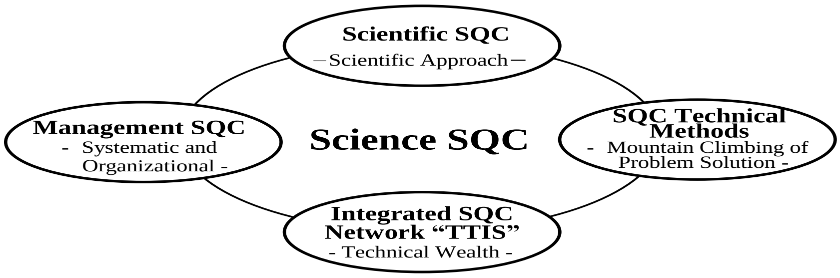


Figure 3. Schematic Drawing of Science SQC, New Quality Control Principle

4. Necessity of Revolutionary Japanese Automobile Development Design and Production in Global Marketing

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 the effective corporate management. In recent years, the "Toyota Production System" (TPS) representing Japanese manufacturing has been adopted as the "Just-in-Time/Lean System" as the developed in various systems shared international manufacturing system (Ohno, 1978; Amasaka, 2000a, 2000b; Taylor & Brunt, 2001; Evans & Dean, 2003).

However, it is no longer Japanese (or Toyota's) exclusive technology. In the "Advanced countries and Developing countries" ("United States, European countries" and "India, China, Southeast Asia" etc.), the importance of quality control has been increasingly recognized through studies of "Japanese corporate management utilizing TPS and TQM" (Amasaka, Ed., 2007a, 2012; Amasaka, 2015b, 2017a).

Against this background, to be successful in the future, Japanese global marketer must provide excellent quality products in a timely manner through a "new perspective corporate management" for global marketing and production in the 21st century (Goto, 1999; Amasaka, 2002).

Then, as a key to realize them, the author researches to create the "attractive design and high performance and highly functional new products" to offer "customers' high value-added products and prevail in the worldwide quality competition" (Amasaka, 2000a, 2006, 2008e).

Specifically, the author posed the question, "What are some of the issues that need to be addressed in order to prevail in the 21st century?" to a total of 154 respondents chosen from the top management class (board members) and managers (of divisions and departments: marketing, research/development, manufacturing technique/manufacture, business/administration and quality assurance) of the twelve manufacturers of the top Japanese enterprise (Toyota, Fuji-Xerox, Sanden, Daikin, JFE Steel, NEC, YANMAR, YOKOGQWA etc.) that participated in the "Workshop on Quality Management of Manufacturers" (hosted by Kakuro Amasaka, Professor of Aoyama Gakuin University from May 2004 to March 2006) (Amasaka, Ed., 2000, 2007a; Amasaka, 2015b).

Figure 4 is an example of the summary and analysis results of these interests (or the free opinions gathered from the survey) "What is the Important Issue which should be tackled?" As shown in Figure. 4, their interests center on "technological development, human resources, globalization, product differentiation, quality/safety, organization/management". From these results of the various scientific analyzes using CSp with Science SQC above, especially, as for a matter of concern of the automobile commonness, it is important to developing the "high Quality Assurance (QA), super-short-term product development design process and simultaneous achievement QCD. To carry out the various subjects, there are two critical management issues in the "product plan, development design, product engineering and manufacturing to raise that position as a top-runner in the world" as follows;

First, concretely, as customers' values become increasingly diverse, automobile exterior design is becoming one of the most critical elements influencing customer purchase behavior. Unfortunately, as people's values and subjective preferences become more varied and complex, it becomes increasingly difficult to accurately define their wants and needs. Therefore, it is important for mapping up exterior design strategy to study on "what style of vehicles would sell in the future?" However, in many cases, automaker's vehicle designers do not have a clear idea of future vehicle styling (Amasaka, 2004b, 2005, 2007c; Amasaka et al., 1999; Amasaka & Nagasawa, 2000; Amasaka, Ed., 2007a).

Second, in the midst of rapid change of management technologies, a key challenge facing the automakers is important to develop the "New Japanese product development design system and total quality production system" which provides the latest, highly reliable and customer-oriented products so that they can survive the worldwide quality competition. There, focusing on management technology for product development design and production processes, it is clear that there has been excessive

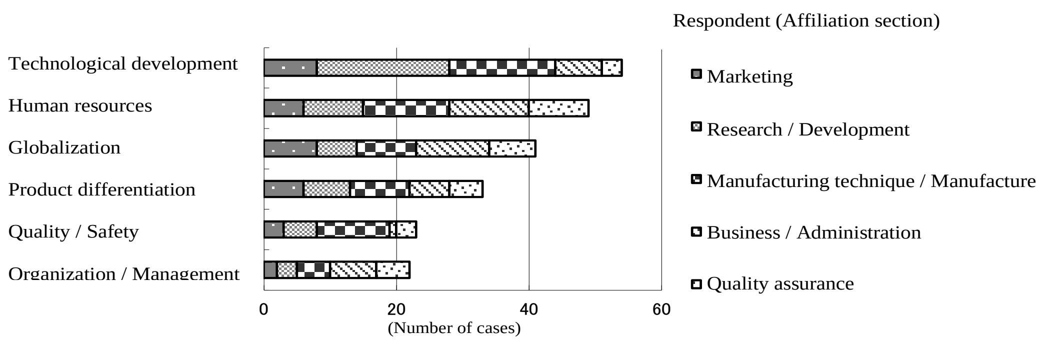


Figure 4. What is the Important Issue which should be Tackled?

repetition “trial-and-error” of prototyping, testing and evaluation for the preventing of “scale-up effect” in the bridging stage between product development design and mass production (Amasaka, 2007d, 2008d; Amasaka, Ed., 2007a, 2007b).

5. Creation of a New Automobile Customer Value Creation Model for Realizing Attractive Cars Employing a Dual Corporative Engineering Strategy

For realizing “attractive cars”, the author has established a “New Automobile Customer Value Creation Model” (NA-CVCM) employing a “Dual Corporate Engineering Strategy”. Then, NA-CVCM develops to advance the “Excellent Designing, Production & Sales Marketing, super short-term products development design process and High-Quality Manufacturing in Optimal Locations for realizing “both of the Appearance quality and Functional quality”.

Specifically, NA-CVCM develops the CSp by employing “*Affective Engineering*” named “*Kansei Engineering*” in Japan with statistical science: “Science SQC, new quality control principle” through “employing of the “Strategic Stratified Task Team Model” (SSTTM) for excellent QCD activities” as shown in Figure 5 (Amasaka & Nagaya, 2000, 2002; Amasaka, 2004b, 2005, 2007b, 2008b, 2010a).

Concretely, NA-CVCM contains both of the “Exterior design engineering strategy and Driving performance design engineering strategy” for the developing “appearance quality and functional quality” that contributes to strengthening of Japanese automobile global corporate strategy. Because of that realization, to develop the “Customer value creation activities through Simultaneous Achievement QCD”, the foundation of NA-CVCM consists of the “Automobile Exterior Design Model with 3 Core Methods (AEDM-3CM), Automobile Optimal Product Development Design Model (AOP-DDM) and CSP-Customer Information Analysis and Navigation System (CSp-CIANS)” as follows;

5.1 Key to Auto-business Process Renovation for Realizing Customer Value Creation

Firstly, to provide the attractive products with customer’s orientation permanently, the establishment of “new development design technologies” to take customer’s needs in advance is today’s challenge and current issue. Then, to strengthen the business process of product design, production and sales marketing, the author has developed the “Intelligent Customer Information Marketing Model” (ICIMM) as the key to success of “NA-CVCM” strategy in automobile global production as shown in

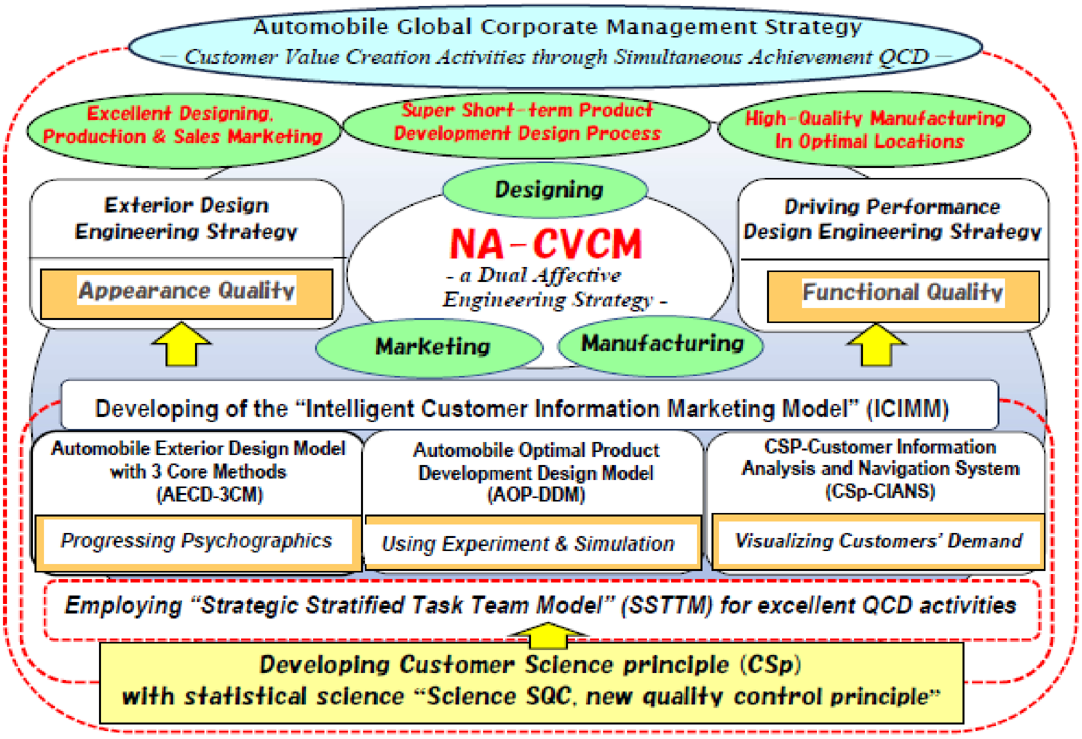


Figure 5. A New Automobile Customer Value Creation Model for Realizing Attractive Cars Employing a Dual Corporate Engineering Strategy

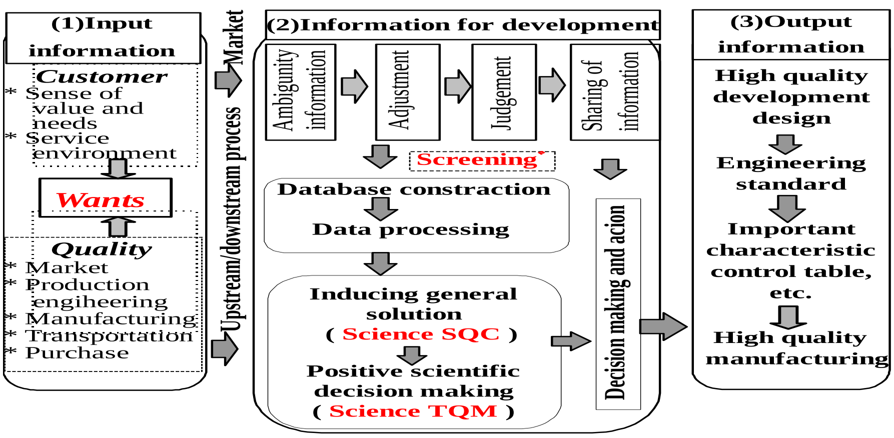


Figure 6. Intelligent Customer Information Marketing Model (ICIMM)

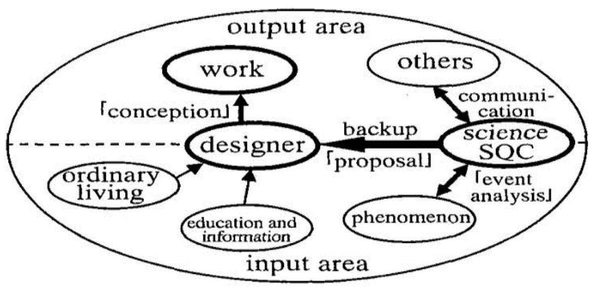
Figure. 6 (Amasaka, 2007a, 2007b, 2008a, 2019a).

In Figure 6, then, use this information to create "Wants" as part of a market creation activity and also to establish an intellectual structure and system for development and production that is capable of offering new products. In the implementation stage, it is important to apply the "Science SQC based on the Science TQM", via a verifiable scientific business approach, to each step: (1) Input information, (2) Information for development, and (3) Output information of the business process in "product plan and development design, manufacturing and sales marketing” (Amasaka, 2004b; Amasaka, Ed., 2012).

5.2 Automobile Exterior Design Model with 3 Core Methods for progressing Psychographics

Secondly, as customers’ values become increasingly diverse, automobile exterior design is becoming one of the most critical elements influencing customer purchase behavior for automakers. Unfortunately, as people’s values and subjective preferences become more varied and complex, it becomes increasingly difficult to accurately define their wants and needs. Therefore, it is important for mapping up exterior design strategy to study on “what style of vehicles would sell in the_future?". However, in many cases, automaker’s vehicle designers do not have a clear idea of future vehicle styling (Amasaka & Nagaya, 2002).

Success of designing directly affects the sale of enterprises. Therefore, design business is established as a marketing strategy and its significance lies in the quality of the proposal. True market-in should be in proposing a desirable thing before it is desired. From Figure 7, it is important for “Design SQC” to contribute to enhancing individual designer’s proposing capability using “Science SQC”. Conventionally, designing is generally developed directly to the profile design after analyzing the research itself (event analysis) (Amasaka et al., 1999; Amasaka, 2004b).



” **Figure 7. Desirable Relationship between “Designing” and “Design SQC”**

Specifically, to develop the “Design SQC”, the author has created the automobile concrete conception tool “Automobile Profile Design Concept Method” (APD-CM) by applying “SQC Technical Methods” as shown in Figure 8 (Amasaka & Nagaya, 2002; Amasaka, 2018). From Figure 8, the analysis process that turns implicit knowledge into explicit knowledge constitutes a secret to the conception. Concretely, to develop the “Designing”, bridging is attempted to span the research-oriented analysis as the event analysis to the exterior design in Steps 1 to 3 of Figure 8.

Step 1 analyzes relationships between images of vehicles desirable to customers and those actually selected to research, and it actualizes apparent relevancy whereby a vehicle type can be specified by the desirable image. Step 2 grasps what part of a vehicle customers observe to evaluate it. By coming down from the overall assessment, partial assessment and detailed assessment, this report clarifies which design factor should better be given priority to satisfy customers. By thinking that true customer-in is to propose a desirable thing before it is desired. In Step 3, the designers research the excellent exterior design by grasping the relevance of vehicle images and profile design (called proportion) data.

APD-CM improves the designing process (work) for creation of exterior design image involving the

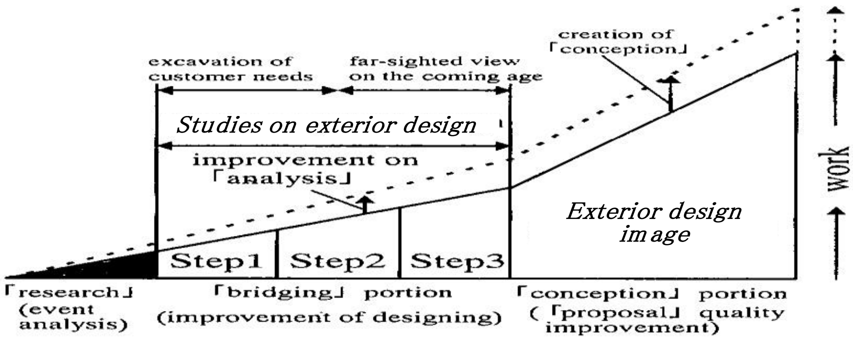


Figure 8. Automobile Profile Design Concept Method (APD-CM)

matching profile design, form, and color. By accumulating the improvement processes, this study intends to improve the quality of designing—"creation of conception" as the dotted line indicates in Figure. 8. Actually, to develop the "Design SQC using APD-CM" for progressing "Psychographics", the author has conducted the "Advanced Exterior Design Project using Science SQC" named "ADS" (Advanced Design SQC) for raising customers worth in Toyota in the following (Nunogaki et al., 1996; Amasaka et al., 1999; Amasaka & Nagaya, 2002; Amasaka, Ed., 2012; Amasaka, 2018).

As for the development of ADS, the author as the chief examiner of TQM Promotion Div. (1992-2000) and Amasaka's New JIT Laboratory" of Aoyama Gakuiin Univ. (2000-2017) has organized the (i) Design Div. I of Vehicle Development Center I for the development of new world car "Lexus", Design Div. II of Vehicle Development Center II for other model change of various mid-size cars and Toyota Design Laboratory Tokyo for Advanced design cars, (ii) Marketing Service Div., Dealer Marketing System Div., Auto-salon Amulux Tokyo, U.S. Office, Europe Office and others for the internal and external customers information gathering, and (iii) TQC Promotion Div. for developing Design SQC (Nagaya et al., 1998; Amasaka et al., 1999; Amasaka, 2018).

In ADS projects, the author has developed the "Automobile Exterior Design Model with 3 Core Methods" (AEDM-3CM) as shown in Figure 9 as follows; (A) Improvement of "Business Process Methods for Automobile Profile Design" (BPM-APD), (B) Creation of "Automobile Profile Design using "Psychographics Approach Methods" (APD-PAM) and (C) Actual studies on "Automobile profile design, form and color matching support methods" (APFC-MSM) described in Figure. 8.

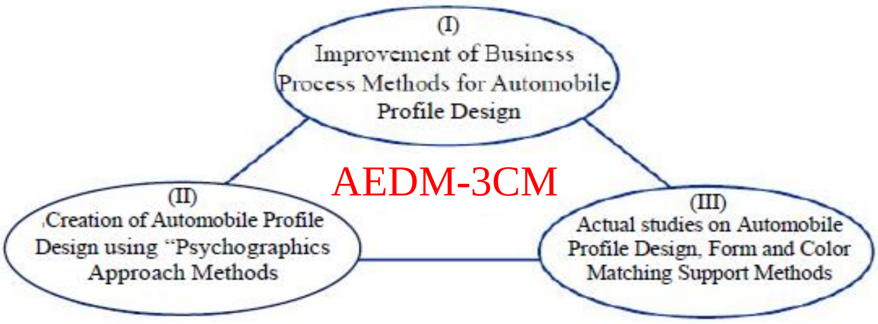


Figure 9. Automobile Exterior Design Model with 3 Core Methods (AEDM-3CM)

As developing CSp, the actual studies for AEDM-3CM have been applied to Toyota and others. In core technology (I), the 1st aim was to hold the characteristic of the profile design (proportion) such as "BMW518, Benz W123, Jaguar X16 etc." placed on the famous car of the world rationally by the concrete development of AEDM-3CM using "Design SQC and APD-CM" (Amasaka, 2018).

To realize the above knowledge, in core technology (II), the 2nd aim was the realization of the profile design, which is the main elements of exterior design of Toyota's strategic prestige car "new-model, Lexus" surpassing BMW/Benz by using the "Psychographics" approach method. In core technology (III), the 3rd aim was the realization of the profile design development of various mid-size cars by the application of Lexus exterior design development employing both of (I) and (II).

Specifically, then, the design work of (III) "Automobile Proportion, Form and Color Matching Support Methods" (APFC-MSM) which is the core technology of the strategic development of "ADS projects" at present is illustrated by developing the various psychographics approaches as shown in Figure 10 (Toyoda et al., 2015; Amasaka, 2018).

In Figure. 10, APFC-MSM starts with the three elements (1) profile design (proportion), (2) form, and (3) color. Recent design work strategies make it a point to optimize business processes so that they are in line with the vehicle design concept from the product planning stage. Next, each element must be matched: (4) profile design and form, (5) form and color, and (6) profile design and color. Finally, (7) all three elements "profile design, form, and color" must be integrated harmoniously to address modern market demands. At present, based on the knowledge acquired by above-mentioned subsection (A) and (B), the authors are tackling the development of "AEDA-3CM" by using "APFC-MSM" currently. These studies were carried out in "Amasaka's New JIT laboratory" by collaboration with "Toyota Motor Corp., Toyota Tokyo Design Research Laboratory, Nissan Motor Corp., Honda Motor Co., Ltd., Mazda Motor Corp., Nippon Paint Co., Ltd., Kansai Paint Co. Ltd." and others (Amasaka. 2018).

Concretely, to realize the validity of the "Design SQC and APD-CM", the author has expanded "AEDM-3CM" employing CSp with "CSp-CIANS" described in Figure 11, and indicates the applications (I), (II) and (III) in the next Chapter 6: "Application examples" (subsection "Actual

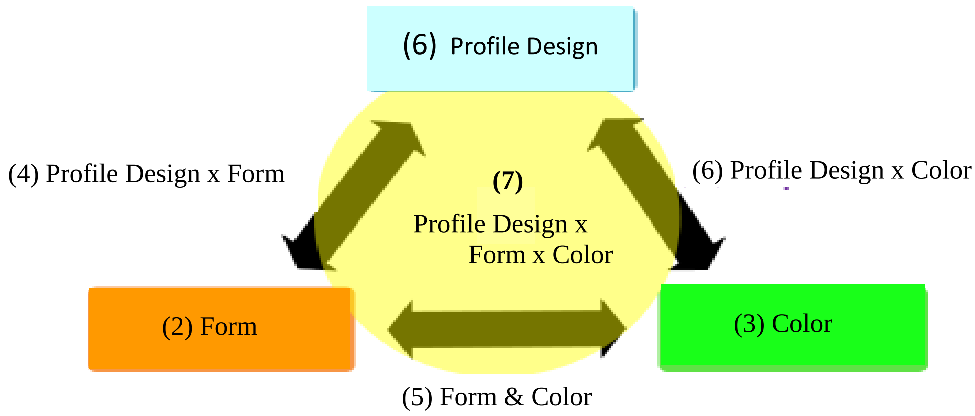


Figure 10. Automobile Profile design, Form & Color Matching Support Methods (APFC-MSM)

studies on automobile exterior design optimization") (Amasaka, 2015a, 2021, 2022a, 2022b, 2024).

As a concrete instance, to develop the APFC-MSM using AEDM-3CM with APD-CM, the author has established an "Automobile Profile Design, Form and Color Matching Optimization Model" (APFC-MOM) based on the investigation of "optimum profile design and form matching, form and color matching, and proportion and color matching" described in Steps 1 to 3 of Figure 11. APFC-MOM outlined was applied to young people in their 20s to see whether the model selected by the method would match their preferences. The effectiveness of the research was thus confirmed (Toyoda et al., 2015; Amasaka, 2018).

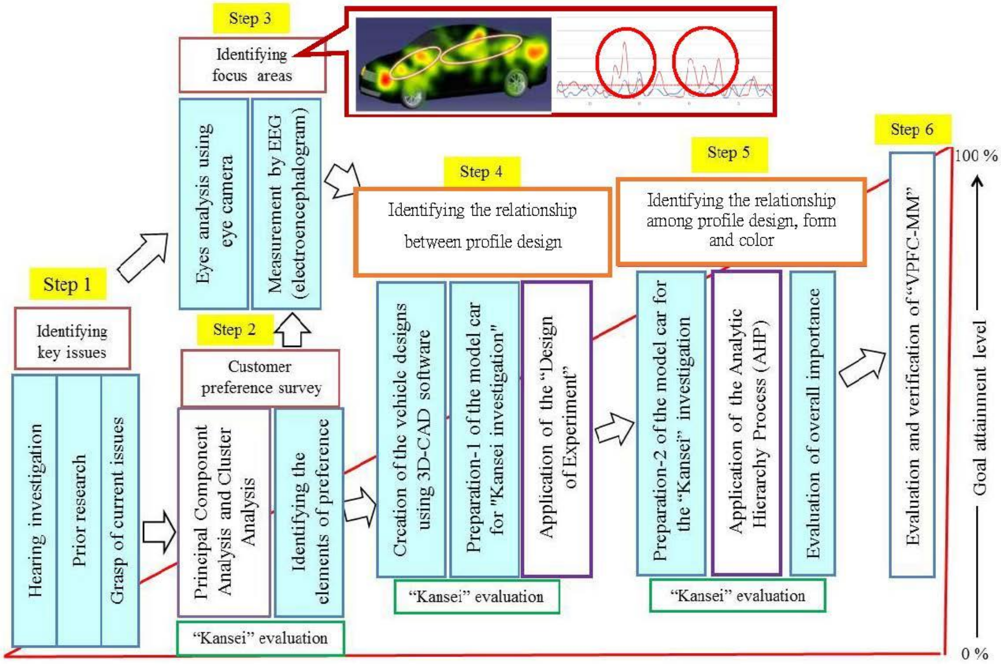


Figure 11. Automobile Profile Design, Form and Color Matching Model (APFC-MM)

In Step 1, the author began by conducting interviews with key automakers and dealers as well as with customers. They also consulted prior research to see which issues had already been addressed and which had yet to be clearly identified.

In Step 2, the author conducted a customer preference survey based on the key issues identified above.

In this step, customers were given a questionnaire to find out which vehicles they were interested in, and to pinpoint the main factors they considered when purchasing a vehicle. Once the data was collected, the authors subjected it to a principal component analysis and a cluster analysis in order to quantitatively determine the relationships between different customer senses.

In Step 3, the author used the insights gained from the customer preference survey in Step 2 to recruit test subjects that resembled target customers. Once the test subjects were selected, they were each fitted with an eye camera to analyze line-of-sight information. This told the authors where the subjects placed their attention when looking at vehicles. At the same time, an electroencephalogram (EEG) was used to measure brain waves. This device ascertained how the subjects were feeling when they looked at certain parts of the car.

In Step 4, the author continued to build upon the information gained in the previous steps in order to identify the relationship between the profile design and the form, two of the critical elements in exterior automotive design. To do this, they used 3D-CAD software to actually convert vehicle characteristics into numerical specifications, thus actually creating the vehicle designs that customers' wants.

In Step 5, the models designed in Step 4 were then analyzed using statistics (Design of Experiments (DOE) and Analytic Hierarchy Process (AHP)) to select the model that had the optimum combination of design elements.

In Step 6, the authors evaluated the success of the model selected in Step 5. Test subjects were again fitted with EEG equipment as the authors compared their reactions to the selected model and other vehicle designs.

5.3 Automobile Optimal Product Development Design Model (AOP-DDM) Realizing High Precision & Control

Thirdly, the time between product design and production has been drastically shortened in recent years with the rapid spread of global production. Quality assurance, or QA, has become increasingly critical. This makes it essential that the development design process—a critical component of QA—be reformed to ensure quality (Amasaka, 2010a, 2013).

Specifically, the author shows the “Total Intelligence CAE Development Design Model” (TI-CAE-DDM) as the “typical product development design process” currently, and used by many companies as shown in Figure 12) (Amasaka, 2007d, 2015b; Amasaka, Ed., 2007b). In Figure 12, the author shows that companies first create product development design instructions based on the “market research and product planning”. Then, they use these instructions to make development design specifications (drawings) and to promptly convert them to digital format so that they can be suitably

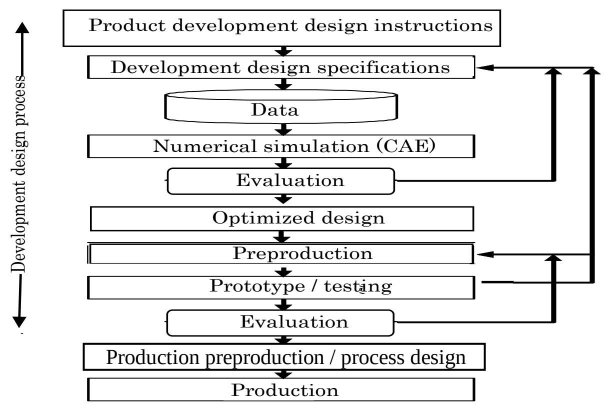


Figure 12. Total Intelligence CAE Development Design Model (TI-CAE-DDM)

processed and applied. The data is primarily used in numerical simulations known as Computer-Aided Engineering (CAE). CAE and other numerical simulations have been applied to a wide variety of business processes in recent years, including research and development, design, preproduction and testing /evaluations, production technology, production preparation, and Production. These applications are expected to have effective results (Magoshi et al., 2003; Amasaka, 2010b).

In this age of global quality competition, using CAE for predictive evaluation method in design work is expected to contribute a great deal to shortening development design time and improving quality (Amasaka, 2007d, 2007f, 2008c, 2008d, 2010b). However, generally, at the design and development stage, there is a gap (discrepancy) between "prototype evaluation and CAE analysis results" (Amasaka, Ed., 2007). It has become evident that some manufacturers are not fully confident in CAE results. Then, to win for the world quality competition. the author organized both of the "Study group of the ideal situation on the quality management of manufacturing industry" in "Union of Japanese Scientist and Engineers" (JUSE) and "Working Group No. 4 studies for establishment of a needed design quality assurance for numerical simulation at automobile industry in "Japanese Society for Quality Control" (JSQC).

Concretely, to develop this model, the author has created the "Highly Reliable CAE Analysis Technology Component Model" (HR-CAE-ATCM) with four components "problem-modeling-algorithm-theory-computer" as shown in Figure 13 was designed to make the shift from conventional prototype testing methods to effectively applying CAE in predictive evaluation methods. The comprehensive issuance of this model is essential to achieving the desired shift (Amasaka, Ed. 2007b; Amasaka, 2007d, 2008c, 2009b, 2010b, 2015b).

In Figure 13, the critical aspects of this model include "(i)-(v)"; (i) *defining the problem* (physically checking the actual item) in order to clarify the mechanism of the defect, using visualization technology to identify the dynamic behavior of the technical issue; (ii) full use of *formulization techniques* to generate logical *modeling* (statistical calculations, model application); (iii) constructing compatible a*lgorithms* (calculation methods); (iv) developing *theories* (establishing theories required to clarify problems) that ensure the precision of numerical calculations and sufficient computational capability; (v) comprehensively putting the above processes in action using *computer* (selection of *calculation technology*).

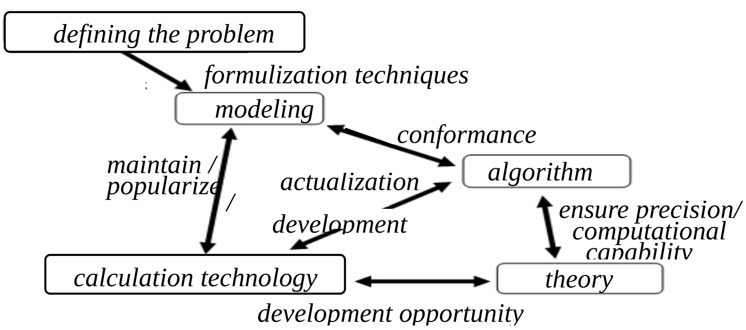


Figure 13. Highly Reliable CAE Analysis Technology Component Model (HR-CAE-ATCM)

As a concrete instance, to develop the HA-CAE-ATCM using CSp, the author has developed the "Automobile Optimal Product Development Design Model" (AOP-DDM) realizing high precision & control in order to achieve highly-accurate CAE analysis equivalent to prototype testing results as shown in Figure. 14, which contributes to high quality assurance as well as QCD simultaneous achievement in automobile development design (Amasaka, 2008b, 2009b, 2010a, 2012b, 2015b, 2017b, 2019b, 2023c; Amasaka, Ed. 2007b; Amasaka et al., 2012).

In Figure 14, many manufacturers are aware of the gap between evaluations of actual vehicles and CAE, and not fully confident in CAE results, they prefer to conduct Step (I) "survey" tests with actual vehicles rather than CAE evaluation. Even among leading corporations, Step (II) CAE utilization is limited to "relative evaluation". The author noticed a situation where, as shown in the figure, the application ratio of CAE to actual vehicles is about 25% for surveys and about 50% for relative evaluation revealing the dilemma that the effectiveness of CAE invested for reduction in development time has not been fully utilized. Based on the above, in Step (III), as seen in the figure, the mechanism of the pending technical problem was clarified through visualization technology, and the technical knowledge which enables "absolute evaluation" through the creation of generalized models was incorporated in the CAE software.

As a result, it was confirmed that the accuracy of CAE analysis had improved and the application ratio of CAE had increased to about 75%. Based on the technical analysis derived from Steps (I) to (III), Step (IV) further incorporated a "robust design" which takes into consideration the influential factors and contributing ratio needed for optimal design, thus enhancing the accuracy of CAE calculation, and demonstrating a remarkable increase in the ratio of CAE application.

Then, to successfully develop the AOP-DDM, the author has created the "Highly Precise CAE Analysis Technology Component Model" (HP-CAE-TCM) required for highly precise CAE analysis software as shown in Figure 15 (Amasaka, 2007b, 2007d, 2008c, 2008d, 2009b, 2015b, 2019b; Amasaka, Ed. 2007b, 2012).

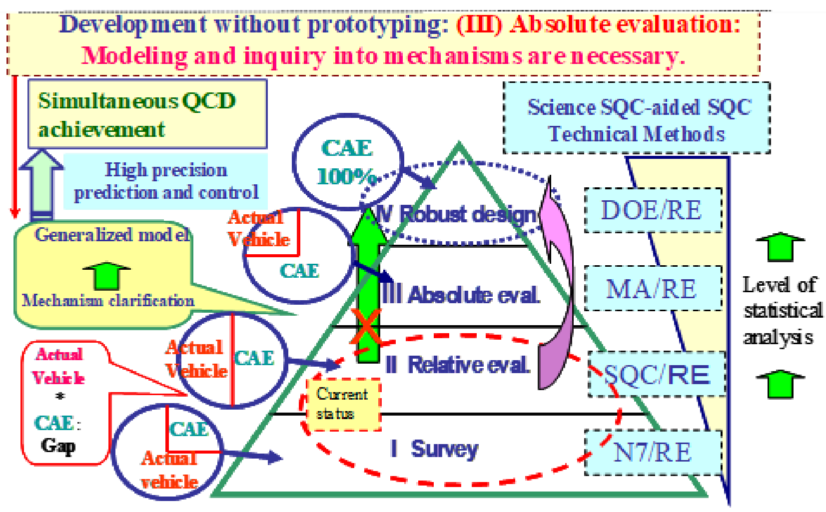


Figure. 14. Automobile Optimal Product Development Design Model (AOP-DDM)

Moreover, from the viewpoint of achieving highly-reliable CAE analysis, the author illustrates the "Intelligence CAE software creation requirements" described in Figure. 15 as follows (illustration: Knowhow linkage-cycle with reciprocal action from (i) to (iv)); In linkage-cycle, Figure. 15 shows the (i) Modelling visualization, (ii) Simulation (Structural analysis, collision analysis, fluid analysis, chemical process analysis etc.), (iii) Optimization tool, (iv) statistical analyses, (v) knowledge base.

Specifically, in Figure 15, the process of CAE first starts with (1) "Problem"— Setting of problems to be solved, as well as (2) "Modeling"—Modeling of these problems as some type of mathematical formula. In CAE, when using calculators as a means to analyze the model, such a means of analysis needs to be provided in the form of a calculation procedure, namely, (3) Algorithms—So that the software can perform calculation. (4) "Theory"—The validity, applicable range, and performance or expected precision of such algorithms themselves can be deduced from some kind of theory. (5) "Computer"—Needless to say, the technology related to the computer itself functioning as "hardware" to realize the algorithms, is undoubtedly a factor having a large effect on the success of CAE.

Success in AOP-DDM depends on the "collective strengths" of the elemental technologies. The formulation of such "implicit knowledge" confined to the personal know-how of the engineers is an indispensable step to be taken for sophistication of CAE as the "Problem-Solving methods".

Then, skilled CAE engineers are not experts in all the fields of the elemental technologies. But they understand their characteristics and interactions as the "implicit knowledge" and thus conduct selection combination to obtain favorable interactions and consequently the desired results. Therefore, it is positioned as a major theme in author's work (Amasaka, 2007d, 2008c, 2009b, 2010b; Amasaka, Ed., 2007b, 2012; Amasaka et al., 2013).

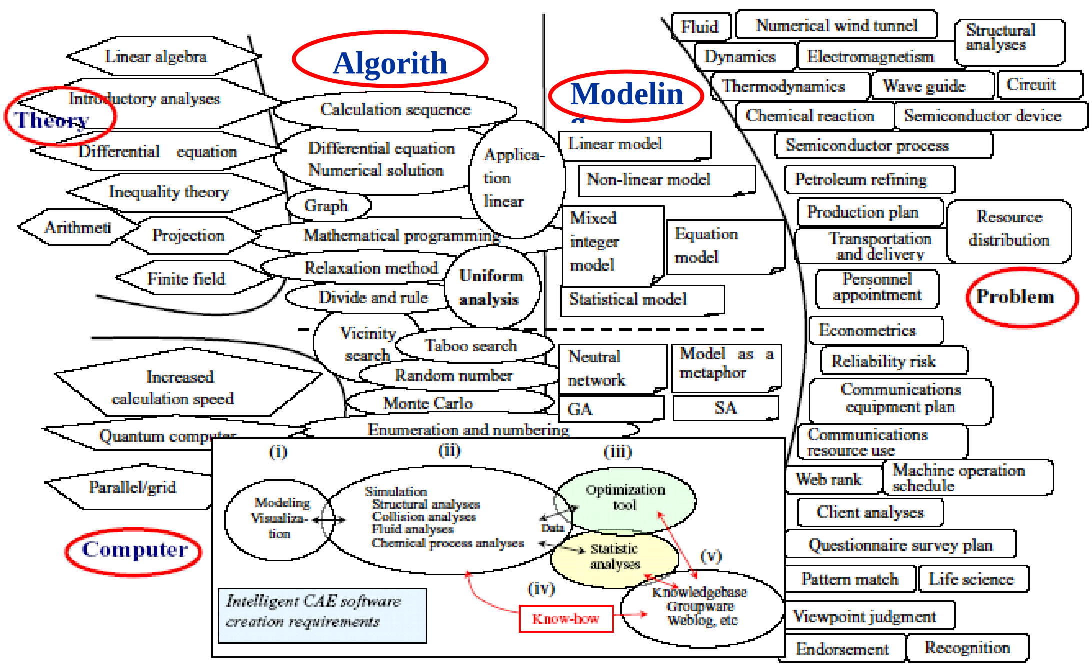


Figure 15. Highly Precise CAE Technology Component Model (HP-CAE-TCM)

5.4 CSp-Customer Information Analysis and Navigation System (CSp-CIANS) for Visualizing Customer Demand

Forthly, today, growing companies both in Japan and abroad try to grasp the unprejudiced desires of their customers from the viewpoint of customer-oriented business management and to reflect these desires in future product development design. However, the actual behavioral patterns (conception methods) of designers (new product planners and development designers) in trying to grasp latent customer desires depend heavily on the designers' empirical skills.

For the realization of strategic products, the collection as well as intellectual analysis of information for creating customers' demands is the core essence for success in "CSp". To advance the level of execution of "Customer Science activities" for the developing "CSp" strategy, it is necessary to evolve customer information-sharing among the "marketing, sales & service, merchandise for "Product planning and product development design, production engineering, manufacturing and overseas" from off-line to on-line (Amasaka, 2005, 2015a).

Specifically, to realize this, for "strategic product development design" employing "AEDM-3CM and AOP-DDM" above, it is important to explore consumer values, which are the basis for visualizing "customers' demands" in "customer value creation", through the collection/analysis of customer information, and to reflect as well as exteriorize such values in product development design.

Against this background, the "CSp-Customer Information Analysis and Navigation System" (CSp-CIANS) was constructed as shown in Figure 16 (Amasaka, 2005). As indicated therein, this system enables the networking the (1) Merchandise Div. to strengthen strategic product planning which explores customer value creation and (2) each division of the "Product Planning, Development 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 using statistical science approach—Science SQC (8) (Amasaka, 2004b).

Actually, the core system of SQC integration network system contains the "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 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 (Amasaka, 2005; Amasaka, Ed., 2012).

CSp-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

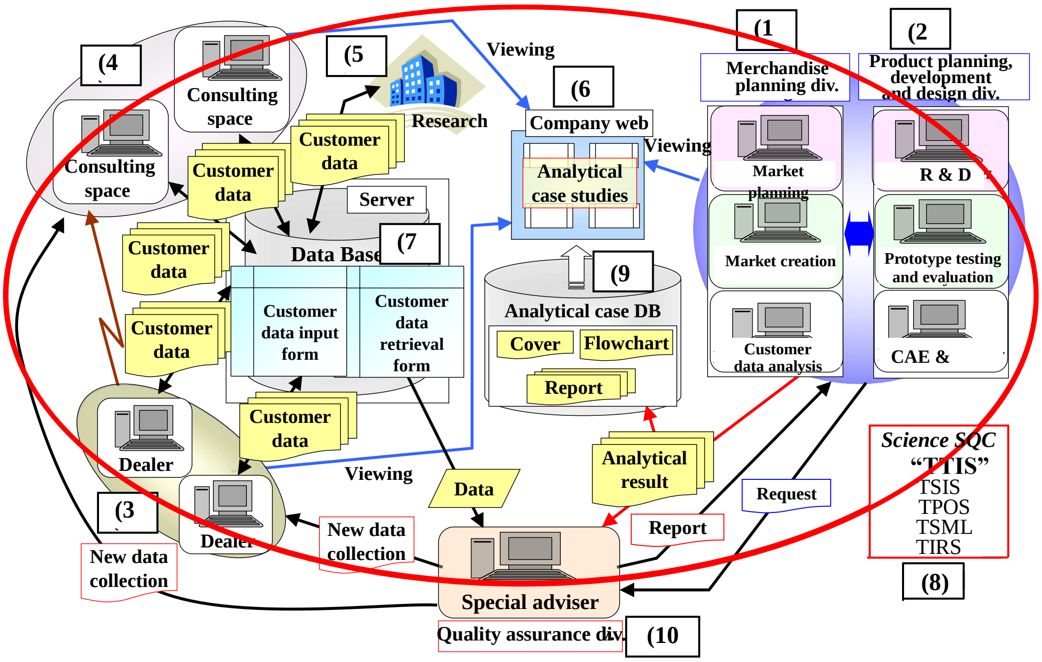


Figure 16. CSp-CIANS, Networking of Customer Science application system

development of analytical technology (Amasaka, 2015a, 2015b, 2022a, 2022b, 2023a, 2024).

6. Application Examples

6.1 Actual Studies on Automobile Exterior Design Optimization

6.1.1 Developing Exterior Design Engineering Strategy Using APFC-MSM

In developing APFC-MSM based on AEDM-3CM, examples of actual case studies for the business process innovation that addresses optimizing the exterior design using psychographics and Design SQC, corresponding to "(1)-(7)", are as follows (Amasaka, 2015b, 2018, 2021, 2022a, 2022b, 2023a, 2023c, 2024).

(1) The development of prestige car "Lexus GS400/LS430" which realized the compatibility of profile design and package design (interior space) using "Automobile Package Design Concept Support Method" (APD-CSM). This research realizes a more creative product design process as an "Intelligence Profile Design Concept Method" (IPDCM) (Amasaka et al.,1999; Okabe et al., 2007; Amasaka, 2018).

(2) Construction of the "Automotive Design Form Support Methods" (ADFSM) to fully understand the visualizing the relationship between "form modifications as a whole (which consists of front, side and rear elements) and subjective customer's impressions" using eye-tracking camera, 3D Design

CAD software (CATIA V5) and Design SQC (Asami et al., 2010; Yazaki et al., 2013).

(3) The author has created an "Automobile Exterior Color Development Approach Model" (AECDAM) to visualize the success design colors in customer demands (Muto et al., 2011; Takebuchi et al., 2012). Specifically, this model determined the 4 factors (classy, luxurious, dignified and sporty) and 6 elements (hue, luminosity, intensity, shine, opacity and graininess) most desired by young buyers,

(4) The author has created the "Strategic Automobile Design Support Method" (SADSM) for the profile design and form matching. Specifically, the author has visualized the preferences of younger generation by combination of the "Design SQC and 3D Design CAD" (Takimoto et al., 2010).

(5) The author has constructed the "Automobile Exterior Design Approach Model" (AEDAM) for the form and color matching, which uses biometric devices along with visualization technology, 3D Design CAD and Design SQC to establish the relationship between form and body color which customers observe the overall vehicle design (Takebuchi et al., 2012; Muto et al., 2013).

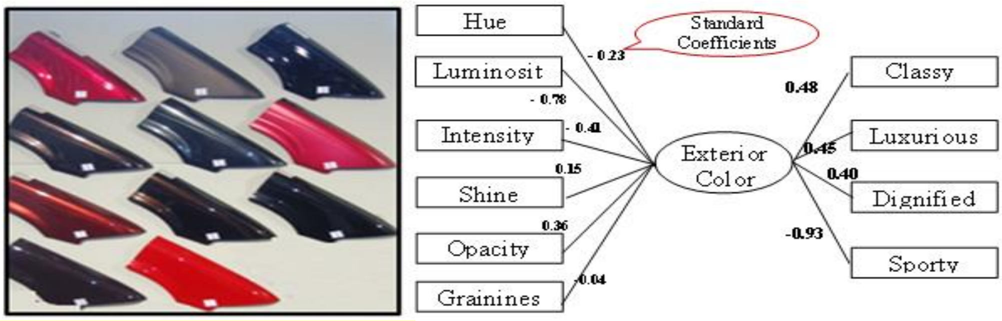
(6) The author has created the "Amasaka-Lab's Vehicle Exterior Design Approach Model" (AL-VEDAM) for the form and color matching using "market and preference survey, form and color analysis, creation of CAD models and verification". This focuses on the "young women preference car—luxurious, stylish, high-end & chic" using collage boards (girlish, elegant, casual, trendy and boyish) (Asami et al., 2010).

(7) The author has created the "Vehicle Proportion, Form, and Color Matching Model" (AL-PFCM) to analyze and catch the customers' attention using "eye camera and electroencephalograph". Specifically, to identify ideal relationships among proportion, form, and color, the author has created the "3D-CAD model cars using experimental design and analytic hierarchy process methods" (Toyoda et al., 2015; Amasaka, 2018).

For example, in (5) "form and color matching", Figure 17 shows a "matching of form and color optimization" using front fender panels in medium sedan car. In this study, the panels were shaped and pained like car panels to show the relevant textual expression.

Figure 17(i) shows the "varying the effect of the opacity and graininess equally to produce a total of 11 panels with the six elements of color (hue, luminosity intensity, shine, opacity, and graininess". Each panel gave the desired impression for the preferences (classy, luxurious, dignified and sporty). Aesthetic evaluation data was obtained from the results. The survey was aimed at men and women in their twenties, and the answers were obtained from a total of 94 men and women.

Figure 17(ii) shows the "Path diagram from color elements of exterior color". This path diagram of covariance structure analysis was conducted to determine the correspondence relationship between



(i) Painted panels used for

(ii) Path diagram from color elements of exterior

Figure 17. An Example for Matching of Form and Color Optimization Using Front Fender Panels

color elements and preferences. The absolute values of these standardized coefficients indicate the degree of influence while the direction of influence is indicated by positive or negative numbers.

In this path diagram used for this covariance structure analysis, the "exterior color" latent variable was chosen as the latent variable that would satisfy the four vehicle design preferences of those who value self-expression. Respondents in the self-expression group were asked to freely evaluate the three developed colors. The respondents gave positive evaluations, saying they liked how classy the colors were and that they would like a car with colors such as these (Takebuchi et al., 2012).

6.1.2 Expanding APFC-MSM for Raising Attractiveness to Custom

Furthermore, the author has been advancing the "New deployment of APFC-MCM" in AEDA-3CM for "mid-size and small-size cars" for raising attractiveness to customer as follows; 1st is the development of "Auto-exterior and interior color matching" and "Auto-instrumentation design" (Shinogi et al., 2014; Koizumu et al., 2014). 2nd is the "Attractive exterior design concept for indifferent customers" (Kobayashi et al., 2015, 2016), "auto-instrumentation for young male customers" (Yazaki et al., 2013), and "Bicycle design model for young women's fashion" (Koizumi et al., 2013). 3rd, moreover, the author has created the "Creation of 3 typical "New profile design: (A) Advanced type, (B) Elegant type and (C) Progress type" in near future as shown in Figure 18 (Refer to Kobayashi et al. (2016) and Amasaka（2017c, 2022b）in detail).

(A) Advanced type (B) Elegant type (C) Progress type

Figure 18. Creation of 3 Typical "New Profile Design" in Near Future

6.2 Actual Studies on Automobile Product Development Design Optimization

6.2.1 Automobile Intelligent CAE Management Approach System (AI-CAE-MAS) Using Experiment and Simulation

In general, experienced development design staff and CAE engineers understand the mechanism that is causing the bottleneck technical problem as implicit knowledge (Amasaka, 2007a, 2007f, 2009b). 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 by developing AOP-DDM (Amasaka, Ed., 2007b; Amasaka, 2010b; Amasaka et al., 2012). Then, the author has created the "Automobile Intelligent CAE Management Approach System" (AI-CAE-MAS) in an effort to help solve the bottleneck technical problem that had become a global technological issue as shown in Figure 19 (Amasaka, 2007a, 2007b, 2008c, 2008d, 2009b, 2015b).

As the first stage, to accomplish this, it was important to the (A) "Visualization"- visualize the dynamic behavior of the problem by employing "Actual vehicles and equipment and carrying out testing" using "Hypothesis". At this point the expertise of specialists from both inside and outside the company was brought together through the "Partnering" activities.

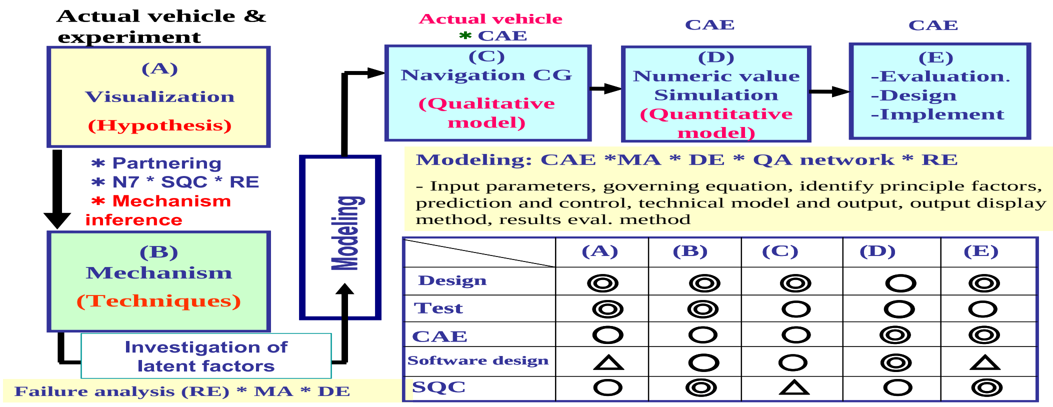
As the second stage, it was vital to deduce the (B) "Mechanism"—fault mechanism using various "Techniques". To carry out the precise fault analysis and factor analysis, "New Seven Tools (N7), Statistical Quality Control (SQC), Reliability Engineering (RE), Multivariate Analysis (MA) and Design of Experiment (DOE)" 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 "Modeling".

As the third stage, moreover, all of this knowledge and information was then unified through the (C) 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, it was important to carry out actual vehicle and testing work so that this 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 fourth 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, as the (E) "Evaluation, Design and Improvement", 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 19), 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).



	(A)	(B)	(C)	(D)	(E)
Design	◎	◎	◎	○	◎
Test	◎	◎	○	○	○
CAE	○	○	○	◎	◎
Software design	△	○	○	◎	△
SQC	○	◎	△	○	◎

Figure 19. Automobile Intelligent CAE Management Approach System (AI-CAE-MAS)

6.2.2 Application to AI-CAE-MAS for Raising Attractiveness to Customers

Then, as the application of AI-CAE-MAS for raising attractiveness to customers, the author was able to apply the AOP-DDM to critical development design technologies for automobile production, including predicting and controlling the typical applications of the “transaxle oil seal leakage, brake pad quality assurance, Urethane Foam Modeling Simulator, looseness of bolt-nut tightening” and others (Amasaka, 2003, 2004b, 2007d, 2008c, 2008d, 2009b, 2010a, 2010b, 2016b, 2017b, 2019b,; Amasaka et al., 2012; Okutomi & Amasaka, 2013).

For example, Figure 20 shows a “Highly Accurate Analysis Approach Model” (HAAAM) by using Science SQC for improvement of “automobile transaxle oil seal leakage” which is a “bottleneck technological problem for auto-manufacturers worldwide”. This was achieved through an analysis process involving problem clarification, visualization experiments, theoretical conceptualization, CAE analysis, and optimal design.

First, the author began 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;

(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 general design technology elements were incorporated into the "Technology Component Model

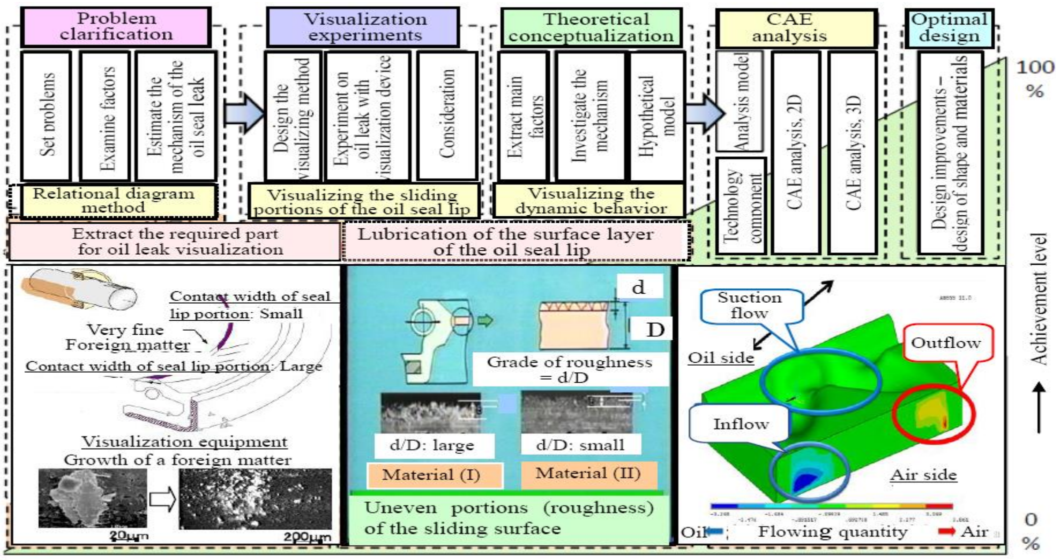


Figure 20. Highly Accurate Analysis Approach Model (HAAAM) using Science SQC

for the Oil Seal Simulator" using "Highly Precise CAE Technology Component Model" (HR-CAE-TCM) to create "Highly-Reliable CAE analysis software" capable of accurately reproducing the oil seal leak phenomena, enabling them to be identified and controlled as shown in Figure 21.

The following methods were proposed: (i) Identifying the problem: simulation of variously converging physiochemical phenomena (methodology: (1) to (3)), (ii) Modeling: building of problem-solving models (methodology: (1) to (3)), (iii) Practical algorithms: calculation methods (methodology: (1) to (2)), (iv) Rational theories: adoption of 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 model. 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) (Refer to Amasaka (2007b) and Amasaka et al. (2012) in detail).

In each of these applications as well, discrepancy was 3%-5% versus prototype testing. Based on the achieved results, the model is now being used as an intelligent support tool for optimizing product design processes (Amasaka, 2007b, 2007d, 2008c, 2008d, 2010a, 2010b, 2012a, 2012b, 2015a, 2019b, 2022a, 2022b, 2023a, 2023c, 2024; Amasaka, Ed. 2007a,b; Amasaka et al., 2012, 2013).

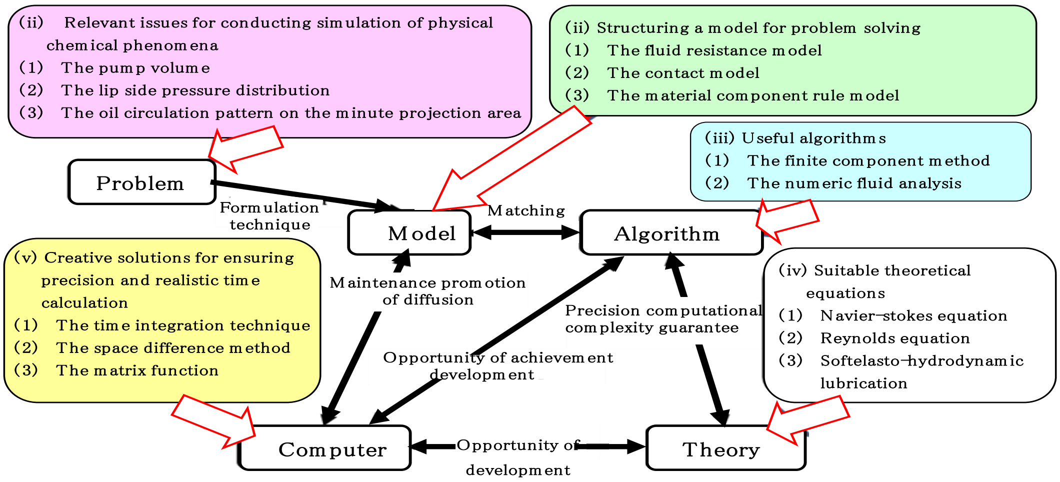


Figure 21. Technology Component Model for the Oil Seal Simulator Using

7. Conclusion

In this study, the author has created a NA-CVCM using a "Dual Affective Engineering Strategy" for the innovation of automobile products engineering fundamental by developing CSp. Specifically, NA-CVCM contains the both of the "Exterior design engineering strategy and Driving performance design engineering strategy" for the developing "appearance quality and functional quality" that contributes to strengthening of Japanese automobile global corporate strategy utilizing Science SQC based on the SSTTM activity. Concretely, to develop the "Same quality worldwide and products development design at optimal locations", the foundation of NA-CVCM consists of the AEDM-3CM, AOP-DDM and CS-CIANS. The validity of NA-CVCM is then verified through the actual applications to automobile products development design in Toyota and others.

Acknowledgements

The author would like to acknowledge the generous support of the following researchers. All those at Toyota Motor Corp., Yamaha Motor Co. Ltd., Nippon Research Center Ltd., many affiliated/nonaffiliated suppliers, Study group of the Ideal Situation the Quality Management of Manufacturing Industry in JUSE, Interim Report of WG4's Studies Research on Simulation and SQC in JSQC, and those connected with the Amasaka New JIT Laboratory in Aoyama Gakuin University.

References

Amasaka, K. (1998a). A study on "Science SQC" by utilizing "Management SQC": A demonstrative study on a new SQC concept and procedure in the manufacturing industry. *International Journal of Production Economics*, 60-61, 591-598.

Amasaka, K. (1988b). Concept and progress of Toyota Production System (Plenary lecture). *Co-sponsorship: The Japan Society of Precision Engineering, Hachinohe Regional Advance Technology Promotion Center Foundation and others, Hachinohe, Aomori, Japan*. (in Japanese)

Amasaka, K. (2000a). A demonstrative study of a New SQC Concept and Procedure in the manufacturing industry—Establishment of a New Technical Method for Conducting Scientific SQC—. *An International Journal of Mathematical & Computer Modeling*, *31*(10-12), 1-10.

Amasaka, K. (2000b). Basic principles of JIT—Concept and progress of Toyota Production System (Plenary lecture). *The Operations Research Society of Japan, Tokyo*. (in Japanese)

Amasaka, K. (2002). *New JIT,* a new management technology principle at Toyota. *International Journal of Production Economics*, *80*, 135-144.

Amasaka, K. (2003). Proposal and Implementation of the "Science *SQC*" Quality Control Principle. *International Journal of Mathematical and Computer Modelling*, *38*(11-13), 1125-1136.

Amasaka, K. (2004a). Development of "Science TQM", a new principle of quality management—Effectiveness of Strategic Stratified Task Team at Toyota—. *International Journal of Production Research*, *42*(17), 3691-3706.

Amasaka, K. (2004b). *Science SQC, new quality control principle: The quality strategy of Toyota*. Springer-Verlag, Tokyo.

Amasaka, K. (2005). Constructing a *Customer Science* application system "*CS-CIANS"*—Development of a global strategic vehicle "*Lexus*" utilizing *New JIT*. *WSEAS Transactions on Business and Economics*, *2*(3), 135-142.

Amasaka, K. (2006). A new principle, next generation management technology: Development of New JIT (Editorial). *Production Management, Transaction of the Japan Society for Production Management*, *13*(1), 143-150. (in Japanese).

Amasaka, K. (2007a). *New Japan Production Model*, an advanced production management principle: Key to strategic implementation of *New JIT*. *The International Business & Economics Research Journal*, *6*(7), 67-79.

Amasaka, K. (2007b). High linkage model "*Advanced TDS, TPS & TMS*": Strategic development of "*New JIT*" at Toyota. *International Journal of Operations and Quantitative Management*, *13*(3), 101-121.

Amasaka, K. (2007c). The validity of "*TDS-DTM*", a strategic methodology of merchandise: Development of *New JIT*", Key to the excellence design "*LEXUS*". *The International Business & Economics Research Journal*, *6*(11), 105-115.

Amasaka, K. (2007d). Highly Reliable CAE Model: The key to strategic development of *New JIT*. *Journal of Advanced Manufacturing Systems*, *6*(2), 159-176.

Amasaka, K. (2007e). The validity of *Advanced TMS,* A strategic development marketing system utilizing *New JIT*. *International Business and Economics Research Journal*, *6*(8), 35-42.

Amasaka, K. (2008a). Science TQM, a new quality management principle: The quality management strategy of Toyota. *The Journal of Management & Engineering Integration*, *1*(1), 7-22.

Amasaka, K. (2008b). An Integrated Intelligence Development Design CAE Model utilizing New JIT: Application to automotive high reliability assurance, *Journal of Advanced Manufacturing Systems, 7*(2), 221-241.

Amasaka, K. (2008c). Proposal and validity of the High-Quality Assurance CAE Model for automobile development", *Journal of the Japanese Society for Quality Control, 38*(1), 38-44. *(in Japanese)*

Amasaka, K. (2008d). Strategic QCD studies with affiliated and non-affiliated suppliers utilizing New JIT, *Encyclopedia of Networked and Virtual Organizations, III*(PU-Z), 1516 -1527.

Amasaka, K. (2008e). Simultaneous fulfillment of QCD - Strategic collaboration with affiliated and non-affiliated suppliers, *New theory of manufacturing - Surpassing JIT: Evolution of Just-in-Time*, (*Amasaka, K., Kurosu, S. & Michiya, M., Eds.*), *Morikita-Shuppan, Tokyo,* 199-208. *(in Japanese)*

Amasaka, K. (2009a). New JIT, advanced management technology principle: The global management strategy of Toyota (Invitation lecture), *International Conference on Intelligent Manufacturing and Logistics System*, *Kitakyushu, Japan,* 1-16. (in Japanese)

Amasaka, K. (2009b). An Intellectual Development Production Hyper-cycle Model: *New JIT* fundamentals and applications in Toyota, *International Journal of Collaborative Enterprise*, *1*(1), 103-127.

Amasaka, K. (2010a). (Chapter 4) Product Design, Quality Assurance, *(New Edition) Guide Book of Quality Assurance, Edited by JSQC (The Japanese Society for Quality Control), JUSE (Union of Japanese Scientists and Engineers)* Press, Tokyo, 87-101. (in Japanese)

Amasaka, K. (2010b). Proposal and effectiveness of a High-Quality Assurance CAE Analysis Model", *Current Development in Theory and Applications of Computer Science, Engineering and Technology, 2*(1/2), 23-48.

Amasaka, K. (2011). Changes in marketing process management employing TMS: Establishment of Toyota Sales Marketing System, *China & USA Business Review, 10*(7), 539-550.

Amasaka, K. (2012a). Constructing Optimal Design Approach Model: Application on the Advanced TDS, *Journal of Communication and Computer, 9*(7), 774-786.

Amasaka, K. (2012b). Prevention of the automobile development design, precaution and prevention, *Japanese standards Association Group, Tokyo*, 219-241. (in Japanese)

Amasaka, K. (2013). The development of a Total Quality Management System for transforming technology into effective management strategy, *The International Journal of Management, 30*(2), 610-630.

Amasaka, K. (2014). New JIT, new management technology principle: Surpassing JIT, *Journal of Procedia Technology (Special issues), 16*, 1-11.

Amasaka, K. (2015a). *New JIT, new management technology principle*, Taylor and Francis Group, CRC Press, Boca Raton, London, New York.

Amasaka, K. (2015b). Constructing a New Japanese Development Design Model “NJ-DDM”: Intellectual evolution of an automobile product design, *TEM Journal*, *4*(4), 336-345.

Amasaka, K. (2017a). *Toyota: Production system, safety analysis and future directions*. NOVA Science Publishers, New York.

Amasaka, K. (2017b). Strategic Stratified Task Team Model for realizing simultaneous QCD fulfilment: Two case studies. *Journal of Japanese Operations Management and Strategy*, *7*(1), 14-35.

Amasaka, K. (2017c). Attractive automobile design development: Study on customer values (Plenary Lecture). *Executive Lecture in Rotary Clube, Tokyo*. (in Japanese)

Amasaka, K. (2018). Automobile Exterior Design Model: Framework development and supporting case studies. *Journal of Japanese Operations Management and Strategy*, *8*(1), 67-89.

Amasaka, K. (2019a). Studies on New Manufacturing Theory. *Noble International Journal of Scientific Research*, *3*(1), 42-79.

Amasaka, K. (2019b). Establishment of an Automobile Optimal Product Design Model: Application to study on bolt-nut loosening mechanism. *Noble International Journal of Scientific Research*, *3*(9), 79-10.

Amasaka, K. (2021). New Japan Automobile Global Manufacturing Model: Using Advanced TDS, TPS, TMS, TIS & TJS. *Journal of Advanced Manufacturing Systems*, *6*(6), 499-523.

Amasaka, K. (2022a). *New Manufacturing Theory: Surpassing JIT*. Lambert Academic Publishing, Germany, Printed by Printforce, U.K.

Amasaka, K. (2022b). *Examining a New Automobile Global Manufacturing System*. IGI Global Publisher, Hershey, PA, USA.

Amasaka, K. (2023a). *New Lecture—Surpassing JIT: Toyota Production System—From JIT to New JIT—*. Lambert Academic Publishing, Germany, Printed by Printforce, U.K.

Amasaka, K. (2023b). A New Automobile Sales Marketing Model for innovating auto-dealer’s sales. *Journal of Economics and Technology Research*, *4*(3), 9-32.

Amasaka, K. (2023c). A New Automobile Product Development Design Model: Using a dual corporate engineering strategy. *Journal of Economics and Technology Research*, *4*(1), 1-22.

Amasaka, K. (2024). *Revolutionary Automobile Production Systems for Optimal Quality, Efficiency, and Cost*. IGI Global Publisher, Hershey, PA, USA.

Amasaka, K. (Ed.). (2000). *Science SQC, Reform of quality within business processes, Nagoya QST Study Group Edition*. *Japan Standards Association*, *Tokyo*. (in Japanese)

Amasaka, K. (Ed.). (2007a). *New Japan Model: Science TQM—Theory and practice of strategic quality management*. Study group on the ideal situation on the quality management on the manufacturing, Maruzen, Tokyo. (in Japanese)

Amasaka, K. (Ed.). (2007b). *Establishment of a needed design quality assurance framework for numerical simulation in automobile production*. Edited by Working Group No. 4 Studies in JSQC, Study group on simulation and SQC, Tokyo. (in Japanese)

Amasaka, K. (Ed.). (2012). *Science TQM, new quality management principle: The quality strategy of Toyota*. Bentham Science Publishers, UAE, USA, The NETHELANDS.

Amasaka, K. (Ed.). (2019). *The Fundamentals of the manufacturing industries management: New Manufacturing Theory—Operations Management Strategy 21C-*. Shankei-Sha, Nagoya, Japan. (in Japanese)

Amasaka, K., Ito, T., & Nozawa, Y. (2012). A New Development Design CAE Employment Model. *The Journal of Japanese Operations Management and Strategy*, *3*(1), 18-37.

Amasaka, K., & Nagasawa, S. (2000). *Fundamentals and application of sensory evaluation: For Kansei Engineering in the vehicle*. Japanese Standards Association, Tokyo. (in Japanese)

Amasaka, K., Nagaya, A., & Shibata, W. (1999). Studies on Design SQC with the application of Science SQC improving of business process method for automotive profile design. *Japanese Journal of Sensory Evaluations*, *3*(1), 21-29. (in Japanese)

Amasaka, K., & Nagaya, A. (2002). Engineering of the new sensitivity in the vehicle: Psychographics of *LEXUS* design profile”. *Development of articles over the sensitivity—The method and practice* (pp. 55-72). Japan Society of Kansei Engineering. Nihon Suppan Service Press. (in Japanese)

Amasaka, K., Onodera, T., & Kozaki, T. (2013). Developing a Higher-Cycled Product Design Model: The evolution of automotive product design and CAE. *International Journal of Technical Research and Applications*, *2*(1), 17-28.

Asami, H., Ando, T., Yamaji, M., & Amasaka, K. (2010). A study on Automobile Form Design Support Method “AFD-SM”. *The Journal of Business & Economics Research*, *8*(11), 13-19.

Asami, H., Owada, H., Murata,Y., Takebuchi, S., & Amasaka, K. (2011). The A-VEDAM for approaching vehicle exterior design. *Journal of Business Case Studies*, *7*(5), 1-8.

Evans, J. R., & Dean, I. W. (2003). *Total quality management, organization and strategy*. Thomson, South-Western, Mason, United States.

Goto, T. (1999). *Forgotten Management Origin*. Seisanse-Shuppan, Tokyo. (in Japanese)

JD Power and Associate. (1998). *Vehicle Dependability Study*. Retrieved from https://www.jdpower.com/releases/80401car.html/

Kobayashi, T., Yoshida, R., Amasaka, K., & Ouchi, N. (2015). A study for creating an vehicle exterior design at teaching in different customers. *Hong Kong International Conference on Engineering and Applied Science, Hong Kong*, 1-7.

Kobayashi, T., Yoshida, R., Amasaka, K., & Ouchi, N. (2016). A statistical and scientific approach to deriving an attractive exterior vehicle design concept for indifferent customers. *Journals International Organization of Scientific Research*, *18*(12), 74-79.

Koizumi, K., Kawahara, K., Kizu, Y., & Amasaka, K. (2013). A Bicycle Design Model based on young women's fashion combined with CAD and statistical science. *China-USA Business Review*, *12*(4), 266-277.

Koizumi, K., Muto, M., & Amasaka, K. (2014). Creating Automobile Pamphlet Design Methods: Utilizing both "Biometric Testing and Statistical Science". *Journal of Management*, *6*(1), 81-94.

Lockman, M. A. (2010). *Design & Emotion: The Kansei Engineering Methodology*, *1*(1), 1-14.

Magoshi, R., Fujisawa, H., & Sugiura, T. (2003). Simulation technology applied to vehicle development. *Journal Society of Automotive Engineers of Japan*, *53*(3), 95-100. (in Japanese)

Matsuoka, Y., & Harada, Y. (1997). Bottleneck Design Elements of Automotive Development Process. *Bulletin of Japanese Society for the Science of Design*, *43*(5), 57-64. (in Japanese)

Muto, M., Miyake, R., & Amasaka, K. (2011). Constructing an Automobile Body Color Development Approach Model. *Journal of Management Science*, *2*, 175-183.

Muto, M., Takebuchi, S., & Amasaka, K. (2013). Creating a New Automotive Exterior Design Approach Model: The relationship between form and body color qualities. *Journal of Business Case Studies*, *9*(5), 367-374.

Nagaya, A., Matsubara, K., & Amasaka, K. (1998). A study on the customer tastes of automobile profile design (Special Lecture). *Union of Japanese Scientists and Engineers, The 28th Sensory Evaluation Sympojium, Tokyo*. (in Japanese).

Nihon Keizai Shinbun. *(1) Corporate survey (68QCS)—Strict assessment of TQM (July 15, 1999), (2) Worst record: 40% increase of vehicle recall (July 6, 2000), (3) Risky "Quality": Apart from production increase, it is recalling rapid increase (February 8, 2006), and (4) Toyota recalls 880,000 trucks* (August 2, 2012).

Nunogaki, N., Shibata, K., Nagaya, A., Ohashi, T., & Amasaka, K. (1996), A study of customers' direction about designing vehicle's profile. *The Japanese Society for Quality Control, The 26th annual conference, Gifu, Japan* (pp. 23-26). (in Japanese).

Ohno, T. (1978). *Toyota Production System: Beyond Large-scale production*. Diamond-Sha, Tokyo. (in Japanese)

Okabe, Y., Yamaji, M., & Amasaka, K. (2007). Research on the Automobile Package Design Concept Support Methods "CS-APDM": Customer Science approach to achieve CS for vehicle exteriors and package design. *Journal of Japan Society for Production Management*, *13*(2), 51-56. (in Japanese).

Okutomi, H., & Amasaka, K. (2013). Researching Customer Satisfaction and Loyalty to boost marketing effectiveness: A look at Japan's auto dealerships. *International Journal of Management & Information Systems*, *17*(4), 193-200.

Shinogi, T., Aihara, S., & Amasaka. K. (2014). Constructing an Automobile Color Matching Model (ACMM). *IOSR Journal in Business and Management*, *16*(7), 7-14.

Takebuchi, S., Asami, H., & Amasaka, K. (2012). An Automobile Exterior Design Approach Model linking form and color. *Journal of China-USA Business Review*, *11*(8), 1113-1123.

Takebuchi, S., Nakamura, T., Asami, H., & Amasaka, K. (2012). The Automobile Exterior Color Design Approach Model. *Journal of Japan Industrial Management Association*, *62*(6E), 303-310.

Takimoto, H., Ando, T., Yamaji, M., & Amasaka, K. (2010). The proposal and validity of the Customer Science Dual System. *China-USA Business Review*, *9*(3), 29-38.

Taylor, D., & Brunt, D. (2001). *Manufacturing operations and supply chain management—Lean approach*. Thomson Learning, London.

Toyoda, S., Nishio, Y., & Amasaka. K. (2015). Creating a Vehicle Proportion, Form & Color Matching Model. *Journals International Organization of Scientific Research*, *17*(3), 9-16.

Yazaki, K., Takimoto,H., & Amasaka, K. (2013). Designing vehicle form based on subjective customer impressions. *Journal of China-USA Business Review*, *12*(7), 728-734.