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Science TQM, New Quality Management Principle:

The Quality Management Strategy of Toyota

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CHAPTERS

About the Author

Dr. Kakuro Amasaka was born in Aomori Prefecture, Japan, on May 5, 1947. He received a Bachelor of Engineering degree from Hachinohe Technical College, Hachinohe, Japan, in 1968 and a Doctor of Engineering degree specializing in Precision Mechanical and System Engineering, Statistics and Quality Control from Hiroshima University, Japan, in 1997.

Since joining Toyota Motor Corporation, Japan, in 1968, Dr. Amasaka worked as a quality control (TQM and SQC) consultant for many divisions. He was an engineer and manager of the Production Engineering Division, Quality Assurance Division, Overseas Engineering Division, Manufacturing Division and TQM Promotion Division (1968-1997), and the General Manager of the TQM Promotion Division (1998-2000).

Dr. Amasaka became a professor of the School of Science and Engineering, and the Graduate School of Science and Engineering at Aoyama Gakuin University, Tokyo, Japan in April 2000. His specialties include: production engineering (Just in Time, JIT and Toyota Production System, TPS), probability and statistics, multivariate statistical analysis, reliability engineering and information processing engineering. Recent research conducted includes: “Science SQC, new quality control principle”, “Science TQM, new quality management principle”, “New JIT, new management technology principle”, “Customer Science”, “Kansei Engineering” and numerical simulation (Computer Aided Engineering, CAE).

Positions in academic society and important posts: He is the author of a number of papers on strategic total quality management, as well as the convener of JSQC (Journal of Japanese Society for Quality Control), JOMSA (Japanese Operations Management & Strategy Association), JIMA (Japan Industrial Management Association), ISCIE (The Institute of System Control and Information Engineers), JJSE (Japanese Journal of Sensory Evaluation), and other publications (*e.g.* POMS in USA and EurOMA in Europe). He has been serving as the vice chairman of JSPM (2003-2007) and JOMSA (2008-2010), the director of JSQC (2001-2003), and the commissioner of the Deming Prize judging committee (2002-Present). Now, he is inaugurated as the vice chairman (2009-2010) and the chairman of JOMSA (2011-present).

Patents and prizes: He acquired 72 patents concerned with quality control systems, production systems, and production engineering and measurement technology. He is a recipient of the Aichi Invention Encouragement Prize (1991), Nikkei Quality Control Literature Prizes (1992, 2000, 2001 and 2010), Quality Technological Prizes (JSQC, 1993 and 1999), SQC Prize (JUSE, Union of Japanese Scientists and Engineers, 1976) and Kansei Engineering Society Publishing Prize (2002).

Aims and Structure

The Japanese management technology that made the biggest impact on the world in the second half of the 20th century were: the Toyota Production System, often also referred to as to Just-In-Time (JIT), which is the most famous Japanese production system; Total Quality Control (TQC) and Total Quality Management (TQM). However, as these management technologies became practiced as "lean systems" around the world and were further developed and popularized, they lost their status as unique Japanese systems—and in recent years, the superior quality of Japanese products has rapidly lost ground.

As we enter a new era of remarkably competitive technological innovation (figuratively referred to as "global quality competition"), there is a strong desire for a codified management system that overhauls Japanese management techniques once again and updates them for the next generation. Executives and managers are concerned with generating rational management outcomes through Customer-first Quality Management.

The aim of this eBook is to reassess the way quality management was carried out in the manufacturing industry and establish "Science TQM, new quality management principle", as a next-generation management technology. This new principle of Japanese management science aims to be a scientific quality management method— the key to success in global production is globally consistent levels of quality and simultaneous production worldwide (production at optimal locations).

More specifically, Science TQM consists of several core technologies designed to address specific areas of corporate operations: the "Total Marketing System, TMS" for sales, the "Total Development System, TDS" for development and design, the "Total Production System, TPS" for production technology and manufacturing, and the "Total Intelligence Management System, TIS" and "Total Job Quality Management System, TJS" for administrative and managerial functions. These systems are then effectively linked through "Science SQC, new quality control principle", to rationally achieve strategic quality management.

The focus of this eBook is thus the theory and application of strategic quality management through the application of "Science TQM". The effectiveness of Science TQM is then demonstrated at Toyota Motor Corporation—one of the world's leading companies.

Overview of the eBook

In this eBook, the author proposes the "Science TQM, new quality management principle" aimed at the evolution of manufacturing, and demonstrates its effectiveness.

Chapter 1 gives an overview of "Science TQM, new quality management principle", a new methodology for the next generation of quality management technology.

In Chapter 2, the author asserts the need for "evolution in manufacturing" in order to deal with the management issues currently facing Japanese manufacturers. It is clear that the key to success in global production is globally consistent levels of quality and simultaneous production worldwide (production at optimal locations). Therefore, in this chapter, the author reconsiders the "steps of management technology of the manufacturing industry" and discusses the necessity for an evolved principle of next generation administrative management technology.

In Chapter 3, the author explains the importance of "scientific quality management" which aims to create "wants" that are indispensable for the creation of attractive products, and proposes the "Product Development Technological Method—Customer Science" a highly reliable business approach that can realize the foregoing. In order to offer precisely and quickly what the customers want before they know they want it, line staff will increasingly need to work together to create a framework to enable "total business linkage" and thereby increase the effectiveness of Customer Science.

Chapter 4 focuses on the further development of Japanese quality management, and the author proposes "Science TQM, new quality management principle" as a next-generation management technology. Science TQM systematically and organizationally contributes to the solution of current management technology problems, aiding advanced companies aiming to gain the position of top runner by enabling them to create 21^{st} century manufacturing quality.

In Chapter 5 - Chapter 7, the author discusses and demonstrates the effectiveness of the following as the "Driving Force in Developing Science TQM": Science SQC, New Quality Control Principle, Strategic Quality Management—Performance Measurement Model, and Partnering Chains as the Platform for Strategic Quality Management.

In Chapter 8 - Chapter 10, the author discusses and demonstrates the effectiveness of the following as the "Innovation Models Utilizing Science TQM": Strategic Marketing Development Model, High Quality Assurance CAE Analysis Model, and Partnering Performance Measurement Model.

In Chapter 11 - Chapter 13, the author discusses the following examples of the "Strategic Development of Science TQM", thereby demonstrating its effectiveness: Change in Marketing Process Management, Evolution of Development Design Process Management, and Strategic QCD Studies with Affiliated and Non-affiliated Suppliers.

In Chapter 14 - Chapter 17, the author introduces the following case studies in Science TQM, thereby demonstrating its effectiveness: Developing a Strategic Advertisement Method, Effectiveness of Flyer Advertising, Highly Precise CAE Analysis Approach Method, and Patent Value Appraisal Model in the Corporate Strategy.

Finally, this eBook is concluded by the Afterword.

FOREWORD

This is an eBook to be benchmarked by research professionals and practitioners who are interested in developing competitive quality of the company in the prevailing global competition. A huge pile of books related to manufacturing and quality practices is available, but almost none instructs how to implement them consistently to achieve competitive quality.

The essence of TQM is reflected in "Total" Quality Management. Science and technology, team work, collaboration with internal as well as external members, training and skill, data and information, knowledge, and organizational alignment are all important ingredients to be combined systematically and strategically. Linking all ingredients for quality in consistent and effective ways is a key to competitiveness.

The author, an ex-leading general manager of TQM promotion division of Toyota Motor Corporation, shows how to align them to develop competitive quality throughout the business process that covers from the creation of product concept through manufacturing and selling to delivery to clients by actual cases.

Readers will find not only quality related practices, but also the linking capability executing the practices. They will understand the capability consists of scientific, behavioral and organizational insights into quality. Also, cautious readers will recognize or become aware of another important factors not mentioned explicitly to achieve real TQM. TQM is really management itself.

This eBook, in this sense, is also strongly recommended to senior managers including top who are not directly involved in so-called quality management because quality is the outcome of the dynamics of most activities of the company as well as kernel part of competitiveness. The content is such stuff as the company's competitive quality is made on.

Prof. Michiya Morita

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PREFACE

When we loose our passion for science—our inquisitiveness—we often end up postponing problems that need to be addressed, wasting time with constant trial-and-error efforts.

The result is that the same problems occur over and over again as we get caught up in the work right in front of us. The number of task supervisors increases and the organization as a whole loses its drive to come out on top—and actions without substance begin to pervade the company.

When we look at the quality management issues that have faced both Japan and the rest of the world recently, it is clear that a next-generation quality management technology, featuring a rational overhaul that will motivate people and revitalize organizations, is urgently needed.

Japanese corporations—who by all rights should be leading global production—are seeing an increase in recalls. They seem to be losing a grip on the scientific quality management methods that were once an exclusive feature of Japanese quality management practices. These are warning signs that existing quality management technology must be reinforced.

In order to put a stop to empty imitation and keep pace with advancing technology, now is the time to reformulate the principles of quality management—those that have led the world and are uniquely Japanese—into a new quality management principle that will take hold in the next generation.

The author revisits the importance of scientific quality management in order to create "Science TQM, new quality management principle". The effectiveness of Science TQM is then demonstrated at Toyota Motor Corporation—one of the world's leading companies.

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These days, there have been cases where leading companies undergo hard times with unanticipated quality management problems, and cases where companies loses sight of customer needs and fail to catch up with technological advancement, placing their corporate existences in danger. In such circumstances, the author believes that management should aim for justifiable customer first quality management. The key to achieving customer-oriented quality management is establishment and utilization of demonstrative scientific methodology.

The author continues to propose "Science TQM, New Quality Management Principle", as a next-generation total quality management principle, and verified its validity through a number of demonstrated studies. During his time working at Toyota Motor Corporation (1968-2000) and Aoyama Gakuin University (2000-present), the author leads Toyota's total quality management (TQM) mainly through effective applications of Science TQM to Toyota group companies and other advanced companies.

This eBook is a complication of past studies, new scientific books and major academic journals, and explains the comprehensive theory and practices of Science TQM so called New Japan Model that has been widely used and are evolving as Toyota's new scientific quality management methodology. The author would like to acknowledge the generous support received from the following researchers. All these at Toyota Motor Corporation and Amasaka's Laboratory in Aoyama Gakuin University that assisted with author's research, especially, Mr. M. Yamaji, Mr. T. Ito, Mr. M. Sato, Mr. S. Hifumi, Mr. T. Sakatoku, Mr. T. Ueno, and Mr. T. Takahashi. Furthermore, The author says gratitude to Professor Morita's "Foreword" deeply in publication of this eBook.

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CHAPTER 1

Introduction

Kakuro Amasaka*

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Abstract: In this chapter, a new methodology for the next generation of quality management will be proposed by focusing on the further development of Japanese quality management (TQM). In the main discussion, a new principle of the next generation TQM - "Science TQM, new quality management principle", will be proposed, and its effectiveness will be demonstrated. Science TQM systematically and organizationally contributes to the solution of management technology issues by capitalizing on the "Science SQC, New Quality Control Principle".

Keywords: Science TQM, science SQC, customer science, next generation TQM.

1. IMPORTANCE OF SCIENTIFIC QUALITY MANAGEMENT

When we loose our passion for science—our inquisitiveness—we often end up postponing problems that need to be addressed, wasting time with constant trial-and-error efforts. The result is that the same problems occur over and over again as we get caught up in the work right in front of us. The number of task supervisors increases and the organization as a whole loses its drive to come out on top—and actions without substance begin to pervade the company.

When we look at the quality management issues that have faced both Japan and the rest of the world recently, it is clear that a next-generation quality management technology, featuring a rational overhaul that will motivate people and revitalize organizations, is urgently needed (Amasaka, 2002: Amasaka, Ed., 2008: Amasaka, *et al.*, 2009). Japanese corporations—who by all rights should be leading global production—are seeing an increase in recalls (Gabor, 1990: Joiner, 1994: J. D. Power, 2009).

They seem to be losing a grip on the scientific quality management methods that were once an exclusive feature of Japanese quality management practices. These are warning signs that existing quality management technology must be reinforced. In order to put a stop to empty imitation and keep pace with advancing technology, now is the time to reformulate the principles of quality management—those that have led the world and are uniquely Japanese—into a new quality management principle that will take hold in the next generation (Amasaka, 2004b).

2. SCIENCE TQM, NEW QUALITY MANAGEMENT PRINCIPLE

The Japanese management technology that made the biggest impact on the world in the second half of the 20^{th} century were: the Toyota Production System called JIT (Just in Time) or a "Lean System", the most famous Japanese production system; and Total Quality Control (TQC) and Total Quality Management (TQM) (Ohno, 1972). However, as these management technologies became practiced as "lean systems" around the world and were further developed and popularized, they lost their status as unique Japanese systems—and in recent years, the superior quality of Japanese products has rapidly lost ground (Hayes and Wheelwright, 1984: Doos, *et al.*, 1991: Womack and Jones,1994: Taylor and Brunt, 2001).

As we enter a new era of remarkably competitive technological innovation (figuratively referred to as "global quality competition"), there is a strong desire for a codified management system that overhauls Japanese management techniques once again and updates them for the next generation. Executives and managers are concerned with generating rational management outcomes through Customer-first Quality Management.

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Kakuro Amasaka (Ed)

The aim of this eBook is to reassess the way quality management was carried out in the manufacturing industry and establish "Science TQM, New Quality Management Principle", as a next-generation management technology (Amasaka, 2004, 2008: Amasaka, Ed., 2007). This new principle of Japanese management science aims to be a scientific quality management method— the key to success in global production is globally consistent levels of quality and simultaneous production worldwide (production at optimal locations).

More specifically, Science TQM consists of several core technologies designed to address specific areas of corporate operations: the "Total Marketing System, TMS" for sales, the "Total Development System, TDS" for development and design, the "Total Production System, TPS" for production technology and manufacturing, and the "Total Intelligence Management System, TIS" and the "Total Job Quality Management System, TJS" for administrative and managerial functions. These systems are then effectively linked through "Science SQC, New Quality Control Principle", to rationally achieve strategic quality management (Amasaka, 2003, 2004a).

The focus of this eBook is thus the theory and application of strategic quality management through the application of Science TQM. We revisit the importance of scientific quality management in order to create Science TQM (Amasaka, Ed., 2008).

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CHAPTER 2

Evolution in Manufacturing, The Key to Success in Global Production

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Abstract: In this chapter, consideration is given to the "evolution in manufacturing" needed for dealing with the management issues facing Japanese manufacturers, that is, the "key to success in global production is globally consistent levels of quality and simultaneous production worldwide (production at optimal locations)". The author reconsiders the "steps of management technology of the manufacturing industry", grasps the necessity for an evolved principle of next generation administrative management technology, from the standpoint of "creation of a new management technology", and then discuss its effectiveness.

Keywords: Global production, manufacturing, management technology, JIT and TPS, TQM, next generation management technology.

1. WHAT ARE THE MANAGEMENT ISSUES OF JAPANESE MANUFACTURING?

The change in the environment surrounding the current manufacturing sector is truly relentless. Due to the advancement of IT (Information Technology) and the permeation of the Internet, consumers have easy access to the latest information available all over the world.

In recent years, consumers (hereafter called, customers) selected products which fit their lifestyles and set of values, and they thus created a market environment in which they strictly judge the "reliability of manufacturers," by means of the reliability (quality and use value) of their products. For this reason, it might become a prerequisite for the "survival" of Japanese manufacturers to take into consideration the needs of customers all over the world and to become successful in "global marketing", which will allow them to quickly offer products of high quality and the latest models so as to best enhance customer value.

It is not an exaggeration to say that manufacturers' success or failure in "global marketing" shall depend on whether or not they are able to precisely grasp the customers' preference and to advance their "manufacturing" to adequately respond to the demands of the times. This is done with a view to realizing "global production", which enables the so-called "globally consistent levels of quality and simultaneous production worldwide (production at optimal locations)" ahead of other manufactures, so that they will not be pushed out of the market (Amasaka, 2002a, 2004).

In the midst of the drastic change taking place at manufacturing sites caused by "digital engineering," we can say that the reconstruction of world-leading, uniquely Japanese "principles of management technology" or "management technology", which can be used even in the next generation, are what is needed now so as not to lag behind the "evolution in management technology". This is the "mission" imposed on Japanese manufacturers today.

In order to accomplish the foregoing, it is imperative for such management related departments as technical management, production management, sales management, and information technology, which make up the core of corporate management, to closely cooperate with the administrative departments, such as personnel affairs, general planning, TQM (Total Quality Management) promotion, or overseas business, and even to carry out strategic collaborations with onsite departments handling technical, production, or sales matters, as well as suppliers (parts makers) (Amasaka, 2008).

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Kakuro Amasaka (Ed)

At present, “manufacturing” in Japan is facing two major paradigm shifts. One is the shortening of the life cycle of products due to the sophistication and diversification of customer needs. This makes it necessary to realize the shortest lead time possible, which encompasses the process of development, manufacturing, and sales, and even involves parts suppliers. The other shift is the “creation of management technology” capable of embodying the globalization of production bases needed for reconstructing the so-called “global production system” and a systematic, organizational operation of such a technological principle (Amasaka, 2004, 2005, 2008a: Amasaka, Kurosu and Morita, 2008).

However, do we have a sound basis for our confidence in the future of Japanese “manufacturing” which is expected to provide “an example” of implementing and carrying out the items presented above? It is evident that the lack of such confidence will result in difficulty in strategically deploying “global production” which carries out the manufacturing of products overseas at the same quality level as in Japan (Amasaka, 2004: Ebioka, *et al.*, 2007).

2. RECONSIDERATION OF THE “STEPS OF ADMINISTRATIVE MANAGEMENT TECHNOLOGY IN THE MANUFACTURING SECTOR”

With a view toward assuring that the future management technology is a new leap forward for Japanese “manufacturing”, the “Progress of management technology” taken so far by the manufacturing industry are summarized in Fig. **1** (Amasaka, 2007a).

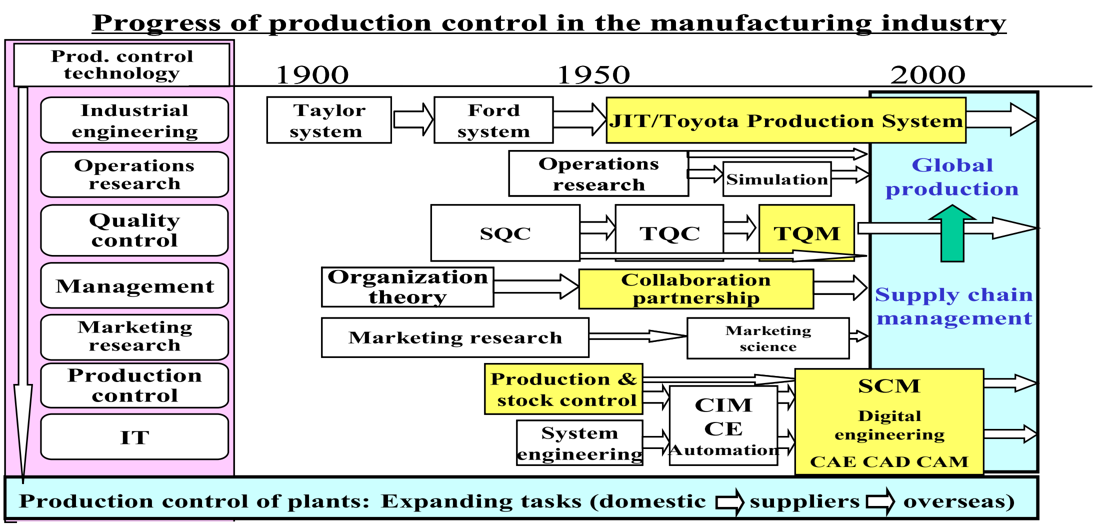

Figure 1: Progress of Management Technology in the Manufacturing Industry.

In the figure, the basis of major “management technology methods” such as Industrial Engineering, Operations Research, Quality Control, Management of Administration, Marketing Research, Production Control, and Information Technology are plotted along the vertical axis. Along the horizontal axis, some of the key elemental technologies, management methods, scientific methodologies, *etc.* are mapped out in a time series.

Since the beginning of this century, the operation of manufacturers has shifted from domestic production in Japan to overseas production bases, and management technology has become increasingly complicated, as depicted in the figure. The tasks directly before each of the departments related to management technology hold the key to success in “global production”. The key lies in the modeling of “strategic SCM (Supply Chain Management)” in cooperation with domestic and overseas suppliers (parts makers) and the systemization of its operation methods (Amasaka, 2000, 2004, 2007a, 2008b).

It can be confirmed that, particularly at the implementation stage, it will be necessary to conduct an in-depth study for the integration of "Just in Time" (JIT) (Womack *et al.*, 1991), the Toyota Production System (TPS) (Ono, 1977), TQM, Partnering, and Digital Engineering, etc.

3. THE "JAPANESE PRODUCTION SYSTEM" WHICH LEAD "MANUFACTURING IN THE 20TH CENTURY"

The Japanese management technology that contributed to the world in the latter half of the 20th century can be typified in the Japanese production system represented by the TPS. TPS is a production system developed by Toyota which is also called JIT or a "Lean System" in other parts of the world. This system aimed to improve product quality while pursuing maximum efficiency through the application of TQM into the manufacturing process, as well as applying the principle of cost reduction (Amasaka, 2002a, Amasaka, Ed., 2007).

In order to cater to the customers' needs and to conduct "manufacturing" successfully, a study into the timely "simultaneous achievement of QCD (Quality, Cost and Delivery)" is the top priority (Amasaka, 2008a, 2008b). To accomplish this, Toyota has been viewing TPS and TQM as the dual pillars of management technology (Amasaka, 2002a). As shown in Fig. **2**, through the combination of these two pillars, deviations like "large tidal waves" can be reduced to small fluctuations similar to "gentle ripples" which enable the improvement of average values at all times. This involves the continuation and improvement of QCD study activities while incorporating SQC (Statistical Quality Control) from the standpoint of hardware technology based TPS, and software technology based TQM, which are represented on the vertical and horizontal axis respectively (Amasaka, 2003).

As a result of being highly evaluated all over the world as the concept that renovated automobile production of Toyota, the concept of JIT and its approach have been established as a core concept of the world's manufacturing (Goto, 1990: Womack and Jones, 1994).

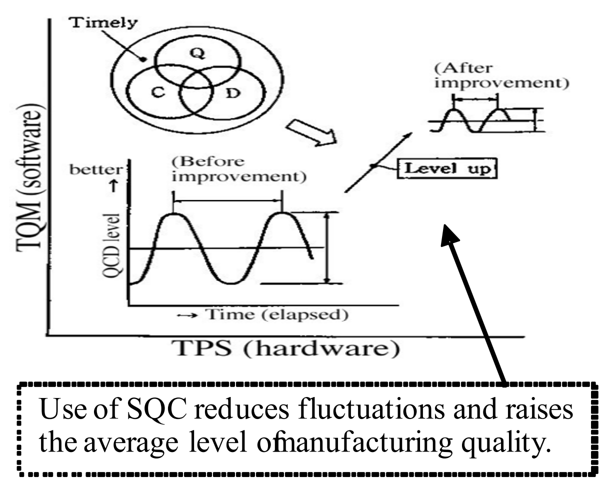

Figure 2: Relation Between TPS and TQM.

4. AT PRESENT, THE EVOLUTION OF ADMINISTRATIVE MANAGEMENT TECHNOLOGY IS BEING DEMANDED

In today's rapidly changing technological environment, one of the first management technology issues that needs to be addressed in order to realize customer first "simultaneous achievement of QCD" is the creation of a "new development designing system" capable of reforming the technological development business process of development designing related departments (Amasaka, 2007b, 2007c).

Secondly, it is increasingly important for production business related departments to develop new production technologies and advance the "production management technology system" which enables global production (Amasaka, 2007a: Amasaka and Sakai, 2005a, 2005b, 2006, 2009, 2010). Thirdly, it is necessary for sales related departments to concentrate their view on global marketing and to establish a "new marketing system" that breaks away from conventional systems, with a view to strengthening ties with their customers.

Additionally, it is increasingly an indispensable requirement, even from the standpoint of assuring "corporate reliability", for the office administrative departments and management related departments to cooperatively establish and implement a "new administrative management technology" which enhances the business process of all departments involved in corporate management (Amasaka, 2004, 2008).

The above statements also apply, without exception, to Toyota. Toyota's TPS has been adopted and further developed in various systems shared internationally, such as JIT or the Lean System (Taylor and Brunt, 2001), and therefore, it is no longer Toyota's exclusive technology. In the United States also, the importance of quality management has been increasingly recognized though studies of Japanese TQM. TQM has been actively promoted, thus encroaching on the quality superiority which Japanese products have previously enjoyed (Gabor, 1990: Joiner, 1994: Nezu, 1995: Nihon Keizai Shinbun-sha, 1999, 2000, 2001, 2002, 2006a, 2006b).

What can be deduced from these facts is that it is clearly impossible to continue to lead the next generation simply by adhering to and maintaining the production-based traditional "Japanese management technology" (Amasaka and Sakai., 2010). In order to overcome these problems, it is essential not only to advance TPS, a core technology of production processes, but to also establish a core technology for the service sales, development designing, production, office administration, and management related departments (Amasaka, 2002a, 2004, 2008: Amasaka and Sakai, 2010).

Furthermore, for the purpose of assuring the reform of the business process among all departments, as well as "reinforcement of inter-department cooperation", it is vital to reconstruct an intelligent system for information sharing. In the implementation stage, it will be important to further upgrade the advantages of the "Japan Supply System" (Amasaka, 2000a, 2001), a cooperative system between assembly parts makers and automotive manufacturers that has long been established in Japanese manufacturing, to a "Partnering Chain Management System on Platforms" and also to establish its method of operation.

Given such a corporate management environment, the author (Amasaka, 2001, 2007a) is currently proposing an "evolved model of next generation management technology*"*, which is expected to be the key to success in global production, and is promoting the demonstration of its effectiveness.

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CHAPTER 3

Scientific Quality Management through Customer Science

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Abstract: The main concern among the top management or manager class is "quality management which gives customers top priority". It is extremely important for production creation from now on to "offer precisely and quickly what the customers want before they know they want it". Grasping the importance of a highly reliable business approach that can realize the foregoing, the author proposes here the "Product Development Technological Method — Customer Science". This enables highly reliable quality management, "scientific quality management which is aiming to create "wants" that are indispensable for the strategic creation of attractive products".

Keywords: Total marketing, highly reliable business approach, product development technological method, customer science, wants, scientific quality management.

1. WHAT IS THE MAIN CONCERN OF TOP MANAGEMENT AND THE MANAGER CLASS?

A close look at recent corporate management activities can reveal various situations wherein an advanced manufacturer, which is leading the industry, is having a difficult time due to unexpected quality related problems. Some companies have failed to see through the customers' feelings and have slowed down in product development or in their production engineering development/production management systems, and are thus facing a crisis of their own survival as a manufacturer.

On the other hand, quite a few manufacturers have been thriving and enjoying steady growth for the past few decades by actively and bravely taking a scientific approach toward (concretizing) their customers' feelings and thereby conducting a reform program in product development and the service/sales systems, thus carrying out a company-wide "total marketing" activity through partnering with their suppliers.

What is the cause of this situation wherein major differences between manufacturers have developed? When considering the main concern on the minds of top management and the manager class, it is obtaining reasonable management results by means of the "creation of a corporate environment for utilizing human resources and activating the organization" that is indispensable for realizing "quality management that gives customers top priority" (Amasaka, 2004: Amasaka, Ed., 2007).

The fact that many Japanese companies recruit graduates having a similar academic ability from all over Japan makes it evident that the key to the rise and fall of a company is held by these newly employed young business persons, and whether they are engaging in creative work and have proved to be on the leading edge of corporate environment reform.

With regard to the management issues facing Japanese manufacturers, the studies conducted by the author (Amasaka, 2009a: Amasaka, Ed., 2007), have pinpointed, among other things:

1) The "vulnerability of management technological capability" in corporate management.

2) More specifically therein, the lack of ability at manufacturing sites is pointed out.

3) The lack of reliability in technological development designing is also brought up.

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Kakuro Amasaka (Ed)

4) The need for conducting reasonable marketing activity regardless of traditional methods is presented for sales/service related departments.

5) The need for taking a new scientific approach for creating a new market is brought to the forefront of the general planning, merchandize planning, and the product planning related departments.

6) As the basis of the reinforcement measures for global production, "simultaneous achievement of QCD" is necessary for office administration/management departments by reforming the quality of their business process while breaking away from the conventional, reactive ways of business and performing proactive work as the core of the corporate management activity.

2. FUTURE QUALITY MANAGEMENT AIMING FOR HIGH RELIABILITY OF THE COMPANY, ORGANIZATION, AND HUMAN RESOURCES

In the midst of this severe worldwide quality competition for the survival of manufacturers inside and outside of Japan, the top management and manager class need to recognize anew the "way of manufacturers' quality management", particularly when considering the repeated cases of quality problems in recent years that can considerably harm customer satisfaction. The recent increase in recalls by advanced manufacturers expected to lead the world in global production is providing a warning reminder about the need of manufacturers to reinforce "quality management" (Goto, 1999: Nihon Keizai Shimbun, 1999, 2000, 2001, 2002, 2006: Nikkei Sangyo Shimbun, 2000: Asahi Shimbun, 2005).

Against this background, the author (Amasaka, 2008: Amasaka, Ed., 2007) has focused attention on the "way of future quality management aiming for high reliability of company, organization, and human resources" which is necessary for the "creation of highly reliable products", and therefore discussed the importance of systematic and organizational cooperation among all departments involved.

Fig. **1** is given here to present a business process which realizes "high quality assurance manufacturing" and shows an organization chart of an onsite work department belonging to a typical manufacturer, as well as an example of its QCD activity. The figure clearly indicates the representative 13 departments ranging from engineering, to production, to sales, and their respective missions.

Figure 1: A Typical Corporate Organization Chart and QCD Activity.

As shown in the Fig. **1**, in each step of the cyclical business process made up of "merchandise planning - product planning - designing - design drawing - research and development - prototyping/experiment evaluation - production engineering development - production preparation (production management) - purchase and procurement - manufacturing/inspection - promotion/sales - service - marketing", it is vital to engage in so-called "total marketing" activities.

That is, activities that improve the "reliability of the work performed" in close cooperation with each other in order to best perform the cyclic "missions" of: "how it is to be - what is needed - how to make it - how well it is made – how to sell it (whether the customers are pleased with it or not) – how it was all done" (Amasaka, 2004).

At this point, consideration shall be given to the reason of why market claims and recalls occur, and how important it is for all the departments to systematically and organizationally cooperate in order to prevent such problems. For this reason, the author (Amasaka, 2008a) incorporates the theory of probability as the "importance of cooperative activity among departments for improving the work reliability".

Table **1** illustrates the work quality of each department converted into the degree of reliability for Cases 1 to 6. To present it simply, the theory of probability is incorporated here for interpreting the overall work quality of all the 13 departments into their degree of reliability (credibility) to show the total reliability (or total unreliability, hereafter called claim ratio).

Table 1: Job Reliability of 13 Departments

Case 1: 99.9 %/department
→ $0.999^{13} = 0.987$ (1.3 % problems)
Case 2: 99.0 %/department
→ $0.990^{13} = 0.878$ (12.2 % problems)
Case 3: 95.0 %/department
→ $0.950^{13} = 0.513$ (48.7 % problems)
Case 4: 90.0%/department
→ $0.900^{13} = 0.254$ (4.6 % problems)
Case 5: When 12 departments are 99.99 % but 1 department is 50.0%:
→ $0.999^{12} \times 0.500 = 0.499$ (50.01% problems)
Case 6: 99.99 %/department
→ $0.9999^{13} = 99.88\%$ (0.12 % problems)

On the assumption that cooperation between departments (ratio of circulating information) is indexed at 1.00(100%), even when the reliability of Department 1 is 99.9%, the total reliability is rated at 98.7%, indicating that claims can occur in the market at the probability of 1.3%.

Similarly, in Case 2, (99.00%/department) 12.2% of recall probability can be deduced. The recall probability increases to 48.7% in Case 3 (95.00%/department) and it jumps further to 74.6% in Case 4 (90.00%/department). In Case 5, although 12 departments are marked with a high reliability of 99.99%, 1 department performs poor quality work (50.00%/department) due to inexperienced workers or careless mistakes overlooking certain things, and the result is a devastating 50.01% claim probability, indicating that corporate reliability can be deeply undermined. In Case 6 (99.99%/department) where the total reliability reaches 99.88%, the claim probability can finally be reduced to the order of ppm (0.12%).

The above analysis makes it easier to understand why all the departments are required to perform high quality work in order to maintain reliability. The table also makes it very clear that when the circulation of information is not sufficiently conducted between departments, that the total reliability can drop even lower. Such a situation is far too serious to categorize simply as "something like a traffic accident! (or bad luck!)" as can be seen in the recent recall-related social responsibility crisis.

3. PROPOSAL OF "SCIENTIFIC QUALITY MANAGEMENT" THROUGH "CUSTOMER SCIENCE"

The mission of a 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. In order 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, 2005).

In order 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, 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". In order to do this, it is vital to clearly grasp the hazy, ambiguous feelings of customers. The "product development technological method - Customer Science" (Amasaka, 2002a, 2008a) shown in Fig. **2** is what gives concrete shape to such customer wants. 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.

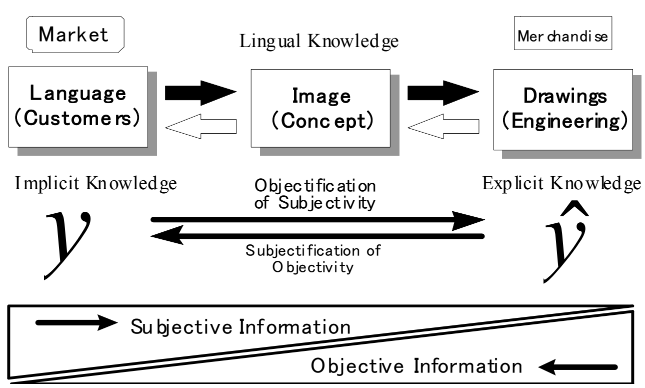

Figure 2: Schematic Drawing of Customer Science.

As depicted in the Fig. **2**, so-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).

When using the methodology of Customer Science 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 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 the customers actually want and thereby confirm the accuracy of the work being performed, thus subjectifying the objectivity using correlation techniques (Amasaka, *et al.*, 1999: Amasaka, 2003, 2002b, 2007a).

By conducting "total marketing", that is, an approach focusing on "quality management that gives customers top priority" incorporating Customer Science, 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 quality management" can definitely be realized (Amasaka, *et al.*, 2005).

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 in order 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 activity (Amasaka, 2007b, 2007c, 2008b, 2009b).

This approach is common to SQC (Statistical Quality Control) introduced to Japan by Dr. Shewhart and Dr. Deming and has immensely contributed to postwar Japanese manufacturing and the development of quality management technology (Shewhart, 1986: Mary, 1988: Joiner, 1994: Gabor, 1999).

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CHAPTER 4

Science TQM, New Quality Management Principle

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Abstract: In this paper the author proposes, “Science TQM”, New Quality Management Principle. This principle consists of the “Total Development System, TDS”, “Total Production System, TPS”, “Total Marketing System, TMS”, “Total Intelligence Management System, TIS”, and “Total Job Quality Management System, TJS”. It aims to realize an integrated form of a next- generation management strategy. Furthermore, this paper demonstrates how the utilization of “Science SQC” and a “Strategic Stratified Task Team” contributes systematically and organically to solving quality management problems. Its validity has also been verified through its application within the Toyota Motor Corporation, Toyota group companies, and others.

Keywords: Science TQM, new quality management principle, TDS, TPS, TMS, TIS, TJS, science SQC, strategic stratified task team, toyota, toyota group

1. INTRODUCTION

Looking closely at the quality management issues facing advanced corporations both domestically and overseas in recent years, it has become clear that a new TQM (Total Quality Management) principle is being strongly sought after (Amasaka, 1999: Nikkei Keizai Shinbun, 1999, 2000, 2006: Asahi Shinbun, 2005).

This new principle needs to employ a rational concept and methodology that will break away from the conventional ideas of quality management and contribute to the restoration of quality. In the main discussion of this paper, the next generation of TQM – “Science TQM, New Quality Management Principle” (Amasaka, 2004, 2008a), will be proposed and its effectiveness will be demonstrated. Science TQM systematically and organizationally contributes to the solution of company-wide management technology problems.

Science TQM is composed of five core principles, namely: (1) the “Total Development System, TDS”, (2) the “Total Production System, TPS”, (3) the “Total Marketing System, TMS”, (4) the “Total Intelligence Management System, TIS”, and (5) the “Total Job Quality Management System, TJS”. By implementing Science TQM and it’s five core systems each work department will become equipped with the core technology and linked with one another cooperatively.

This paper demonstrates how the utilization of “Science SQC, New Quality Control Principle” and a “Strategic Stratified Task Team” contributes systematically and organically to solving quality management problems. Its validity will then be been verified through its application within the Toyota Motor Corporation, Toyota group companies, and others (Amasaka, Ed., 2007).

2. THE KEY TO SUCCESS IN GLOBAL PRODUCTION, AN EVOLUTION IN MANUFACTURING

In this chapter, consideration is given to the “evolution in manufacturing” that is needed for dealing with the management issues facing Japanese manufacturers today. In other words, the key to success in global production is globally consistent levels of quality and simultaneous production worldwide.

2.1. The Japanese Production System which led Manufacturing in the 20th Century

The Japanese administrative management technology that contributed most to the world in the latter half of the 20th century can be typified by the Japanese production system represented by the Toyota Production

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System. This system is a production system developed by Toyota that is also called JIT (Just in Time) or a "Lean System" in other parts of the world.

This system aimed to improve product quality while pursuing maximum efficiency through the application of TQM into the manufacturing process, as well as applying the principle of cost reduction (Ohno, 1977: Amasaka, 2002a). In order to cater to the customers' needs and to conduct manufacturing successfully, a study into the timely "simultaneous achievement of QCD (Quality, Cost, and Delivery)" is the top priority. To accomplish this, Toyota has been focusing on Toyota Production System and TQM as the dual pillars of management technology (Amasaka, 2002a, 2008b).

As shown in Fig. **1**, through the combination of these two pillars, deviations visualized in the form of "large tidal waves" can be reduced to smaller fluctuations similar to "gentle ripples" that enable the improvement of average values at all times. This involves the continuous application and improvement of QCD study activities, while at the same time, incorporating SQC (Statistical Quality Control) from the standpoint of hardware technology based TPS, and software technology based TQM, which are represented on the vertical and horizontal axes respectively (Amasaka, 2002a).

As a result of being highly praised all over the world as the concept that revolutionized automobile production at Toyota, the concept of JIT and its approach have been established as a core concept of manufacturing around the world (Womack and Jones, 1994).

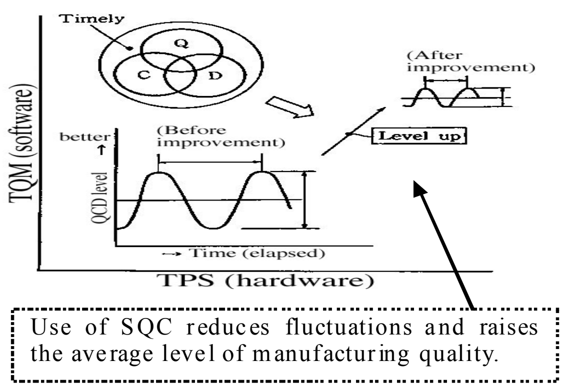


Figure 1: Relation Between TPS and TQM.

2.2. What are the Critical Management Issues for Japanese Manufacturing?

In recent years, consumers (hereafter called, customers) have been selecting products that fit their lifestyles and their set of personal values. Consequently, a market environment was created in which customers strictly judge the reliability of manufacturers according to the reliability (quality and value gained from use) of their products. For this reason, it is not an exaggeration to say that 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.

This is being done in order to realize global production that will achieve the so-called "globally consistent levels of quality and simultaneous production worldwide (production at optimal locations)" ahead of other manufactures. Achieving this will allow the manufacturer to not be pushed out of the market (Amasaka, Ed., 2007). In the midst of the drastic changes taking place at the manufacturing site due to the use of digital engineering, the author (Amasaka, 2008a) can say that the reconstruction of world-leading, uniquely Japanese principles of management technology and administrative management technology, which will be viable even for next-generation manufacturing, are urgently needed in order to keep up with this evolution in management technology.

This is the mission imposed on Japanese manufacturers today (Amasaka, Ed., 2007). In order to accomplish this, it is imperative that management related departments, such as technical management, production management, sales management, and information technology, which make up the core of corporate management, closely cooperate with the administrative departments, such as personnel affairs, general planning, TQM promotion, and overseas business.

Furthermore, management-related departments also need to carry out strategic collaborations with on-site departments handling technical, production, and sales matters, as well as with suppliers (parts manufacturers) (Amasaka, 2004a: Amasaka, Ed., 2007).

2.3. The Evolution of Administrative Management Technology is Now Being Demanded

In today's rapidly changing technological environment, one of the first management technology issues that needs to be addressed in order to realize the "simultaneous achievement of QCD" and place the customer first, is the creation of a new development designing system capable of reforming the technological development business processes of the development designing-related departments. Second, it is increasingly important for departments concerned with production to develop new production technologies and advance the "production management technology system" that enables global production. Third, it is necessary for sales-related departments to concentrate their view on global marketing and to establish a "new marketing system" that breaks away from the conventional systems in an effort to strengthen ties with the customers.

Furthermore, it is becoming increasingly necessary, even from the standpoint of assuring "corporate reliability", for the general administration departments and management-related departments to cooperatively establish and implement a new administrative management technology which enhances the business processes of all departments involved in corporate management (Amasaka, 2004a, 2008a). The above statements also apply, without exception, to Toyota's TPS, which has been adopted and further developed in various systems shared internationally, such as JIT or Lean Systems (Taylor and Brunt, 2001), and therefore, it is no longer Toyota's exclusive technology. In the United States as well, the importance of quality management has been increasingly recognized though studies of Japanese TQM. TQM has been actively promoted, thus encroaching on the quality superiority that Japanese products have previously enjoyed (Gabor, 1990: Joiner, 1994: Goto, 1999).

What can be deduced from these facts is that it is clearly impossible to continue to lead in the next generation of manufacturing simply by adhering to and maintaining the traditional, production-based "Japanese management technology". In order to overcome these problems, it is essential not only to advance TPS, a core technology of production processes, but to also establish a core technology for the service and sales, development designing, production, general administration, and management-related departments (Amasaka, 2004a: Amasaka, Ed., 2007).

Furthermore, for the purpose of ensuring the reform of the business process in all departments, as well as reinforcing inter-department cooperation, it is vital to reconstruct an intelligent system for sharing information. During the implementation stage of this system, it will be important to further upgrade the advantages of the "Japan Supply System" (Amasaka, 2004a, 2007a), a cooperative system between the assembly parts manufacturers and the automobile manufacturers that has long been a part of Japanese manufacturing, to a "Partnering Chain Management System on Platforms", as well as to establish the method of this system's operation.

3. SCIENCE TQM, A NEW QUALITY MANAGEMENT PRINCIPLE

In this chapter, a new principle of next generation TQM – Science TQM, will be proposed, and its validity will be demonstrated. Science TQM systematically and organizationally contributes to the solution of management technology problems by capitalizing on the "Science SQC, New Quality Control Principle" and a "Strategic Stratified Task Team".

3.1. The Proposal of Science TQM, A New Quality Management Principle

The goal of TQM activities in manufacturing is to offer attractive products. Therefore, in order to reform the foundation of TQM activities and keep pace with the changing times it is necessary to implement "Customer Science" (Amasaka, 2005a) (see chapter 3 in detail).

To implement this it is vital for all departments to share the same values toward work and improve the quality of their work through cooperation. More specifically, a new principle of TQM will be needed that can establish the factors for reasonable management technologies and link them together.

In recent years however, the concept of quality has been expanding to include not only product quality, but also the quality of the business process and even that of corporate management. In step with this trend, the scope of TQM activities has also become more wide-ranging. Therefore, the generators, mentors, and promoters of TQM have had a hard time managing every single technique and skill of all the individuals belonging to different positions or departments, as well as the technology related to workplace management (workplace formation). This is because the existing TQM activities are based on past successes brought about by each person's particular experience or skills, and this is not enough to encompass all the new diversified technologies, such as those mentioned above.

In order to create customer-oriented, attractive products that can truly satisfy the customer's demands, a core technology needs to be established. This technology would allow the (1) technological development designing, (2) production engineering and manufacturing, and (3) the advertising, promotion, and sales-related departments, to be organically linked together by (4) the management department, and (5) the personnel and general administration departments. These departments have the role of effectively utilizing human resources in all of the other departments in order to activate the organization and to improve the quality of their work. It is imperative that all these departments are linked with one another systematically and organizationally.

Therefore, Science TQM is hereby proposed and illustrated as shown in Fig. **2**. This is a new principle of TQM which links and rationalizes the business process of each department into a continuous circular ring in order to grasp the mission of each department involved in management technology. It is composed of five core principles, namely: (1) the Total Development System, TDS, (2) the Total Production System, TPS, (3) the Total Marketing System TMS, (4) the Total Intelligence Management System, TIS, and (5) the Total Job Quality Management, System, TJS. This ensures that each department is equipped with the core technology and is linked to the others.

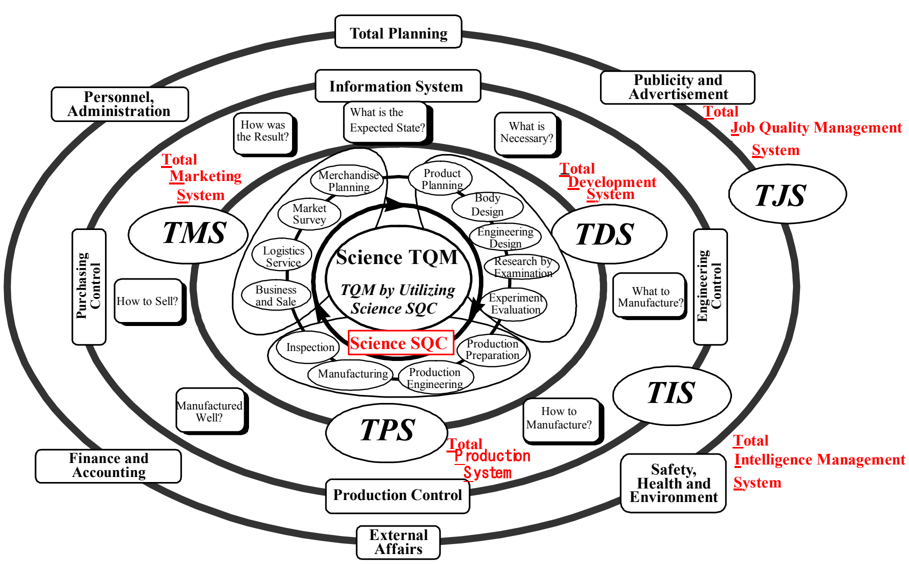


Figure 2: Science TQM, New Quality Management Principle.

3.2. Science SQC, the Key to the Strategic Development of Science TQM

The main focus of Science TQM is to strategically utilize Science SQC (Amasaka, 2003, 2004b) in order to strengthen the core technology and to have it contribute systematically and organizationally to the activities of QCD, CS (Customer Satisfaction), ES (Employee Satisfaction), and SS (Social Satisfaction).

To achieve these management tasks, it is important for all divisions to turn the implicit knowledge of their business processes into explicit knowledge through integrated and collaborative activities and sharing objective awareness. To accomplish this, Science SQC, a new quality control principle was proposed by the author and developed under a new concept using a new methodology that applied the four core SQC principles in order to enable work to be performed scientifically as shown in Fig. **3**.

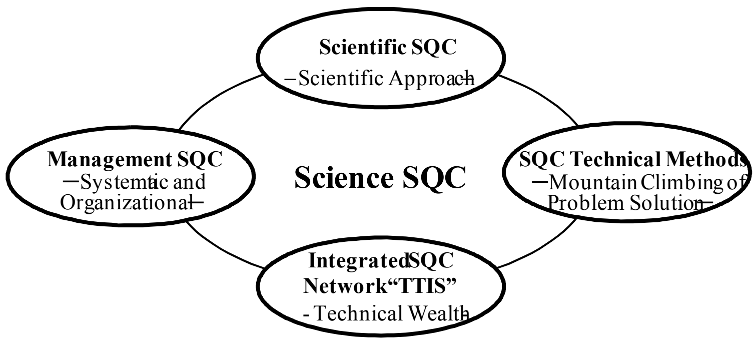


Figure 3: Outline of Science SQC.

The first of the four principles, "Scientific SQC" is a scientific approach, and the second principle, "SQC Technical Methods", is a methodology for problem solving. The third principle, the Integrated SQC Network, which is called "TTIS" (Total SQC Technical Intelligence System), is designed to turn management technologies that deal with proprietary technologies or business processes into owned assets. The fourth principle, "Management SQC", interprets the gap between the theory and reality of technical problems as the problems existing between departments and organizations. It then verbalizes the implicit understanding inherent in the business process in order to present it as explicit knowledge and also as a general solution to the technical problems.

Science SQC takes a scientific approach to work operations based on these four principles, and is not limited to an "individual solution", which only provides a special or partial solution to the problem. Rather, it is a new principle that describes a next generation quality management technique for the manufacturing business. It aims to provide a universal "general solution" and thereby create a new technology for problem solving.

3.3. A Strategic Stratified Task Team, the Driving Force Behind Science TQM

In addition as a management technology strategy that enables sustainable growth, the author (Amasaka, 2004a) has proposed a "Strategic Stratified Task Team" that will become the driving force of Science TQM. This is shown in Fig. **4**.

The expected role of the strategic stratified task team and the benefits it will provide are not limited only to cooperation among the departments inside the company. It will also contribute to the strengthening of the ties among group manufacturing companies, non-group companies, and even overseas manufacturers. Two measures must be taken in order to realize this proposal. First, is eliminate cast the work methods that rely too heavily on the techniques and experiences of individuals. Second, is to revolutionize the business process through the proposed "structural model of a stratified task team (Task 1 to Task 8)" that places emphasis on cooperation among the departments, with suppliers, and others.

As the technology level involved expands to include higher strata, for example moving from Production Strategy I to Production Strategy II, and from to Quality Management Strategy I to Quality Management Strategy II, the structure of the task team extends its boundaries (cooperation) upward starting from the level of groups/sections, to divisions/departments, to the entire company, and finally to suppliers (group companies, non-group companies, and overseas companies).

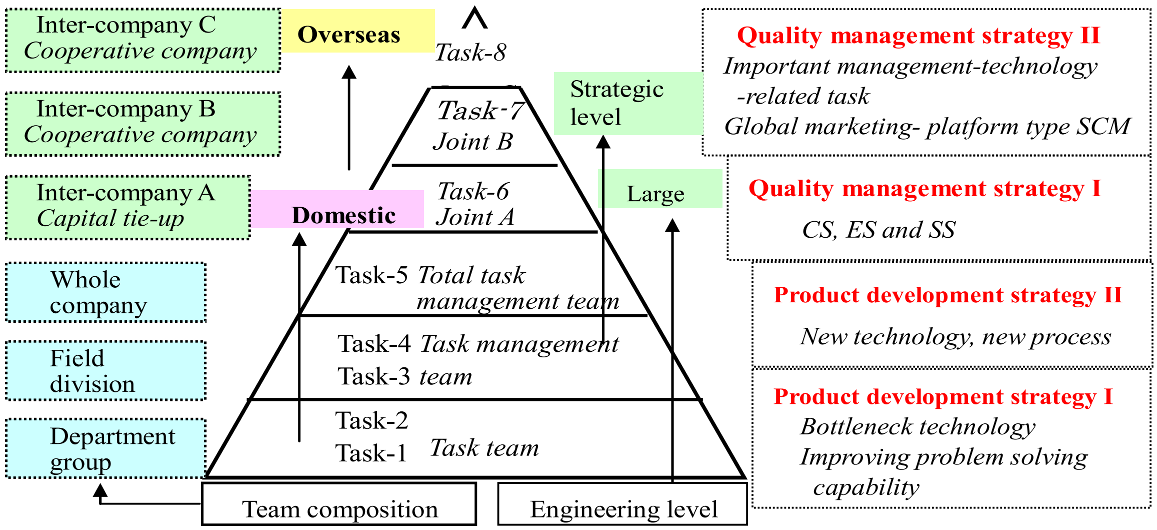


Figure 4: Structured Model of Stratified Task Teams.

4. DEVELOPMENT OF SCIENCE TQM FOR THE EVOLUTION OF MANAGEMENT TECHNOLOGY

Having said the above, in this chapter the five core principles of TDS, TPS, TMS, TIS, and TJS will be established and integrated for the purpose of strategically realizing the deployment of Science TQM that is necessary to carry out the innovation of management technology.

4.1. Strategic Integration of the Five Core Principles -TDS, TPS, TMS, TIS and TJS

In order for the principle of Science TQM proposed by the author to contribute to the permanent innovation of management technology, it is essential to organically integrate the five core principles and strategically link the business processes in each department in a highly cycled manner as shown in Fig. **5** (Amasaka, 2005b).

More specifically, as illustrated in Fig. **6**, it will be vital to collect and analyze product quality information gathered from outside and inside the company. Then use this information to create "wants" as part of the market creation activity and also to establish a structure for development and production that is capable of offering new products (Amasaka, 2002b).

In the implementation stage, it is important to apply Science SQC and 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 of development designing and manufacturing. This is done in order to effectively carry out the strategic integration of the five core principles and also to bring about the evolution of management technology that can ensure high reliability.

By means of the synergy effect generated through the linkage cycle for improving the business process improving, it is expected that a universal technological solution method can be established to replace the "individual solutions" created from the accumulation of partial solutions.

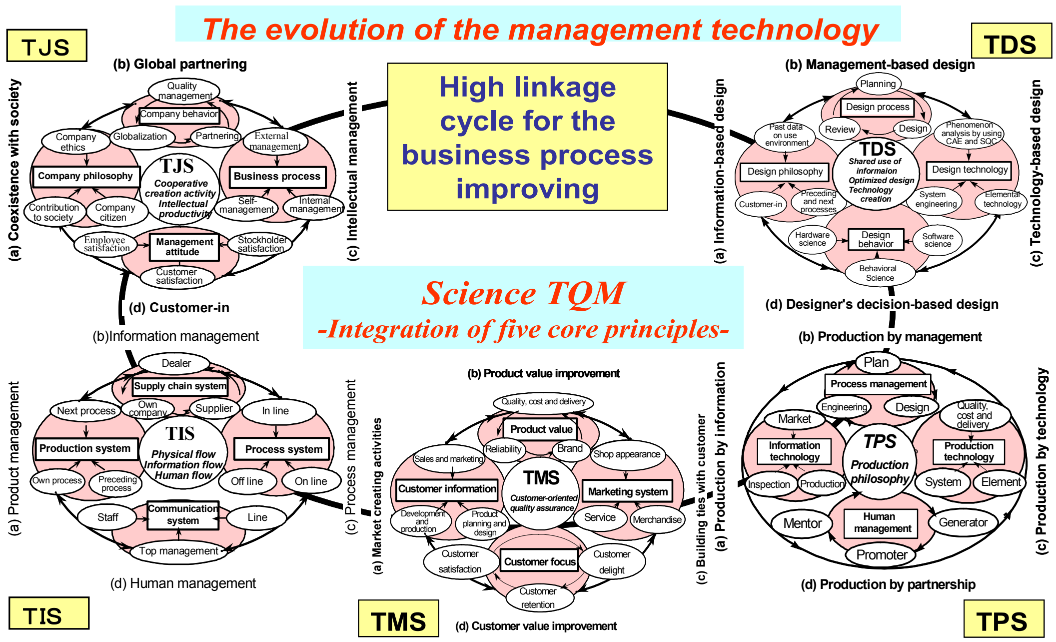


Figure 5: Science TQM Strategy Using Integration of the Five Core Principles.

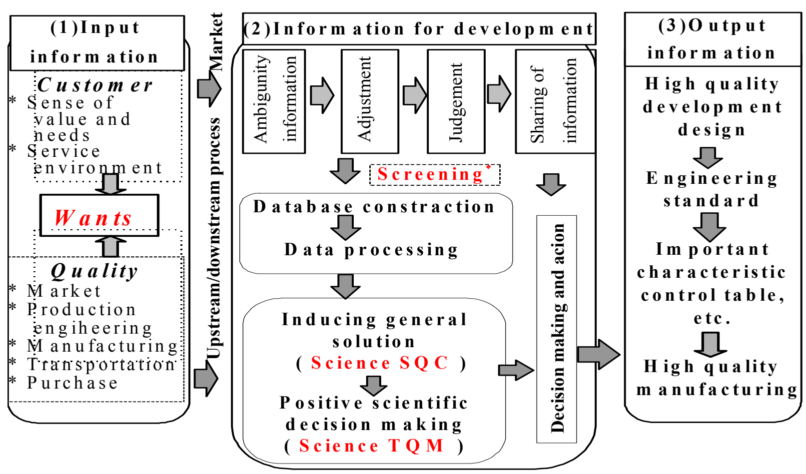


Figure 6: The Business Process of Development Design and Manufacturing.

4.2. Establishment of the Five Core Principles

4.2.1. The First Core Principle – TDS

Taking a close look at recent product recall incidents, it is clear that a crisis in reliability is rapidly arising from the areas of technological development and design evaluation. What is required is not simply the solution to a single separate technological problem, but the creation of a core technology that will lead to the reform of the whole business process for technological development, as well as the establishment of a core technology that will also improve "human reliability".

The main focus of the first principle, TDS is, as seen in Fig. **5**, to promote the "sharing of information" by incorporating the four sub core elements (a) to (d), and to make possible "the creation of the latest technology" and "optimal designing" in response to the advancement of technology. The required technological elements are, (a) designing based on internal and external information that places priority on the design philosophy, (b) development design management aiming to achieve a rational design process, (c) creation of a design method that incorporates the latest design technology in order to obtain universal solutions (general solutions), and (d) systemization of the development design management method to clarify and set the design policy of the development designers (theory → action → decision-making).

4.2.2. The Second Core Principle – TPS

In the midst of the recent drastic changes in manufacturing methods caused by the introduction of digital engineering, it is vital to reconstruct a world-leading, next generation production management technology so that the core part of manufacturing does not lag behind the “advancement of production management”.

The main focus of the second principle, TPS is, as seen in Fig. **5**, to enable the strengthening and enrichment of “customer-oriented, employee-focused, process management”. This is done by incorporating the four sub core elements (a) to (d). The required technological elements are, (a) innovation to introduce a customer-oriented production management system that puts the highest priority on the quality of information obtained from inside and outside the company, (b) creation of a rational production process and management of its workplace implementation, (c) QCD study activities using the latest production technology, and (d) creation of an active workplace environment which is able to manage the partnership proactively.

4.2.3. The Third Core Principle – TMS

As more and more emphasis is given to CS, CD (Customer Delight), and CR (Customer Retention), the advertising and promotion, sales, and service departments are expected to play new roles. What is necessary is the kind of marketing activity that is not merely based on past experience, but which promotes the strengthening of ties with the customers, the building of reliability into the products or corporate activities, and gathering information that will be helpful in the creation of next-generation products. This will be the basis for quality management activities in the future.

The main focus of the third principle, TMS, is, as seen in Fig. **5**, to enable “customer-focus, customer value creation, and high quality assurance”. This is done by incorporating the four sub core elements (a) to (d). The required technological elements are, (a) market creation activities through gathering and utilizing customer information, (b) improvement of the product value through understanding the vital elements that will enhance this value, (c) establishment of a marketing system from the standpoint of creating trusting ties with the customer, and (d) the creation and enforcement of a code of corporate conduct to increase the customer value and continually improve customer satisfaction.

4.2.4. The Fourth Core Principle – TIS

The management department is the core of corporate activity and therefore it is vital for it to reinforce the functions of “business management technology” so as to strengthen and enrich both internal and external management. This is also done in order to create a business linkage with the general administration department and cooperate with the on-site departments, such as development designing, production, and sales departments, as well as with business partners.

The main focus of the fourth principle, TIS, is, as seen in Fig. **5**, to enable the strategic implementation of JIT (Just in Time) for the business flows involving human resources, technical information, and product information. This is done *via* the utilization of intelligent information, so as to establish a new quality management technology system that incorporates the four sub core elements (a) to (d). The required technological elements are, (a) the product management system, in which the pre-process and post-process are integrated, (b) the intelligent information management system, which combines the dealers and suppliers, (c) the knowledge-intensive type total business process management system, which connects the congested off-line, in-line, and on-line process systems, and (d) the communication management system, which improves human management as the basis for the integration of the cooperative activities participated in by the top line staff.

The mission of the management department is to accurately handle the current issue of "global production - worldwide simultaneous production and production at optimal locations", so as to realize the so-called, "worldwide quality competition - simultaneous achievement of QCD".

4.2.5. The Fifth Core Principle - TJS

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. It should also cooperate with the management department so as to strengthen internal and external management. In order to achieve this, it is urgently necessary to position human resource development at the core of management policy in order to enhance "corporate, organizational, and human reliability" as the basis of strategic quality management. It is also necessary, at the stage of utilizing human resources, to strengthen the function of improving intelligent productivity through cooperation with all the related departments.

Having said that, the main focus of the fifth principle, TJS, is to produce substantial results from the process of "improving intelligent productivity - cooperative activity - human resource development". This is done through cooperation with the development designing, production, customer and sales, and management-related departments. It also involves, as seen in Fig. **5**, the establishment of an "intelligent productivity improvement business model" that is able to solve pressing problems inside and outside the company by incorporating the four sub core elements (a) to (d).

The behavioral code for the general administration-related department, which involves the "corporate philosophy, corporate behavior, and business process management attitude", has been designed to totally link the four sub core elements. These elements are, (a) coexistence with the society, (b) global partnering (c), intelligent management, and (d) customer-in. This code will then be turned into a model and put into effect.

As discussed above, these five core principles are implemented in order to combine the intelligence of all departments utilizing the Strategic Stratified Task Team activity and to apply Science SQC *via* a verifiable scientific business approach as the high linkage cycle for improving the business process (Amasaka, 2004a: Amasaka, Ed., 2007).

5. APPLICATION - PUTTING INTO PRACTICE AND VERIFYING THE VALIDITY OF SCIENCE TQM AT TOYOTA

In this chapter, the author introduces a few study examples of how Science TQM improved the management technology at an advanced corporation, Toyota, and also at Toyota Group companies and others.

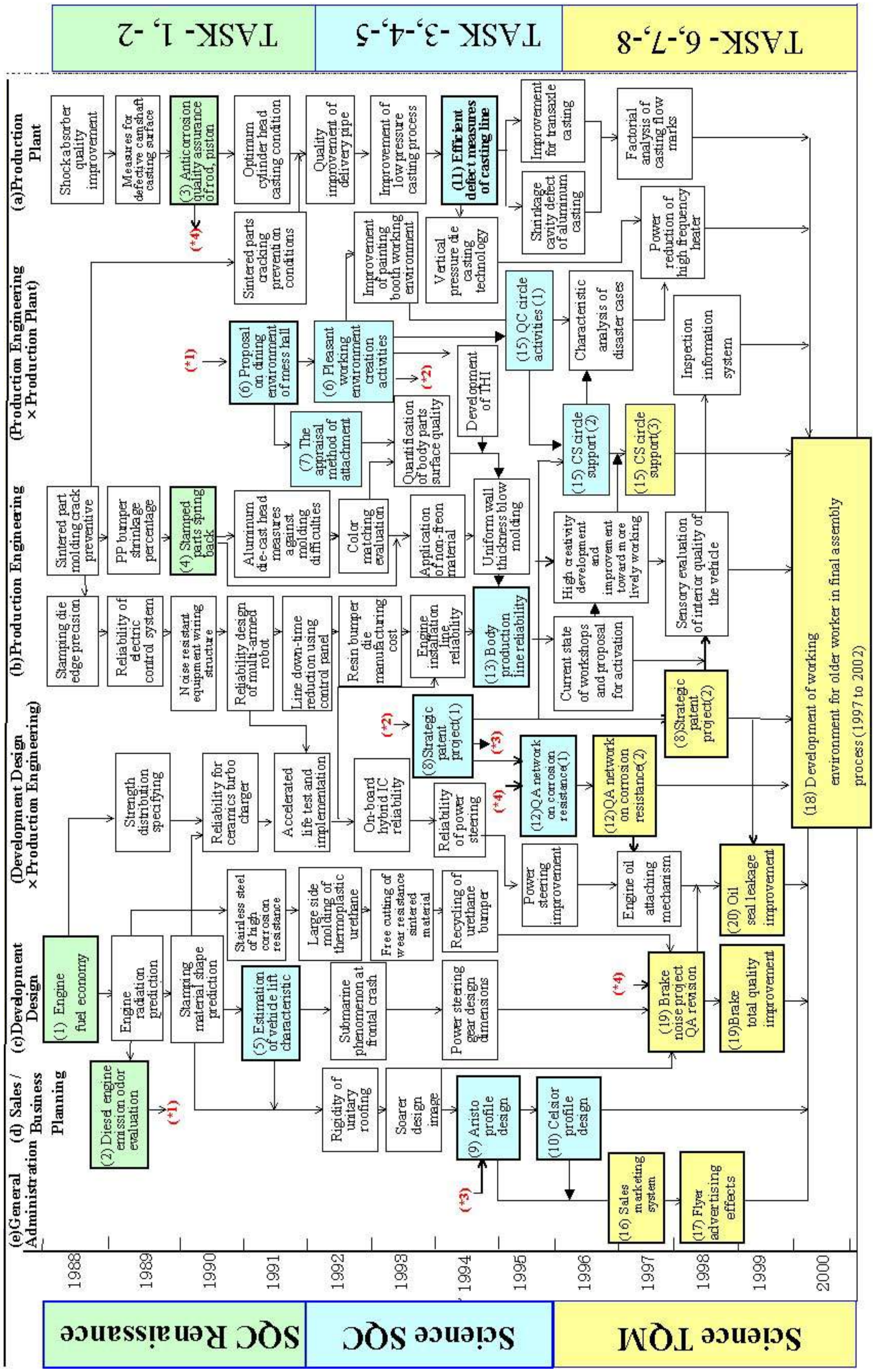
5.1. Transition in and Validity of the Strategic Joint Task Team Activities

In this section, the author will introduce the transition and validity of Science TQM through the Strategic Joint Task Team Activities in order to advance the evolution of management technology. In concrete terms, the author proposed and developed the formation of Strategic Stratified Task Teams (Task-1 to 8) as seen in Fig. **4**, and the validity of these task teams was verified through their application within Toyota and Toyota Group companies (Amasaka, 2004a).

The author was in charge of promoting strategic quality management, and therefore organized and led the task teams. The task teams tackled various engineering issues. Table **1** is a chart of the activity themes that were undertaken and accomplished by the task teams. From 1988 to 2000, about 15,000 staff and 5,000 managers carried out 4,000 task team activities. Some of these activities were later presented to Japanese and overseas academic organizations in the form of theses. The table covers about one-fifth of all those activities.

Corporate divisions such as (a) production plant, (b) production engineering, (c) development design, (d) sales and business planning, and (e) general administration are arranged in the horizontal direction. An "×" in the table is the symbol for cross-divisional collaboration, while an arrow means that the technical findings obtained from an activity were passed on to the next study (handing down of technologies).

Table 1. Changes in the Strategic Task Team Activities of Toyota (1988-2000)



Tasks are stratified vertically from the top: (1) Task-1 (small group level) and Task-2 (group and department level) task team activities were part of the "SQC Renaissance" (1988 on) (Refer to Appendix A). In the middle are (2) Task-3 (division level) and Task-4 (field level) task team activities that were part of Science SQC (1992 on). At the bottom is (3) Task-5 (across different fields and companies), task team activities that were part of Science TQM (1996 on). Furthermore, the table also includes (4) Task-6, "joint total task management team" activities in which Toyota collaborated with group manufacturers, (5) Task-7, team activities with non-group manufacturers, and (6) Task-8, team activities with overseas manufacturers.

The Table **1** indicates how the technical themes organizationally and systematically evolved from Task-1 to Task-8, thereby enhancing the level of the strategies employed.

5.2. Validity of the Five Core Principles

5.2.1. The Effectiveness of TDS

Two of the study examples that contributed to the establishment of TDS, the core technology of development designing are: (i) the business process method for "Automotive Profile Design Methods" (Amasaka, *et al.*, 1999), to support the designer's conceptual process, and (ii) the application of advanced and accurate CAE for the "Prediction Model of Automotive Dynamic Lift Characteristics" (Amasaka, *et al.*, 1996) that shortened the period needed for highly reliable designing and development. Moreover, through the cooperation of the development designing, production, sales, service, and purchasing procurement departments with the suppliers, (iii) the failure mechanism of such worldwide technical issues as "Brake Squeal" (Amasaka and Osaki, 1999), and the (iv) "Oil Leak in the Drive-train Oil Seal" (Amasaka and Osaki, 2002), were also clarified.

Then, by utilizing the acquired technical results for improving the prediction accuracy of (v) the CAE numerical simulation (Amasaka, 2007b), a substantial quality improvement was successfully achieved. All of these are the results of the "Strategic Joint Task Team Activities", in which the top management assumed the leadership role in finding the solution to the management technology issues. Through company-wide partnering with both the Toyota Group and non-group supplier manufacturers, QCD was simultaneously achieved and the strategic innovation of quality management was realized (Amasaka, 2000a, 2007c, 2008b).

5.2.2. The Effectiveness of TPS

Two of the study examples which contributed to the establishment of TPS, the core technology for production engineering and manufacturing are: (i) the implementation of the global production compatible, "TPS-QAS, -Quality Assurance System" (Amasaka and Sakai, 2009) and (ii) the "facility operation, maintenance management system - ARIM-BL" (Amasaka and Sakai, 1998), in which TPS and IT are intelligently integrated by making full use of intelligent "In Line-On Line SQC".

Another example is (iii) the next generation "innovation of the work environment" (Amasaka, 2007d) through collaboration among all departments. In this activity, all the departments related to safety, health management, and human resource development cooperated together in a program to improve the working environment. This program, called "AWD-6P/J" (Aging & Work Development 6 Programs Project), was promoted to make the work environment more accommodating to older workers and female workers. The expected results have been achieved through arranging the on-site automotive assembly shops to accommodate older employees, who are being actively deployed in the production plants inside and outside of Japan.

Furthermore, in order to realize (iv) the key to success in "global production" - "uniform quality and simultaneous plant start-up worldwide (production at optimal locations)", the manufacturing, production engineering, production management, and information system-related departments are currently collaborating with one another, and results are being obtained in which the previously acquired results are being integrated and further developed (Sakai and Amasaka, 2006, 2007).

5.2.3. The Effectiveness of TMS

One of the study examples that contributed to the establishment of TMS, which is the core technology of sales, advertising, and promotions-related departments is: (i) the implementation of the "Toyota Sales Marketing System" (Amasaka, 2001a) that aims to improve the "formation of ties with the customer".

Through scientific verification of the customers' purchasing patterns, (ii) the mixture effect of advertising promotion, consisting of TV commercials, newspaper ads, radio ads, flyers, and DM/DH (direct mail/direct handing), was enhanced to raise the rate of customers' visits to automobile shops, as well as to realize "market creation" (Amasaka, 2007e). (iii) "Market creation" in this sense means the reform of the (dealer) shop front advertising and promotions, sales, and customer services, so that the expected results can be successfully achieved (Amasaka, 2001b).

5.2.4. The Effectiveness of TIS and TJS

Study examples that contributed to the establishment of TIS are: (i) the creation of "HI-POS" (Human Intelligence–Production Operating System) that cultivates "highly skilled, intelligent production operators" capable of handling the advanced production system. After realizing high quality assurance, the improvements in the production facility operating rate or innovation of the facility maintenance system through (ii) the application of "V-MICS" (Visualization - Maintenance Innovated Computer System) have been promoted (Sakai and Amasaka, 2005).

The establishment of (iii) the "TPS-LAS" (Process Layout Analysis Simulation) has been promoted as typified by the "optimization" of the entire production plant and formulation of the production process, including the work operators, robots, logistics, and delivery, by making full use of CAE numerical simulation (Sakai and Amasaka, 2006). A fourth example is (iv) where the purchasing procurement, production management, TQM promotion, and quality assurance-related departments constitute a core, and then cooperate with the technical management, production engineering, production management, manufacturing inspection, and sales promotion-related departments (Amasaka, 2000b).

In this way (v) "Partnering Chains on a Platform Basis" have been established collaboratively as the basis of the quality management system "CS-CIANS" (Customer Science utilizing Customer Information Analysis and Navigation System) in systematic and organizational cooperation with supplier manufacturers (Amasaka, *et al.*, 1999). Through this activity, (vi) the establishment of a "Quality Management Strategy Model" necessary for the "strategic simultaneous achievement of QCD" with Toyota Group and non-group manufacturers is also being developed (Amasaka, 2005b, 2006).

Similarly, study examples that contributed to the establishment of TJS are: the establishment of the (vii) "Knowledge Management System" to convert intelligent technologies into the form of assets so that they may be passed on to future generations and further developed. This was accomplished through cooperation among the technical management, intellectual property, production engineering, TQM promotion, and personnel affairs-related departments.

One example of this system is (viii) the development and operation of the "Quick Registration and Retrieval System for Technical Reports, TSIS-QR" (Amasaka, 1997) and the "SQC Integrated Network System" (Amasaka, 2000a) in which Science SQC was incorporated and the priority management technology issues were solved. Other examples are the development and operation of the (ix) "Patent Value Evaluation Method" (Amasaka, 2007), a business model for strategic patent creation, and (x) the quality management assessment business model, "Measurement System for Strategic Quality Management Performance" (Amasaka, 2004c).

6. CONCLUSION

In this paper, a new, next-generation quality management principle, Science TQM was proposed, and its validity has been verified through the demonstrative study examples undertaken at an advanced corporation, Toyota. Recently, the creation of new management models is being demanded to achieve a significant leap forward in the Japanese style of quality management and this new principle can serve as just such a model. At the present, Science TQM, the principle proposed by the author, is now going through a verification process to prove its validity in many other advanced Japanese companies. This is being done in order to deploy and establish it as the "*New Japan Model*" that is expected to help realize strategic quality management (Amasaka, Ed., 2007).

APPENDIX A: THE SQC RENAISSANCE

The author has been engaged in *SQC promotion cycle activities* (Implementation – Practical Effort – Education – Developing Human Resources) under the banner of the SQC Renaissance, as shown in Fig. **7**. This was done in order to capture the true nature of making products and in the belief that the best way to develop personnel is through practical research that will raise the technological level. The aim of SQC that is being promoted by Toyota is to take up the challenge of solving vital technological assignments (Amasaka, 2007).

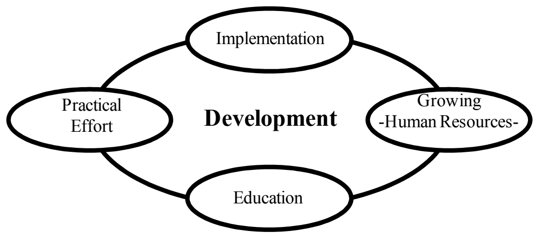


Figure 7: SQC Promotion Cycle Activities.

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CHAPTER 5

Science SQC, New Quality Control Principle: Driving Force in Developing Science TQM - 1

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Abstract: In forecasting operation of the manufacturing industry in the 21st century, the authors recently proposed "Science SQC, New Quality Control Principle" as a demonstrative-scientific methodology and discussed its effectiveness on the basis of verification studies conducted by Toyota Motor Corporation. This study outlines a new SQC principle "Science SQC", as a demonstrative-scientific methodology, which enables the principle of TQM (Total Quality Management) to be improved systematically.

Keywords: Manufacturing, a demonstrative-scientific methodology, "science SQC, new quality control principle", TQM, toyota.

1. INTRODUCTION

To promote quality control that contributes to the world in the future, it is necessary for us to carry on lucid and reasonable TQM activities that will enhance the business process of all departments. To do this, it is important to give thought to quality control of the manufacturing industry in the future, change the principle of TQM activities accordingly and show a good example so that a brighter future may be obtained.

In this connection, the authors have proposed "Science SQC, New Quality Control Principle" as a demonstrative-scientific methodology and discussed the effectiveness of this method which improves the systematic development of the principle of TQM (Amasaka, 1997, 1999, 2000). This paper positions the proposed Science SQC as the "next generation TQM - TQM by utilizing Science SQC, TQM-S" that improves the principle of TQM and verifies its effectiveness through development at Toyota and subsequent results (Amasaka, 1999a, 2003).

2. NEEDS FOR NEW SQC TO IMPROVE THE PRINCIPLE OF TQM BY MANUFACTURING INDUSTRIES

2.1. Delay in Systemization of Quality Management System that Improves Manufacturer's Management Technology

It is generally agreed that quality management activities have contributed largely to Japan's economic prosperity today. Quality management by manufacturers originated in Japan when Statistical Quality Control (SQC) was introduced, used and deployed by Walter. A. Shewhart (1986) and W. Edwards Deming (Mary, 1998), who proposed that "quality management began and ended by control chart" (Rice, 1947), which is the basis of "quality built into process" (Kusaba, *et al.*, 1995). These activities and results were advanced by J. M. Juran (1988, 1989), systematically advancing the concept and progress method of the company-wide Total Quality Control (TQC) activities. This TQC has further advanced to today's Total Quality Management (TQM) activities (1998).

In the 1980s and after, U.S. companies were stimulated by introductions made by Andrea Gabor (1990) and Brian L. Joiner (1994) and a MIT (Dartouzos, 1989) report to change the concept of quality from product quality to quality of customer's sense of value by learning the quality management system in Japan. There, they reviewed Japanese- style cooperative activities and the effect of SQC as a scientific approach and deployed the new quality management nationwide, while also receiving instructions from W. Edwards Deming.

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In the 1980s and 90s, however, Japanese manufacturers were too caught up in the economic boom both in Japan and overseas countries that they did not necessarily establish management technology bases sufficiently to prepare for the next generation. They put too much emphasis on JIDOKA (automation) introducing large-scale equipment and taking a long period of time and large investment for completion, transferring the production system accordingly. As a result, the production system became non-profitable. Some companies put too much importance on automatic adjustment with equipment having automatic adjustment functions even if 5M-E (Man, Machine, Material, Measuring, Method and Environment) deviate. In others, control charts simply disappeared from their manufacturing processes, reducing the scientific process management level.

As the situation continued, it became increasingly difficult to check the workmanship of products currently under production in real time. Not only for the production division, but also for the product design, production engineering and quality assurance divisions, workmanship became difficult to confirm. It seemed that the process maintenance, management and improvement cycle did not turn well, as the skill and problem solving capability of workshops, supervisors and auditors that could be improved through "observation of actual products" and "processes built into processes" had been abandoned for the reasons described above (Amasaka, *et al.*, 1999a).

As alerted by T. Goto (1999), Japanese manufacturers forgot the origin of quality management in the latter half of 1980s toward the early 1990s, resulting in a slowdown in growth. The most important factor was the delay in systemizing next-generation type management technology to be developed and introduced in accordance with technical advancements and changes occurring in the management environment around each manufacturer, making the whole Japanese industry fail to establish a new method (reasonable and scientific method for quality management) capable of improving the management technology. These are discussed in more detail by K. Yoshida (1999) and K. Amasaka (1999).

2.2. Necessity of New SQC as Demonstrative Scientific Methodology

The secret of successful quality control activities on the part of the manufacturing industries aimed at providing customers with attractive products consists of a reasonable way of thinking about quality control and the actual procedure to be established and followed accordingly. To be more precise, it means correctly converting customers' wishes (tacit knowledge) into engineering terms (explicit knowledge) by using the correlation technique, *etc*., replacing it with well-prepared drawings, and enhance the process capability for early embodiment into products.

In retrospect, the transition of quality control that developed from the manufacturing industry initially started with application of the mathematical method of SQC. It then developed into TQC using control technology, and more recently, into TQM using various management control techniques comprehensively. And the concept of quality has been undergoing expansion from conventional product quality-orientedness to business process quality, before becoming management technique quality-oriented. Along with this, the area of quality control activities expanded.

For the generator, the mentor and the promoter, it is becoming more difficult to bundle individual or workshop techniques of the total hierarchies or departments through existing quality control activities based on past successes that depended on proprietary rule of thumb or empirical techniques. Therefore, to produce really attractive products that satisfy customers, that is, to produce customer-oriented products, common terms (Management Technology: Quality Management System) become necessary for the circular business process cycle of all departments to correctly turn from sales, service, planning, development and design, to production engineering, manufacturing and logistics. As far as the writer knows, however, no SQC application system nor demonstrative methodology for effective renovation of the business process as a language common to all departments has been seen for the new TQM activity for the coming age.

In this connection, Amasaka (1999a, 2003, 2004) at Toyota proposed Science SQC as a demonstrative scientific methodology for the five core techniques (TMS, TDS, TPS, TIS and TJS) that form the principle of TQM activities called “Science TQM” to be linked organizationally. They also propagate and develop systematic and organized quality control. This represents the systematization of a new SQC application for creating technology by finding solutions using “general solutions” that can be generalized as “the principles of Toyota’s quality control”.

They position this as the “next generation TQM management (TQM by utilizing Science SQC, TQM-S)” that enhances the centripetal force of Toyota’s TQM activities. They further discuss the effectiveness of this Science SQC (Amasaka, *et al.*, 1998a: Amasaka, 2004a).

3. PROPOSAL AND IMPLEMENTATION OF THE “SCIENCE SQC”, NEW QUALITY CONTROL PRINCIPLE

For today’s demonstrative research, it is necessary to implement customer science that converts customer’s wishes into engineering terms (Amasaka, *et al.*, 1998b, 1999b). It is important for all departments concerned to share the objective awareness and turn tacit knowledge on business processes into explicit knowledge through coordinated activities.

The demonstrative-scientific methodology for realizing this conversion is called Science SQC (Amasaka, 1997, 2003, 2004a), in which SQC is utilized systematically and organically under a new concept and procedures so as to allow the four cores shown in Fig. **1** to mutually build on one another. This conceptual diagram shows the “Quality Control Principle” which forms the nucleus of TQM activities at Toyota (Amasaka, 1997). For details on the demonstrative research, refer to references (Amasaka, 1995).

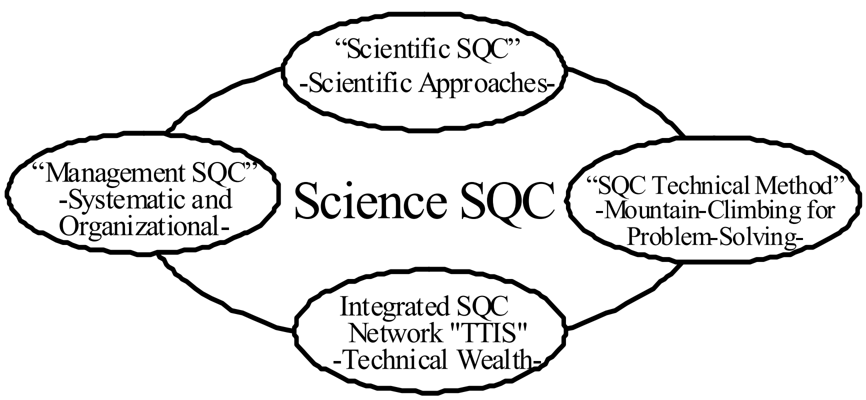

Figure 1: Schematic Drawing of “Science SQC”.

3.1. Practical Application of “Scientific SQC”

The primary objective of SQC as applied by the manufacturing industry is to enable all engineers and managers (hereinafter referred to as businessmen) to carry on excellent QCD (Quality, Cost and Delivery) research activities through insight obtained by applying SQC to scientific and inductive approaches in addition to the conventional deductive method of tackling engineering problems.

It is important to depart from mere SQC application for statistical analyses or trial and error type analysis, and to scientifically use SQC in each stage from problem structuring to goal attainment by grasping the desirable form. Fig. **2** shows a conceptual drawing of “Scientific SQC” (Amasaka, 1998).

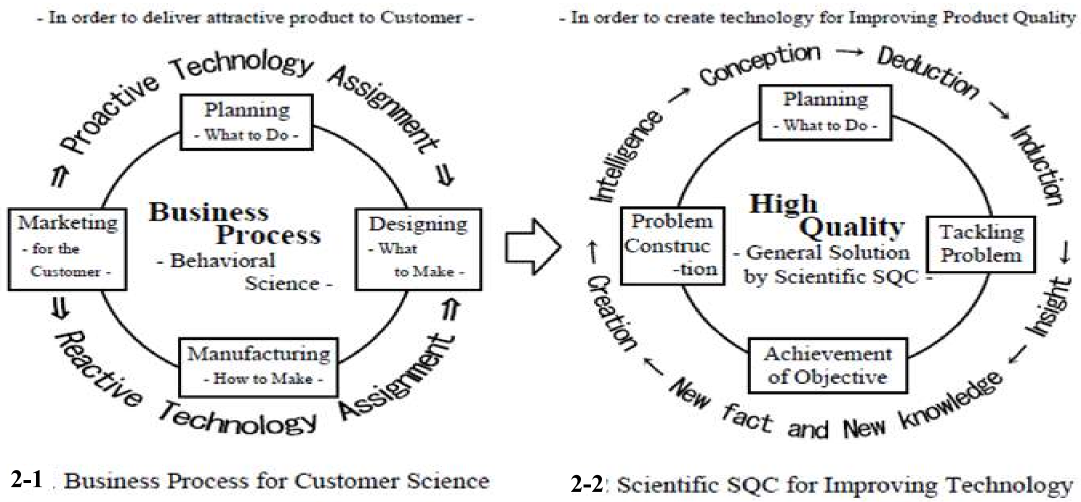

Figure 2: Schematic Drawing of "Scientific SQC".

3.2. Establishment of "SQC Technical Methods"

For solving today's engineering problems, it is possible to improve experimental and analysis designs by using N7 (the New Seven Tools for TQC) and the basic SQC method based on investigation of accumulated technologies. Moreover, it is possible to mountain-climbing problem solving by using a proactive combination of design of experiments as may be required using multivariate analysis amalgamated with engineering technology.

The methodology in which the SQC method is used in combination at each stage of problem solving has spread and established as "SQC Technical Methods" (Amasaka, 1998) for efficiently improving the jobs of businessmen. Fig. **3** shows a conceptual diagram of the established "SQC Technical Methods" (Amasaka, 1998).

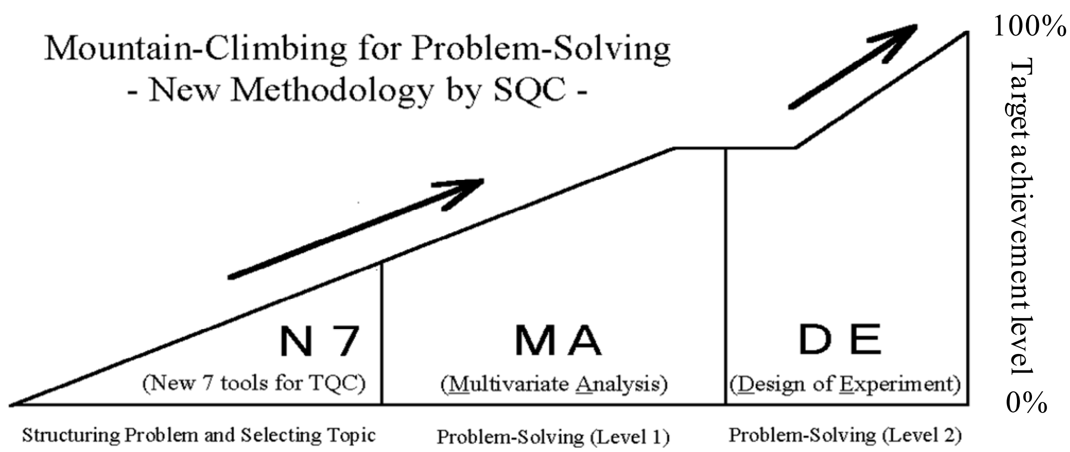

Figure 3: Schematic Drawing of "SQC Technical Methods".

3.3. Construction of Integrated SQC Network "TTIS"

Various cases of successful SQC application to actual business need to be systematized in order for them to contribute to forming engineering assets and help inheritance and further development. This is a prerequisite for the development of Science SQC.

This methodology is achieved with the "Toyota SQC Technical Intelligence System ("TTIS"), an integrated SQC network system that supports engineering problem solving as shown in Fig. **4** (Amasaka, 2000). The TTIS is an intelligent SQC application system consisting of four main systems integrated for growth by supplementing one another. For further details, refer to the references (Amasaka and Maki, 1992).

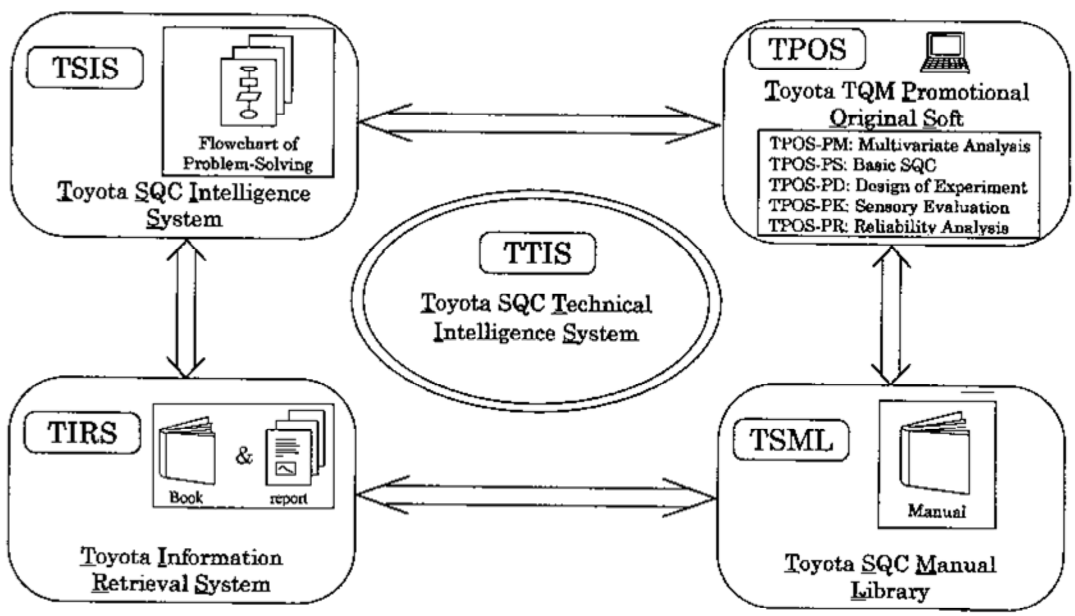

Figure 4: Schematic Drawing of "TTIS".

3.4. Recommendation of "Management SQC"

The main objective of SQC in the manufacturing industry is to support quick solution of deep-rooted engineering problems. Therefore, the main objectives of Science SQC is to find a scientific solution for the gap generated between the theories (principles and fundamental rules) and reality (events). Especially in the application of Science SQC, the differences from the principles and rules in an engineering problem should be scientifically analyzed to clarify six gaps that occur between theory, calculation, experiment and actual result to obtain a general solution. Filling these gaps results in an organizational problem.

For problem solving, it is necessary for the planning, design, manufacturing and marketing departments to clarify the six gaps, in other words to turn tacit knowledge on the business process to explicit knowledge for good understanding and coordination among the departments (Amasaka, 1997).

The methodology for organizationally managing the development of Science SQC is called "Management SQC". Recently, Amasaka *et al.,* (1997) further discussed and studied Management SQC through demonstrative cases of "Total Task Management Team activities" at Toyota Motor Corporation. Fig, **5** shows a conceptual drawing of "Management SQC" for "Science SQC" development.

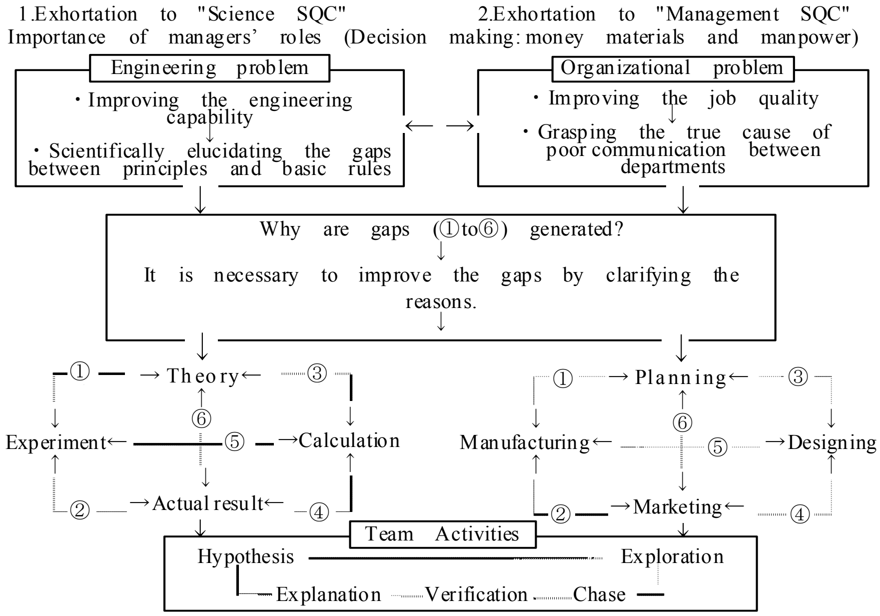

Figure 5: Schematic Drawing of "Management SQC".

4. DEMONSTRATION CASES OF SCIENCE SQC AT TOYOTA

In view of recent changes in the environment surrounding manufacturing industries, enterprises are once again required to make efforts in further enhance the technology development capabilities of engineers. To do this, the need for SQC as a behavioral science must be newly recognized. SQC must be applied from a scientific standpoint for not only solving apparent engineering problems but also for foreseeing latent engineering problems, thereby contributing to the development of new technologies. The following subsections describe the demonstrative cases of Science SQC as it is applied at Toyota.

4.1. Consistency in "SQC Promotion Cycle"

Development of the "SQC Promotion Cycle" (Implementation, Practical Results, Education, and Growth of Human Resources) illustrated in Fig. **6** is essential for continuously increasing the expectations and effects of SQC applications. Amasaka (2000) utilize this cycle as the principle for promoting "Science SQC" at Toyota. Practically, the SQC promotion cycle means a spiral activity where SQC is used for challenging today's engineering problems to enhance proprietary and management technologies.

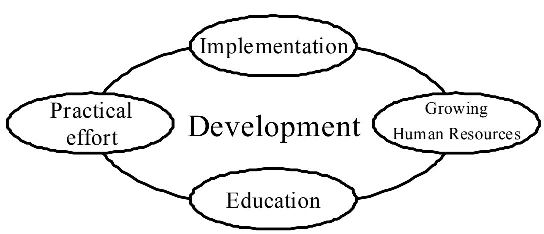

Figure 6: Schematic Drawing of "SQC Promotion Cycle".

This will contribute to improving technologies, and subsequent results are reflected on hierarchical and practical SQC education to expand human resources, who in turn reflect the new technology in the performance of their operations. This mode of promotion constitutes the essence of Science SQC. The figure schematically illustrates the concept of the SQC Promotion Cycle at a manufacturer (Amasaka, 1997).

4.2. Systematization of Hierarchical SQC Seminar and Growth of Human Resources

To make the SQC Promotion Cycle spiral as illustrated in Fig. **4**, it is important to establish a system that allows companywide development of systematic and organizational new SQC education and the growing of human resources. Conventionally, SQC seminars used to provide education on SQC basics, reliability analysis and design of experiments for many years. But each of them was based on manual calculation and the curriculums were set up for individual SQC methods, dependent on analyses. As a result, a dilemma was experienced by some participants in that they were unable to put what they learned into practice.

It is important to improve the contents of seminars to make them practically applicable to SQC education. To keep abreast of the times, it is important to apply SQC personal computer software "TPOS" (Amasaka and Maki, 1992; Toyota TQM Promotional Original SQC Software) and give importance to experimental and analytical designs so as to prevent us from ending up merely conducting trial and error analyses. From the viewpoints of Sections 2 to 3, hierarchical SQC education as shown in Fig. **7** is systematized as follows, and a step-up SQC seminar is planned and implemented for six hierarchies of Beginner SQC, Business SQC, Intermediate SQC, Lower Advanced, Upper Advanced, and SQC Advisor courses. The seminar attendant ratio is set up as illustrated in the figure for a total of 17,000 businessmen from all departments to ensure full growth of human resources (Amasaka and Osaki, 1999).

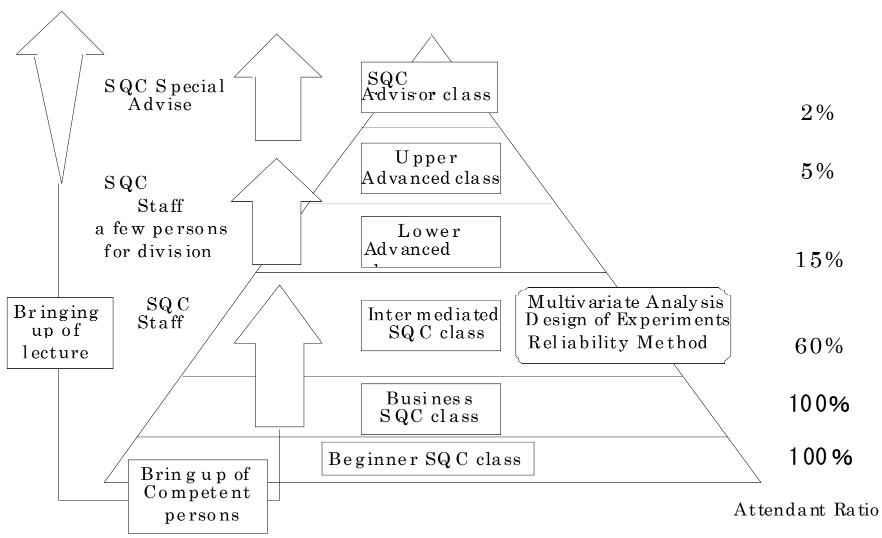

Figure 7: Division of SQC Seminarian and Human Resources Training.

The Beginner and Business courses are for all staff and the program is designed to provide enough training for them to carry on their routine business. The Intermediate course is for professionals who can freely apply the advanced SQC methods. Fig. **8** shows the curriculum established by Amasaka, *et al.,* (1998a), for the Advanced SQC course (for engineering staff). During the initial period, they learn the concept and procedures of "Science SQC" at Toyota (SQC Review 1 to 5; SR1-5) from the instructors for the SQC advisory staff (advanced course). Each participant tackles individually registered themes (problem structuring and setting) and reflects what is learnt in their business.

The second period is for experiments and analysis designs which are important for maximizing problem solving. Lectures are given by an SQC level advisor of managerial position. The participants learn TMS (SR6-8) required for implementing "Science SQC" to improve the principle of TQM, and study demonstrative cases of "Science SQC" that help construct TDS (SR9-10), and TPS (SR11-12). In SR13 and SR14 in the third period, group discussion of registered themes takes place with the participation of instructors. This offers the opportunity for mutual study where the participants present their registered themes and verify the problem solving process.

Students having finished the advanced course and higher are qualified to be SQC special staff or SQC specialist advisors (approx. 1100 persons up to 2000). Under this system, they can display their ability as promotion leaders for company-wide "SQC Promotion Cycle" development. Recently, Amasaka (1998a, 1999c) set up a new 5-year course (1996 onward; for a total of 3000 engineering managers from all departments) for all managerial personnel (from directors down to divisional, departmental and sectional managers; approx. 2200 persons up to 2000) in an effort to strengthen the development of Science SQC for improving the principle of TQM.

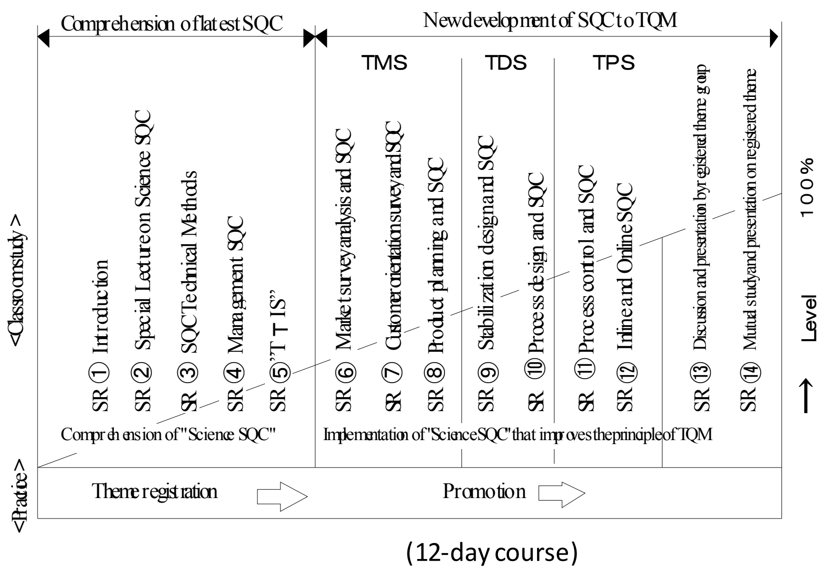

Figure 8: Curriculum for Advanced SQC Course.

4.3. Quality Improvement of Drive System Unit – Sealing Performance of Oil Seal for Transmission -

This is a typical example where engineers, who completed the new SQC training courses explained in Sections 4.2, challenged under instructions by the SQC special staff and advisors (Amasaka, *et al.*, 1998c).

4.3.1. Engineering Problem

The oil seal for the drive system works to seal lubricant inside the unit. The cause and effect relationship between the oil seal design parameters and sealing performance is not necessarily fully clarified. As a result, oil leakage from the oil seal is not completely eliminated, presenting a continual engineering problem.

4.3.2. Conventional Approaches to Quality Improvement

So far, oil seal quality improvement has been made as follows. A development designer having empirical engineering capability recovers the leaking oil seal parts from the market, analyzes the cause of leakage with proper technology and incorporates countermeasures into the design. Many of the recent leaking parts, however, exhibit no apparent problem and the cause of the leakage is often undetectable. This makes it difficult to map out permanent measures to eliminate the leakage.

4.3.3. "Total Task Management Team" Activities

It is necessary to clarify the engineering problems to be tackled by sharing the essence of the problems as a team by combining the empirical technology of each individuals. Therefore, to explicate the essential engineering problems, it is necessary to improve the engineering problems generated by the lack of information among the related organizations (tacit knowledge), and their business processes. To do this, "Total Task Management Team" (Amasaka, *et al.*, 1997) methodology which was successfully used to improve brake performance quality is employed.

To be more precise, a total task management team named "DOS-Q5" (Drive-train Oil Seal Quality 5 Team) was organized in which the oil seal manufacturer participated. Fig. **9** is a Relational Chart Method showing the outline of the quality assurance (QA) team's activities. The QA teams in the figure are QA1 and 2 in charge of inquiries into the cause of oil leaks and design engineering problems, and QA3, 4 and 5 which handle manufacturing problems relating to the drive shaft, vehicle, and transaxle. QA1 and QA2 represent collaboration type team activities joined by the oil seal manufacturer (responsible for research, design, manufacture and quality assurance) which carries on quality improvement of the oil seal part.

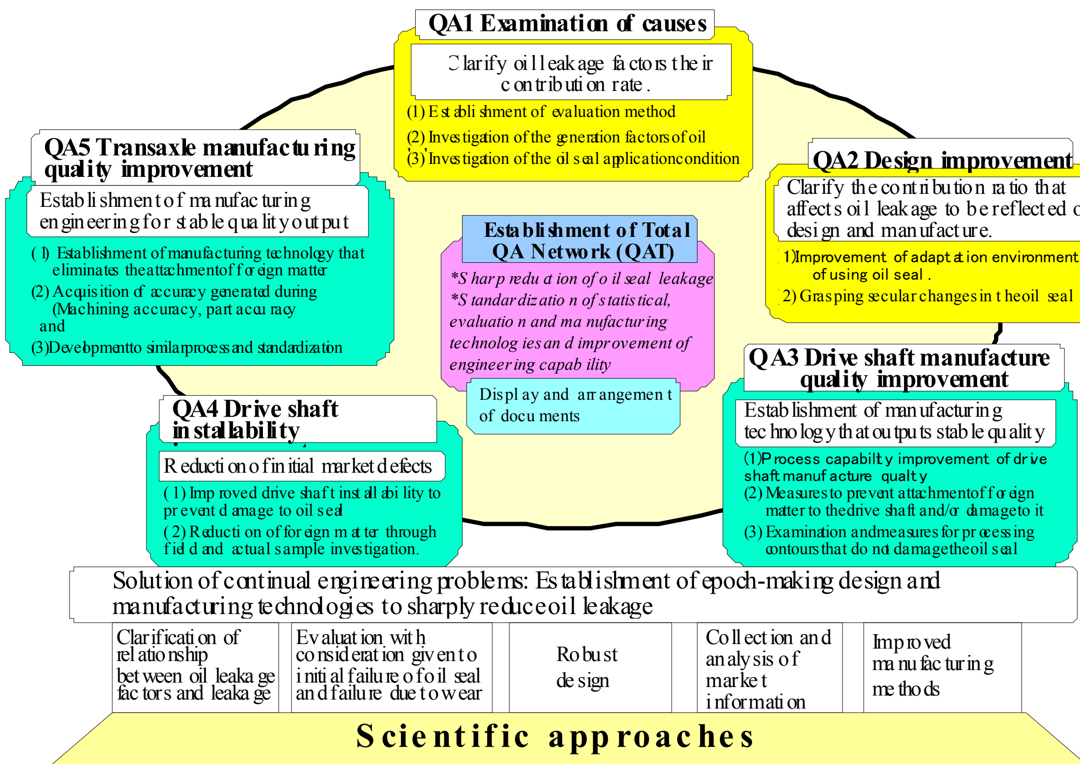

Figure 9: Relation Chart Method of Activities by "Total Task Management Team".

4.3.4. Implementation of Management SQC

To utilize proprietary intelligent technology and the insight of the team members (consisting of generators, mentors and promoters) by applying Science SQC as shown in Fig. **2**, the core technology of Management SQC is implemented. To do this, it is found that the total quality assurance activities require further upgrading. Accordingly, Toyota's "Total QA (Quality Assurance) Network" is being developed based on actual records of solving of this type of problem (Amasaka, *et al.*, 1997).

Moreover, to promote overall optimization by maximizing the efforts of individual teams QA1 through QA5, problem solving is formulated using the SQC Technical Methods shown in Fig. **10**. To realize optimization of the "DOS-Q5" business process, the Management SQC concept is applied in implementing information, production and engineering management.

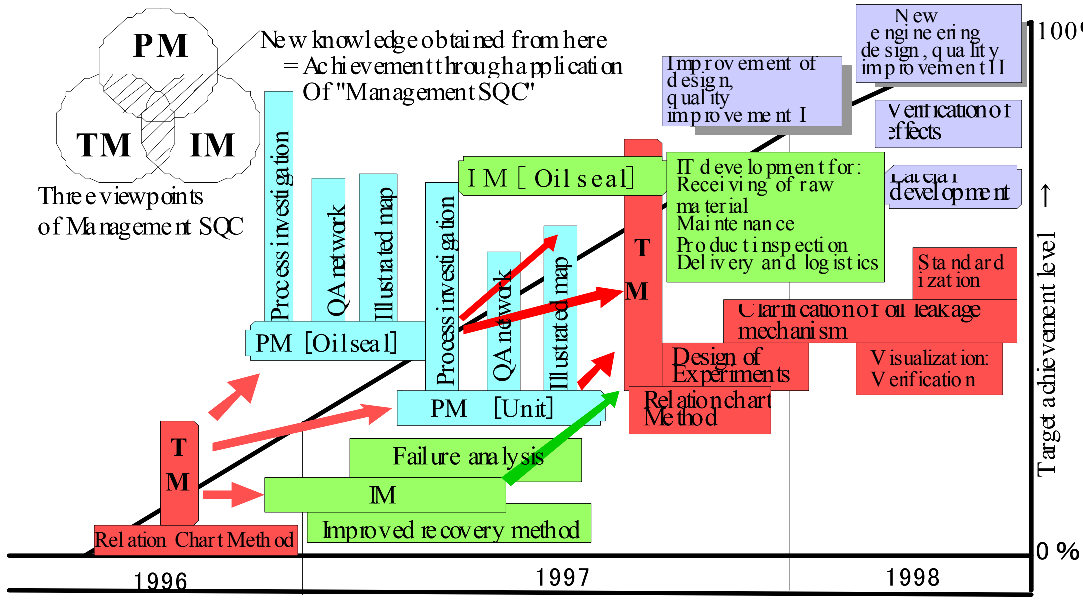

Figure 10: Problem Solving by Utilizing the "SQC Technical Methods".

1: Improvement of Failure Analysis Process Using "Information Management [IM]"

The recovery method for oil leaking parts, the investigation method for oil leakage information and other failure analysis processes are devised to explore the true cause of oil leaks. For example, "non-leaking parts" are recovered together with leaking parts and subjected to discriminate analysis as shown in Fig. **11** and other cause and effect analysis. As a result, new knowledge is obtained indicating that the hardness of oil seal rubber affects oil leakage. Moreover, Weibull analysis using DAS (Sasaki, 1972), Toyota Dynamic Assurance System for failure analysis) reveals a new fact, that is, a mixed model consisting of three types of oil leakage (initial, random and wear) according to the running distance is acquired.

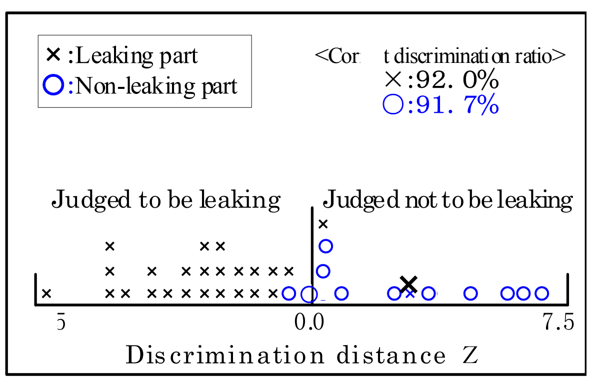

Figure 11: Result of Discriminate Analysis.

2: Visualization of Oil Leakage Mechanism Using "Technology Management [TM]"

To study the oil leakage mechanism, a device is developed to visualize the dynamic behavior of the oil leakage from the oil seal lip section. Through factorial analysis of the collected data using multivariate and experimental analyses employing a new experimental design, the oil leaking mechanism is visualized and the following causal analyses are conducted:

a) Association of running distance, lip surface roughness and pumping volume [new fact].

b) Association of the inside diameter of the differential case, the lip wear width and the roughness of the axis [new fact and quantification].

c) Association of roughness of the axis and pumping volume [new fact].

d) Association of differential case wear and driveshaft eccentricity [new fact].

e) Association of the lip tightening margin and lip wear [quantification].

f) As the result, the above-mentioned associations are explicated. New knowledge is acquired including the quantification of conventional empirical technology and the creation of new technology not found in the empirical technology. The oil leaking mechanism shown in Fig. **12** is thus estimated.

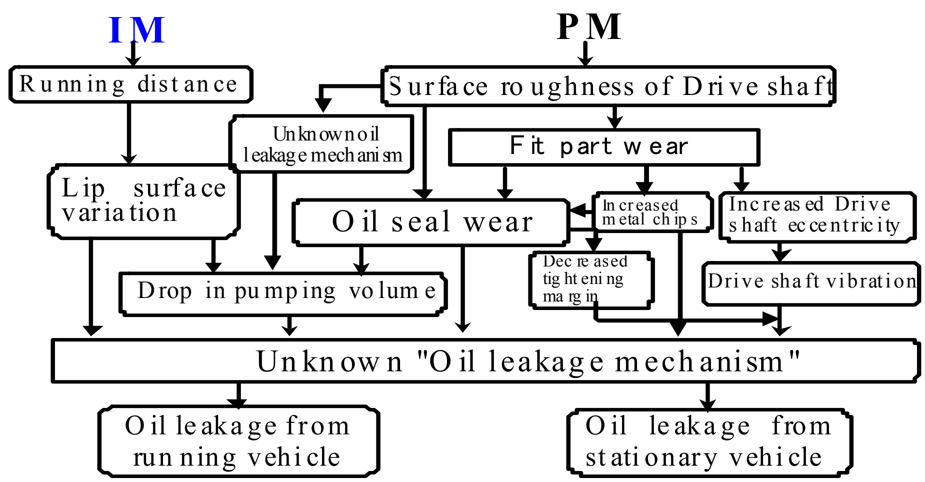

Figure 12: Estimated Oil Leakage Mechanism.

3: Development of Total QA Network Using "Production Management [PM]"

For example, to improve the quality of the oil seal parts by incorporating the above- mentioned IM and TM knowledge, QA1 and 2 analyzed and stratified the types of oil leakage and problems in the manufacturing processes, then developed illustration mapping by making relative analysis of these two elements. The analytical results are reflected on the "QA Network Table" (Amasaka, *et al.*, 1999b) used to develop process control into a science (visualize).

The business process could be visualized from receiving to delivery inspection and logistics (distribution). Next, QA3, 4 and 5 teams similarly developed the QA Network for the drive system manufacturing process. Then they established the process control science all the way from receiving to delivery. With the coordination of QA1 and 2, they could clarify the fact (visualization of behavior) that, for example, oil leakage occurs if foreign matter the thickness of a hair (75 (m) is attached to the drive shaft.

4: Achievement of "DOS-Q5"

Through implementation of Science SQC, the oil seal leaking mechanism whose cause was unknown has been scientifically visualized and verification obtained using cause and effect analysis, with more proprietary knowledge of the technology subsequently acquired. We thus eliminated the oil leakage problem and achieved our target.

5. CONCLUSION

Demonstrative and scientific methodology is established for SQC applications aimed at improving technology. Science SQC is proposed as a new, systematic and organizational SQC application methodology for the manufacturing industry. Toyota Motor Corporation has demonstrated that this methodology can improve the quality of work of engineers in every stage of their business process and contribute to creating products of excellent quality. In the future, Science SQC will be positioned as a quality control principle and applied to solving various practical problems. And with the accumulation of demonstrative studies, Next Generation TQM (TQM-S) designed to improve the principle of TQM will hopefully be established (Amasaka, 2004b, 2008).

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CHAPTER 6

Strategic Quality Management – Performance Measurement Model: Driving Force in Developing Science TQM - 2

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Abstract: The "Strategic Quality Management—Performance Measurement Model, SQM-PMM" was established to enhance the key elements of successful "Science TQM, New Quality Management Principle" proposed by the author. The validity of SQM-PMM as a measurement methodology to ensure future management results through strategic quality management was verified.

Keywords: Science TQM, strategic quality management - performance measurement model SQM-PMM, CAID, graphical modeling, canonical correlation analysis.

1. INTRODUCTION

In the current market, where "worldwide quality competition" continues to intensify, production of equal quality in optimum locations is essential for successful global marketing. With this in mind, the "Science TQM, New Quality Management Principle" was proposed for improving quality management techniques, and its validity was demonstrated (Amasaka, 2004a, 2008).

This study presents the "Strategic Quality Management—Performance Measurement Model, SQM-PMM" as a new methodology for enhancing the key elements of successful Science TQM and ensuring future management results through strategic quality management. SQM-PMM was developed based on the actual company management practices of top management. The validity of SQM-PM as the key to maintaining competitive corporate management was verified. Through the establishment of SQM-PMM, quality management techniques are maximized, thus bringing in a new phase of strategic quality management (Amasaka, 2004b, 2004c).

2. BACKGROUND

Amidst increasingly fierce competition in the manufacturing industry both at home and abroad, developing a renewed awareness of how the industry is approaching quality management is critical. Companies must use this awareness when tackling recent quality problems—problems so severe that they have seriously undermined customer satisfaction (CS). Increasing recalls among the major corporations that should be leading the world in global production are a wake-up call for the manufacturing industry to reinforce the strength of their quality-related technologies (Goto, 1999: Nihon Keizai Shinbun, 2000, 2006: Amasaka, 2007, 2008).

In recent years, digital engineering has resulted in a dramatic shift in how manufacturing worksites operate. One occasionally sees a phenomenon where scientific quality management methods designed to "build in" quality during the manufacturing process are becoming diluted due to several factors—including a decline in manufacturing (worksite) technology, the realization that employees' ability to discover and solve problems is weakening, and a general fading of the concept of "building in" quality. Companies cannot afford to limit themselves by their past successes or cling to outdated forms of quality management; setting up new quality management methods appropriate to production sites equipped with digital engineering technology is an urgent task (Joiner, 1994: Amasaka, 1999, 2004a).

As worldwide quality competition has come to define the new century, success in producing consistent

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global quality at optimum locations has become a crucial part of deploying the new global marketing strategies that are key to corporate survival (Amasaka, 2004a, 2008). There is thus a need for strategic quality management performance measures: they allow companies to solidify their management achievements and are the key to maintaining competitive superiority in the years to come. Furthermore, these measures must contribute to the strategic deployment of quality management technologies for the next generation (Amasaka, 2004b, 2004c).

3. SCIENCE TQM, NEW QUALITY MANAGEMENT PRINCIPLE

When the author looked at recent corporate activities both inside and outside Japan, he found cases where leading companies had lost customer trust. The loss of customer trust was due to stagnant R&D activities for enhancing QCD (Quality, Cost and Delivery), an issue stemming from chronic internal and/or external quality problems. As a result, the companies lost sight of customer needs and fell behind in technological development. At the same time, other companies are focusing on the "customer first" principle while actively innovating in product development, sales and marketing. These companies are conducting company-wide quality management activities, successfully enhancing CS (Amasaka, 2004a, 2005).

The author strongly believes that the key difference between the successful and unsuccessful companies lies in strategic quality management based on a "customer first" principle that allows them to grasp future trends. With this in mind, the author has proposed a new quality management principle called Science TQM (Amasaka, 2004b, 2008) [also referred to as the "New Japan Model" (Amasaka, 2007)], to many leading Japanese companies, including Toyota Motor Corporation and others. Implementing *Science TQM* utilizing "Science SQC, New Quality Control Principle" (Amasaka, 2003) involves the five elements of core competence: the Total Development System (TDS), Total Production System (TPS), Total Marketing System (TMS), Total Intelligence Management System (TIS), and Total Job Management System (TJS).

The author therefore endeavored to create strategic quality management performance measures to respond to the top concern of corporate management: how to solidify management achievements in the years to come. As the key to maintaining competitive superiority, these measures serve as a compass for corporate management activities. This process is outlined in the following chapters.

4. ESTABLISHMENT OF SQM-PMM FOR SCIENCE TQM

The Strategic Quality Management-Performance Measurement Model (SQM-PMM) was established as a key to the strategic application of Science TQM in order to ensure superior management achievements (Amasaka, 1999, 2004b, 2004c: Amasaka, ed., 2000: Amagai & Amasaka, 2003).

4.1. Significance of constructing SQM-PMM

The present study is based upon the viewpoints of management at leading companies (actual quality management activities undertaken by management and the resulting achievements), rather than existing international standards (ISO 9004 and QS9000) or awards (the Deming Prize, Malcolm Baldrige National Quality Award, European Foundation Quality Award, Japan Quality Award, Balanced Scorecard, *etc.*) (see Amagai & Amasaka, 2003 for examples) (ISO 9004, 2000; Chowdhury & Zimmer, 1996; Deming Prize Committee, 2003 Boesen, 2000; Japan Quality Award Committee, 2003; EFQM, 2003).

The factors of quality management systems and practices were extracted and a model of causal relationships between these factors and QCD management achievements was constructed. The ultimate aim was to establish an SQM-PMM that ensures effective application of Science TQM and strategic quality management. This cause and effect analysis, which directly links performance measurement to corporate management performance, is unprecedented.

4.2. Questionnaire overview

A survey of top management at Japanese manufacturers (see Table **1**) was conducted in order to investigate (I) TQM Activity Structures and Practices and (II) TQM Achievements (quality, CS and productivity) and Future Tasks. (Survey targeted 898 companies and resulted in 354 valid responses for a rate of 39.4%.)

Questions in the TQM Activity Structures and Practices section (I) fell into the following categories (see Table **2**): [1] Quality assurance and CS (8 items), [2] Product and technological development (3 items), [3] Lively corporate culture (10 items), and [4] Conventional TQM methods (7 items).

For these items, the respondents were asked to evaluate their existing activity structure and practices on a 5-point scale and state their reasons for that evaluation. Questions in the TQM Achievements (quality, CS and productivity) and Future Tasks section (II) included those in the [1] Quality and CS (5 items) and [2] Productivity (4 items) categories. The respondents evaluated their achievements and future tasks on a 3-point scale with an explanation of their reasons for that evaluation and future plans (see Table **2**).

Table 1: Sample Composition

Number of replies		Type of industry								Total
		Machinery	Primary metals	General materials	Natural resources	Direct materials	Service	Electricity	Petrochemistry	
Number of employees	Below 100	1	1	1	0	3	0	0	0	6
	100 – 299	15	4	8	0	6	6	2	5	46
	300 – 499	9	3	6	0	6	4	0	1	29
	500 – 999	29	1	13	0	12	11	0	5	71
	1,000 – 4,999	63	6	20	1	28	5	0	6	129
	5,000 – 9,999	18	1	6	0	9	0	1	3	38
	10,000 or more	23	0	1	0	6	3	1	1	35
Total		158	16	55	1	70	29	4	21	354

Table 2: Questionnaire Content

I. TQM Activity Structure and Practice	II. TQM Achievements and Future Tasks
[1] Quality assurance, CS (1) Quality assurance to (8) CR structure [2] Product and technological development (1) Planning analysis and results incorporation to (3) Technological development and product planning [3] Lively corporate culture (i) Total participation activities (1) Decision making speed to (5) Intra-divisional team activity (ii) Creative workplace (1) Improvement motivation to (5) ES [4] Conventional TQM methods (1) Vision and strategy to (7) Top assessment and audit	[1] Quality and CS achievement (1) Customer complaint resolution cost reduction (2) Customer complaint reduction (3) CS improvement (4) New product development (5) Sales and marketing share enhancement [2] Productivity achievement (1) Sales per head (2) Hourly productivity (3) Cost reduction (4) Lead time reduction

4.3. Analytical Survey Results

4.3.1. State of TQM implementation (Question 1, see Fig. 1)

The current state of TQM activities in Japan can be summarized by looking at the following common shortcomings: (i) expected product quality has been retained; (ii) improvements aimed at more attractive quality are lacking; (iii) low division-to-division coordination and organizational vitality; (iv) structures exist for developing vision and strategies, but implementation and/or evaluation of achievements is weak; (v) organizations only partly utilize SQC and do not accumulate techniques; and (vi) a TQM structure exists, but is not sufficiently implemented.

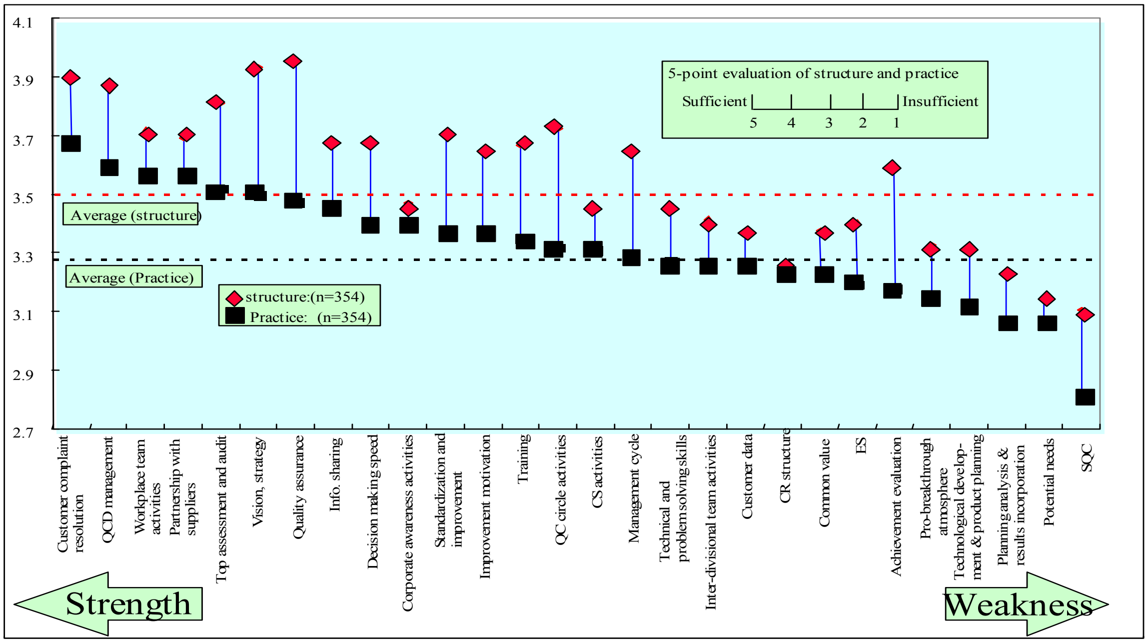

Figure 1: TQM Structure and Practice.

4.3.2. TQM achievements and future tasks (Question 2, see Fig. 2)

TQM achievements and future tasks are summarized as follows: (i) TQM, in principle, contributes to improvement of quality, cost and delivery; and (ii) current TQM activities do not contribute much to promote sales, improve CS, or address other important management issues.

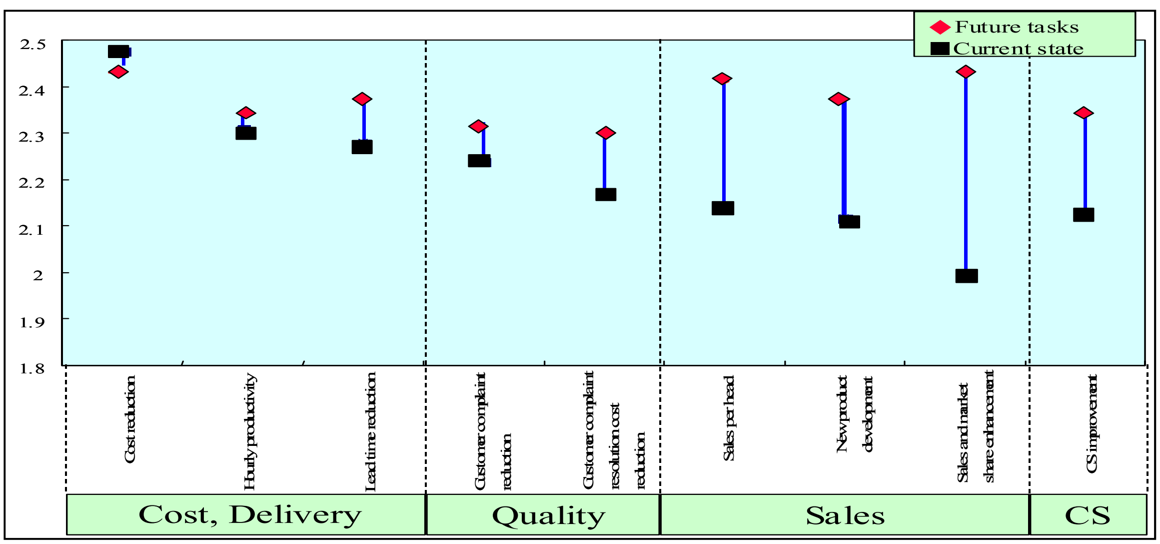

Figure 2:. TQM Achievements and Future Tasks.

4.4. CAID Analysis

Based on these findings, the author conducted a CAID (categorical automatic interaction detector) analysis (Murayama, *et al.,* 1982: Amasaka, *et al.,* 1998: Amasaka, 1999) in order to identify the major elements of TQM that lead a company to success. The results of this analysis are shown in Fig. **3**. For example, companies that rated CS, CR (Customer Retention), and product and technological development as important contributors to sales and market share growth showed excellent achievements in terms of QCD.

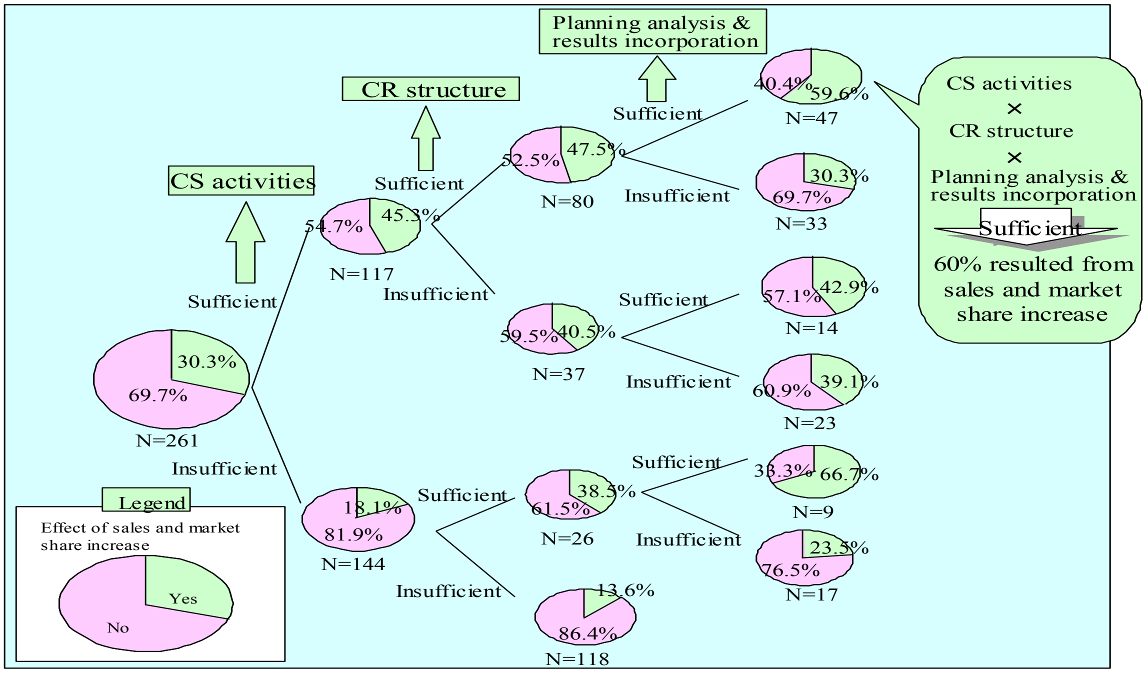

Figure 3: Causal analysis for sales and increased market share - CAID Analysis.

These results underscore the necessity of quality management performance measurements that enable top management to evaluate their company's quality management status and strategically utilize TQM activities in the future. Among the companies that implemented sufficient CS activities (N=117), 45.3% were able to increase their sales and/or market share.

Furthermore, among the companies that put a sufficient CR structure in place, performed a results analysis, and incorporated these results into their technological development and merchandise planning (N=47), about 60% were able to increase their sales and market share.

These results make it clear that companies must devote themselves to CS, CR, and results analysis, and then reflect the results in technological development and merchandise planning to improve sales and market share.

4.5. Graphical Modeling Method

In the course of SQM-PMM formulation, further analysis was conducted using the graphical modeling method. Based on the correlations among the 28 TQM activity practice items (confirmed using a partial correlation coefficient), interrelation of the six categories—quality, CS, product and technological development, total participation, creative workshops, and TQM methods using SQC—and their contribution to corporate achievements was confirmed visually through the relation chart method shown in Fig. **4**.

Fig. **4** suggests that TQM methods, technological development, CS, quality assurance, and corporate culture are all associated with management achievement. In particular, a strong correlation was found between quality assurance and product quality as well as between technological development/CS and sales.

For example, the relationship marked with Arrow (1) indicates that in order for their vision/strategy and top management to function effectively, companies must enhance achievement assessment, control cycles, and standardization/improvement. The two arrows marked with (2) indicate that a correct vision/strategy is necessary for technological development and CS to effectively contribute to sales.

The arrows marked (3) signify that a creative workplace, backed by SQC, is necessary as a foundation for effective technological development. The arrows marked (4) illustrate the relationship between total participation activities and a creative workplace, as well as the importance of QC circle activities as participation opportunities for all employees.

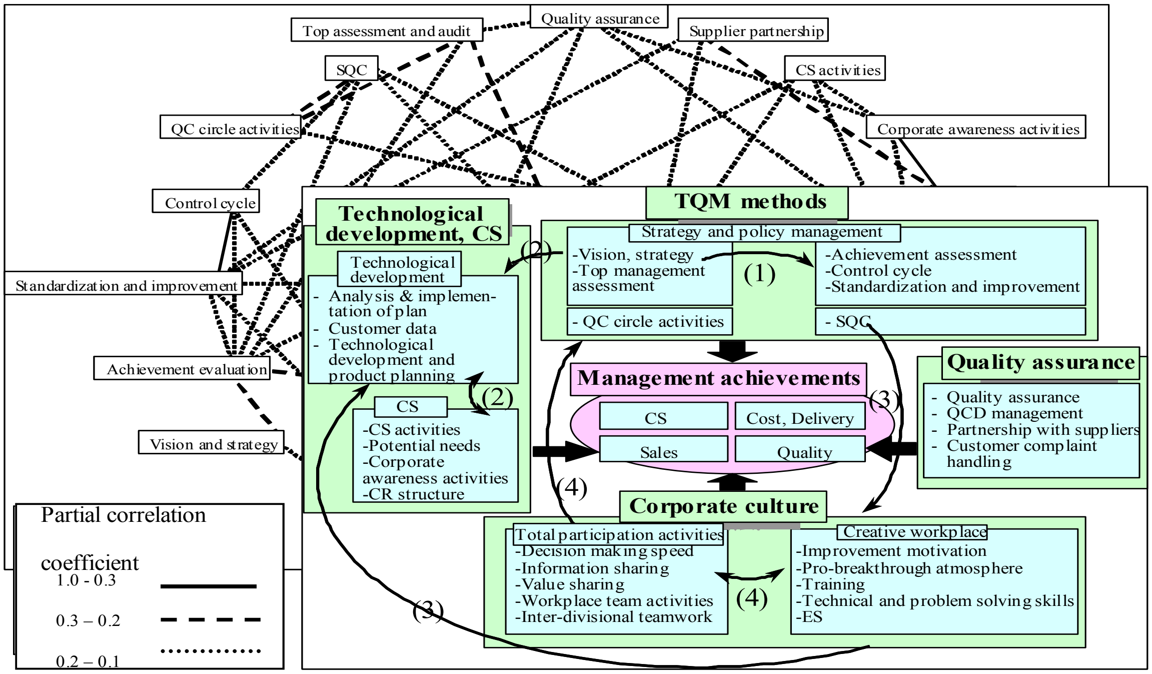

Figure 4: Relationships among TQM Practices and Achievements-Graphical Modeling.

4.6. Formulation of the SQM-PMM Model through Canonical Correlation Analysis

Finally, canonical correlation analysis was conducted to clarify the correlation between the two main variables (practice items and management achievement items). The analysis focused on weighing factors of the selected first canonical variable. As a result, a SQM-PMM was successfully formulated as below: The 28 items for (I) TQM Activity Structure and Practice were sequentially determined as x_1 to x_{28}.

The first canonical variable f_1 (f_{11} to f_{16}) was divided into six categories, of which the relational expressions are indicated in (1) through to (6). Items x_1 to x_4 are quality assurance, x_5 to x_9 are CS, x_{10} to x_{12} are product and technological development, x_{13} to x_{17} are total participation activities, x_{18} to x_{22} are creative workshops, and x_{25} to x_{28} are conventional TQM methods.

1) $f_{11}=0.418x_1+0.232x_2+0.530x_3+0.160x_4$

2) $f_{12}=0.160x_5+0.878x_6+0.156x_7+0.494x_8+0.533x_9$

3) $f_{13}=0.335x_{10}+0.712x_{11}+0.063x_{12}$

4) $f_{14}=0.089x_{13}+0.477x_{14}+0.064x_{15}+0.058x_{16}+0.332x_{17}$

5) $f_{15}=0.230x_{18}+0.316x_{19}+0.259x_{20}+0.052x_{21}+0.210x_{22}$

6) $f_{16}=0.105x_{23}+0.254x_{24}+0.254x_{25}+0.251x_{26}+0.119x_{27}+0.190x_{28}$

4.7. Standardization of SQM-PMM

These six categories—(i) Quality Assurance (ii) TQM Methods (iii) Creative Workshops (iv) Total Participation Activities (v) Product and Technological Development, and (vi) CS—were standardized using formulas (1) to (6) and evaluated using a radar chart. Table **3** shows the 5-point scale evaluation of category (iii), Creative Workshops. Practical application of the SQM-PMM has begun using the AMASAKA LABORATORY (http: //133.2.218.195/~amalab/H) website (see Fig. **5**).

Table 3: Example of SQM-PM Standardization (Creative Workshop)

	Evaluation Item	5	4	3	2	1
Creative workplace	Activities to maintain improvement motivation	Original activities implemented and are effective	Implemented generally	Implemented partially	Not implemented very much	Not implemented at all
	Activities to create pro-innovation atmosphere	Original activities implemented and are effective	Implemented generally	Implemented occasionally	Not implemented very often	Not implemented at all
	Training to enhance all employees' capabilities	Implemented regularly and is effective	Implemented generally	Implemented partially	Not implemented very much	Not implemented at all
	Practice and accumulation of special skills and problem solving capabilities	Practiced and accumulated	Practiced and accumulated generally	Practiced and accumulated to some extent	Not practiced and accumulated very much	Not practiced and accumulated at all
	Activities to enhance employee satisfaction (e.g. self realization, evaluation, treatment)	Implemented regularly and is effective	Implemented generally	Implemented partially	System exists but not implemented very much	Not implemented at all

5. VERIFYING THE VALIDITY OF SQM-PMM

Subsequent to the development of the model, the author asked top management and division general managers of leading companies in Japan to use the SQM-PMM in order to examine its validity (Amagai and Amasaka, 2003: Amasaka, 2004b, 2004c).

5.1. Verification Objectives and Method

Verification was conducted to see whether SQM-PMM correctly reflected the evaluators' (management of leading companies) understanding of quality management. The extent of dispersion was also verified as a function of the evaluators' positions in their organizations. Furthermore, if evaluators made appropriate evaluations with SQM-PMM when calculating the results for (1) to (6) in 4.6, it was possible to identify the evaluation items (x_1 to X_{28} in 4.6) that should be improved to enhance management achievement items (f_{11} to f_{16} in 4.6) (Amagai and Amasaka, 2003).

SQM-PMM was utilized on a trial basis at five companies (A: Fuji-Xerox, B: Nihon-Hatsujyo, C: Yanma, D: Kawasaki-Seitetsu, and E: Sanden) and evaluated by eight evaluators (A_1, B_1–B_3, C_1, D_1–D_2 and E_1). Five evaluators were in positions that allowed them to grasp company-wide quality management status (top management: A_1, B_1, C_1, D_1, and E_1), while three evaluators were in positions that allowed them to observe business category–level quality management status (general managers: B_2, B_3, and D_2). Possible dispersions based on evaluator position and the validity of SQM-PM were examined.

5.2. Implementation Results and Discussion

Fig. **5** is a radar chart prepared by evaluator A_1 indicating the results of the SQM-PMM trial at Company B. The chart is based on relationships (1) to (6) using the SQM-PMM. As shown in the figure, results were balanced, exceeded the average in all aspects, and corresponded to the evaluator's prior evaluation that product development is relatively strong. Similar evaluations were also obtained from other evaluators.

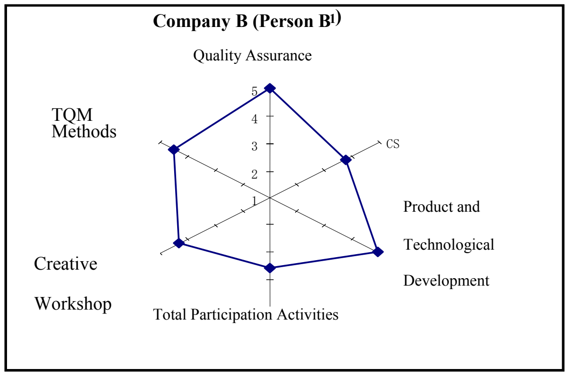

Figure 5: Radar Chart Sample-1.

In addition, evaluator positions were analyzed using the principal component analysis shown in Fig. **6**. This analysis was based on the SQM-PMM evaluation and performance measurement results. The analysis classified the evaluators into two groups—one (Group G_1) made up of those who confirmed the validity of performance measurement for company-level quality management performance (positions where it was possible to grasp company-wide quality management status), and the other (Group G_2) made up of those who wanted performance measurement designed exclusively for each business category (positions where it was possible to observe business category–level quality management status).

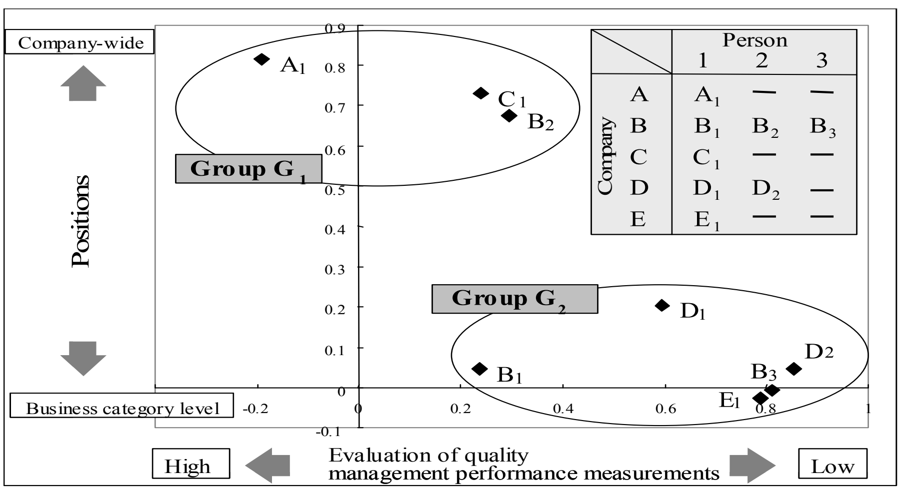

Figure 6: Evaluator Positions.

In Fig. **6**, the primary component axis (horizontal axis) represents the evaluation scores (SQM-PMM) and the secondary main component axis (vertical axis) represents the evaluation focus (company-wide perspective or business category–oriented). Judging from the positioning shown in the figure, the G_1 group (company-wide level) tended to give higher ratings while the G_2 group (business category level) tended to give lower ratings. Moreover, business category–oriented evaluations were confirmed. While evaluator B_2, a division general manager, made his evaluation from a company-wide standpoint, even the top management evaluators B_1, D_1, and E_1 showed a business category–oriented viewpoint.

Upon presenting these findings (the positioning in Fig. **7**) to all evaluators, it was proven that the results correctly reflect the evaluators' implicit prior evaluation, thus demonstrating the general validity of SQM-PM. Based on the evaluation guidelines (*e.g.* an evaluation sheet for each of the six categories and a radar chart for the evaluation results), top management evaluated the state of their company's quality management. As a result, the strengths and weaknesses of quality management recognized in advance were expressed objectively.

4.3. Verification of SQM-PMM validity

To verify the validity of SQM-PMM, additional investigations were conducted at companies A (Fuji-Xerox: 2 persons, 2 sections), B (Nihon-Hatsujyo: 5 persons, 2 sections), E (Sanden: 13 persons, 3 sections), F (Calsonic-Kansei: 6 persons, 3 sections) and G (Daikin-Kogyou: 17 persons, 6 sections) in the same way. The validity of SQM-PMM was reconfirmed as shown in Fig. **7**, proving the effectiveness of SQM-PM as a tool to identify what TQM actions are necessary for strategic quality management.

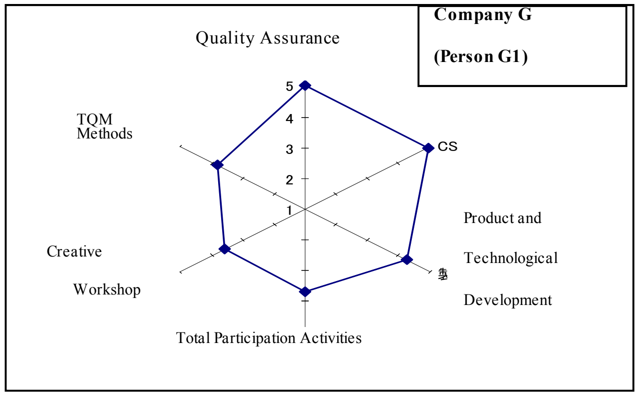

Figure 7: Radar Chart Sample-2.

6. CONCLUSION

The Strategic Quality Management Performance Measurement Model (SQM-PMM) is an important key to successfully implementing a new principle, Science TQM for next-generation quality management. The model was hereby established as a methodology to enable top management to accurately evaluate corporate quality management. The validity of SQM-PMM was proven successfully.

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CHAPTER 7

Partnering Chains as the Platform for Strategic Quality Management: Driving Force in Developing Science TQM - 3

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Abstract: This study discusses inter-enterprise link = partnering chains that concretely carries out the platform functions of strategic quality management activities of Toyota group while depending on a framework that recognizes collaborating relation between a parts manufacturer and an assembly manufacture, which is indispensable in producing good products.

Keywords: Partnering chains, platform, quality management, toyota supply system, brake pad quality assurance activities, toyota, toyota group.

1. INTRODUCTION

This study discusses on inter-enterprise link = partnering chains that concretely carries out the platform functions of strategic quality management activities of Toyota group companies while depending on a framework that recognizes collaborating relation between a parts manufacturer and an assembly manufacture, which is indispensable in producing good products (Amasaka, 2000, 2008a).

This paper approaches the quality control activities in the Toyota group companies from a new angle of view of partnering. It also touches on actual study of new development that is looked upon with expectation in the future. Therefore, the paper studies on potential development by the "Total Task Management Team", which draws attention as a new development in the quality management, by quoting a concrete case of the brake pad quality assurance activities by Toyota as an example.

2. BACKGROUND

2.1. Outline of Toyota Motor Corp. and Toyota Group

In 1982, Toyota Motor Industry and Toyota Motor Sales merged to form Toyota Motor Corporation. Toyota Motor Corp. (Toyota) is a super world enterprise from either viewpoint. Toyota group consists of a total 14 enterprises (Toyota, 1987). Twelve enterprises, which branched from Toyota Automatic Loom Works, Ltd. form the nucleus of the primary group parts manufacturers (called "Kyohokai") that supply parts directly to Toyota, to which join Hino Motors, Ltd. and Daihatsu Motor Co., Ltd. Each of the group companies is closely linked to Toyota in a wide and solid supplier-assembler relation "Toyota Supply System" called "Japan Supply System" as shown in Fig. **1** (Amasaka, 2000, 2008a).

An automobile is assembled with some 20,000 parts. Since it is not economical for the assembler to manufacture all the parts in-house, considerable portion of the parts are normally purchased from outside suppliers (parts manufacturers). Therefore, to years, and the situation still remains unchanged for it.

2.2. Relationship between Assembler and Suppliers

If parts purchased from the supplier (parts manufacturer) have low dependability, vehicles assembled with them have also low dependability naturally. This is exactly the reason why "performance of a vehicle almost depends on the parts" (Amasaka, 2000). In this sense, the assemblers and suppliers are the inhabitant of the same fate-sharing community. Actual supplier-assembler relation is generally quite complex and many-sided.

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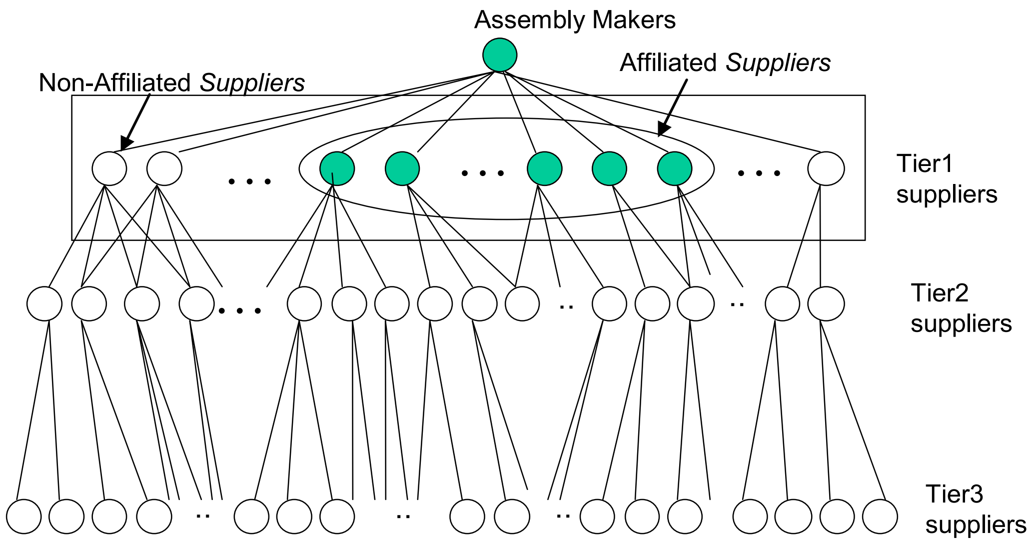

Figure 1: Japan Supply System.

Relationship between Toyota and its suppliers is unique in many points compared with those of other assemblers. There is the saying that "Toyota wrings a towel even when it is dry", indicating Toyota's strict demand to suppliers for their prices and quality. At the same time, no other assemblers are so enthusiastic as Toyota in raising strong suppliers through education and training. As early as in 1939, Toyota established its basic concept of the purchasing activities for promoting coexistence and co-prosperity.

To realize this, Toyota strengthened its suppliers by making it a rule to continue transaction forever once started. No other assemblers have their supplier groups as powerful as those of Toyota. The 14 Toyota group companies form the nucleus of the powerful supplier system. As thus far stated, close relation between Toyota and its group members is quite cooperative in one sense while simultaneously very competitive in another. This represents the supplier-assembler relation unparalleled elsewhere.

There is no denying that the strength of Toyota that can keep on supplying popular vehicle model such as "Lexus" of high dependability originates from within Toyota's own. But it is also the fact that part of Toyota's strength comes from the strength of its supply system consisting of Toyota group and thousands of other suppliers or Toyota's skill in managing such powerful supply system.

In the following, the authors intend to zero in on Toyota's Quality Management activities in exploring the secret of the strength of Toyota that continues to manufacture vehicles of high dependability. This is because it is quality management activities themselves that provide important bonds to cooperation or partnering between Toyota and its group companies.

3. "PARTNERING" AS THE QUALITY MANAGEMENT PLATFORM AMONG TOYOTA GROUP

3.1. Using Divisional and Functional Management by Toyota

At Toyota, functions such as product planning, product design, production engineering, purchasing, manufacturing, sale and others are called "Division" as shown in Fig. **2**, and control given based on this classification is called "Divisional Management". On the other hand, quality, cost, engineering, production, marketing, human resources and administration are called "function" and management given according to this classification is called "Functional Management" (Aoki, 1981: Toyota Motor Corp., 1987). In addition, TQM (Total Quality Management) promotion activities was inaugurated to establish the functional management system supported by two pillars of quality management and cost management.

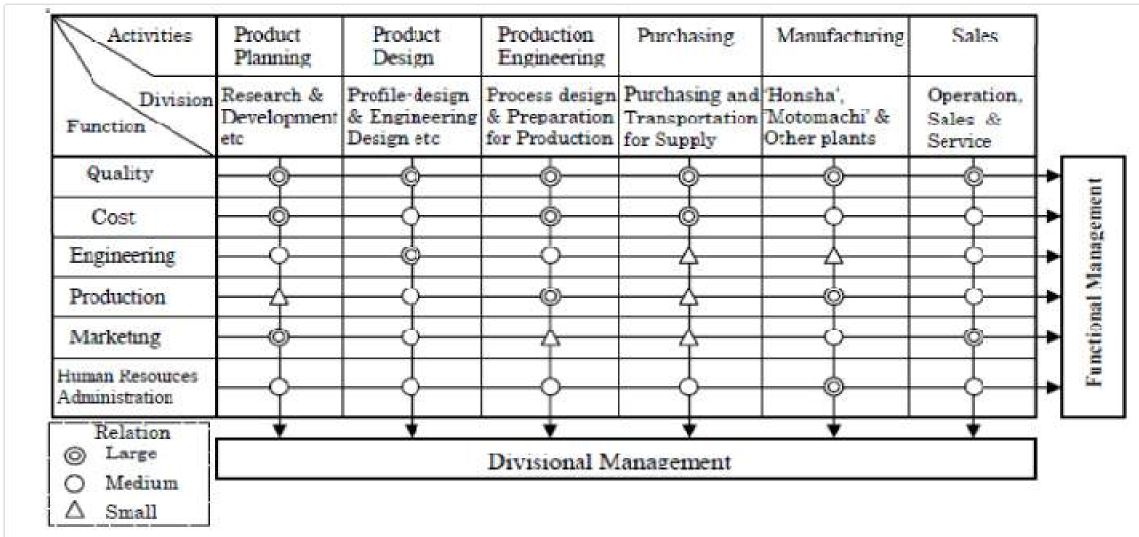

Figure 2: Divisional and Functional Management by Toyota.

3.2. Partnering

Partnering refers to multiple enterprises developing business by concluding equal partnership in principle while each retaining independency. Actual form of partnering is varied from the integrated manufacture and sale, supply chain and other vertical development to the joint development of new technology and products, integrated production, joint logistics and other horizontal business tie-up and integration (Doz and Hamel, 1998).

Toyota and its group companies are in a typical assembler-supplier relation, that is the work division relation in the vertical direction, where Toyota generally purchases and assembles parts manufactured by the parts manufacturers of the group. Besides, there are varieties of other cases where other assembler, like Toyota Auto Body Co., purchases engines from Toyota to assembly vehicles or Toyota manufactures part of the parts in-house in a completely competitive relation to the parts manufacturer as far as the parts in question are concerned. Basically, however, they are in the supplier-purchaser relation or in the preceding and following process relation in a vertical division of labor.

As Fig. **1** is self-explanatory, Toyota is the customer = purchaser for each of the Toyota group companies. For each of them, Toyota is not only the top customer with the highest sale but it is the large shareholder of own company. Therefore it is quite natural to think that Toyota is special and exceptional. However, unless Toyota is supplied with quality parts at low prices, it cannot manufacture vehicles of high dependability by itself. In this sense, mutual relation can be virtually almost equal to both sides, particularly on the level of a role of persons in charge of TQM (Total Quality Management) activities.

Consequently, it is correct to say that each of the Toyota group companies and Toyota are in a very partnering relationship toward the promotion of Quality Management. Moreover, as described in Section 2, respective companies in the partnering are mutually very closely related and quite cooperative. But at the same time, they can be quite competitive to each other concerning a part in question. Such two-sidedness is the most remarkable characteristic of the partnering among Toyota group and one of the sources of Toyota's strength.

3.3. TQM Activities as Lateral Operation of Organization

Suppose that Fig. **2** deals not with an enterprise but with a series of business process of the group as a whole, which consists of parts planning-development, manufacture, delivery to Toyota and assembly. Then the group companies replace the divisions in the figure. To manufacture vehicles of high dependability by combining all the capabilities of the group companies, a cross group enterprise-like quality control becomes essential (Amasaka, 2000).

In other words, "functional management", which is the "partnering" of all Toyota group companies becomes indispensable for promoting Quality Management. Understanding that Toyota style "functional management" signifies a cross-organizational operation, it is a re-engineering (Umezawa, 1994) of traditional divisional management in an enterprise or a sort of supply chain management (SCM Study Committee, 1988) when the object of management is the enterprises themselves that integrate operations in vertical direction.

When we proceed with the manufacturing of highly dependable vehicles by "All Toyota", it is the matter of course that quality control activities (re-engineering) will not simply remain the matter of individual enterprises but these activities will grow to the cross group enterprise type quality control activities (a sort of supply chain management).

It is apparent that there would be a major difference in product quality depending on whether a parts manufacturer manufactures parts by thinking that Toyota, to whom he delivers the parts is his customer or this manufacture thinks that the purchaser of an assembled vehicle is the true customer for him and he makes efforts in manufacturing quality parts by working together with the assembler, Toyota (Amasaka, 2004).

3.4. Subcontractor Management and Hierarchical Supply System of Toyota Motor

Parts manufacturers of Toyota group consists of three groups; the primary supplier, who can delivery parts directly to Toyota; the secondary supplier who can deliver parts to the primary supplier; and the tertiary supplier below. As Fig. **1** is self-explanatory, Toyota's supply system forms a distinctive hierarchical structure.

Immediately after being awarded the "Deming Prize", Toyota Motor vigorously promoted propagation of TQC (Total Quality Control) activities and the "Kanban" system (Toyota Motor Corp., 1987) to the group parts manufacturers under a motto of "Quality Assurance by All Toyota". Concretely, Toyota provided frequently the members of "Kyohokai", an association of the primary suppliers, with the lecture meetings and the plant diagnoses. Toyota also dispatched the specialists to various committees of Kyohokai to give thorough guidance on quality control and the Kanban system.

In addition to this, purchasing control division of Toyota Motor held a long-term study meeting for the purchasing staff of respective primary suppliers to teach them Toyota's subcontractor control method comprehensively. By so doing, Toyota intended to have these primary suppliers give guidance to the secondary suppliers the same way as it taught them TQC and the Kanban system.

It was apparent that Toyota had still far-reaching objective to have the secondary suppliers repeat the same for the tertiary suppliers. As the result of the organizational guidance that stretched staggering far from the 1970's to 1980's and into the 1990's, a gigantic and powerful Toyota Supply System of hierarchical structure was completed quality control, the Kanban system technique and know-how are beginning to proliferate autonomously everywhere on each layer.

This paper deals Toyota group's partnering as merely seen among the top or the crown of the pyramid. It is not difficult to imagine that countless partnering does exist and function similarly to Toyota group on the secondary and tertiary supplier levels. This is the very strength of Toyota that accomplished that surprising performance of "Lexus". Truly, "Roma was not built in one day".

4. DEVELOPMENT OF NEW TQM THROUGH "PARTNERING" - CASES OF THE "BRAKE PAD QUALITY ASSURANCE ACTIVITIES -

In a general assembly industry like the automotive manufacturing, a through "Quality Assurance (QA)" plays an important role. It includes not only the parts and unit quality control, but also the optimization of adaptive engineering for assembly by the vehicle manufacturers and the quality of production, sale and services.

Therefore, when working on the solution of a pending engineering task, separate and independent team activities by the vehicle manufacture or parts manufacturers alone often fail to clarify the engineering area, which exists in-between or across the two teams, often turning it into implicit knowledge. In this connection, it is important to zero-in on the end users from the view point of customer-in and to create new devices by mutually disclosing their software and hardware techniques to each other.

Here, this paper intends to verify the effectiveness of a new TQM development called Toyota's Science TQM activities (Amasaka, 2008b) through the "partnering" between the vehicle assembler and the parts manufacturers on the "investigation of the mechanism of the brake pad noise and quality assurance" (Amasaka, 1997: Amasaka and Osaki, 1999), which has become one of the continual engineering problems of the automotive manufacturers of the world.

4.1. Objectives

Disk brakes work on a principle that the pressing of pads to the rotors by the calipers generate braking force. Brake noise is generated when the pad and the rotor are in contact with each other in a delicately unstable condition. The condition that allows noise or abnormal sound to be generated with ease and the response quality of brake are items contrary to each other. Therefore, it is important to analyze the properties of pads and the response quality of noises and brake, and reduce dispersions in the properties of pads that affect the generation of noises and the braking effect (Miller, 1978).

The key point of this activity lies in establishing technologies that make sensitivity analysis of factors on the braking effect and noise in the aspect of design engineering, and to make these mutually contrary braking performance compatible with each other through bi-directional interaction with the manufacturing engineering.

4.2. "Total Task Management Team" Activities

To establish an organizational system that allows the vehicle design, parts design, production process design, manufacture, inspection, maintenance, sale (service, marketing quality) divisions including these of automotive manufacturer to share know how and information supports engineers' conception. This links to the improvement of technology and improves the quality of business process.

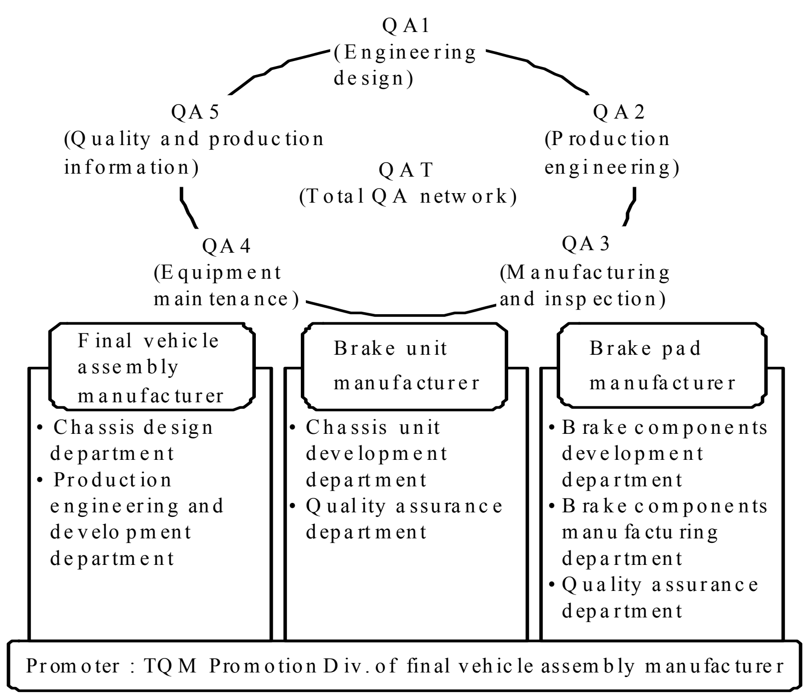

Figure 3: Organizational Outline of Total Task Management Team.

Here, this organization is realized in the form of a "Total Task Management Team", as shown in Fig. **3**. Five teams were formed, which consisted of QA1 (Engineering design), QA2 (Production engineering), QA3 (Manufacture and Inspection), QA4 (Facility Maintenance) and QA5 (Quality and Production information). These five teams mutually cooperated in developing Total QA Network (QAT) (Amasaka and Osaki, 1999).

4.3. Three Pillars of "Total QA Network (QAT)"

One of the nuclei of customer-oriented TQM activities is "QA Network" (Amasaka, 1999: Amasaka *et al.*, 1997) activities. For the current studies, it is necessary to develop the "Total QA Network" (hereinafter referred to as QAT) in order to optimize the total business process that spans from the design to production line then to the marketing and servicing.

As a key technology of quality assurance activities, we propose here three pillars of management namely "Total Technical Management (TM)", "Total Production Management (PM)" and "Total Information Management (IM)". QAT activities are implemented by fusing the three total management in Fig. **4** into one.

1: Total Technical Management

Makes a sensitivity analysis of dispersion in both raw materials and the process condition for the brake response quality and the brake noise, and reviews the engineering method and clarifies process condition control items.

2: Total Product Management

To realize the process conditions and control items, divisions such as Design, Production Engineering, Manufacturing, Maintenance, and Quality Assurance all combined carry on production activities using the "QA Network" (Amasaka, 1995) table of manufacturing based on the matrix diagram method and the process FMEA (Failure Mode and Effect Analysis), *etc.*

3: Total Information Management

Establishes a system for making a timely feedback of the market quality information (dealers), following process information (completed vehicle manufacturers) and self-process information (parts manufacturers) to the process.

4.4. Cases of Application (A Case of Brake Pad)

To promptly optimize the Total QA Network of Fig. **4** systematically and organically, the "SQC Technical Methods" (Amasaka, 2003), which is popularly used as the "Mountain Climbing of Problem Solution" as shown in Fig. **5** is applied. Various types of arrows in the figure represent team activities of QA1 through QA5 respectively.

4.4.1. Total Technical Management

Makes analysis on each material (Fig. **5**, TM1), conducts a market survey (Fig. **5**, TM2), and makes factorial analysis on the basis of the above results (sensitivity analysis), boiling down the material to a short term. For example, in the factorial analysis I (Fig. **5**, TM3), it is found, by using the principal component analysis and other, that in the raw material characteristics, stratified mineral particle size and the diameter of inorganic fiber are related with the noise and friction characteristics (Fig. **6**). Area a represents an area where the noise and friction are in considerably bad condition, while area b representing an area where the effect remains. The authors found area c where the both characteristics are not contrary to each other.

The authors have found through the factorial analysis I that variation of the process and manufacturing conditions (Fig. **5**, PM1) is important. With regard to ground components (inorganic fibers and hard fine particles), we verified the factorial effect in combination with a technical analysis of a single material and the state of dispersion in the pad through the electron microscope observation. The authors were thus able to clarify the mechanism of variation of the braking effect caused by manufacturing dispersion of inorganic fibers. This led to a successful improvement in cooperation with the material manufacturers.

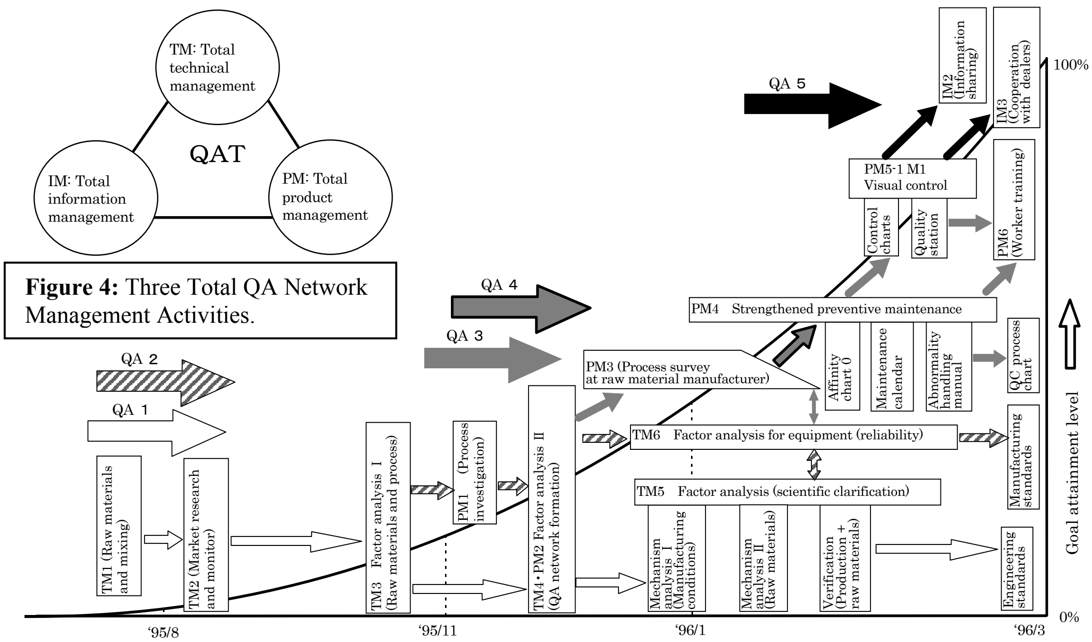

Figure 4: Three Total QA Network Management Activities.

Figure 5: Development of Total QA Network using SQC Technical Methods.

On the stage of production preparation, the drawings of the product were created using the "QA Network" of engineering (Fig. **5**, TM4) according to the market quality. The drawings of the equipment were created using the "QA Network" of manufacturing (Fig. **5**, PM2) on the basis of quality of conformance. On this stage, we boiled factors down to important factors, which are related to the acceptance of raw materials and the management of the condition and state of manufacturing process.

The authors then analyzed phenomena on respective factors selected (Fig. **5**, TM5). The authors grasped the equipment condition quantitatively to optimize tolerance in the product drawing scientifically. For example, by using unbalanced regression plotting, The authors came to understand that the thermoforming temperature and the substitute characteristics of the braking noise are in causal relation (Fig. **7**).

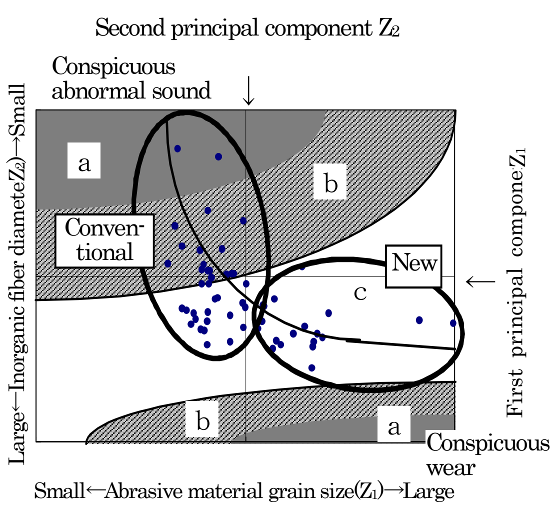

Figure 6: Example of Analyzed Influences of Raw Material Properties.

Each Area "a" represents an area where there is the lack of strength or an area not suitable for the forming while Area "b" representing an area having residual effect of the lack of strength or unsuitableness for forming. Considering the strength and formability, The authors decided on Area "c" for the management condition of thermoforming process.

To retain the management condition of Area "c", we implemented a factorial analysis on the side of the equipment (Fig. **5**, TM6). For example, The authors made a factorial analysis of dispersion in the temperature of the forming dies. This enabled us to provide the uniform pad forming temperature.

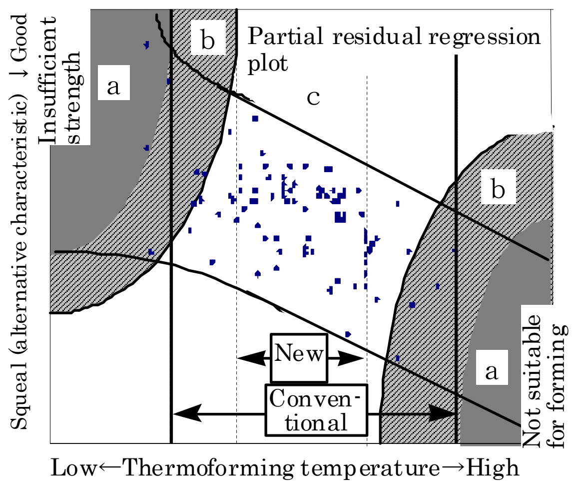

Figure 7: Causal Relation between Alternative characteristic of Squeal and Thermoforming Temperature.

4.4.2. Total Product Management

To realize the process conditions found through "Total Technical Management", factors for non-conformance were investigated with the process survey (Fig. **5**, PM1) and association with quality characteristics was determined with the "QA Network" of manufacture (Fig. **5**, PM2). Moreover, to complete the "QA Network", a brake unit manufacturer, a brake pad manufacturer and raw material manufacturer formed a task team, for instance, to carry on quality review mutually (Fig. **5**, PM3).

As the result, present process capability became known. This developed to the prevention of defect and flow-out of defectives, then to the strengthening of preventive maintenance (Fig. **5**, PM4: Preventive maintenance calendar), visual management (Fig. **5**, PM5: In line SQC), Worker Training (Fig. **5**, PM6: Manual for measures of abnormal quality).

4.4.3. Total Information Management

The authors quality check station (Fig. **5**, IM1), which readily provides process information as the result of the "Total Product Management". Moreover, we established routes by which market information (DAS ; Dynamic Assurance System) (Sakaki, 1972) held by the completed vehicle manufacturer can be shared by parts manufacturers (Fig. **5**, IM) and the route by which actual parts information can be acquired from dealers (Fig. **5**, IM3).

At present, we are summarizing the market information, process information, engineering information and other quality information of QA1 through QA5. The authors promote to upgrade the pad performance and quality by analyzing the above-mentioned information. In addition, we wish to state that the scheduled development of wide QCD studying activities by both companies realized given results where market claim was reduced to one-sixth and under.

5. CONCLUSION

As thus far stated, the authors have been able to verify the development of a new TQM through the "Partnering" and its effectiveness by quoting concrete cases. To realize the problem solution, the "Partnering" by joint effort and cooperation as indicated in the above cases will become more important to reduce logical gap among the organizations such as the planning, product design, process design, manufacture and sale.

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CHAPTER 8

Strategic Marketing Development Model: Innovation Model Utilizing Science TQM - 1

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Abstract: A future successful global marketer must develop an excellent quality marketing system that impresses users and continuously provides excellent, quality products in a timely manner through corporate management. In this paper, the author verifies the validity of a "Strategic Marketing Development Model, SMDM" for developing core principle "Total Marketing System, TMS" of "Science TQM". This paper aims to create a "Scientific Customer Creative Model, SCCM", a form of strategic marketing utilizing SMDM. Concretely, the author will also introduce the effectiveness of SMDM that reflects latent customer needs through scientific marketing application examples *via* "Toyota's Intelligent Customer Information Marketing System, T-ICIMS".

Keywords: Total marketing system, strategic development marketing model, scientific customer creative model, toyota's intelligent customer information marketing system, science TQM, toyota.

1. INTRODUCTION

Recently, the author (Amasaka, 2008) has touched on the development of the "Science TQM, New Quality Management Principle" and its validity as a new management technology for 21st century manufacturing. Science TQM innovates the business process of each division, which encompasses sales and service, development designing, production, general administration, and management – related departments.

In this paper, the author (Amasaka, 2007) verifies the validity of "Strategic Marketing Development Model, SMDM" for developing core principle "Total Marketing System, TMS" of Science TQM. In concrete terms, a model that enables the sales, marketing and service divisions nearest the customer to systematically determine their tastes and desires is necessary. At present, however, the system for applying scientific analytical methods to customer data has not been satisfactorily established.

In some cases, its importance has not even been recognized. This paper aims to create a "Scientific Customer Creative Model, SCCM" which a form of strategic marketing utilizing SDMM. Concretely, the author will also introduce the effectiveness of SMDM that reflects latent customer needs through scientific marketing application examples *via* "Toyota's Intelligent Customer Information Marketing System, T-ICIMS".

2. NEED FOR A MARKETING STRATEGY WHICH CONSIDERS MARKET TRENDS

Today's marketing activities require more than just short-term strategies, such as 4P (Product, Price, Place and Promotion) activities by the business and sales divisions. After the collapse of the bubble economy, the competitive environment in the market has drastically changed. Since then, companies that have implemented strategic marketing quickly and aggressively have been the only ones enjoying continued growth (Okada, *et al.*, 2001). After close examination, it was said that strategic marketing activities must be conducted as company-wide, core corporate management activities that involved interactions between divisions inside and outside of the company (Jeffery and Bernard, 2005).

Therefore, a marketing management model needs to be established so that business/sales/service divisions,

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which are carrying out development and design for appealing products projects, and which are also in the closest position to customers, can organizationally learn customers' tastes and desires by means of the continued application of objective data and scientific methodology (James and Mona, 2004: Amasaka 2005). However, at present, the organizational system has not yet been fully established in these divisions; in some cases, even the importance of this system has not been commonly realized (Gary and Arvind, 2003).

3. SIGNIFICANCE OF TMS, THE KEY TO APPLICATION OF SCIENCE TQM

To develop and provide customers with appealing products is the mission of all enterprises and the basis of their existence. Recently, the author (Amasaka, 2004, 2008) has touched on the development of the principle of Science TQM and its validity as a new management technology for 21st century manufacturing. Science TQM innovates the business process of each division, which encompasses sales, designing, production, general administration, and management – related departments.

Science TQM includes hardware and software systems developed according to new principles to link all activities throughout a company. The hardware system comprises five core elements: "TMS" (Total Marketing System), "TDS" (Total Development System), "TPS" (Toyota Production System), "TIS" (Total Intelligence Management System) and "TJS" (Total Job Quality Management System). The software system is the deployment of "Science SQC, New Quality Control Principle" (Amasaka, 2003a).

The core technology of TMS is the key to the Science TQM. The aim is to promote market creation as shown in Fig. **1** and to realize quality management to be relied on by customers through scientific marketing and sales, not by sticking to conventional concepts.

As shown in the figure, in order to realize quality assurance with an emphasis on the customer, TMS is composed of the technological elements (a) market creation activities through collection and utilization of customer information; (b) strengthening of merchandise power based on the understanding products are supposed to have to retain their value; (c) establishment of marketing systems from the viewpoint of building bond with customers; and (d) realization of the "Customer information network" for CS (Customer Satisfaction), CD (Customer Delight) and CR (Customer Retention) elements needed for the corporate attitude (behavior norm) to enhance customer values.

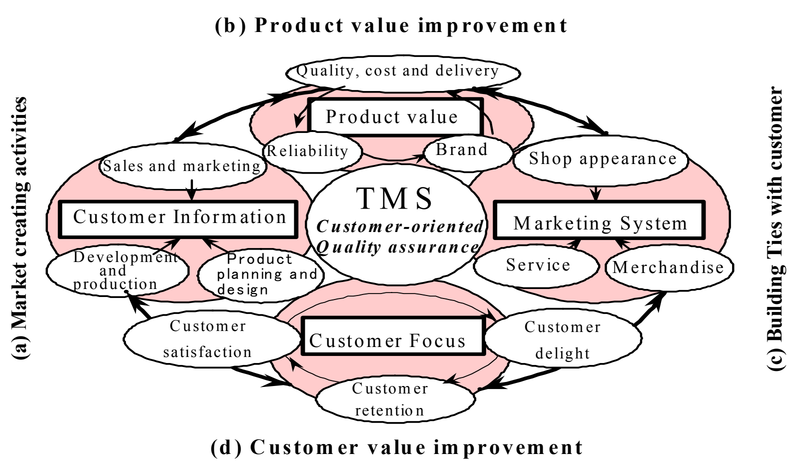

Figure 1: Total Marketing System.

4. PROPOSAL OF STRATEGIC MARKETING DEVELOPMENT MODEL, SMDM

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.

"Contact with customers" has never called for more careful attention and practice and to offer an appealing, customer-oriented marketing strategy, it is important to evolve current market creation activities (Nikkei Business, 1999: Amasaka, 2001, 2007, 2011).

Therefore, the author (Amasaka, 2007) proposes "Strategic Marketing Development Model, SMDM" as described in Fig. **2**, that further updates TMS. SMDM is aimed at the implementation of a successful "Global Marketing Strategy" by developing "same quality worldwide, and marketing at optimum Locations".

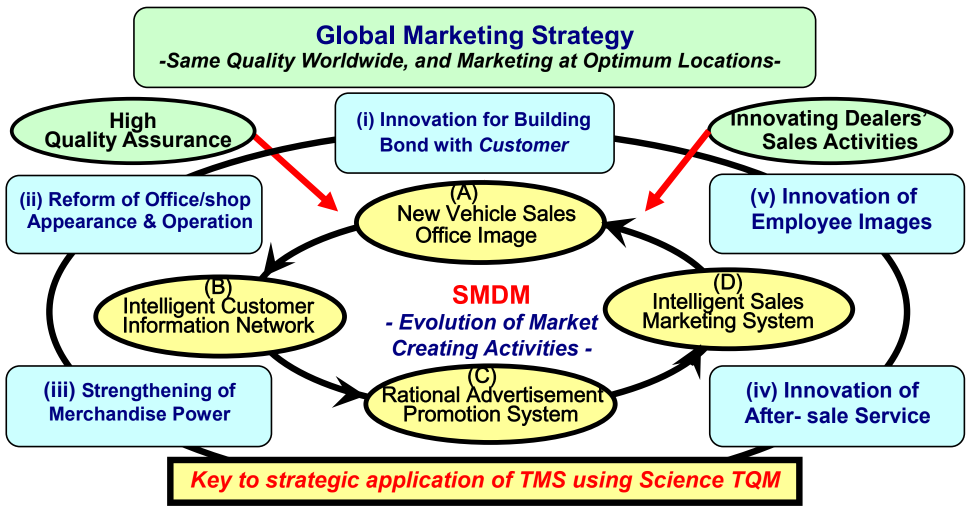

Figure 2: Strategic Marketing Development Model, SMDM.

As shown in the figure, SMDM aims to achieve "a high cycle rate for market creation activities" and is composed of four core elements (A)-(D) : Core element (A), a "new vehicle sales office image" to achieve a high cycle rate for market creation activities by, (i) innovative bond building with the customer and (ii) shop appearance and operation, is particularly important, These constitute the basis for the innovation of (iii) business talk, (iv) after sale service, and (v) images of the employee image.

At a certain stage of execution, for example, it is more important to construct and develop (B) an "Intelligent customer information network", （C） a "Rational advertisement promotion system" and a (D) an "Intelligent Sales Marketing System" that systematically improves "Customer information software application know-how" about users who patronize vehicles of various makes.

This information network turns customer management and service into a science by utilizing TMS according to customers' involvement with their vehicles in daily life. The strategic new marketing model which applies the proposed SMDM is presented in the next chapter.

5. CREATION OF SCIENTIFIC CUSTOMER CREATIVE MODEL UTILIZING SMDM

One vital point of the strategic marketing structure is its definition; marketing activities should be defined from "Closed marketing activities" that are limited to the Business and Sales Division to "Open marketing activities" that can be performed through steady linkage with all other divisions in a company-wide framework. The aim is for an "Evolution of Market Creating" through "High Quality Assurance and Innovating Dealers' Sales Activities" by utilizing the scientific approach of SMDM. So, the author (Amasaka, *et al.*, 2004: Shimakawa., *et al.*, 2006) present a "Scientific Customer Creative Model, SCCM" which takes the form of strategic marketing as shown in Fig. **3**.

In the Fig. **3**, 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. The outline of SCCM is shown in the following. First of all, in the (1)

Marketing Strategy domain, the key point is how the market segment and the target market are determined. In general, the target market is determined based on the company's core competencies, competition strategy, and resource strategy over the medium and long term basis.

By introducing a scientific analysis approach that uses IT, it clarifies a potential target market from the changing market or the customer structure analysis. Secondly, in the (2) *Manufacturing Process* domain, the key point is to collect/analyze customers' demands and expectations precisely. At this time, it is important to consider what value the customers 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→ production.

Furthermore, in the (3) *Market/Customer* domain, the key point is to learn the structure of the customer's motivation to buy products, customer satisfaction (CS) and loyalty. Then, it is necessary to extract the elements for customer retention (CR) from this data and utilize it for specific kaizen activities such as reflecting it in future products. 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 these three domains stated above from a strategic marketing viewpoint.

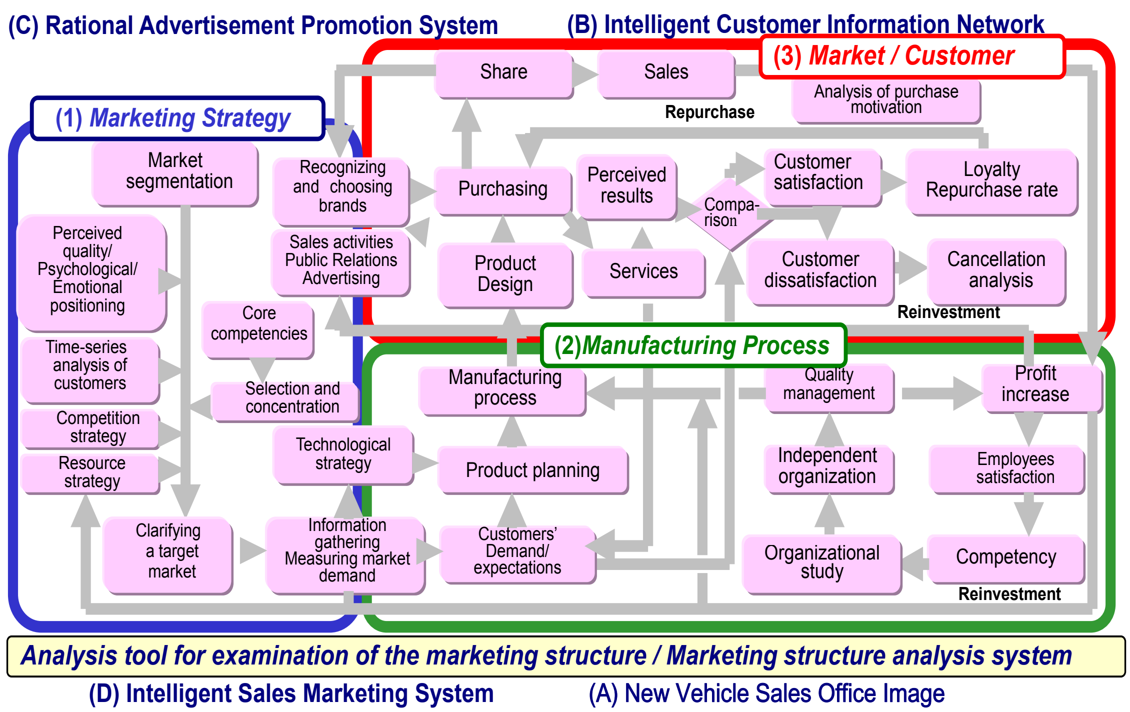

Figure 3: Scientific Customer Creative Model, SCCM.

6. APPLICATION: ESTABLISHMENT OF "TOYOTA'S INTELLIGENT CUSTOMER MARKETING SYSTEM, T-ICIMS"

In this chapter, the reality and effectiveness of "Toyota's Intelligent Customer Information Marketing System, T-ICIMS", which the author established recently through the application of SCCM will be indicated clearly. The typical execution example of T-ICIMS is composed of "Toyota's Sales Marketing System, TSMS" which involve the "Customer Purchasing Behavior Model of Ad. Effect, CPBM-AE".

6.1. Customer Purchasing Behavior Model of Advertisement Effect for Automotive Sales

Recently, the total amount of advertising expenditure by Japanese enterprises has increased almost in-line with increases in GDP (Nikkei Institute of AD, 2001: Dentsu, 2001). The breakdown by medium shows:

TV advertisements (TV-CM, 33.9%), newspaper ads (18.8%), flyers (folders: 8.0%), magazines (7.1%), and radio (3.2%). In the case of Toyota, which has topped Japanese advertising expenditure for 7 consecutive years, the rate of advertising expenditure to operating profit is 7.3% (average). This ratio is constantly high with a number of enterprises.

According to automotive dealers' empirical knowledge, number one in rank for major mass effect is the TV-CM, but as far as the author knows, there are no examples of investigating the quantitative effects of TV-CM, *etc.* such as the proposed "Customer Purchasing Behavior of Advertisement Effect Model" (Niiya and Matsuoka, Eds., 2001).

The author is interested in quantitatively turning the purchasing behavior of customers who visit the dealer 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 sale activities will be drastically enhanced due to an improved understanding of the effects of TV-CM as well as by the media-mix of newspaper ads, flyers, *etc*.

6.1.1. Proposing Customer Purchasing Behavior Model of Advertisement Effect, CPBM-AE

Fig. **4** shows the "Customer Purchasing Behavioral Model of Advertisement Effect, CPBM-AE" to prepared by the research of the author (Amasaka, 2003b, 2009), at the time of introduction of new cars. As background for the influential factors in the figure, the authors established a CPBM-AE1*,* starting with recognition of the vehicle name (R)→interest in the vehicle(I)→desire to visit a dealer to see the vehicle (D-1)→consider purchasing (C-1)→visiting a dealer for purchasing contract (P-1) after influence from TV-CM, newspaper ad, radio, flyer, DM/DH, or presence/business talk over approximately 2 months. From this the authors realized that a *CPBM-AE2* exists, starting from considering purchasing the vehicle (C-2)→desire to visit a dealer (D-2)→impression from actually seeing the vehicle at the dealer (I-2)→purchasing contract (P-2).

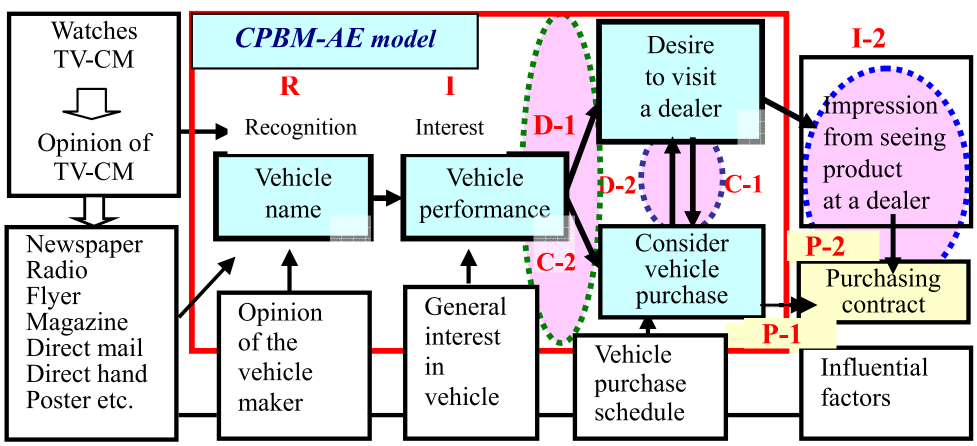

Figure 4: Customer Purchasing Behavior Model of Advertisement Effect, CPBM-AE.

6.1.2. TV Advertisement Effect Introducing Two Newly Released Cars

For example, supposing that customers have their purchasing desire aroused by watching a 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. However, because of the enormous scale of market surveys and the limited opportunities for them, there have been no actual examples of factorial analysis up to the present (Niiya and Matsuoka, Eds, 2001: Amasaka, 2009). With the help of Toyota Motor Corp., the author (Amasaka, 2003b) conducted a dynamic survey of customers' purchasing behavior resulting from a TV-CM introducing two newly passenger vehicles "Japanese names: "*Funcargo/Platz*". As a result of the investigation analysis, the author could confirm a CPBM-AE-1/2 for Customer Purchasing.

Fig. **5** shows the results of analysis that applied the *CPBM-AE-1* at the time of the introduction of the new vehicle, "*Funcargo*". The total mean curve indicates that 1/3 (34.6%) of customers recognize the new vehicle name (R) from the TV-CM alone. The number of customers drops by half (18.4%) at the interest stage (I), dropping by a further a half (8.1%) at the desire to visit a dealer stage (D-1). At the considering purchase stage (C-1), the figure drops to 9.6% at best, even with the addition of D-2→I-2 as stated above. Moreover, at the visiting stage in the figure, the ratio of customers that visited a dealer fails to reach 2%.

This implies the need for establishing an effective media mix model in the future. It has been verified that this analysis has a similar dynamic trend, irrespective of the new vehicle "*Platz*", sex of purchasers, age or area.

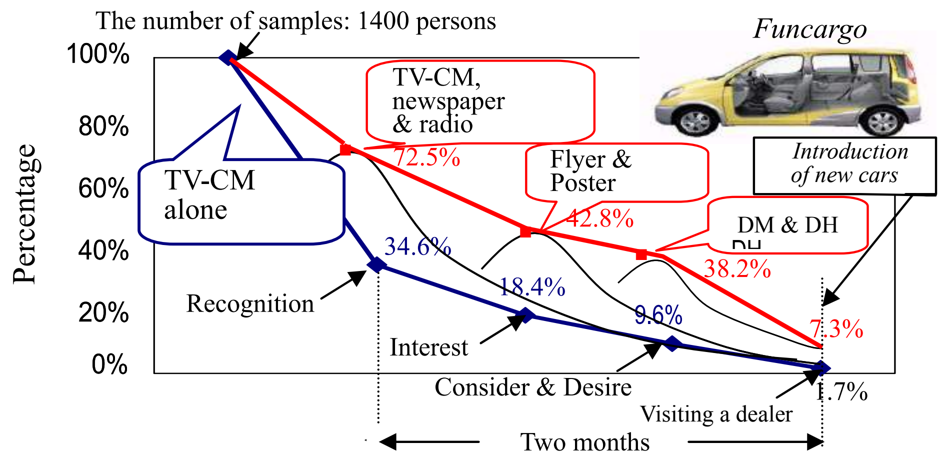

Figure 5: Reality of CPBM-AE of Customer Actions.

6.1.3. Establishment of an Effective Media Mix Model

The author (Amasaka, 2003b, 2009) presents the most effective media mix model (CPBM-AE-2) in order to increase the rate of dealer visits, in Fig. **6** (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%. Use of 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%. However, the problem is to strengthen new initiatives that will lead to an even greater increase in the rate of dealer visits.

6.2. Toyota Sales Marketing System "TSMS"

The author (Amasaka, 2001, 2011) has constructed the "Toyota Sales Marketing System, TSMS", as a way to aid sales marketing through "innovative bond building with the customer". This system combines IT and statistical science to make practical use of customer data in order to (i) increase the rate of customer retention, and (ii) acquire new customers. In order to increase the rate of dealer visits and vehicle purchases by current loyal users, they are stratified into high-probability, medium-probability and low-probability customers, and then a sample is taken of the marketing, sales, and service items which the customers demanded, and provided customer satisfaction.

The system then uses this data to enhance the daily marketing, sales, and service activities. The system can also be made use of when visiting customers, and to help acquire new customers at the time they visit a dealer. Due to the application of *TSMS* which involves the previously introduced *CPBM-AE, T-ICIMS* operation has recently contributed to an increase in the sales share of Toyota vehicles in Japan (40%/1998 to 45%/2005) (Nikkei business, 1999:Yomiuri, 2006).

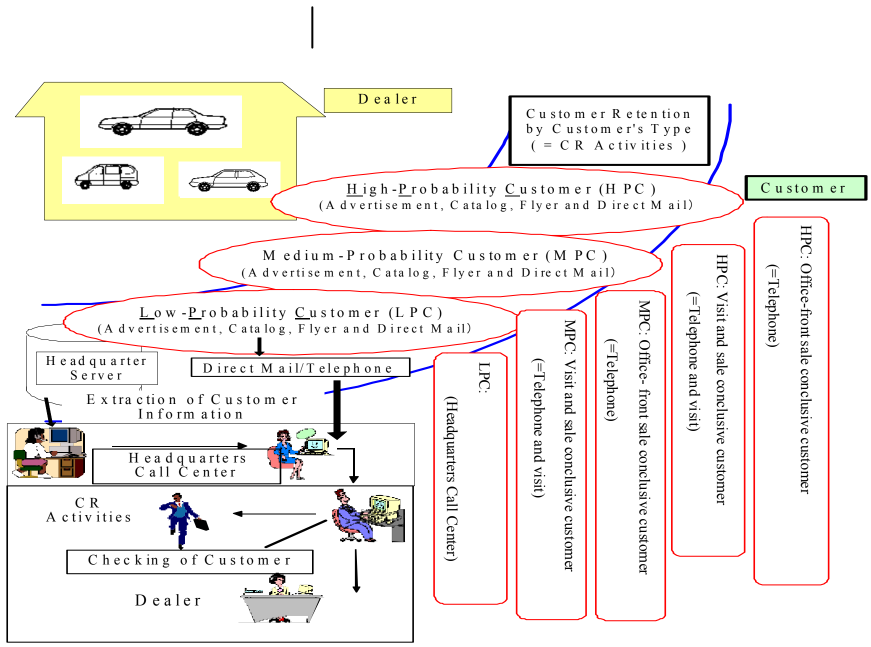

Figure 6: Outline of Toyota Sales Marketing System, TSMS.

7. CONCLUSION

In this paper, the author proposed "Strategic Marketing Development Model, SMDM" for developing core principle "TMS" of Science TQM. The aim is to bring about an "Evolution of Market Creation" through "High Quality Assurance and Innovating Dealers' Sales Activities" utilizing a scientific approach.

So, the author created a "Scientific Customer Creative Model, SCCM" which has the structure of strategic marketing. And further, the author introduced the effectiveness of application examples *via* "Toyota's Intelligent Customer Information Marketing System, T-ICIMS".

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CHAPTER 9

High Quality Assurance CAE Analysis Model: Innovation Model Utilizing Science TQM - 2

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Abstract: This paper proposes a "High Quality Assurance CAE Analysis Model" as part of principle-based research aimed at the innovation of design and development processes to ensure quality assurance in these processes employing statistical science. This model's effectiveness is demonstrated with application examples within the automotive industry. In order to enable the simultaneous achievement of Quality, Cost and Delivery (QCD) to satisfy the requirements of developing and producing high quality products while also reducing the cost and development period, it is necessary to initiate a transition from the conventional prototype testing method to a predictive evaluation method utilizing this model.

Keywords: High quality assurance CAE analysis model, design and development, automotive industry.

1. INTRODUCTION

The technological challenge currently facing Japanese companies is to enable the simultaneous achievement of Quality, Cost and Delivery (QCD) by innovating design and development processes, in order for them to prevail in the "worldwide quality competition". It is therefore, necessary to undertake principle-based research for quality assurance in design and development by utilizing latest numerical simulation technology (Computer Aided Engineering, CAE).

The authors (Amasaka, *et al.*, 2010: Amasaka, 2011) have conducted actual application case studies and proposed a "High Quality Assurance CAE Analysis Model" based on their findings. In order to make the transition from the conventional prototype testing method to a predictive evaluation method utilizing this model, the authors have proposed four core models: "Total Intelligence CAE Management Model", "Intelligent CAE Management Approach System Model", "Highly-Reliable CAE Analysis Technology Element Model", and "Highly-Reliable CAE Analysis System Approach Model".

The authors have succeeded in helping to overcome the current technological challenge through the unified application and systematic, organized deployment of these core models for the innovation of design and development in automotive industry (Amasaka, *et al.*, 2010).

2. SIGNIFICANCE OF THE RESEARCH

2.1. Simulation Technology and Automotive Development and Production

Recently, Japanese automotive enterprises have been promoting global production to realize uniform quality worldwide and production at optimal locations in response to severe competition (Goto, 1999). The mission of the automotive manufacturers in this rapidly changing management technology environment is to be properly prepared for the "worldwide quality competition" so as not to be pushed out of the market, and to establish a new management technology model which enables them to offer highly reliable products of the latest design that are capable of enhancing the value for the customer.

Focusing on management technology for development and production processes, it is clear that there has been excessive repetition of prototyping, testing, and evaluation for the purpose of preventing the "scale-up

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Kakuro Amasaka (Ed)

effect" in the bridging stage between design and development and mass production. This has resulted in unstable built-in quality assurance in the design and development stage, and an increase in the development period and cost. Therefore, it is now vital to reform conventional design and development processes.

More specifically, it is increasingly necessary to realize the simultaneous achievement of QCD to satisfy the requirements of developing and producing high quality products, while also reducing the cost and development period. This is to be achieved through a changeover from the so-called "development through actual product confirmation and improvement" to a process of prediction evaluation oriented development through the effective use of the latest numerical simulation technology (Computer Aided Engineering, CAE) (Amasaka, 2007, 2008b).

Fig. **1** shows transitions in the automotive design and development process in Japan. For model changes in the past (development to production: approx. 4 years), after completing the designing process, problem detection and improvement were repeated mainly through the process of prototyping, testing, and evaluation. In some current automotive development, vehicle prototypes are not manufactured in the early stage of development due to the utilization of CAE and Simultaneous Engineering (SE), resulting in a substantially shorter development period.

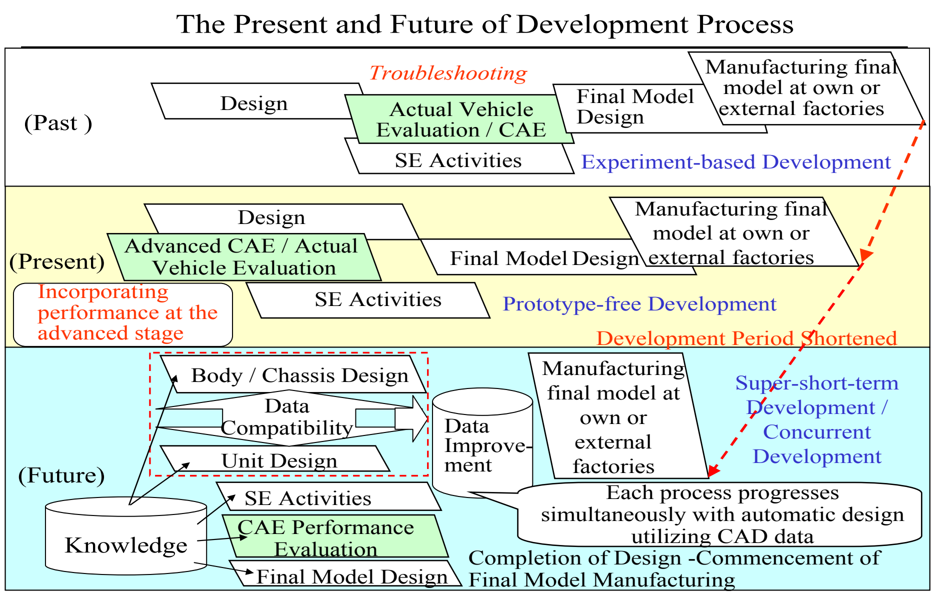

Figure 1: Transitions in the Automotive Design and Development Processes in Japan.

It is now possible to utilize CAE for comparative evaluation, rather than the conventional supplementary "observation" role during the testing of prototypes. This improvement means that CAE is utilized to the same extent as prototype testing. The vehicle design and development and production process has been shortened to one year and there has been a transition to a super short-term concurrent development process based on the utilization of CAE and Solid CAD, allowing individual processes to progress simultaneously. This would be virtually impossible using the conventional repetitive testing of prototypes.

2.2. Problems When Applying CAE to Design and Development Reform

The authors have identified problems that occur when applying CAE to design and development reform, and have summarized the main points in Fig. **2** from the standpoint of the simultaneous achievement of QCD (Amasaka, 2007). It is clear that it is necessary to eradicate the tendency towards prototypes and experimental evaluation in favor of predictive evaluation based on CAE analysis. However, in order to achieve this, the discrepancy (gap) between CAE analysis data and experimental evaluation data (analysis error) must be reduced from over 10 percent to 1-2 percent. Therefore, the authors have conducted factorial analysis as shown in Fig. **2** from the perspective of CAE technology for application, analysis, evaluation, and management.

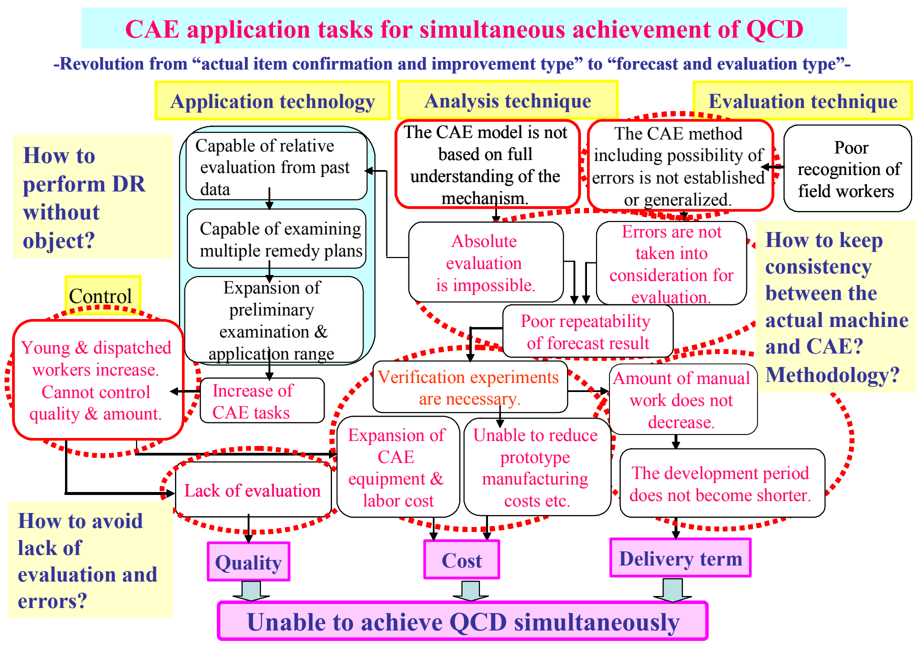

Figure 2: Problems When Applying CAE to Development Design Reform.

In order to realize the simultaneous achievement of QCD, it is necessary to enhance CAE analysis technology (Whaley *et al.*, 2000). It is therefore important to determine the mechanisms behind the main technological problems, and accurately represent them with numerical calculations (simulation) as shown in the figure. Specifically, this means that it is vital to improve CAE analysis in order to more accurately and precisely reproduce the results of prototype testing.

2.3. Effectiveness of Statistical Science in Enhancing CAE Analysis Technology

This section demonstrates the effectiveness of statistical science (Statistical Quality Control, SQC) in helping to overcome technological problems associated with the application of CAE. Research by the authors (Amasaka, *et al.*, 2008a) indicates two aspects that are important for designers and developers: (1) Intelligent CAE analysis as an idea generation support tool, and (2) Highly-accurate CAE analysis equivalent to prototype testing results. The main aims of SQC in realizing the required improvement of CAE analysis technology are summarized as follows;

I. First is variation factor analysis. In this case, many of the design factors that constitute the structure of the problem are elucidated as "empirical knowledge", and can be identified in terms of technical theory in order to solve the problem. However, there are cases where the contribution rate of these solutions can not be clarified sufficiently.

II. Second is identification and control of the principal design factors to solve the problem quickly. In this case, the structure of technological problems can be surmised in terms of technical theory, but they exist in a technological domain that encompasses multiple design factors. Therefore, it is likely that the unknown contribution rate of the design factors will need to be investigated further. Also, the countermeasure factors should be identified, and the results controlled (adjusted) by means of variation factor analysis utilizing statistical science. For statistical science analyses conducted in recent years, curve fitting (or polynomial approximation) has been utilized as an approximate means of accomplishing this.

III. Third is theoretical modeling for prediction and control in cases where the structural mechanism of the technological problems is unknown. This is most useful for finding the solution to new technological problems for which empirical knowledge or intrinsic technology is not sufficiently developed, or bottleneck technological problems which are still ongoing. In this case it is necessary to take a demonstrative scientific approach to identify the dynamic behavior at the time that the problem occurs through the use of visualization techniques. This will clarify the structure (mechanism) of the problem, and then allow for rigorous modeling of the relevant cause-and-effect relationships.

3. PROPOSAL OF HIGH QUALITY ASSURANCE CAE ANALYSIS MODEL FOR AUTOMOTIVE DESIGN AND DEVELOPMENT

3.1. High Quality Assurance CAE Analysis Model

In design and development for mass production, it is important to eradicate the repetitive trial-and-error testing of prototypes, and reform low-productivity processes by introducing the latest CAE technology. In order to achieve this, the relevant departments must strategically cooperate to accumulate the necessary know-how (Steinberg, 1996).

Therefore, rather than adhering to the old systems, the authors (Amasaka, 2008b) have proposed a High Quality Assurance CAE Analysis Model as shown in Fig. **3**, with the aim of innovating design and development processes. As shown in the diagram, the high cyclization of design and development processes is the key to realizing the quality assurance required for global production and the simultaneous achievement of QCD. Some technological challenges that must be overcome in order to achieve this are (a) Computerization of design processes, (b) Progress of design and development systems, (c) Evolution of super short-term development process, (d) Enhanced accuracy of predictive control, (e) Sharing of intelligent technology.

In order to achieve the necessary advancements in theoretical CAE analysis utilizing a High Quality Assurance CAE Analysis Model, the authors (Amasaka, 2011) have proposed the unified application and systematic, organized deployment of four closely linked core models: Total Intelligence CAE Management Model, Intelligence CAE Management Approach System Model, Highly-Reliable CAE Analysis Technology Element Model, and Highly-Reliable CAE Analysis System Approach Model. The characteristics of these four core models will be covered in more detail below.

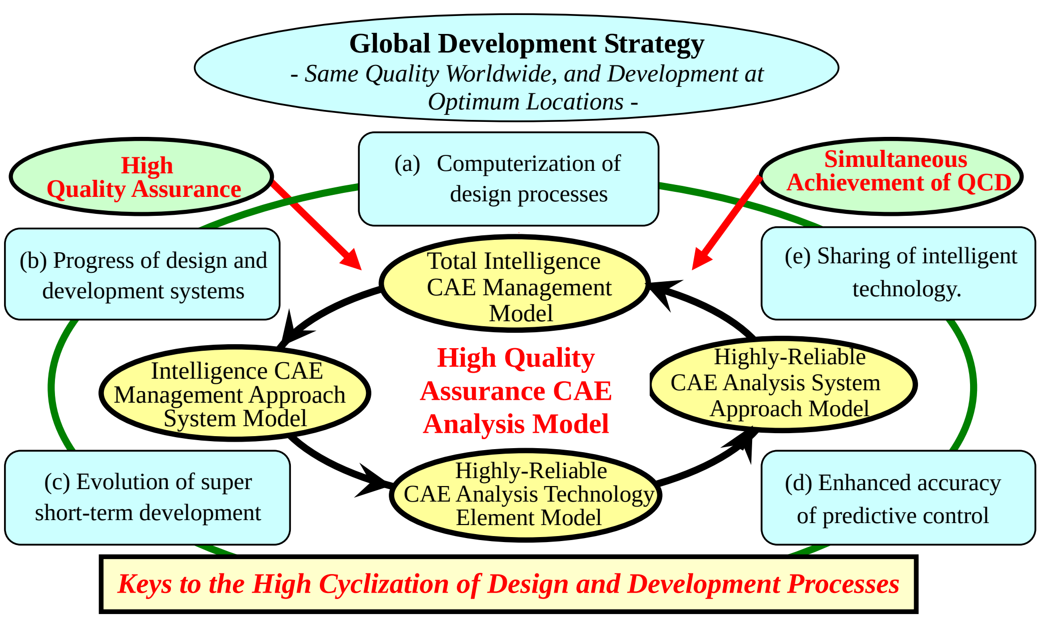

Figure 3: High Quality Assurance CAE Analysis Model for Automotive Design and Development.

3.2. Total Intelligence CAE Management Model

The aim of the Total Intelligent CAE Management Model (Stratified Intelligence CAE Development Design Model) proposed by the authors (Amasaka, 2008a) is to enable intelligent CAE analysis as an idea generation support tool, and achieve highly-accurate CAE analysis equivalent to prototype testing results as shown in Fig. **4**. Generally, at the design and development stage, there is a gap between prototype evaluation results and CAE analysis results (Magoshi, *et al.*, 2003). It has become evident that some manufacturers are not fully confident in CAE results, and prefer to conduct survey tests with actual vehicles rather than CAE analysis at Step I on the bottom layer of this Figure. This means that the application ratio of CAE is low at 15%, compared to the 75% application ratio of actual vehicle evaluation. Even among leading corporations, CAE analysis at Step II is limited to relative evaluation, and the application ratio of CAE is 50%, about the same as for actual vehicle evaluation. This is far from sufficient.

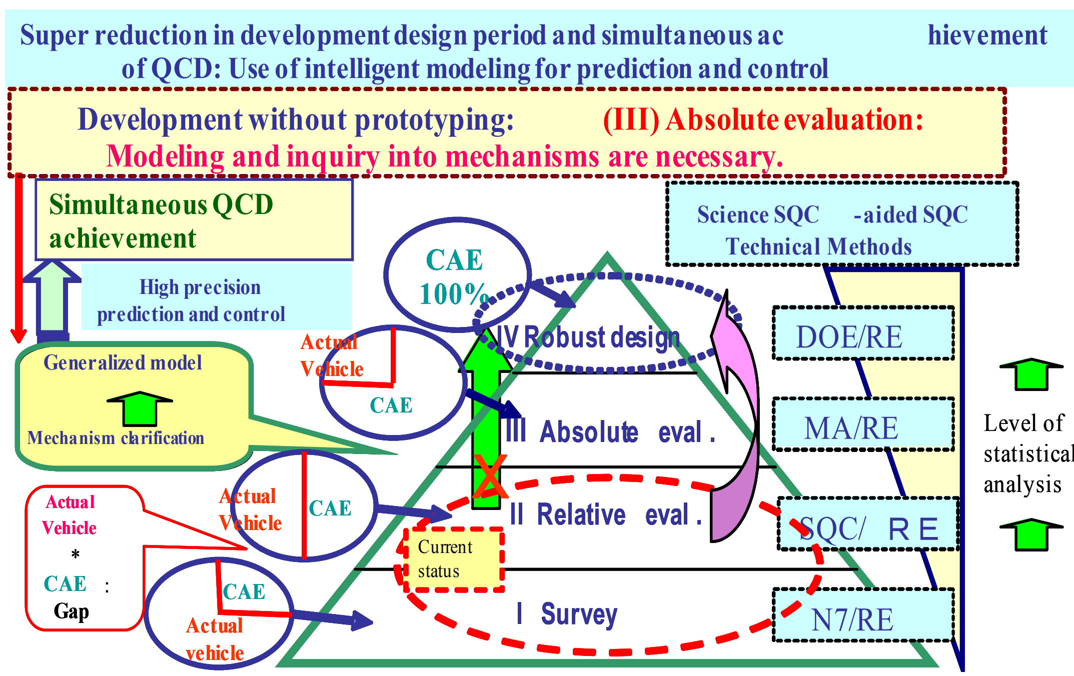

Figure 4: Total Intelligence CAE Management Model.

In order to break through this problem, the authors have utilized visualization technology and statistical science in order to clarify the mechanisms involved, and focused their attention on the results of research that contributes to improving the accuracy of CAE analysis. Then, in step III, the authors identified the causal relationships involved in bottleneck problems to create a generalized model, thereby enabling absolute evaluation. As a result, it was confirmed that the accuracy of CAE analysis had improved and the CAE application ratio had increased to 75%. In Step IV, the CAE analysis technology derived from Steps I to III was incorporated, taking into consideration the influential factors and contribution ratio needed for a robust optimal CAE design capable of producing accurate results equivalent to actual vehicle evaluation. Thus, the accuracy of prediction and control was enhanced, demonstrating a remarkable increase in the ratio of CAE application to 100%. Solving similar problems in this way has made it possible to conduct design and development and related evaluation based on the results of CAE analysis.

This means that the evaluation of actual vehicles is now used to verify results, a role previously fulfilled by CAE analysis. As shown in the figure, the authors (Amasaka, 2008a) have demonstrated the effectiveness of consistently applying statistical science at every step of CAE analysis. The authors (Amasaka, 2003, 2004) therefore strongly recommended the utilization of SQC technical methods, effectively incorporating tools such as Q7 (Seven QC tools), N7 (New seven QC tools), RE (Reliability Engineering), SQC (Statistical Quality Control), MA (Multivariate Analysis), DOE (Design of Experiment).

3.3. Intelligence CAE Management Approach System Model

Skilled CAE engineers are not generally experts in all the fields of the elemental technologies, but they understand their characteristics and interactions as “implicit knowledge” (rule of thumb, empirical knowledge), and are thus able to obtain favorable interactions and consequently the desired results by selecting and combining these technologies (Hashimoto, *et al.*, 2005). The formulation of such “implicit knowledge” confined to the personal know-how of the engineers is an indispensable step in refining CAE as a problem solving method. Thus, the intelligent CAE system approach model is a vital core model for the Quality Assurance CAE Analysis Model.

The authors (Amasaka, 2008a) have proposed the Intelligent CAE Management Approach System Model aimed at the development and intelligent operation of highly-reliable CAE software that generalizes these design and development behavior patterns and applies the aforementioned highly-intelligent CAE management model as shown in Fig. **5**. For example, in the case of the ongoing problems with market claims concerning functional failures, the causes must be established by clarifying the relevant technological problems, such as why the failures occur and what kind of mechanisms are involved.

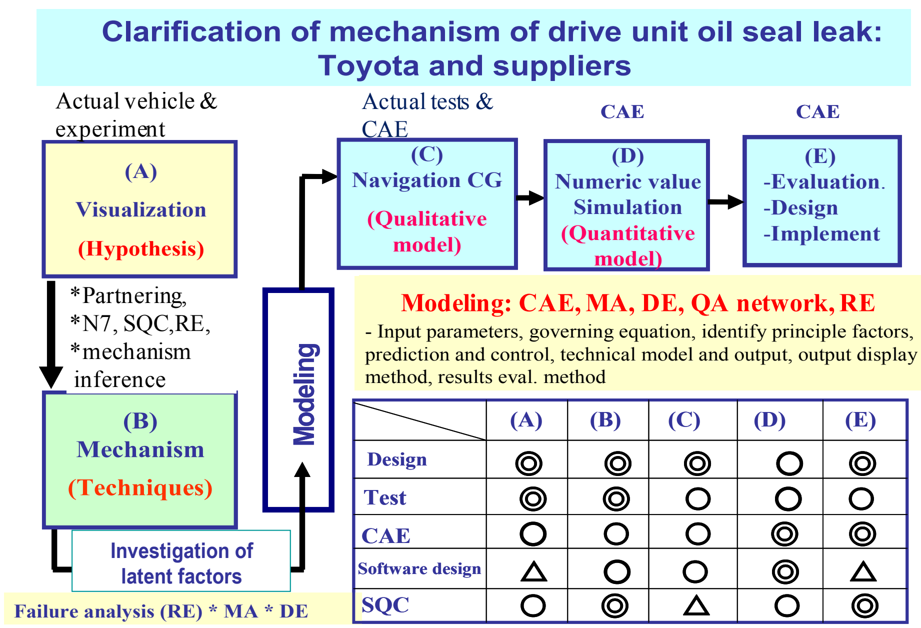

Figure 5: Intelligence CAE System Approach Model.

In order to do this, (A) the actual vehicle must be evaluated to visualize the dynamic behavior of the problems. Next, (B) it is important to cooperatively share the knowledge and know-how of internal and external specialists in order to thoroughly investigate the cause and effect relationships to clarify the mechanisms involved in the failure, utilizing the latest SQC methods. The consistent application of N7, RE, MA, and DOE is highly recommended in order to ensure accurate failure analysis and factorial analysis. Any latent factors that may have previously been overlooked must be discovered at this stage, and theoretical thought processes applied to estimate the mechanisms.

Then, (C) it is necessary to consolidate the findings and incorporate computer graphics (CG) to rationally reproduce the failure by visualizing the moment that the failure occurs (dynamic behavior) during testing. The authors then propose the use of CAE, CG, and navigation software (CAE-CG-NS) to model the problem on a qualitative level. During this CAE-CG-NS modeling stage, it is vital to conduct intelligent testing in order to properly model the cause and effect relationships involved in the unknown mechanisms. Through the use of CAE-CG-NS, it is extremely important to obtain new findings that can help to reduce the discrepancy (gap) in absolute values resulting from a combination of experiments and CAE analysis.

Furthermore, (D) at the stage of developing highly-reliable CAE software, accurate testing must be conducted in order to make the implicit knowledge of the mechanisms sufficiently explicit. It is necessary to consolidate the many findings obtained from these intelligent work processes and highly-reliable numerical simulation (quantitative modeling) to enable prediction and control through absolute values and, finally (E) validate the results through actual tests. For decentralized organizations and business processes, collective partnering through team activities (◎: main,○: sub, △: support) is indispensable among the specialists involved in design, testing, CAE analysis, CAE software development, and SQC throughout the process stages from (A) to (E) indicated in the Fig. **5**.

3.4. Highly-Reliable CAE Analysis Technology Element Model

Based on the above findings, the authors (Amasaka, 2007) have proposed the Highly-Reliable CAE Analysis Technology Element Model required for CAE analysis software in order to achieve highly-reliable CAE analysis as shown in Fig. **6**. As shown in the figure, in order to eradicate quality assurance that relies upon actual vehicle evaluation, it is vital to have a thorough understanding of the following: (1) problem setting (physically checking the actual item), (2) algorithms (calculation methods), (3) modeling (statistical calculation, model application), (4) theory (establishing theories required to clarify problems), and (5) computer (selection of calculation technology and calculators).

This figure clearly shows that there is a sufficiently wide range of options available for elemental technologies in order to introduce CAE analysis on a general level. However, from the standpoint of implementing CAE as a problem solving method on a working level, the number and wide selection of these elemental technologies is not sufficient. This may be because reliable CAE is a process consisting of multiple elemental technologies (Alba, 2005).

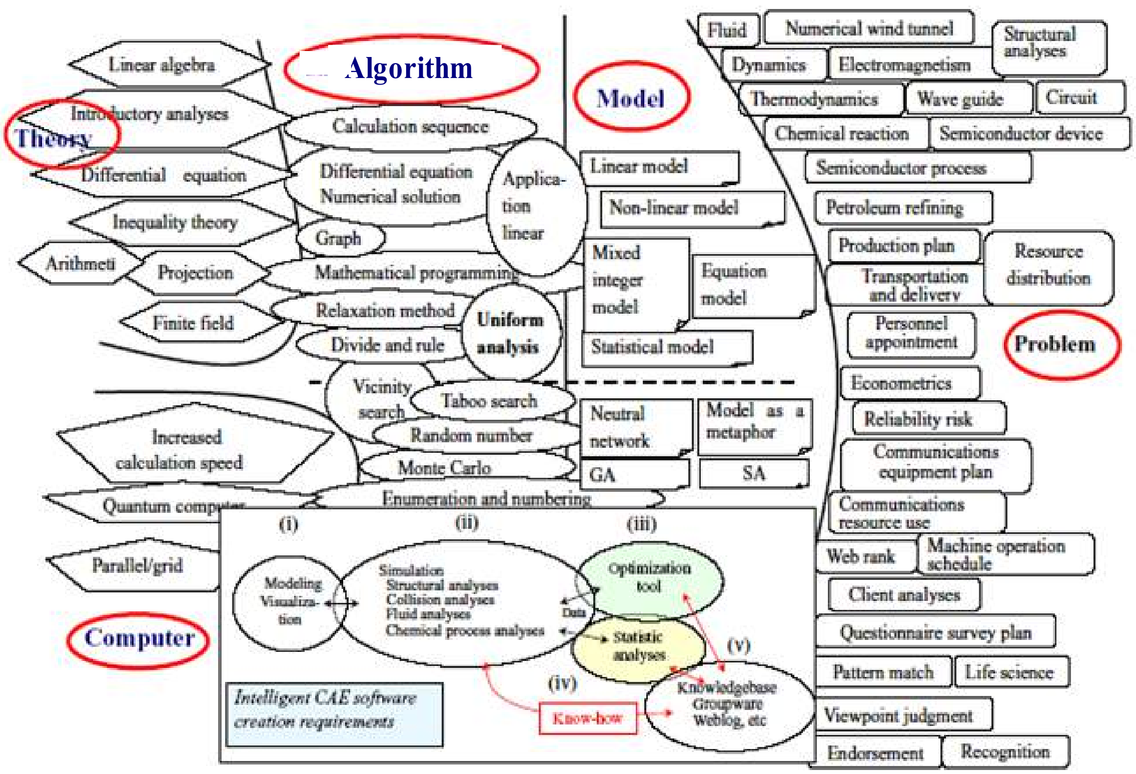

Figure 6: Highly-Reliable CAE Analysis Technology Element Model, (Problem – Model – Algorithm – Theory – Computer).

When implementing CAE analysis, (1) select the problem to be solved and then, (2) start by modeling the problem as an algorithm. Next, during actual CAE analysis, (3) use a calculator to analyze the model. However, the actual analysis method must be reproducible as software. That is to say, it must be set as an algorithm. Then, the suitability of the algorithm itself, its range of application, and performance (expected accuracy), should be indicated theoretically. (5) It goes without saying that the functionality of the calculator used to realize the algorithm will significantly influence the success of CAE analysis. The technological components that constitute the CAE analysis process must be mutually compatible, and must supplement each other's weak points. Even theoretically superior algorithms will not produce the desired results if not applied effectively on a calculator.

The performance of an algorithm also significantly affects its suitability for modeling. Even if the problem is correctly set, the algorithm will not function effectively if it is modeled incorrectly. The compatibility between the algorithm and the calculator cannot be ignored. An algorithm that makes the best use of the characteristics of the calculator will produce the best results. This means that if a suitable combination of technological elements is not used, the whole CAE analysis process will fail to function correctly. Successful CAE analysis depends on the overall capability provided by a wide range of technological components (see figure). The requirements for the business processes involved in producing intelligent CAE analysis software and its effective deployment are also vital elements.

Specifically, it is important to (i) accurately model the mechanisms of the problem, (ii) select suitable analysis methods as a basis for simulation, and (iii) select suitable tools for data analysis and apply them in conjunction with statistical analysis methods. It is also important to (iv) effectively share know-how to (v) develop a comprehensive knowledge base.

3.5. Highly-Reliable CAE Analysis System Approach Model

Thus, the authors (Amasaka, 2008b: Yamaji and Amasaka, 2008) believe that it is vital to achieve advancements in automotive design and development processes from the perspective of quality assured manufacturing. Thus they have proposed the Highly-Reliable CAE Analysis System Approach Model as shown in Fig. **7**, which incorporates numerical simulation and statistical science methods, in order to aid the intelligent operation of CAE analysis.

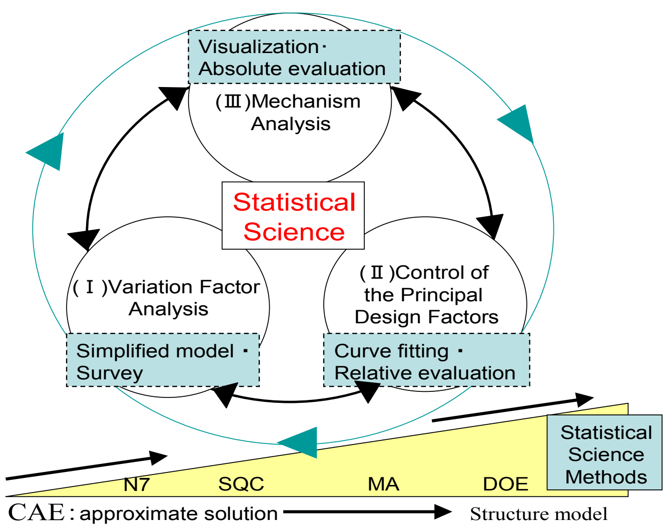

Figure 7: Highly-Reliable CAE Analysis System Approach Model.

The aim was to incorporate statistical science to accurately determine the degree of influence of the technological elements required for design and development (principal design factors), which are vital for solving technological problems, and to provide approximate solutions such as factorial analysis, identification, control, and mechanism analysis, thereby enabling accurate structural modeling (Strassburger, *et al.*, 2003: Leo, *et al.*, 2004).

The specific actions in each case are as follows;

1) Conduct variation factor analysis for cases where design specification factors are identifiable through intrinsic technology (case method-I).

2) Conduct curve fitting through neural networks and multivariate analysis for cases where the identification and control of principal design factors are technically unclear (case method-II).

3) Estimate (insight) the mechanisms involved through visualization experiments and cause-effect analysis for cases where the mechanism of technical problems is unknown (case method-III). Then, conduct both qualitative modeling (CG and navigation) and quantitative modeling (CAE and CAD).

In order to ensure the effective deployment of this model, the authors advocate the utilization of mountain-climbing for problem-solving such as "SQC Technical Methods" (New Seven Tools-N7, Reliability Analysis-RE, Statistical Quality Control- SQC, Multivariate Analysis-MA, and Design of Experiment-DOE), the core principles of "Science SQC", new quality control principle established by the author (Amasaka, 2003, 2004).

4. APPLICATION EXAMPLES

In this section, the authors present examples showing the results of research and effectiveness where the High Quality Assurance CAE Analysis Model mentioned above has been applied in solving current technological problems in automotive design and development (Amasaka *et al.*, 2010: Amasaka, 2011).

4.1. Cases Where Design Factors are Identifiable through Intrinsic Technology: Optimal CAE Anti-Vibration Design for Door Outer Mirrors

First, the authors will discuss company A's optimal CAE anti-vibration design for door outer mirrors as an example of cases where principal design factors are identifiable through intrinsic technology (case method-I).

The prevention of mirror vibration is important to ensure the field of view to the front and back of the truck, as well as to the right and left. This requires optimization of the anti-vibration structure by applying CAE at a minimum cost (simultaneous achievement of QCD) (Takeoka, *et al.*, 2008). In attempting to produce an anti-vibration design without resorting to trial and error methods, the authors (Amasaka, *et al.*, 2008) applied High Quality Assurance CAE Analysis Model utilizing SQC Technical Methods to conduct cause and effect analysis for mirror vibration based on experience and technology.

As shown in Fig. **8**, a numerical simulation was conducted utilizing statistical science in order to ensure that the CAE analysis was equivalent to prototype testing results (to search for principal design factors and optimal standards that will contribute strongly to anti-vibration measures). Then the resonant frequency that prevents mirror vibration was predicted and controlled in an effort to improve the design specifications (for weight and structure).

The steps taken to improve anti-vibration performance are as follows: (Statistical Science Review: SR1) problem establishment, (SR2) factor review (N7: factor schematic, matrix diagram, *etc.*), and (SR3) goal setting (non-resonant point over 30Hz). (SR4) At the CAE initial calculation stage, the discrepancy between the resonant frequency obtained from the experiment results and that obtained from CAE analysis was determined for the deformation mainly at three points on the mainstay holding the main mirrors, which were resonating (vibrating up and down). At the causality analyses of mirror swing (CAE numerical simulation) stage, (SR5) the factor and level setting (thickness and diameter of the mainstay and side sub-stays, five factors and interactions) were specified. (SR6) An orthogonal array experiment (L8: two standards system) was conducted and (SR7) the factors contributing most to the problem were selected.

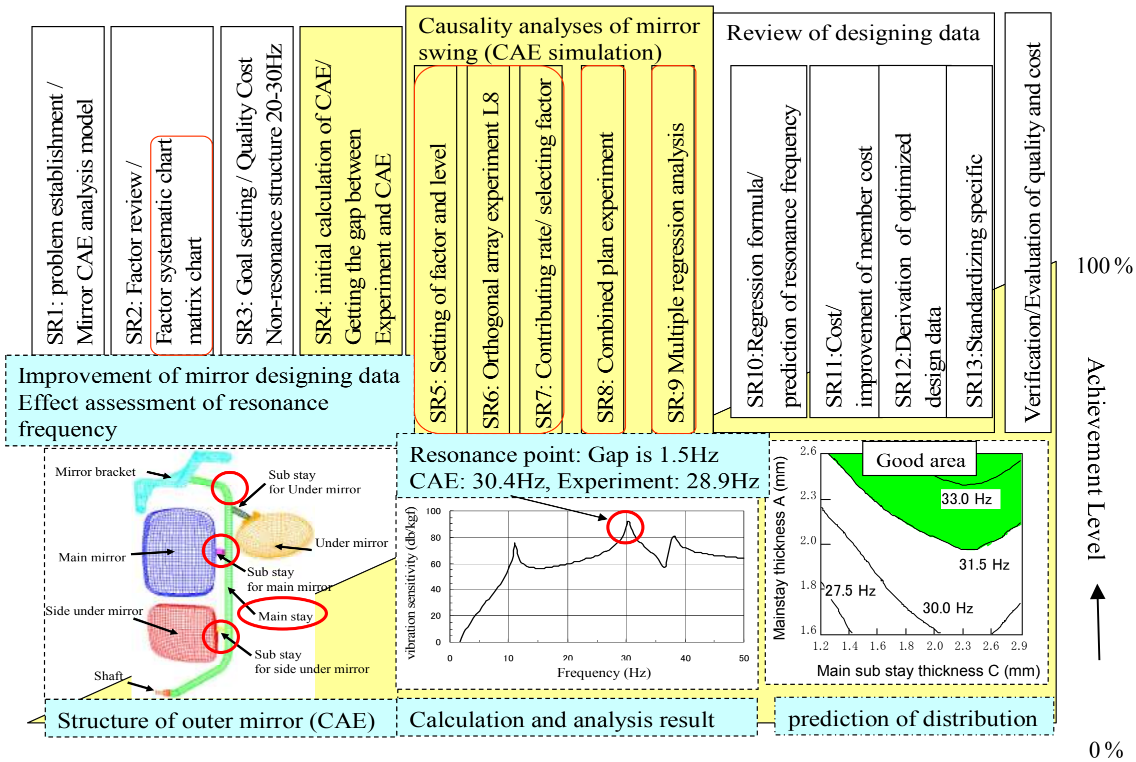

Figure 8: Optimal CAE Anti-Vibration Design Approach for Door Outer Mirrors.

Taking into consideration the secondary effects of the selected factors, (SR8) a combined plan experiment was also carried out. Using the experiment data, (SR9) multiple regression analysis was conducted for the purpose of curve fitting, taking into account the primary and secondary effects. Next, (SR10) the design specifications were examined by applying the derived regression formula. In (SR11), the aim was to balance the performance with the cost (improvement of member cost), and in (SR12) the resonant frequency contour distribution was predicted to determine the optimal design specifications (mainstay and sub-stay thickness in the figure).

By using the approach described above, (SR13) the authors succeeded in implementing scrap-and-build modifications for multiple specification stays through the application of highly-reliable CAE analysis case method-I, while enabling a balance between the performance and cost to be maintained. At the verification stage (evaluation of quality and cost), this has enabled a faster transition to the production stage and the accomplishment of simultaneous QCD by solving similar problems in the same way.

4.2. Cases Where Principal Design Factors are Unknown: Optimal CAE for Determining Vehicle Lift Characteristics with NN and Multiple Regression Analysis

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 (Examples, Tanaka, *et al.*, 1992: Robert, *et al.*, 2000).

Now, the authors (Amasaka, *et al.*, 1996, 2008) will discuss company B's optimal CAE for determining vehicle lift characteristics incorporating statistical science as an example of cases where the identification and control of design specification factors are technically unclear (case method-II). In the development and design stage, there are many cases where cause-and-effect relations are too complex to be solved only by accumulated technology. One such case involved solving a typical problem where the principal design factors required for cause and effect analysis were unclear when using intrinsic technology. The authors (Amasaka, *et al.*, 2010) modeled the identification and control of lift characteristics by testing an actual vehicle in a wind tunnel as shown in Fig. **9**.

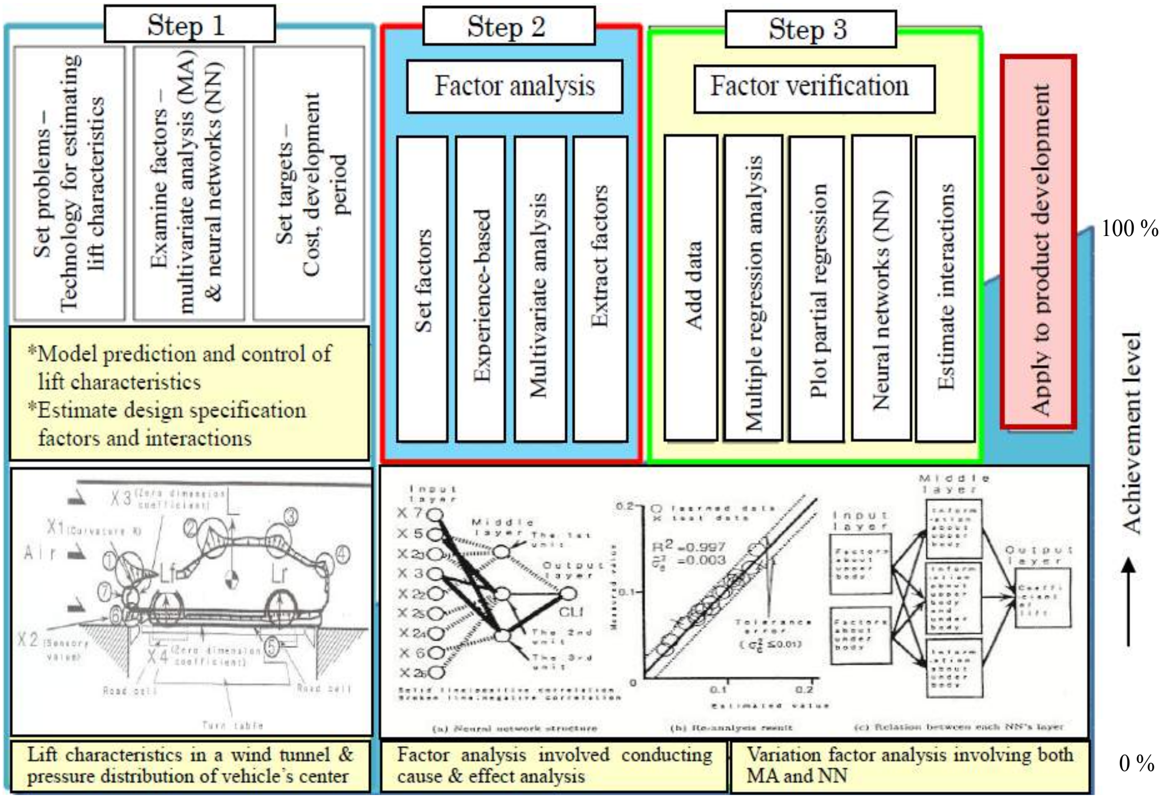

Figure 9: Optimal CAE Design Approach for Determining Vehicle Lift Characteristics.

In this case, we also built a model that enables the identification and control of lift characteristics by incorporating SQC technical methods. First, in step 1, the influence (main effects) of the main design specification factors and the presence of any interactions between them were estimated through variation factor analysis involving both multivariate analysis and non-linear regression analysis (Neural Networks) using the data obtained from the wind tunnel tests. Next, the factor analysis in step 2 involved conducting cause and effect analysis using the findings obtained and empirical knowledge to extract any new composite design specification factors.

Then, the authors determined the suitability (estimate the main effects and interactions of principal design factors) of the lift characteristics identification and control model. In step 3, the factors involved were verified and statistical analysis such as plotting partial regression and NN was carried out to create a sophisticated and practically applicable model, which was then applied to product development (model changes).

More specifically, in step 1 multivariate relational diagrams and non-linear regression analysis were used repeatedly, and residual analysis was used to ascertain the influence (non-linear effects) on the results of design specification factors (lift coefficients for front and rear wheels) incorporated through experience and technology.

Through such approaches to analysis, it was found that in addition to the upper body shape factor of the vehicle, the lower body shape factor is another relevant design factor, and the interactions between these composite factors were also identified. Through close examination of the acquired multiple regression model in step 2, the mechanisms involved were estimated using cause and effect analysis of the lift characteristics and verified by testing actual vehicles. In step 3, the findings were used to (a) conduct NN analysis with the extracted optimum principal design factors, (b) derive a model (NN calculation values) to enable lift coefficients to be predicted accurately, and (c) express (diagrammatically) the cause and effect relationships between lift coefficients and composite principal design factors.

The above findings enabled the use of an optimal CAE design approach for vehicle lift characteristics, thus achieving simultaneous QCD and contributing significantly to the solving of similar problems.

4.3. Cases Where the Mechanism of Technical Problems is Unknown: Highly-Accurate CAE Analysis for Drive Train Oil Seal Leaks

The problem is an unknown mechanism causing an oil seal leakage on the surface of the drive shaft during high-speed rotation (Lopez, *et al.*, 1997). Now, the authors (Amasaka, 2004, 2008a: Ito, *et al.*, 2009) will discuss the application of highly-accurate CAE analysis for drive train oil seal leaks through a partnership between company C (automotive assembly company) and company D (parts supply company) as an example of cases where the mechanism of technical problems is unknown (case method-III). As shown in Fig. **10**, the authors applied an optimal CAE design approach to prevent automobile oil seal leaks, incorporating SQC technical methods.

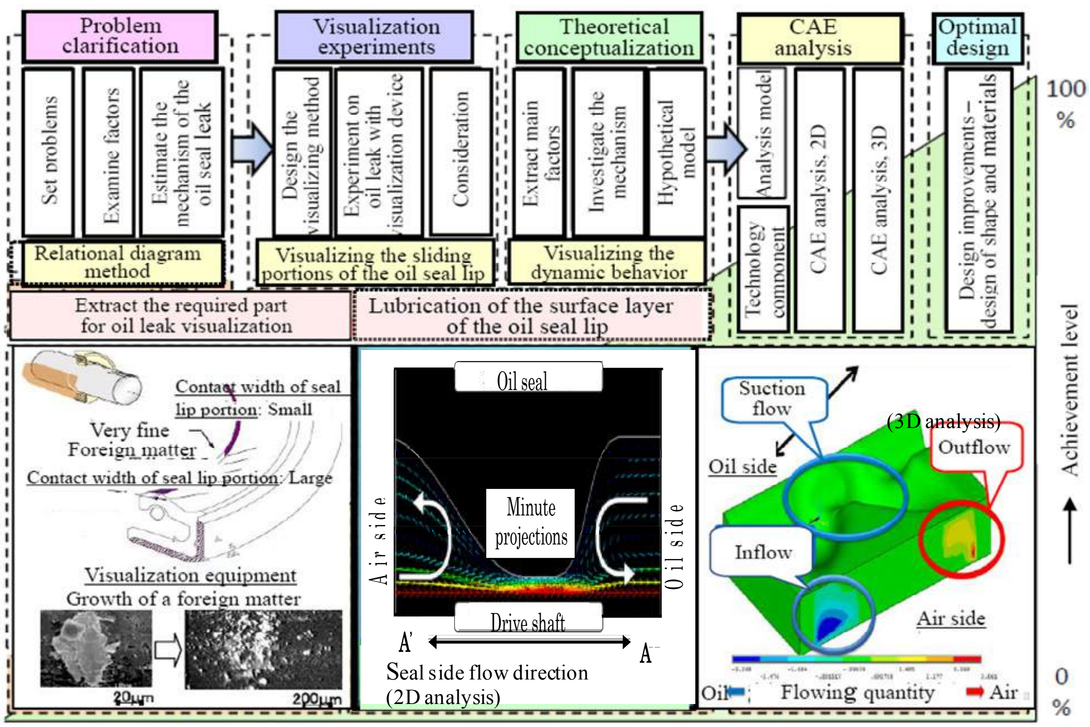

Figure 10: Optimal CAE Design Approach to Prevent Automobile Oil Seal Leaks.

As the figure shows, the authors contributed to solving the problem of drive train oil seal leaks, which is a bottleneck technological problem for automotive manufacturers worldwide. This was achieved through an analysis process involving problem clarification, visualization experiments, theoretical conceptualization, CAE analysis, and optimal design. First, the authors 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 Highly Reliable Analysis Technology Component Model for the "Oil Seal Simulator" to create highly-reliable CAE analysis software capable of accurately reproducing the oil seal leak phenomena, enabling them to be identified and controlled as shown in Fig. **11**. 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).

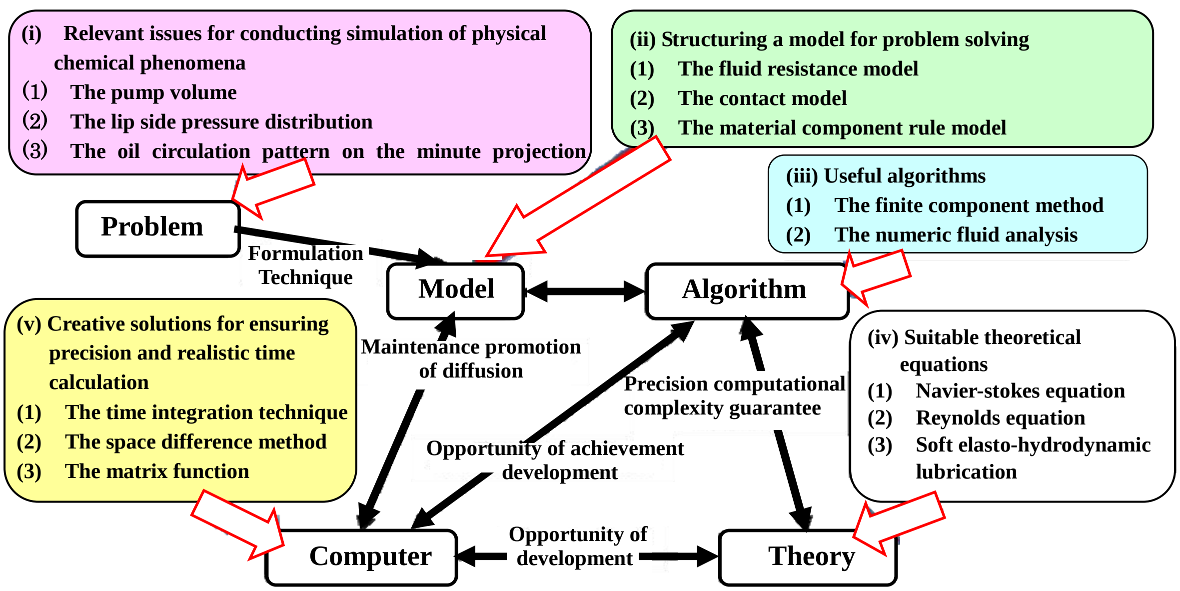

Figure 11: Highly Reliable CAE Analysis Technology Component Model of the "Oil Seal Simulator".

4.4. Results Gained from Horizontal Deployment of High Quality Assurance CAE Analysis Model

In another example of cases where the mechanism of technical problems is unknown (see section 4.3), the authors (Amasaka, 2007) have achieved substantial improvements to built-in quality within production processes by applying the High Quality Assurance CAE Analysis Model to the development of a "Urethane Foam Molding Simulator" for automobile seat pads, with the aim of greatly shortening the prototyping period and improving molding accuracy. The authors (Ueno, *et al.*, 2009) are currently also achieving substantial results through the development of a "Bolt Tightening Simulator", which has been applied to bolt-fastened sections of automobiles.

Each of these results constitutes an effective contribution to the unified application and systematic, organized deployment of the four core models of the High Quality CAE Analysis Model: Highly-Intelligent CAE Management Model, Intelligent CAE System Approach Model, Highly-Reliable CAE Analysis Technology Component Model, and Highly-Reliable CAE Analysis System Approach Model.

5. CONCLUSION

In this paper, the authors proposed a High Quality Assurance CAE Analysis Model as part of principle-based research aimed at the innovation of design and development processes to ensure quality assurance in these processes employing statistical science. The model's effectiveness has been demonstrated with application examples within the automotive industry.

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CHAPTER 10

Partnering Performance Measurement Model: Innovation Model Utilizing Science TQM - 3

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Abstract: In recent years, the management issue in the Japanese automobile industry playing a key role in Japanese manufacturing is “worldwide uniform quality and simultaneous production launch”, in response to current globalization. In order to realize this, it is vital to reinforce Japanese-style partnering, or “Japan Supply Chain Management” between automobile manufacturers and parts suppliers. Against this background, this study proposes and verifies the effectiveness of “Partnering Performance Measurement Model for Assembly Makers and Suppliers, PPM-AS”.

Keywords: Japan supply system, partnering performance measurement model.

1. INTRODUCTION

In the midst of the rapid advancement of “globalization–worldwide quality competition”, Japanese manufacturers are struggling to realize “simultaneous achievement of QCD (Quality, Cost and Delivery)”, “reduction in development periods”, “assurance of high quality” and “production at low cost”. It can be said that they are truly facing an era of new manufacturing in the process of “simultaneous achievement of QCD” (Amasaka, 2009b: Amasaka (ed.), 2007: Amasaka and Sakai, 2010).

For a total assembly industry like auto manufacturing, not only is quality management for parts and units essential, but optimizing manufacturer assembly technology, as well as assuring consistent quality from manufacturing through to sales and service, is a must. If a vehicle manufacturer or supplier wants to improve the reliability of products manufactured in-house, quality management is crucial to jointly improving the reliability of both members’ business processes. It is safe to say that cooperative activities requiring the ability to solve problems will remain important in the future.

In this corporate management environment, the “key to success in global production” is the reinforcement of product power, or the “simultaneous achievement of QCD” (Amasaka, 2008). In order to realize this, it is vital to reinforce Japanese-style partnering (Yamaji and Amasaka, 2007), or “Supply Chain Management (SCM)” between automobile manufacturers and parts suppliers. This is also called the “Japan supply system” (Amasaka, 2000).

Against this background, this study proposes “Partnering Performance Measurement Model, PPM-AS” for Assembly Makers and Suppliers and verifies its effectiveness. The purpose of PPM-AS is to formulate (or visualize) the actual status of “Japanese partnering” between automobile manufacturers and parts suppliers for clearer evaluation and diagnosis. This partnering has been somewhat implicitly carried out in the past, and it is viewed as the basis for deploying “Global SCM”.

2. SIGNIFICANCE OF STRENGTHENING THE CORPORATE MANAGEMENT OF JAPANESE AUTOMOBILE ASSEMBLY MAKERS AND SUPPLIERS

In recent years, the management issue in the Japanese automobile industry playing a key role in Japanese

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manufacturing is “worldwide uniform quality, simultaneous production launch,” in response to current globalization (Amasaka, 2004a, 2007). In this corporate management environment, the “key to success in global production” is the reinforcement of product power, or the “simultaneous achievement of QCD” (Amasaka, 2008, 2009a). In order to realize this, it is vital to reinforce Japanese-style partnering, or “partnering of competition and collaboration - Japan Supply Chain Management” between automobile manufacturers (hereafter termed “assembly makers”) and affiliated or non-affiliated parts manufacturers (hereafter termed “suppliers”) (Amasaka, 2008, 2009a). This is also called the “Japan Supply System,” as shown in Fig. **1**.

For further advancement in this area, Assembly Makers should not only reinforce internal partnering with their own operational departments (such as engineering, production, and sales), but must also strengthen “external partnering”. This means establishing cooperative relationships with other companies while advancing and establishing “global partnering” through strategic collaboration with both foreign and domestic Suppliers. In order to implement such reinforcements, it is fundamental that a new “Partnering Performance Measurement” be deployed. This measurement should serve as a formulation model (radar chart for visualization) for evaluating the actual status of “Japanese Partnering” between Assembly Makers and Parts Suppliers, which has been somewhat implicitly carried out in the past.

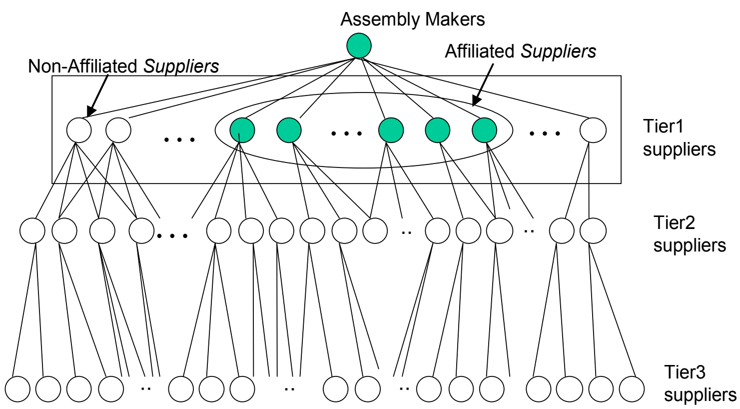

Figure 1: Japan Supply System.

3. “PPM-AS”, PARTNERING PERFORMANCE MEASUREMENT FOR ASSEMBLY MAKERS AND SUPPLIERS

According to a survey conducted by the authors (Yamaji, *et al.*, 2007), assembly makers in general assessed that they are “performing SCM with their Suppliers well overall”. On the other hand, suppliers’ answers indicate that they are “not necessarily conducting SCM the way they would like to with some of their assembly makers”, revealing a difference in evaluation, or so-called “disparity (deviation or gap) in evaluator awareness”. These SCM evaluations are often based on the evaluators’ own implicit empirical knowledge, and (as far as the authors know) evaluation scales are not usually shared (formulated as a model) between them. The authors therefore attempt to “formulate evaluation causes and effects” that account for the difference in implicit evaluations on both sides - the so-called “gap in awareness”. They then attempt to carry out “diagnosis through visualization methods” by utilizing “Science SQC, New Quality Control Principle” (Amasaka, 2004b).

Under such a circumstance, there are many studies abroad for globalization (Gabor, 1990, Lagrosen, 2004; Ljungström, 2005; Manzoni and Islam, 2007) and SCM (Joiner, 1994; Taylor and Brunt, 2001; Pires and Cardoza, 2007). According to the authors’ investigation, a quality management survey (JUSE, 2006) is being jointly conducted by Nihon Keizai Shinbun and the Union of Japanese Scientists and Engineers. It targets 528 corporations, mainly manufacturers, and does not cover the topic of partnering with Suppliers. The OEM-Supplier Working Relations Index (WRI) (Milo Media, 2006) defines the relationship between

Automobile Manufacturers and their Suppliers using index numbers, but specific evaluation items are not indicated.

Against this background, this study proposes PPM-AS, Partnering Performance Measurement for Assembly Makers and Suppliers (Yamaji, *et al.*, 2007). In connection with the PPM-AS proposal, the authors propose (1) “PPM-A”, Partnering Performance Measurement Model for Assembly Makers and (2) “PPM-S”, Partnering Performance Measurement for Suppliers. The authors also integrate the two and propose (3) “PPM-AS”, Partnering Performance Measurement Model for Assembly Makers and Suppliers, as a comprehensive “Dual Performance Measurement” to be shared by both.

3.1. Preparation of Evaluation Sheets for “PPM-A”, PPM-S”, and “PPM-AS”

The authors extracted “evaluations of cause and effect elements” necessary for the preparation of the three types of evaluation sheets (“PPM-A”, “PPM-S”, and “PPM-AS”), based on the response of staff members engaged in practical affairs at SCM-related departments (both Assembly Makers and Suppliers). More specifically, evaluators from related departments on both sides were given a survey. The questions (evaluation sheet) are shown in Table **1**. The survey comprised of a total of 19 evaluation factors (Factor X_1 to X_{19}, with evaluation contents) extracted from an affinity diagram. The diagram was made based on meetings with Assembly Makers and Suppliers.

1) Evaluators of Assembly Makers

Toyota Motor Corporation (Sales div. 1, Production Preparation div. 2, TQM Promotion div. 1), Hino Motors Ltd. (Procurement div. 1, TQM Promotion div. 1), Fuji Heavy Industries Ltd. (TQM Promotion div. 1, Procurement div. 2), Honda Motors Co., Ltd. (Quality Assurance div. 1), Nissan Motor Co., Ltd. (Procurement div.1), GM (Procurement div. 1), Ford (TQM Promotion div. 1).

2) Evaluators of Suppliers.

Jatco (Quality Assurance div. 2), JFE (Quality Assurance div. 2, Procurement div. 1), NHK Spring Co., Ltd. (Quality Control div. 1, SQC Promotion div. 1).

Table 1: Evaluation Sheet

Factor	Contents	Factor	Contents
X_1	Corporate strategy	X_{11}	Price setting considering labor
X_2	Bias in selection of Suppliers	X_{12}	Parts inspection standards
X_3	Selection of affiliated Supplier	X_{13}	Parts inspection items
X_4	Weakening of group affiliation	X_{14}	Response to recalls
X_5	Weight of Suppliers’ opinion	X_{15}	Response to contractual failure
X_6	Spirit of cooperation	X_{16}	Ability to improve
X_7	Appropriate evaluation	X_{17}	Technical capabilities
X_8	Considerate relation	X_{18}	Total satisfaction rate
X_9	Demand on discounting	X_{19}	Gained technology and know-how
X_{10}	Methods of price setting		

3.2. Formulation Model of “PPM-A”, “PPM-S” and “PPM-AS”

Using this evaluation sheet, the authors attempted to derivate a formulation model that incorporated multivariable statistical analysis. First, “cause and effect relationships” were extracted by conducting cluster analysis (Ward method and Euclidean distance squared) and principal component analysis. Next, using categorical canonical correlation analysis, formulation models for "PPM-A", "PPM-S" and "PPM-AS" were derived, while coefficients of each group's factors were calculated and a radar chart was designed for each group. One hundred (100) was set as the highest score.

3.2.1. Derivation of PPM-A

PPM-A for Assembly Makers was derived, with the results of cluster analysis and principal component analysis shown in Figs. **2** and **3**. Based on these results, evaluation factors could be categorized into five elements: "Supplier Follow-up", "Degree of Quality Inspection", "Corporate Capability", "Supplier Decisions", and "Price Setting".

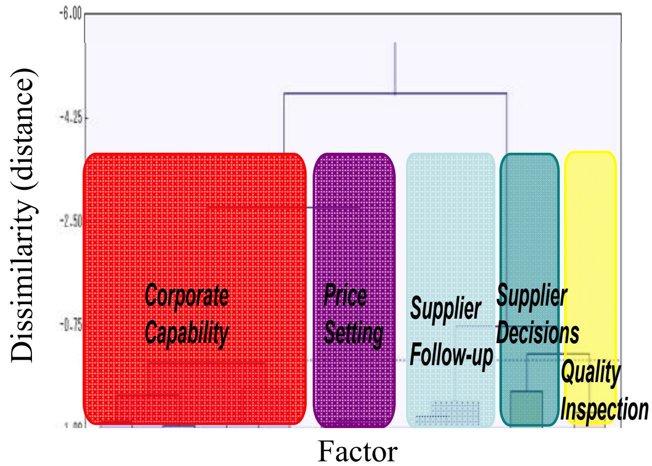

Figure 2: Grouping by Cluster Analysis.

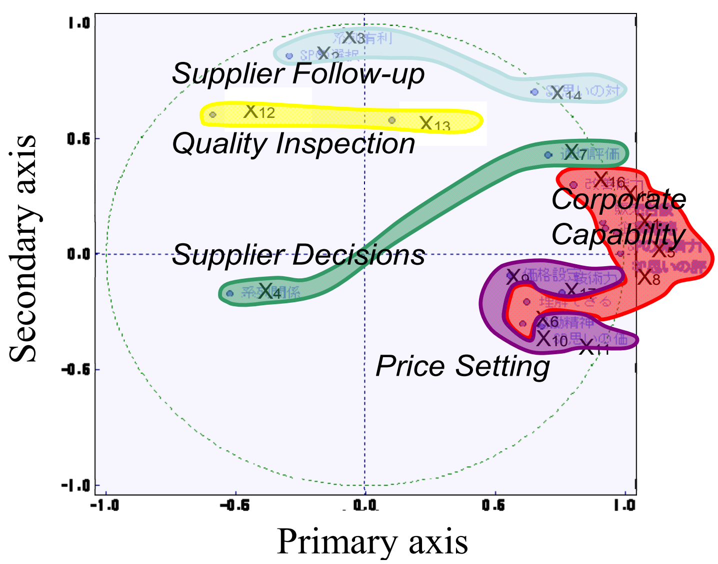

Figure 3: Grouping by Principle Component Analysis.

Consideration was then given to "PPM-A, PPM-S, and PPM-AS" so that formulation models could be derived. With that in mind, categorical canonical correlation analysis was conducted, employing optimum scaling methods in an effort to grasp the relationship between the five evaluation elements and seventeen evaluation factors. Calculation was conducted for "PPM-A" using evaluation element axes (a) through (e). The weighted coefficients shown here were calculated based on component loading values for each of the five evaluation elements, resulting in a full score of 100 points.

a) Supplier Follow-up = $5.24X_4 + 8.86X_7$

b) Quality Inspection = $2.28X_{12} + 12.01X_{13}$

c) Corporate Capability = $1.91X_1 + 2.44X_{16} + 1.85X_6 + 2.46X_{17} + 1.89X_5 + 1.81X_8 + 1.91X_{15}$

d) Supplier Decisions = $5.39X_2 + 7.23X_3 + 1.67X_{14}$

e) Price Setting = $6.80X_9 + 5.84X_{10} + 1.64X_{11}$

Using the above equations, evaluation points for each of the five evaluation elements were calculated and visualized in a radar chart, as seen in Fig. **4** Ex.

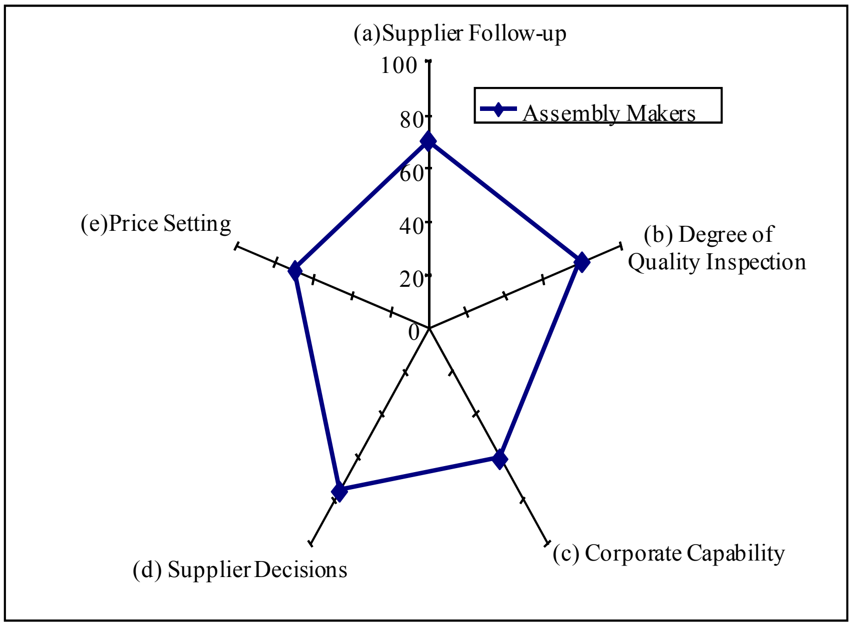

Figure 4: PPM-A Radar Chart Ex.

3.2.2. Derivation of PPM-S

Derivation was conducted in a similar way for Suppliers' PPM-S. As a result, the relationship between the five evaluation elements [(f) Assembly Maker Follow-up, (g) Degree of Quality Inspection, (h) Corporate Capability, (i) Spirit of Cooperation, (j) and Price Setting] and the seventeen evaluation factors was grasped. Calculation was conducted for "PPM-S" using the five evaluation element axes (f) through (j).

f) Assembly Maker Follow-up = $5.83X_1 + 5.59X_4 + 2.75X_{14} + 0.12X_{15}$

g) Quality Inspection = $1.54X_{12} + 12.75X_{13}$

h) Corporate Capability = $5.23X_2 + 2.27X_3 + 1.34X_7 + 0.63X_{16} + 4.81X_{17}$

i) Spirit of Cooperation = $6.46X_5 + 3.26X_6 + 4.56X_8$

j) Price Setting = $4.17X_9 + 5.41X_{10} + 4.70X_{11}$

Using the above equations, evaluation points for each of the five evaluation elements were similarly calculated and visualized by a radar chart, as shown in Fig. **5** Ex.

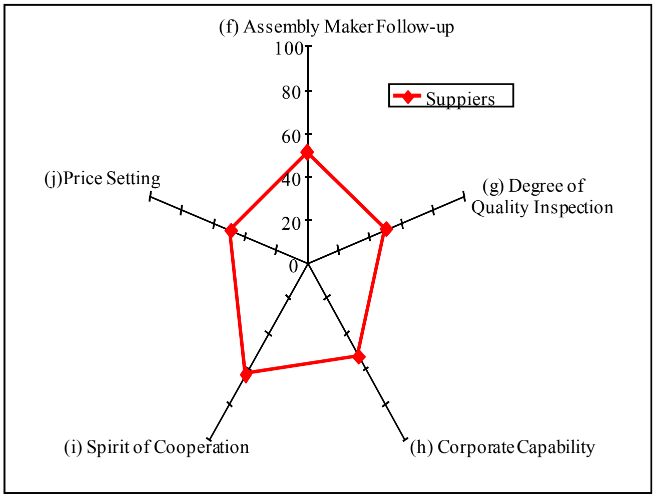

Figure 5: PPM-S Radar Chart Ex.

3.2.3. Derivation of PPM-AS

PPM-AS was derived in order to visualize the gap in the evaluations of both sides. This was done by closely comparing the evaluation measurements of PPM-A and PPM-S. Corporations using PPM-AS can see the gap between their evaluations and those of their Suppliers at a glance. This allows conventional subjective evaluation based on each side's empirical rules to be converted into objective analysis, while also clarifying specific problems using the component evaluation factors.

One of the features of the PPM-AS formulation model is the overlapping of the five evaluation element axes of PPM-A and PPM-S. This is due to the fact that both PPM-A and PPM-S thus far consist of five evaluation elements and seventeen evaluation factors. The three axes of Quality Inspection, Corporate Capability and Price Setting are common to both, allowing these elements to be overlapped for direct comparison. In addition, the two new axes, "Assembly Manufacturer Follow-up" and "Supplier Follow-up" are integrated to create a new axis of "Spirit of Mutual Support". Similarly, "Spirit of Cooperation" and "Supplier Decisions" are integrated to establish a new axis of "Relationship with Business Partners".

As a result, these evaluation elements, made up of (k) Spirit of Mutual Support, (l) Degree of Quality Inspection, (m) Corporate Capability, (n) Relationship with Business Partners and (o) Price Setting are visualized in a radar chart (Fig. **6**). The Figure presents example evaluations of Assembly Makers and Suppliers.

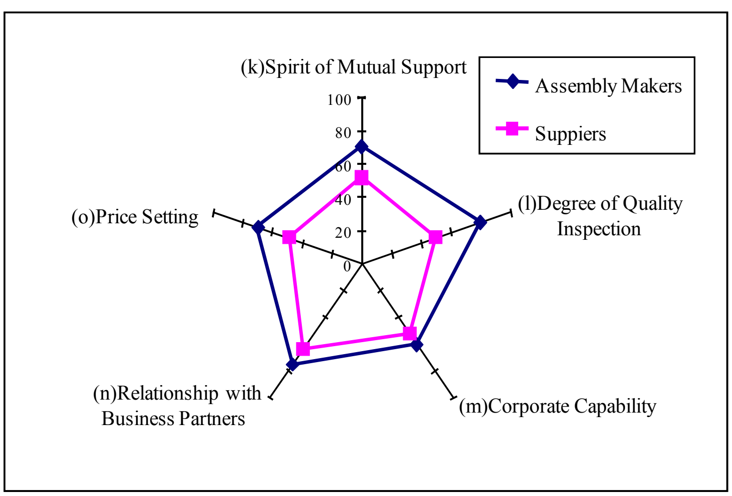

Figure 6: PPM-AS Radar Chart Ex.

4. VERIFICATION OF "PPM-AS"

The authors applied the proposed PPM-AS to three Japanese Assembly Makers (Toyota Motor Corporation and Nissan Motor Co., Ltd.), one overseas Assembly Manufacturer (General Motors), and two Suppliers (Jatco and NHK Springs Co., Ltd.). Its effectiveness was thereby verified. As pointed out in Chapter 3, it can be generally confirmed that Assembly Makers' evaluations are higher than those from Suppliers. Suppliers' evaluations are more severe than the Assembly Manufacturer evaluations assume.

Below are examples of PPM-AS evaluations at various corporations.

4.1. Toyota Motor Corporation

Survey results used for verification are shown in Table **2** (Toyota Motor Corporation), Table **3** (NHK Springs Co. Ltd. (hereafter, NHK)) and Fig. **7** (Toyota and NHK) based on the evaluation sheet in Table **1**. The evaluation example of Toyota Motor Corporation and NHK Springs Co., Ltd. is further described in Fig. **8**. As the figure indicates, evaluations on both sides are generally high. There are no large differences between elements, but a slight gap can be observed in Spirit of Mutual Support and Price Setting.

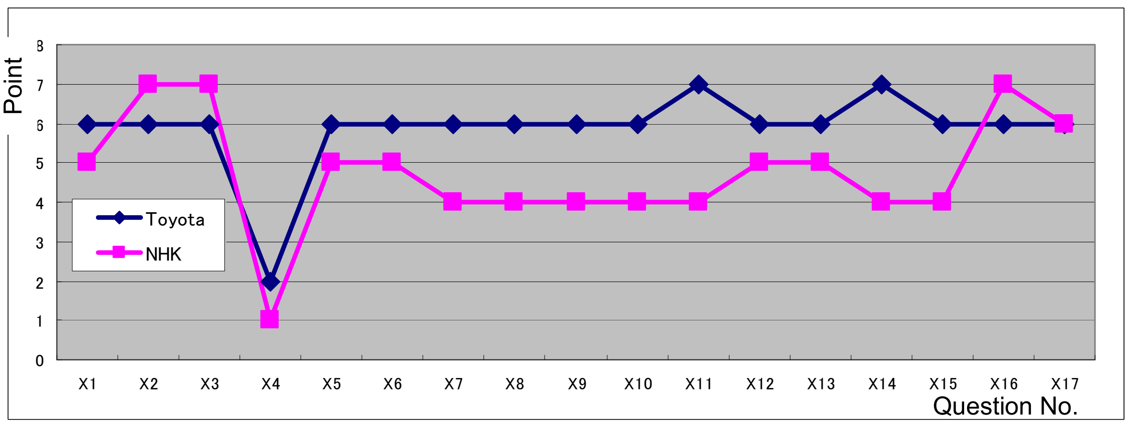

Figure 7: Questionnaire Result of Toyota and NHK.

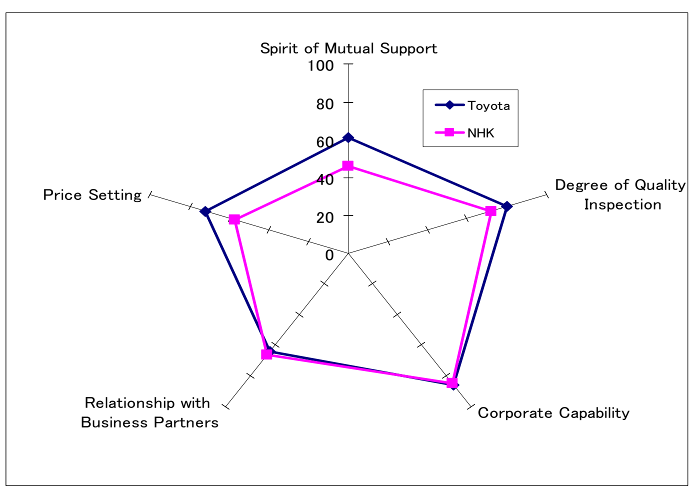

Figure 8: Radar Chart of Toyota and NHK.

Below is an interpretation of the obtained evaluation results. NHK's low evaluation in Price Setting and Spirit of Mutual Support stems from thorough cost price reduction carried out by Toyota, based on the company's Customer First principle. However, there is almost no gap is in the Relationship with Business

Partners category. NHK evaluates Toyota's attitude towards problem-solving and QCD improvement highly, and these activities are carried out with mutual support. Therefore, NHK names Toyota as the corporation they would most like to do business with.

Table 2: Evaluation Sheet of Toyota

	Excellent	Very Good	Good	Fair	Poor	Bad	Very Bad
Corporate strategy	7	6	5	4	3	2	1
Bias in selection of Suppliers	7	6	5	4	3	2	1
Selection of affiliated Supplier	7	6	5	4	3	2	1
Weakening of group affiliation	7	6	5	4	3	2	1
Weight of Suppliers' opinion	7	6	5	4	3	2	1
Spirit of cooperation	7	6	5	4	3	2	1
Appropriate evaluation	7	6	5	4	3	2	1
Considerate relation	7	6	5	4	3	2	1

Table 3: Evaluation Sheet of NHK

	Excellent	Very Good	Good	Fair	Poor	Bad	Very Bad
Corporate strategy	7	6	5	4	3	2	1
Bias in selection of Suppliers	7	6	5	4	3	2	1
Selection of affiliated Supplier	7	6	5	4	3	2	1
Weakening of group affiliation	7	6	5	4	3	2	1
Weight of Suppliers' opinion	7	6	5	4	3	2	1
Spirit of cooperation	7	6	5	4	3	2	1
Appropriate evaluation	7	6	5	4	3	2	1
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1

4.2. Nissan Motor Co., Ltd.

The evaluation example of Nissan and Jatco is shown in Fig. **9**. One outstanding feature is a generally lower evaluation than in the case of Toyota above. Gaps can be observed in both Price Setting and Corporate Capability. These results can be interpreted as showing partnering activity that is not necessarily based on mutual trust, thus generating gaps in Price Setting and Corporate Capability.

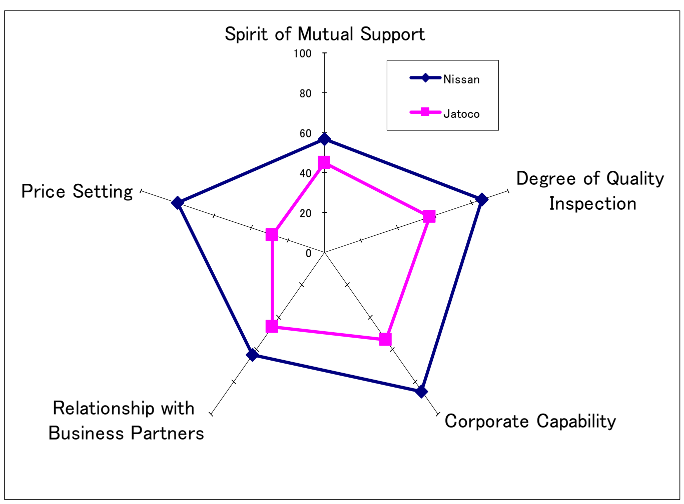

Figure 9: Radar Chart of Nissan and Jatco.

4.3. General Motors

Fig. **10** shows the examples of GM and Jatco. Characteristic of these results is a large gap in the relationship between Price Setting and Relationship with Business Partners. This is because Jatco cannot fully respond to GM's severe, one-sided demands regarding QCD. This leads to a gap in awareness regarding good business partnerships based on mutual trust. Similarly, evaluation was implemented in Fuji

Heavy Industries Ltd. and Honda Motors Co., Ltd., and the expected results were obtained with regard to its effectiveness.

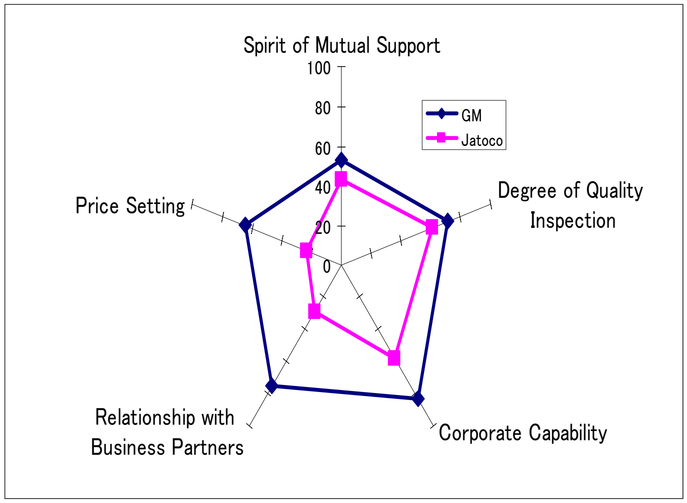

Figure 10: Radar Chart of GM and Jatco.

5. CONCLUSION

This study proposed "PPM-AS, Partnering Performance Measurement for Assembly Makers and Suppliers". The purpose of PPM-AS is to formulate (or visualize) the actual status of "Japanese partnering" between automobile manufacturers and parts suppliers for clearer evaluation and diagnosis. This partnering has been somewhat implicitly carried out in the past, and it is viewed as the basis for deploying "Global Supply Chain Management". This measurement method allowed visualization of gaps in Assembly Manufacturer and Supplier evaluations of partnering among affiliated companies. The evaluation was implemented in advanced companies, and the expected results were obtained with regard to its effectiveness.

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CHAPTER 11

Change in Marketing Process Management: Strategic Development of Science TQM - 1

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Abstract: The purpose of the “Total Marketing System, TMS” is to aid changes in marketing process management by correctly identifying customer demands, conducting proper business and sales activities and implementing “Customer Science” to contribute to merchandise development. As an example application study using “Science SQC”, the author established the “Toyota Sales Marketing System, TSMS”, an intelligent customer information network system, to improve the repeat customer ratio for Toyota vehicles. The achievements of the present study are currently being applied at Netz Chiba and other Toyota dealers.

Keywords: Science TQM, total marketing system, customer science, science SQC, CAID and cramer’s analysis, toyota sales marketing system, toyota.

1. INTRODUCTION

Having predicted the state of manufacturing in the next generation, the author proposed Science TQM as the principle of scientific quality management to enhance the key axis of Total Quality Management (TQM) activities. To apply the proposed “Total Marketing System, TMS” which is the core principle of “Science TQM, New Quality Management Principle”, to the business and sales activities, the author demonstrates its effectiveness through Toyota’s new TQM activities aimed at developing innovate ways to build ties with customers.

As an example application study, “Science SQC, New Quality Control Principe” is used to enable the scientific application of customer information utilization software for Toyota user information, and the intelligent development and application of a customer information network is discussed. Concretely speaking, the study deals with the subject of improving the sales rate for replacement Toyota vehicles, which involves setting up Toyota Netz dealers in a model case.

Categorical Automatic Interaction Detector (CAID) and Cramer’s analysis is used to identify characteristics and variations in customer orientation through the analysis of user questionnaire data. Accordingly, specific models are developed for customers of high replacement probability. Next, the knowledge thus obtained is used to generate specific measures for increasing sales through customer retention (CR) based on customer type, enabling the construction of the Toyota Sales Marketing System (TSMS), an intelligent customer information network system. The achievements of the present study are currently being applied at Netz Chiba and other Toyota dealers.

2. BACKGROUND - NEED FOR A MARKETING STRATEGY WHICH CONSIDERS MARKET TRENDS

Today’s marketing activities require more than just short-term strategies, such as 4P (Product, Price, Place and Promotion) activities by the business and sales divisions. After the collapse of the bubble economy, the competitive environment in the market has drastically changed. Since then, companies that have implemented strategic marketing quickly and aggressively have been the only ones enjoying continued

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Kakuro Amasaka (Ed)

growth (Okada, *et al.*, 2001). After close examination, it was said that strategic marketing activities must be conducted as company-wide, core corporate management activities that involved interactions between divisions inside and outside of the company (Jefferey, *et al.*, 2005).

Therefore, a marketing management model needs to be established so that Business/Sales/Service divisions, which are carrying out development and design for appealing products projects, and which are also in the closest position to customers, can organizationally learn customers' tastes and desires by means of the continued application of objective data and scientific methodology (James & Mona, 2004: Shimakawa, *et al.*, 2006). However, at present, the organizational system has not yet been fully established in these divisions; in some cases, even the importance of this system has not been commonly realized (Niiya, *et al.*, 2001: Gray, *et al.*, 2003: Ikeo, 2006).

3. CHANGES IN MARKETING PROCESS MANAGEMENT EMPLOYING TMS

3.1. Role and Expectations of TMS

To create attractive, customer-oriented products to meet customers' satisfaction, the various divisions of a manufacturer must share a common language, ensuring unity and proper direction. This is necessary for all divisions, including business, sales, service, planning, development, design, production engineering, manufacturing, logistics, administration and management. Thus, the author (Amasaka, 2004, 2008) proposed "Science TQM, New Quality Management Principle" having five core principles - Total Marketing System (TMS), Total Development System (TDS), Total Production System (TPS), Total Intelligence Management System (TIS) and Total Job Quality Management System (TJS) - as a new principle for manufacturers' TQM activities in the next generation.

Fig. **1** shows a conceptual diagram that indicates expectations for the new core technology of Total Marketing System **(**TMS), which is the core principle of Science TQM facilitating new TQM activities of the business and sales divisions. These activities include: (a) market creation activities through collection and utilization of customer information; (b) strengthening of merchandise power based on the understanding of elements required for products to retain their value; (c) establishment of marketing systems from the viewpoint of building ties with customers; and (d) realization of a customer information network for CS (Customer Satisfaction), CD (Customer Delight) and CR (Customer Retention) elements needed for the corporate attitude (behavioral norms) to enhance customer values.

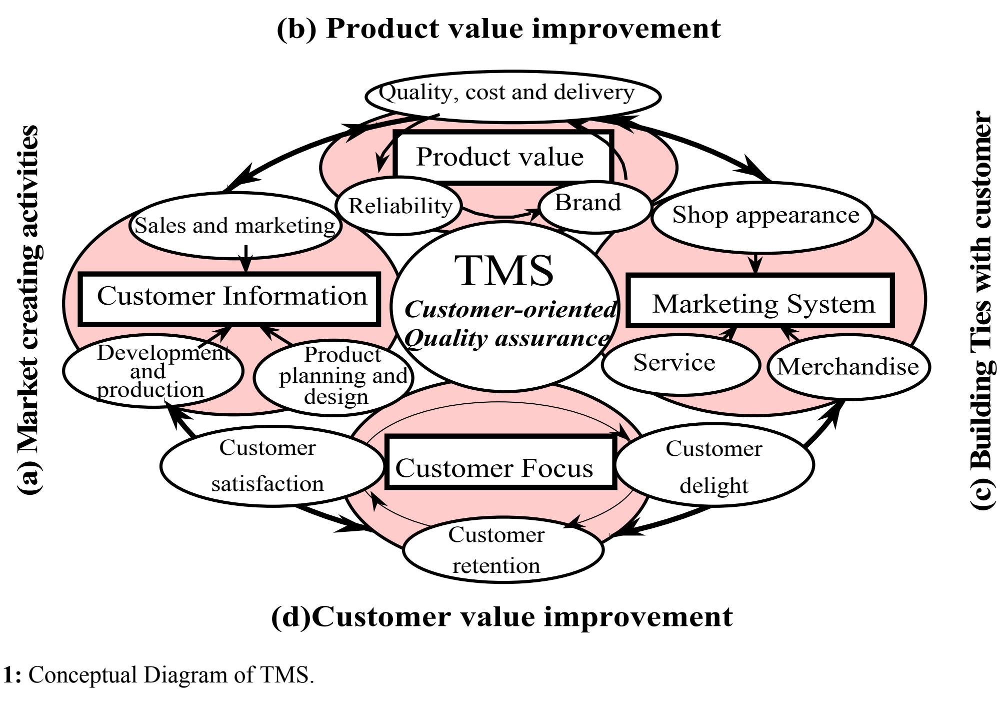

Figure 1: Conceptual Diagram of TMS.

3.2. Need for Customer Science using Science SQC

The author (Amasaka, 2005) proposed Customer Science so as to contribute to systematizing the TMS as shown in Fig. **2**. To plan and provide customers with attractive products is the mission of enterprises and the basis of their existence. It is particularly important to convert customers' opinion (implicit knowledge) to images (linguistic knowledge) through market creation activities, and to accurately reflect this knowledge in creating products (drawings, *etc.*) using engineering language (explicit knowledge).

This refers to the conceptual diagram that rationally objectifies subjective information (y) and subjectifies objective information ($\hat{y}$) through application of correlation technology. Thus, the author (Amasaka, 2003) applies the "Science SQC, New Quality Control Principle" having four core principles – "Scientific SQC", "SQC Technical Methods", Integrated SQC Network "TTIS" and "Management SQC" - for strategic development of Science TQM, which is designed to develop Customer Science in the business and sales divisions as a change in marketing process management as shown in Fig. **3**.

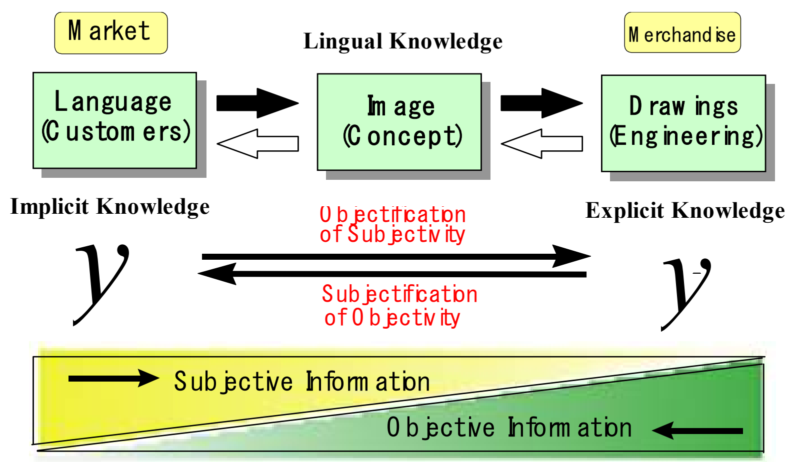

Figure 2: Conceptual Diagram of "Customer Science".

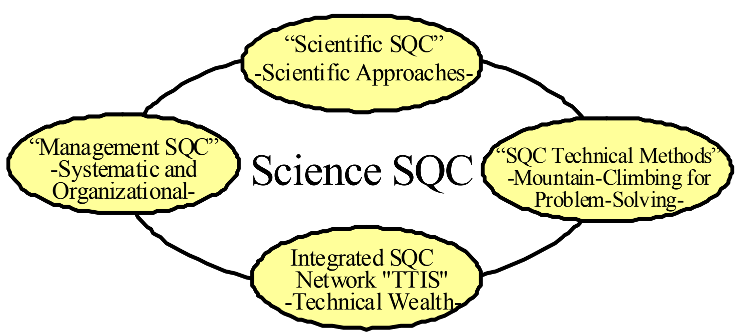

Figure 3: Science SQC, New Quality Control Principle.

4. IMPORTANCE OF INNOVATING DEALERS' SALES ACTIVITIES

Considering recent changes in the marketing environment, it is now necessary to implement innovation of business and sales activities to accurately grasp the characteristics and changes of customer preferences independently of convention. Contact with customers has never called for more careful attention and practice.

For example, it is now more important to construct and develop an intelligent customer information network that systematically improves know-how related to the application of customer information software with respect to users of various vehicle makes. This information network turns customer management and service into a science by utilizing Science SQC according to customers' involvement with their vehicles in daily life.

To realize the innovation of business and sales activities as shown in Fig. **4**, the following three factors are important: merchandise, shop and selling power, and shop appearance and operation. Of these three factors, (a) innovation for building ties with customers is particularly important in innovating shop appearance and operation. It constitutes the base for the innovation of (b) business negotiation, (c) employee images, and (d) after-sales service (Amasaka, *et al.*, 1998).

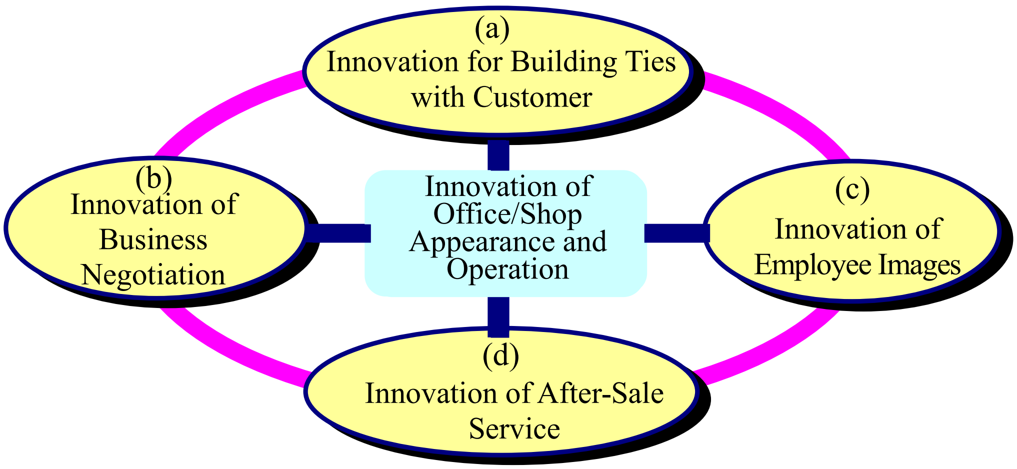

Figure 4: Innovate the Business and Sales Activities.

5. ESTABLISHMENT OF TOYOTA SALES MARKETING SYSTEM

As an example of research studies for innovating the mode of business and sales operation, the author established an intelligent customer information network system called the "Toyota Sales Marketing System, TSMS" to improve the repeat customer ratio for Toyota vehicles. The achievements of the present study are currently being applied at Netz Chiba and other Toyota dealers (Amasaka, *et al.*, 1998: Amasaka, 2001a).

5.1. Trial for Increasing Sales through CR based on Customer Type

The author implemented Customer Science to enable increased sales through customer retention (CR) based on customer type. For a model case, two TOYOTA A-dealers (Netz Chiba and one other) were selected and sales activities were enhanced by developing specific models for customers with a high probability of replacing their Toyota vehicle.

Concretely speaking, this is a change from the current customer information-based uniform CR method to a CR method based on customer type for stratifying customers by ascertaining their orientation and/or changes from a wider area of selection of the conditions.

5.2. Practical Studies on Science SQC

The author solves problems by using scientific approaches such as "Mountain climbing for problem-solving" (development of specific models for customers of high replacement probability) following the steps from (i) to (ix) shown in Fig. **5**. This involves application of SQC Technical Methods (demonstrative scientific methods using a combination of new seven tools (N7), multivariate analysis (MA), experimental design (DE), *etc.*), which is one of the core techniques of Science SQC (Amasaka, 2003).

In steps (i) and (ii) shown in the figure, consideration was given to the development of specific models for high replacement probability customers as shown in Fig. **6**, an "Application type" association diagram. The aim was to increase sales through CR based on customer type, and the tools used include the N7 (affinity diagram, relation diagram, process decision program chart (PDPC), *etc.*). Then, in step (iii), a scenario of implementation plans for about a year was established.

In steps (iv) through (vi), the graphical Categorical Automatic Interaction Detector (CAID) analytical method (Amasaka, 2001a) was implemented. This method has been developed as the new multivariate analysis, and was necessary for the qualitative and categorical data analysis required for questionnaire design, implementation and analysis. Based on the information thus obtained, models were established for high replacement probability customers.

In the next step (vii), the sales method capable of deploying CR based on customer type was obtained using the Cramer's analysis of attribute correlation as the base for developing the customer information network system in step (viii). In the final step (ix), the scenario at Netz Chiba was examined as the basis for deployment to all Toyota dealers for the establishment of TSMS

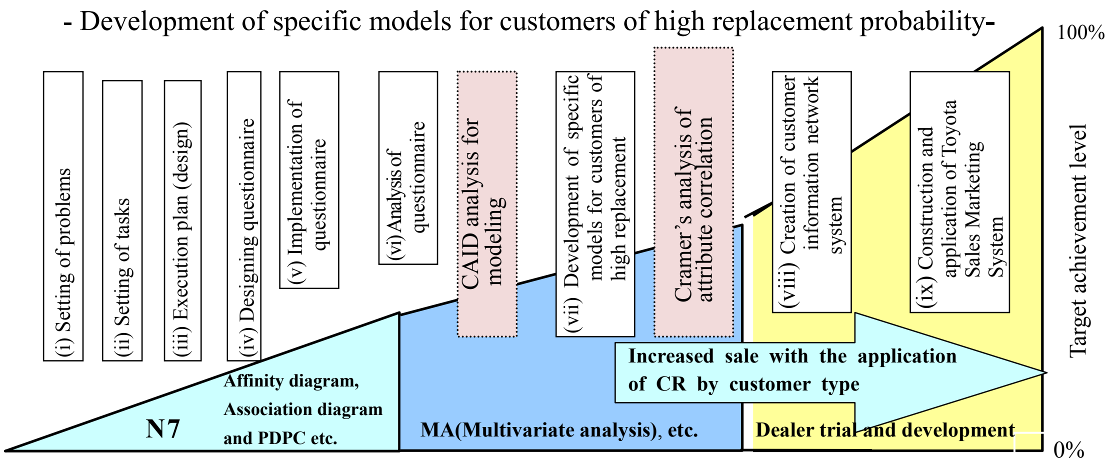

Figure 5: Mountain Climbing for Problem-Solving.

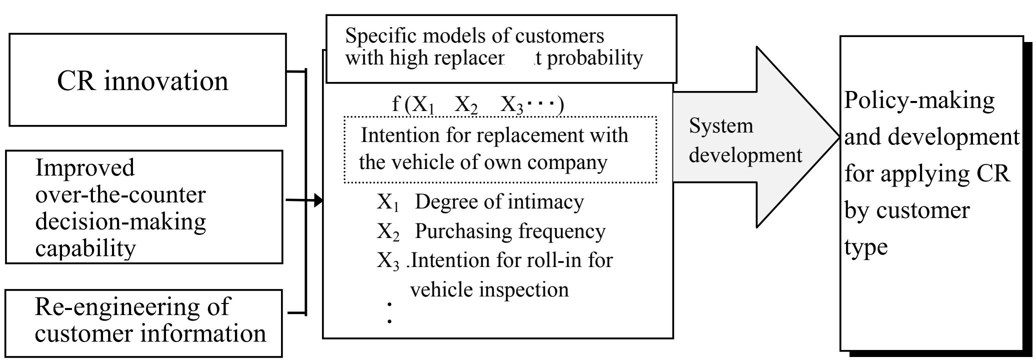

Figure 6: "Application Type" Association Diagram (Step (i)-(iii)).

5.3. Development of Specific Models for High Replacement Probability Customers

5.3.1. Objective and Explanatory Variable for the Planned Questionnaire Form

1) Objective variable: Intention to replace with Toyota vehicle: (Yes, No).

2) Explanatory variable: Records of roll-in (oil change, inspection and maintenance, fault repair, accident repair, vehicle inspection), number of new cars purchased, referral for new car purchase, voluntary insurance contract, degree of intimacy, degree of Toyota card usage, sex, age, *etc.* (categories 3 to 6).

5.3.2. Four Measures to Achieve Design and Implementation of Effective Questionnaire

Prior telephone notification was given to 4,000 customers who bought new Toyota vehicles within the five years on the planned questionnaire. To improve the recovery rate of the questionnaire, a simply-designed questionnaire was adopted with one section of questions laid out on one page as shown in Table **1** (Case-1). The subjects were required to answer methodically within about 15 minutes. Furthermore, introduction of a Questionnaire Information Box helped raise the recovery rate to over 40% (normally 20%) and the valid reply ratio to 98% (normally 70%).

Table 1: Example of Questionnaire Form (Case-1) Designing and Implementation of Questionnaire

We like to inquire on the after-sales services of your dealer.

Q1: Please let us know the present state of the maintenance, fault, repair and other your vehicle-related after-sales service (please give us an answer for each item from ① to ④).

	①Dealer used	②Reason for using	③Method of payment	④Method of roll-in
1. Oil change (please name a principal shop / station you use)	1. Dealer you purchased a new vehicle from 2. Other dealer 3. Vehicle maintenance service shop 4. Car shop 5. Gas station 6. Other ( )	1.Because of acquaintance 2. High level of technique 3. Low price 4. Privilege offered 5. Nearness of location 6. Other ( )	1. Cash 2. TOYOTA CARD 3. Other cards 4. Other ( )	1. Drive to the shop 2. Have the vehicle picked up 3. Other ( )
2. Inspection and maintenance service of your vehicle (Please name a principal shop you use)	1. Dealer you purchased a new vehicle from 2. Other dealer 3.Vehicle maintenance service shop 4. Car shop 5. Gas station 6. Other ( )	1.Because of acquaintance 2. High level of technique 3. Low price 4. Because of guidance 5. Nearness of location 6. Other ( )	1. Cash 2. TOYOTA CARD 3. Other cards 4. Other ( )	1. Drive to the shop 2. Have the vehicle picked up 3. Other ( )
3. Repair service of fault of your vehicle (please name a principal shop you use)	1. Dealer you purchased a new vehicle from 2. Other dealer 3.Vehicle maintenance service shop 4. Car shop 5. Gas station 6. Other ( )	1. Because of acquaintance 2. High level of technique 3. Low price 4. Good attending attitude 5. Nearness of location 6. Other ( )	1. Cash 2. TOYOTA CARD 3. Other cards 4. Guarantee 5. Other ( )	1. Drive to the shop 2. Have the vehicle picked up 3. Other ( )
4. Repair service of your vehicle after an accident (please name a principal shop you use)	1. Dealer you purchased a new vehicle from 2. Other dealer 3.Vehicle maintenance service shop 4. Car shop 5. Other ( )	1. Because of acquaintance 2. High level of technique 3. Low price 4. Good attending attitude 5. Nearness of location 6. Other ( )	1. Cash 2. TOYOTA CARD 3. Other cards 4. Guarantee 5. Other ( )	1. Drive to the shop 2. Have the vehicle picked up 3. Other ( )
5. Next vehicle inspection (what type of service shop would you select?)	1. Dealer you purchased a new vehicle from 2. Other dealer 3.Vehicle maintenance service shop 4. Car shop 5. Other ( )	1. Because of acquaintance 2. High level of technique 3. Low price 4. Because of guidance 5. Nearness of location 6. Other ( )	1. Cash 2. TOYOTA CARD 3. Other cards 4. Other ( )	1. Drive to the shop 2. Have the vehicle picked up 3. Other ( )
6. Purchase of a new vehicle (what type of shop would you select to purchase from?)	1. A shop you purchased your present car from 2. A shop other than one you purchased your present car from 3. Other ( )	1. Because of acquaintance 2. Sales staff is enthusiastic 3. Good attending attitude 4. Using the shop for the check-up and maintenance service of your vehicle 5. Good purchasing condition 6. Other (	1. Cash 2. Installment 3. Lease 4. Other ( )	1. Drive to the shop 2. Have a sales staff come to see me 3. Other ( )

5.3.3. Analysis of Questionnaire with CAID and Cramer's Analysis of Attribute Correlation etc

After analysis of the questionnaire data, the results of analysis of causal relations were indicated graphically to accurately show the proposed measures and decision-making process that led to increased sales through the application of CR based on customer type. Then, CAID analysis (Murayama, *et al.*, 1982: Amasaka, 2001a) and Cramer's analysis of attribute correlation (Perreault, *et al.*, 1980) was applied to enable collation using empirical rules to form analysis I and analysis II as follows.

1. Analysis I:

Analysis I involves arranging customers having a high-probability of replacement with Toyota vehicles into a model using intelligent CAID analysis. Factors affecting replacement by high-probability customers are rearranged in the same manner as the variable designation method of multi regression analysis. This is conducted repeatedly based on empirical techniques of the staff and managers of business/sales divisions (so as to match their experience).

Then, the characteristics and changes in the customers' orientation are ascertained on the basis of actual contact with customers. Customers are stratified into customer types (customers of high, medium and low repeat business probabilities) from the customer CR point of view.

2. Analysis II:

Analysis II involves conducting factorial analysis using "creation of ties with customers" as the key point to map out our business and sales policies. In practice, correlation among influential factors is extracted by the intelligent CAID, including the degree of intimacy and roll-in for vehicle inspection and all other question items using the Cramer's analysis of attribute correlation.

For example, factors which improve the degree of intimacy with customers are identified from the sales activity and after-service activity viewpoints, aimed at deployment for sales policies.

5.3.4. Analytical Result with CAID (Analysis I; from Step vi to Step vii)

Fig. **7** shows the legends of the analytical results. Analysis **a** in the figure indicates that 62% of 1,610 users who answered the questionnaire intend to replace their vehicles with a Toyota vehicle, while 38% do not. Next, analysis **b** is the division by the primary influential factor of the "degree of intimacy". The upper setting of having "intimacy" (customers having good acquaintance with sales staff) indicates that 75% intend to buy Toyota for replacement, and the lower setting of having "no intimacy" (customers not having good acquaintance with the sales staff) indicates that 48% intend to buy Toyota. The difference between them is as much as 27%.

Thereafter, **c** indicates the analytical result for users who bought Toyota for the first time and those for two times and over (no significant difference among 2nd to 5th time purchasers). Similarly, analysis **d** stratifies the users by the "intention for roll-in for vehicle inspection service". From this figure it is known that 90% of customers of level 1 (regular customers) indicated in the top position of **d** intend to buy a Toyota vehicle for replacement. The Fig. **7** combines customer types of whom 70% intend to buy Toyota (**b, c** and **d**) on customer levels 1 through 3 (regular customers), and classifies them as customers of high probability.

Likewise, customer types of whom 50% intend to buy Toyota on the customer levels 4 through 7 (customers) are classified as customers of medium probability. Customers on level 8 are classified as customers of low probability since they fail to hold a majority. The author does not discuss other influential factors (such as **e**: introduction, **f**: sex, and so forth) where difference is noted between two dealers (Netz Chiba and Netz Ehime).

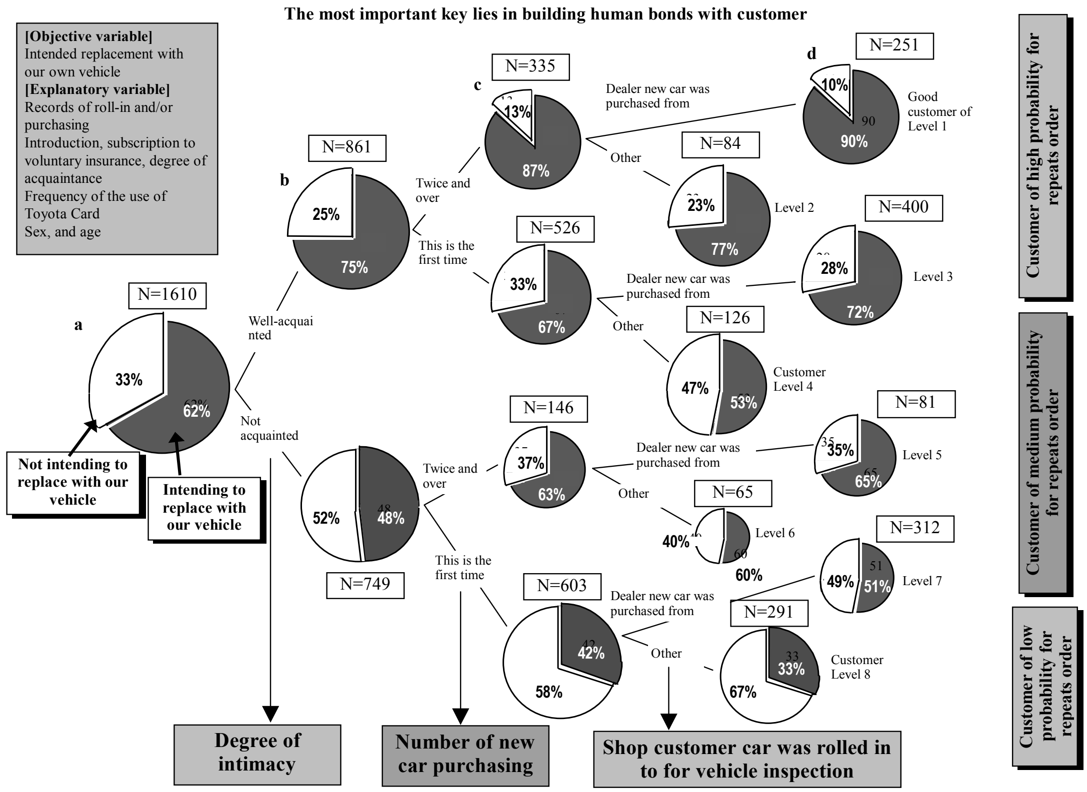

Figure 7: CAID*[1] Analysis (Step (vi)) *[1]: Multiple Cross-section Analysis (Categorical Automatic Interaction Detector).

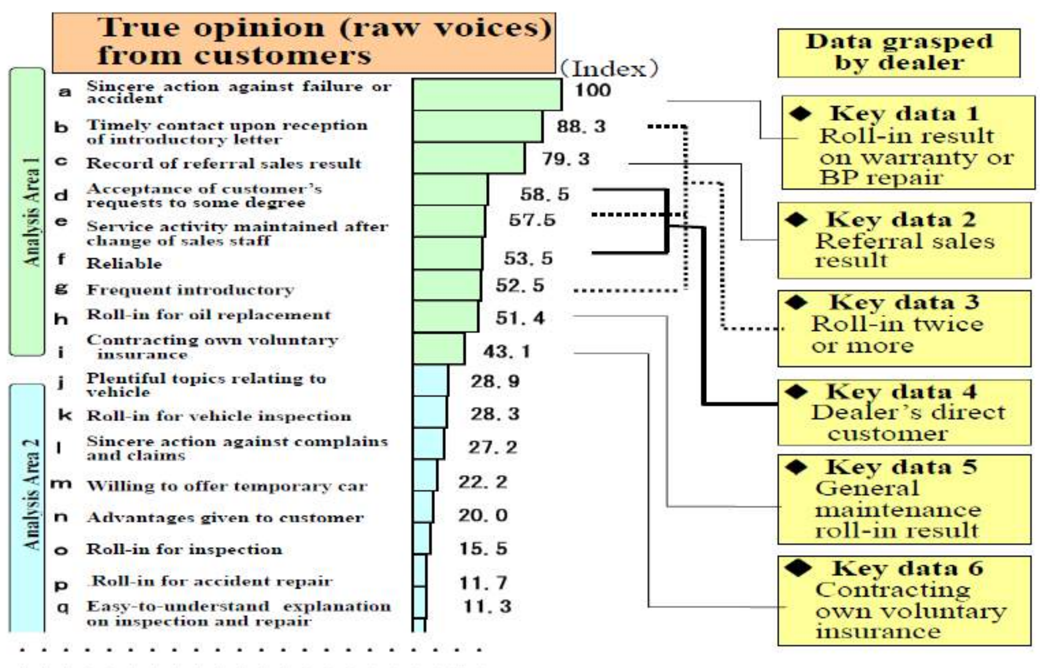

Figure 8: Factor Analysis of Cramer's Analysis of Attribute Correlation (Example of Degree of Intimacy).

5.3.5. Analytical Result with Cramer's Analysis of Attribute Correlation (Analysis II: from Step vii to Step viii)

Practical and detailed analysis is conducted from the sales policy standpoint aimed at increasing the frequency of contact with customers. Here, the correlation between the degree of intimacy extracted in step (vi) and all other questions is explained using a factor and result diagram based on the Cramer's analysis of attribute correlation as shown in Fig. **8**. Area 1 in the figure contains factors a through i influential to the degree of intimacy and area 2, factors j through w affecting the roll-in destination for vehicle inspection. "Index" in the figure represents the customer information numerically.

For example, the 0.14 of "sincere action against failure or accident" is an index when the Cramer's factor correlation coefficient is assumed to be 100. It is technically possible to correlate all factors in area 1 with the 6 key data shown in the figure. Based on the information obtained as a result of these analyses, practical policies can be established for promoting sales and after-service activities capable of improving the degree of intimacy with customers who can be handled by a dealer.

The information can also be used for simulation for sales expansion, which is the basis of innovation for creating strong contact between the dealer and its customers.

5.3.6. Construction and Application of Toyota Sales Marketing System (TSMS)

Fig. **9** illustrates the Toyota Sales Marketing System reflecting the contact between dealer and customers based on the information obtained above and containing the practical policies for sales and service activities in step (ix) of Fig. **5**.

For practical application, the questionnaire in step (vi) is reanalyzed at trial stages of the system in steps (vii) and (viii) of Fig. **5** in order to ensure replacement by Toyota vehicles by adding the following strategies.

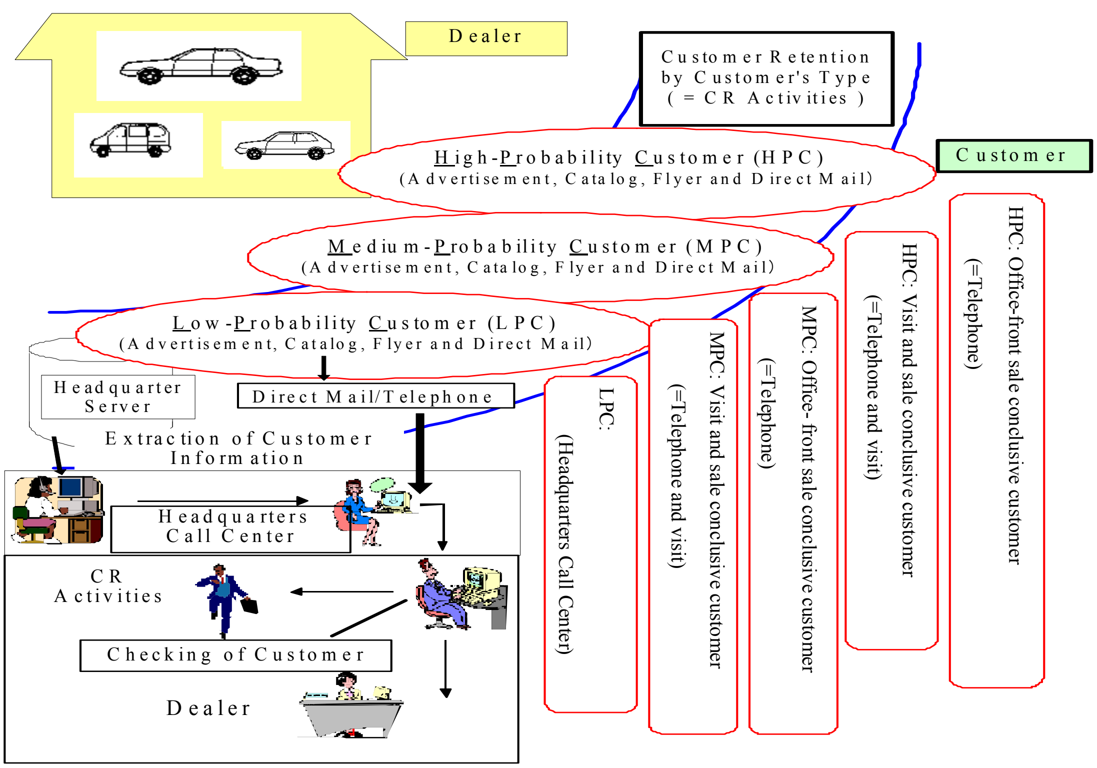

Figure 9: Schematic Drawing of "Toyota Sales Marketing System".

1) The CR activities based on customer type are adopted by classifying high- and middle-probability customers into those who visit the shop and those who must be visited by our staff, taking characteristics at new car purchase into account.

A system is established so that the shop manager directly receives "Medium-Probability Customers (MPC)" upon their visit to the shop without fail in order to promote visits to the shop by "High-Probability Customers (HPC)". Thus, the frequency of contact with customers is increased.

Further, sales and service activities focus on telephone calls for customers who visit the shop, and telephone calls and home visits for those who require visits by our staff, as shown in the Fig. **9**.

2) As for "Low-probability customers (LPC)" who have less contact with the sales staff, a telephone call center is established within the dealer as shown in the Fig. **9** 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 publications, advertisements, catalogs, fliers and direct mail. As expected, excellent results have been reported at Netz Chiba and other Toyota dealers who introduced this system by applying the Toyota Sales Marketing System constructed as above.

In parallel to this study, the author (Amasaka, 2001b, 2007: Kojima, *et al.*, 2010: Ishiguro, *et al.*, 2010) recently studied so called "Database Marketing" where the effects of publications, advertisements, catalogs, fliers and direct mail are quantitatively analyzed to enable effective support for this system. The application of TSMS has recently contributed to an increase in the sales share of Toyota vehicles in Japan (40% in1998 to 46% to 2008) (Nikkei Institute, 2009).

6. CONCLUSION

In applying the proposed Total Marketing System (TMS) to aid changes in marketing process management, the author demonstrated its effectiveness through Toyota's new TQM activities aimed at developing innovate ways to build ties with customers.

As an example application study, Science SQC was used to enable the scientific application of customer information utilization software for Toyota user information. More specifically, the author took up the subject of improving the sales rate for replacement Toyota vehicles. This involved setting up Toyota Netz dealers in a model case.

Employing CAID and Cramer's analysis, the author used user questionnaire data to identify characteristics and variations in customer orientation. This enabled the development of specific models for customers of high replacement probability.

The knowledge thus obtained was then used to establish specific measures for increasing sales through customer retention (CR) based on customer type and construct the Toyota Sales Marketing System (TSMS), an intelligent customer information network system.

The achievements of the present study are currently being applied at Netz Chiba and other Toyota dealers.

ACKNOWLEDGEMENTS

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CHAPTER 12

Evolution of Development Design Process Management: Strategic Development of Science TQM – 2

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Abstract: This paper focus on a strategic development of "High Quality Assurance CAE Analysis *Model*" to be used in development design, then proposes an "Optimal CAE Design Approach Model" that can be used to shorted development design times and improving quality. The model is then used to analyze "cavitation caused by metal particles in the automotive transaxle" and to clarify the technological mechanism generating oil leaks as a result of foreign metallic substances entering oil seals in the drive train.

Keywords: High quality assurance CAE analysis model, optimal CAE design approach model, oil seal leaks, automotive transaxle.

1. INTRODUCTION

Inrecent years, the advanced manufacturing industry has been faced with the urgent task of drastically reduced their development design times in order to respond quickly to changing consumer needs. One of the most important challenges for manufacturers is strengthening and enhancing computer-aided engineering (CAE) of analysis in order to achieve quality development design processes that are also very brief (Amasaka, 2007a, 2008, 2010a, 2010b).

To address these issues, the author conducted research on an Optimal CAE Design Approach Model utilizing "*Advanced TDS, Total Integrated Development Design Model*". In this study, the author addresses the technological problem of oil seal leakage in automotive drive trains as a way to construct an "Optimal CAE Design Approach Model" for quality assurance. The model is used to explain "cavitation caused by the metal particles (foreign matter)" generated through transaxle wear, a pressing issue in the automobile industry (Amasaka, 2011).

2. CAE IN PRODUCT DESIGN – APPLICATION AND ISSUES

2.1. CAE in the Product Design Process

The time between product design and production has been drastically shortened in recent years with the rapid spread of global production. Quality assurance (QA) has become increasingly critical, making it essential that the product design process—a critical component of QA—be reformed to ensure quality (Kume, 1990: Amasaka, 2010a).

Fig. **1** shows the typical product design process currently used by many companies (Amasaka, 2010a). The figure shows that companies first create product design instructions based on market research and planning. They then use these instructions to make specific product design specifications (drawings) and to promptly convert them to digital format so that they can be suitably processed and applied. The data is primarily used in numerical simulations known as computer-aided engineering, or CAE.

CAE analysis enables engineers to determine whether the product design specifications result in sufficient

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product quality — and if not, the specifications are promptly optimized. Manufacturers then carry out effective preproduction, testing and evaluating prototypes (prototype testing). A final evaluation of the development design is conducted, and if there are no problems, companies move to production preparation and process design in order to get ready for full-scale production.

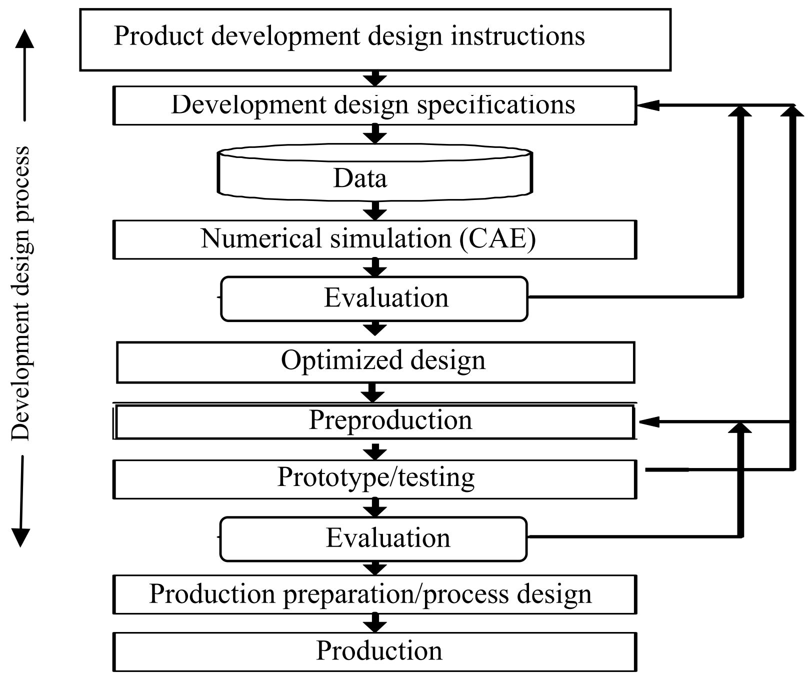

Figure 1: CAE in the Development Design Process.

2.2. CAE Analysis: Current Status and Issues

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 manufacturing. These and other applications are expected to have effective results (Magoshi, *et al.*, 2003: Yoo, *et al.*, 2010: Amasaka, 2010a).

The product design process, for example, is typically one guided by unspoken experiential knowledge and rules of thumb, leading to prototype testing guided by repeated trial-and-error efforts. 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, 2007a, 2008, 2010b).

Despite these high expectations, conventional forms of CAE analysis resulted in figures that deviated as much as 10–20% from those obtained through prototype testing evaluations. This means that many companies are now stuck with applying CAE only to the monitoring task of comparative evaluations of old and new products—despite the enormous amount of funds they have invested in CAE development.

There are two absolute requirements for precise (highly reliable) CAE analysis methods that can both prevent the critical technical problems plaguing manufacturers from recurring and contribute to new product designs. The first is reducing the deviation from prototype testing evaluation figures to 5% or less, and the second is evaluating the absolute values needed for tolerance designs.

3. APPLICATION OF THE HIGH QUALITY ASSURANCE CAE ANALYSIS MODEL

Currently, to continuously offer attractive, customer- oriented products, it is important to establish a "*new development design model*" that predicts customer needs. In order to do so, it is crucial to reform the business process for development design (Amasaka, 2007a, 2008, 2010b). Manufacturing is a battle against irregularities, and it is imperative to renovate the business process in the development design system and to create a technology so that serious market quality problems can be prevented in advance by means of accurate prediction/control.

For example, as a solution to technical problems, approaches taken by design engineers, who tend to unreasonably rely on their own past experience, must be clearly corrected. In the business process from development design to production, the development design 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. In order to tackle this problem, it is urgently necessary to reform the conventional development design process.

Focusing on the successful case mentioned above, the authors deem it a requisite for leading manufacturing corporations to balance high quality development design with lower cost and shorter development time by incorporating the latest simulation CAE and *Science SQC (Statistical Quality Control)* (Amasaka, 2004, 2008). 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 methods.

Having said the above, the authors established the "High Quality Assurance CAE Analysis Model" as the key to the high cyclization of development and design processes so called "*New Japan Development Design Model*" as described in Fig. **2** (Amasaka, 2007a, 2007b). This model is aimed at the simultaneous achievement of QCD (Quality, Cost and Delivery) by high quality manufacturing which is essential to realize CS (Customer Satisfaction), ES (Employee Satisfaction), and SS (Social Satisfaction).

For realization, customers' orientation (subjective implicit information) must be scientifically interpreted by means of "*Customer Science*" (Amasaka, 2005), namely, converting the implicit information to explicit information by objectifying the subjective information using *Science SQC* so as to create "*High Reliable Development Design System*", thereby reducing prototypes with accurate prediction and control by means of "*Intelligence Numerical Simulation*".

To this end, it is important to introduce the "*Intellectual Technology Integrated System*" which enables a sharing of knowledge and the latest technical information possessed by all related divisions.

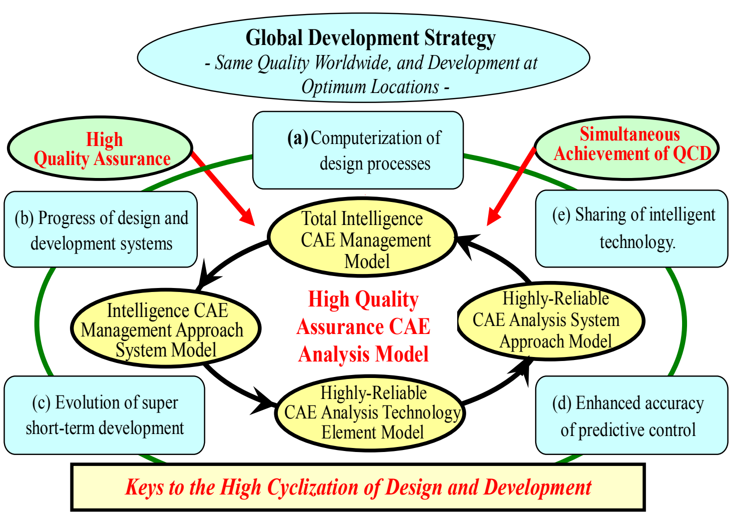

Figure 2: High Quality Assurance CAE Analysis Modelfor Automotive Design and Development.

4. PROPOSAL OF OPTIMAL CAE DESIGN APPROACH MODEL

This chapter presents an Optimal CAE Design Approach Model in Fig. **3**, which shows the procedural elements in steps one through five of the business process used in automotive product design - application to drive train oil seal leaks (Amasaka, 2011).

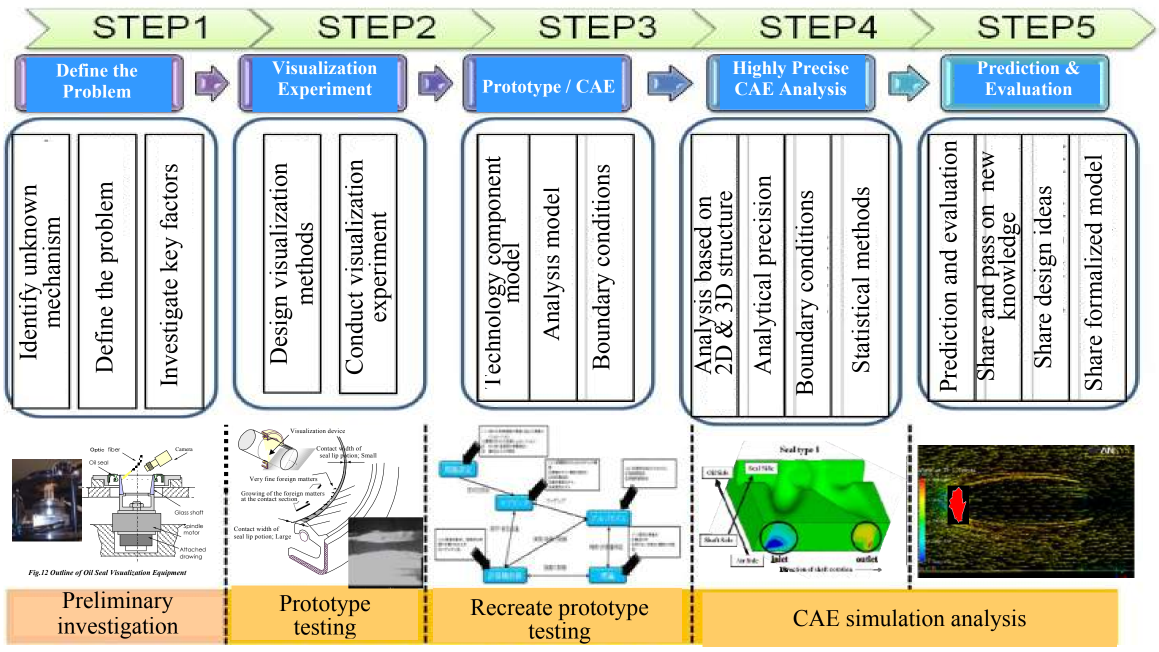

Figure 3: Optimal CAE Design Approach Model.

4.1. STEP 1: Define the Problem

Step 1, defining the current situation, means explaining problematic technological issues where the number of functional breakdowns is to clarify why the breakdowns are occurring as well as the mechanism that is generating them.

Experts inside and outside the company use their collective wisdom in collaborative activities, applying the latest statistical methods and investigating and analyzing complex cause-and- effect relationships to define the problem in minute detail and reason out the faulty mechanism.

4.2. STEP 2: Conduct a Visualization Experiment

In step 2, the visualization experiment, prototype testing is conducted in order to visualize the mechanism (dynamic behavior) that is generating the defect. This is how the faulty mechanism is further defined. Specifically, the *Science SQC* approach—SQC Technical Methods are applied to accurately explain the fault and conduct a factor analysis.

These methods use N7 (seven new QC tools), SQC (general statistical Quality Control methods), RE (reliability analysis), MA (multivariate analysis), and DE (design of experiment) (Amasaka, 2004). The use of these methods allows the discovery of previously overlooked and unidentified latent factors and the faulty mechanism to be demonstrated *via* a logical thought process.

4.3. STEP 3: Aligning Prototype Testing and CAE

In step 3, the key factors (technology components) identified in steps 1 and 2 that are generating the fault are subjected to a numerical simulation (CAE). The numerical simulation makes it possible to match results obtained through prototype testing and CAE analysis (Two and Three dimensional model) using absolute values, values for which there is no discrepancy between the prototype testing and CAE analysis.

At this point, all business processes are scientifically and comprehensively optimized using the following steps, which must be part of a highly precise CAE analysis: clarify the "phenomenon (defining the problem) – theory – algorithm (calculation methods) – modelling – calculation technology (computer)" by using Highly Reliable CAE Analysis Technology Component Model as shown in Fig. **4** (Amasaka, 2007a, 2010a). In doing this, it is absolutely essential to clearly model the cause-and-effect relationships in unexplained mechanisms identified during prototype testing (visualization) (Amasaka, 2007: Yamada and Amasaka, 2011).

In order to conduct a precise numerical simulation, there must be both an accurate theory and an experimental model that can logically define the impact of the latent factors identified during the experiment. Selecting a model with logical calculation procedures, analytical modeling, and algorithms is a must, with the goal of qualitatively modeling the fault (mechanism).

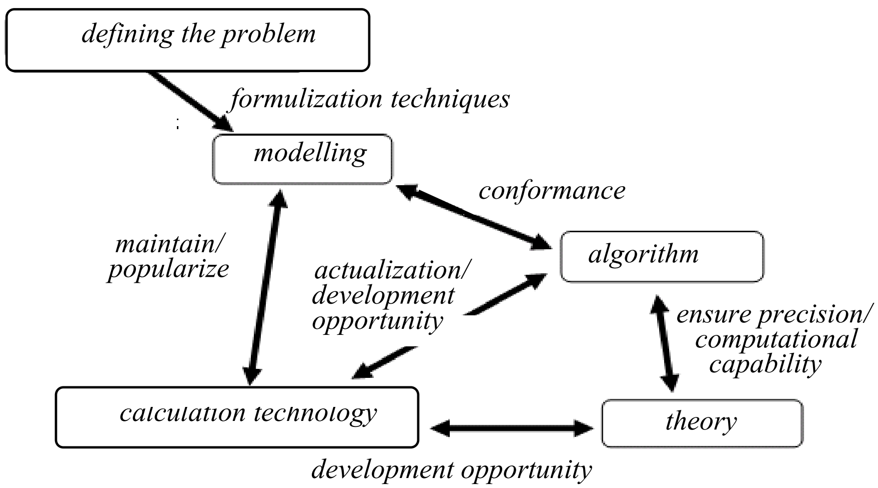

Figure 4: Highly Reliable CAE Analysis Technology Component Model.

4.4. STEP 4: Conduct a Highly Precise CAE Analysis

In step 4, conducting a highly precise CAE analysis, a highly reliable numerical simulation (quantitative modeling/highly precise CAE analysis) is conducted. This makes it possible to predict and control the absolute values needed for the CAE analysis based on the knowledge gained in step 3. In the above case, a mesh was created using optimization and contact conditions were defined.

4.5. STEP 5: Predict and Evaluate

Highly reliable CAE analysis makes CAE analysis for predictive evaluation possible when carrying out the business processes in steps 1 through 4 in minute detail. In the past, CAE modeling was often conducted in an illogical way, with conventional CAE analysis and an undefined faulty mechanism. The result was a significant discrepancy (10–30%) between prototype testing and CAE analysis values, often confining the use of CAE analysis to the auxiliary monitoring task of comparative evaluations of old and new products.

CAE analysis for predictive evaluation (steps 1 through 4) makes precise prediction and evaluation possible by pinpointing key factors, accurately identifying the development design factors that must be optimally controlled, and making them explicit by incorporating them into drawings and manufacturing techniques. This contributes to swift design development that includes the generation of new knowledge, new design ideas, sharing of explicit models, and creating assets out of new technology that gets passed on and developed.

5. APPLICATION DRIVE TRAIN OIL SEAL LEAKS – CAVITATION CAUSED BY METAL PARTICLES IN THE TRANSAXLE

In this chapter, the authors use both prototype testing and CAE, applying the Optimal CAE Design Approach Model to explain undiscovered technological mechanisms and then develop a model based on their investigative process (Amasaka, 2008, 2010b, 2011, Ito, *et al.* 2010: Nozawa, *et al.*, 2011). The model is used to analyze "cavitation" caused by the metal particles in the transaxle oil seal leaks.

5.1. Oil Seal Function

An oil seal on an automobile's transaxle prevents the oil lubricant within the drive system from leaking from the drive shaft. It is comprised of a rubber lip molded onto a round metal casing. The rubber lip grips the surface of the shaft around its entire circumference, thus creating a physical oil barrier. In this case, the sealing ability of microscopic roughness on the rubber surface is of primary importance (Lopez, *et al.*, 1997: Amasaka, 2004).

The parameters for the sealing condition of the oil film involve not only the design of the seal itself, but also external factors such as shaft surface conditions, shaft eccentricity, and so on. Contamination of the oil by minute particles was found to be of particular importance to this problem since these are technical issues which involve not only the seal, but also the entire drive train of the vehicle.

5.2. Understanding of the Oil Seal leakage Mechanism through Visualization

The oil leaks and similar problems can result in immediate and critical vehicle defects. One of the primary causes of oil seal leaks is wear to convex areas of the oil seal (o/s) where it comes into contact with the surface of the drive shaft, which is rotating at high speeds. The author is applying Optimal CAE Design Approach Model to this issue in order to resolve it.

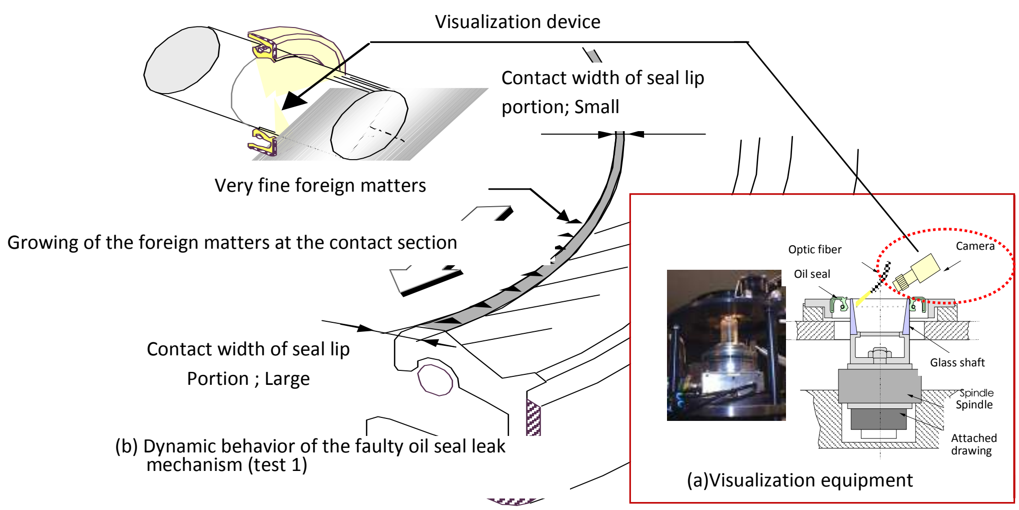

Figure 5: Oil Seal Visualization Device and Oil Seal Leak Mechanism.

5.2.1. Defining the Problem and Conducting a Visualization Device (Step1)

This section addresses a second unexplained problem: metal particles (foreign matter) generated from rotation wear in drive train gears. The dynamic behavior of the faulty oil seal leak mechanism causing these metal particles to form was outlined using the developed visualization device (equipment) in Fig. **5(a)**, in order to turn this "unknown oil leak mechanism" into explicit knowledge.

As shown in the figure, the oil seal was immersed in the lubrication oil in the same manner as the transaxle, and the drive shaft was changed to a glass shaft that rotated eccentrically *via* a spindle motor so as to reproduce the operation that would occur in an actual vehicle. The sealing effect of the oil seal lip was then visualized using an optical fiber. It was conjectured that in an eccentric seal with one-sided wear, the foreign matter becomes entangled at the place where the contact width changes from small to large.

Three trial tests were carried out to ascertain if this was true or not. Based on the examination of faulty parts returned from the market and the results of the visualization experiment, it was observed that very fine foreign matter (which was previously thought to not impact the oil leakage problem) grew at the contact section, as shown in Fig. **5**(**b**) (test-1).

It was also confirmed from the results of the component analysis that the fine foreign matter was a powder produced during gear engagement inside the transaxle gear box.

5.2.2. Identifying the Oil Leakage Mechanism (Step2)

This fine foreign matter on top of microscopic irregularities on the lip sliding surface resulted in microscopic pressure distribution which eventually led to the degrading of the sealing performance as shown in Fig. **6** (test-2). Also, the presence of this mechanism was confirmed from a separate observation that foreign matter had cut into the lip sliding surface, thereby causing aeration (cavitations) to be generated in the oil flow on the lip sliding surface.

This caused deterioration of the sealing performance, as shown in Fig. **7** (test-3). The figure indicates that cavitations occur in the vicinity of the foreign matter as the speed of the spindle increases, even when the amount of foreign matter that has accumulated on the oil seal lip is relatively small.

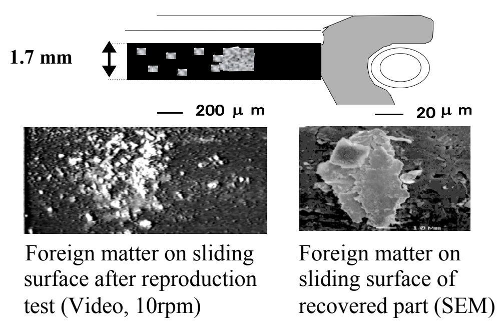

Figure 6: Growing of the foreign matter (test-2).

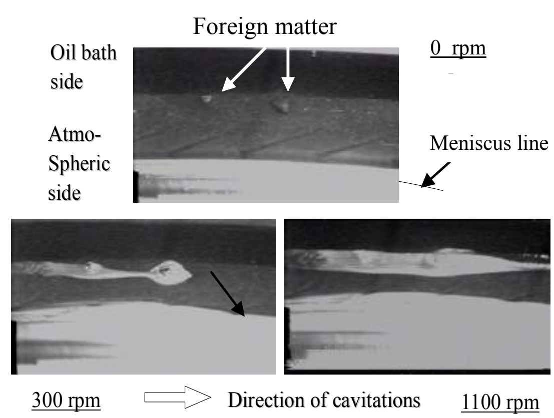

Figure 7: Causing Cavitation (Test-3).

As the size of the foreign matter gets bigger, the oil sealing balance position of the oil seal lip moves more toward the atmospheric side and causes oil leaks at low speeds or even when the vehicle is at rest. This fact was unknown prior to this study, and therefore was not incorporated into the original product design of the oil seals.

As a result of these efforts, the author was able to investigate the mechanism generating the oil seal leaks and use factor analysis to pinpoint the design elements in the oil seal and drive train gears that should have controlled the problem. The mechanism involved cavitation occurring in rotating parts when foreign matter got wedged between sliding surfaces (on the lip surface). This happened in areas where there was variation in the size of the contact surface (from small to large) on the oil seal lip, caused by irregular wear and assembly variations.

The author used the knowledge obtained from the visualization experiment to logically outline the faulty n Fig. **8**. This was done in order to capture the problem using the Highly Reliable CAE Analysis Technology Component Model. Using this process, the author was able to arrive at a hypothesis for why the cavitation was occurring; namely, factors like low pump volume and seal damage had compromised the tightness of the seal and lead to oil leaks.

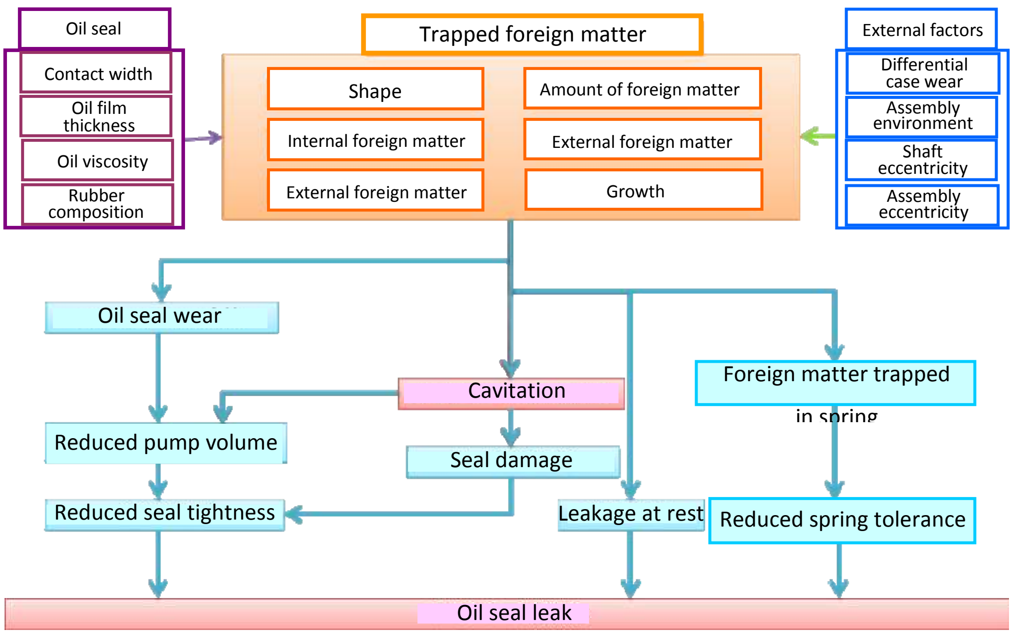

Figure 8: Faulty Mechanism (Oil Leaks due to Foreign Matter).

5.3. Application of Optimal CAE Design Approach Model of "Oil Simulator"

5.3.1. Oil Simulator using Highly Reliable CAE Analysis Technology Component Model (Step 3)

The Oil Seal Simulator using Highly Reliable CAE Analysis Technology Component Model as shown in Fig. **9** was created as an essential requirement for precise CAE analysis. As the figure indicates, the designs are optimized by integrating several aspects of the calculation process, including problem (root cause) identification, conceptualizing the problem logically, and calculation methods (precision of calculators). Once the root causes of the problem are identified, it is critical that there is no discrepancy between the mechanism described and the results of prototype evaluations.

The visualization experiment revealed that cavitation was occurring due to a weakening of the oil seal in areas (surfaces) that were in contact with the rotating drive shaft. This weakening was causing oil seal leaks. The Rayleigh Plesset Model for controlling steam and condensation was used as a CAE analysis model that could explain the problem.

The finite element method and non-stationary analyses were used as convenient algorithms. The Reynolds-averaged Navier-Stokes equation, Bernoulli's principle, and lubrication theory were appropriate theoretical formulas. Accuracy was ensured, and the time integration method was used to perform calculations in a realistic timeframe.

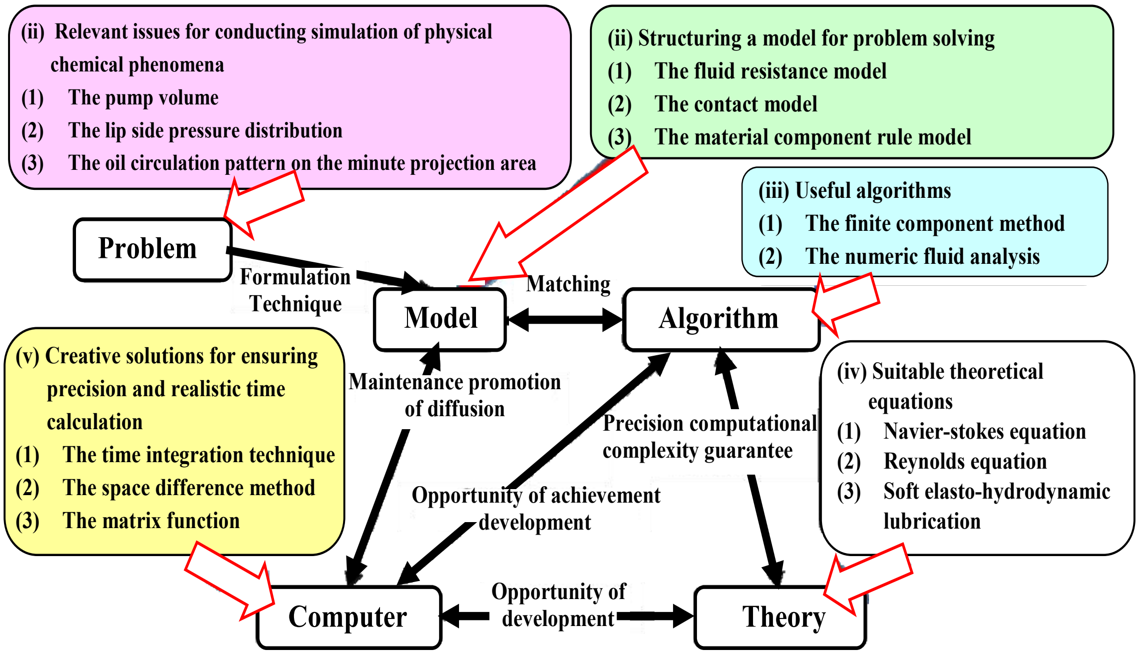

Figure 9: Oil Seal Simulator using Highly Reliable CAE Analysis Technology Component Model.

5.3.2. CAE Qualitative Model of the Basic Oil Seal Lip Structure (Step 4)

1. CAE Qualitative Model

The visualization experiment yielded the conditions on the sliding surface of the oil seal lip as a basic structural element. The author then used this element to construct the CAE qualitative model of the basic oil seal lip structure shown in Fig. **10** in order to demonstrate sealing conditions. The model uses a statistical approximation of the slight roughness on the sliding surface to show the wedge effect created by minute projections.

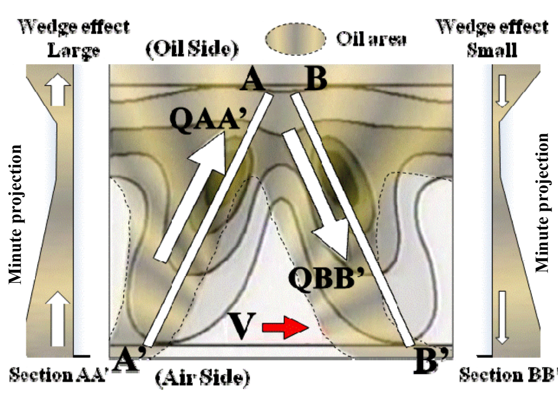

Figure 10: CAE Qualitative Model of the Basic Oil Seal Lip Structure.

In looking at seal conditions on the sliding surfaces as a whole, the author concluded that the volume of inflow was greater at QAA' than the outflow at QBB', based on the fact that minute projections in section AA' created a larger wedge effect than the minute projections in section BB'.

These conditions also generated the oil circulation pattern on the minute projection area of sliding surfaces, which meant that wear could be prevented by separating the two surfaces (Sato, *et al.*, 1999: Kameike, *et al.*, 2000).

2. Two-dimensional CAE Analysis

Using the technological elements mentioned above, a two-dimensional CAE analysis (2D analysis) was used to conduct a numerical simulation that would accurately describe the behavior of the oil on the problematic minute projection areas. Fig. **11** shows the results of this analysis. It shows the space between the shaft near minute projection AA' and minute projection BB' and the seal where oil is getting trapped.

This two-dimensional analysis shows that shear stress is being generated by the fluid (oil) due to the rotation of the shaft and that the seal side flow direction is being reversed as the minute projections narrow the fluid channel.

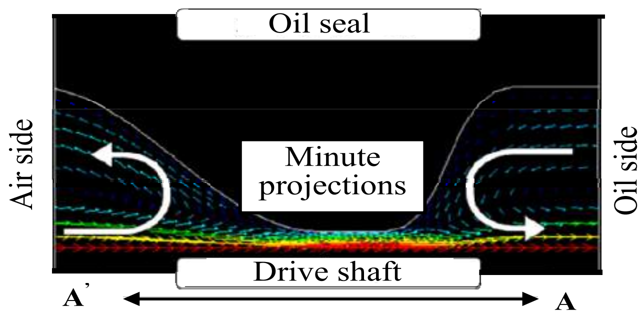

Figure 11: A Two-dimensional Analysis.

3. Three-dimensional CAE Analysis

Next, a three-dimensional analysis (3D analysis) was conducted using a structural model of the sliding surfaces as a whole. The model took into account the direction of oil flow in a third dimension (depth) based on the knowledge gained from the visualization experiment and the two-dimensional CAE analysis.

The model was used to do a numerical simulation of the oil film present on the sliding surfaces. The analytical model shown in Fig. **12** was constructed based the CAE qualitative model of the basic oil seal lip structure shown in Fig. **10**. By imposing conditions such as shaft rotation speed, the amount of oil flow on the oil side and air side could be calculated. The oil flow to the seal side and to the air side was compared, producing similar results to the visualization experiment.

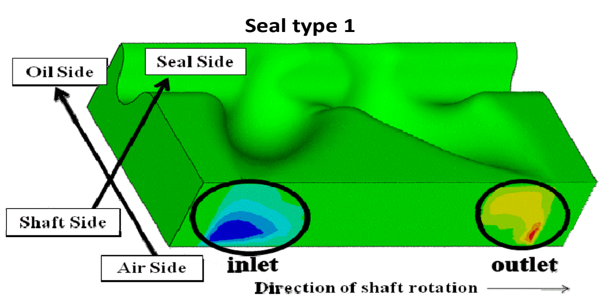

Figure 12: Three-dimensional Analysis.

5.3.3 CAE Analysis (Step 5)

A cavitation is generated at the following steps; Oil collides with a foreign substance - The flow velocity rise near a foreign substance - The fall of pressure - Decreased pressure is carried out to below saturated vapor pressure - Emasculation of oil - Generating of a cavitation.

1. Fluid Speed Analysis Example

The fluid speed analysis like the one in Fig. **13** was then conducted in order to look more closely at the mechanism causing cavitation. The analysis revealed that rapid changes in fluid speed were occuring in the vicinity of foreign particles, and that fluid speed drops immediately before the oil collides with foreign matter. This led to the conclusion that the presence of foreign particle was having an effect on oil flow.

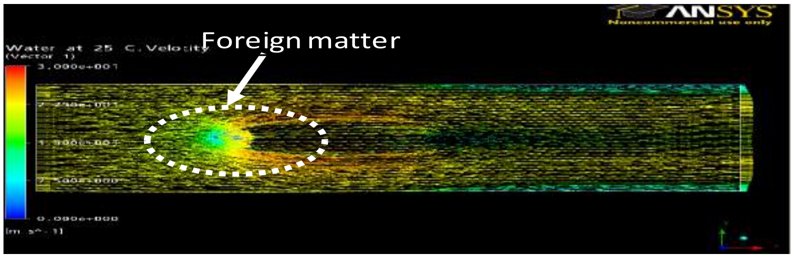

Figure 13: Fluid Speed Analysis around Foreign Matter.

2. Pressure Analysis Example

Comparing cavitation and the fluid speed analysis results against the results of the pressure analysis shown in Fig. **14** reveals that in areas of reduced pressure, oil was disappearing inside the cavities being formed—meaning that drops in pressure were likely being caused by these concave areas.

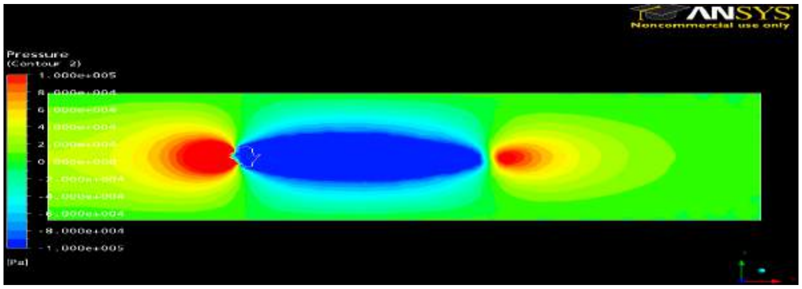

Figure 14: Pressure Analysis around Foreign Matter.

3. Cavitation Analysis Example

Fig. **15** shows the CAE analysis results at a rotation speed of 1100 rpm. This analysis confirmed the cavitation occurring around foreign matter, thus replicating the results of the visualization experiment. At the same time, the finding that cavitation becomes more significant as the rotation speed of the drive shaft increases was similarly replicated.

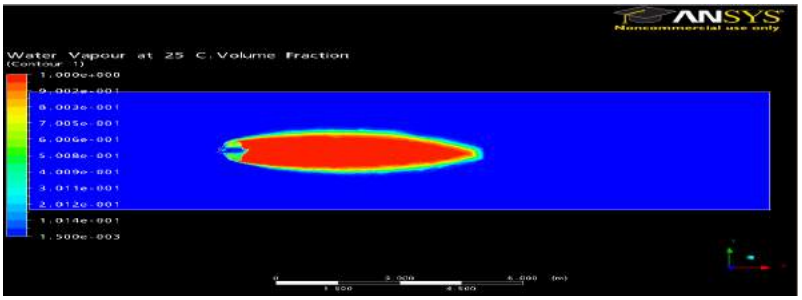

Figure. 15: Cavitation Analysis around Foreign Matter.

4. Verification and Consideration

The above CAE analysis allowed the authors to clarify the faulty mechanism causing cavitation; namely, the presence of metal foreign particles was affecting the strength of the oil flow, causing drops in pressure in areas with faster oil flow and creating cavities.

In addition, a similar analysis of changes in the shape and size of the foreign particles revealed that these changes were also causing changes in cavitation. These CAE analysis results indicate a close link between particle size/shape and cavitation.

Preproduction and testing/evaluation of prototypes adds a significant amount of time and cost to the development process. However, precise CAE allowed manufacturers to eliminate preproduction (as well as prototype testing/evaluation) and still predict the mechanism causing cavitation and oil leaks. Though gaps such as minute surface variations caused by foreign particles and the shape of the oil film model exist, the CAE analysis allowed the authors to recreate the changes in flow speed and pressure around the foreign metal particles that were causing cavitation - changes which typically cannot be identified.

The deviation between the CAE analysis results and the results of the prototype testing were less than 5%, attesting to the usefulness of precise CAE analysis in certain cases.

5. Quality Improvement

These results led to two measures to improve design quality (shape and materials): (1) strengthen gear surfaces to prevent occurrence of foreign matter even after the B10 life (L10 Bearing to MTBF) to over 400,000 km (improve quality of materials and heat treatments) and (2) formulate a design plan to scientifically ensure optimum lubrication of the surface layer of the oil seal lip where it rotates in contact with the drive shaft.

The result of these countermeasures was a reduction in oil seal leaks (market complaints) to less than 1/20th their original incidence as shown in Fig. **16**.

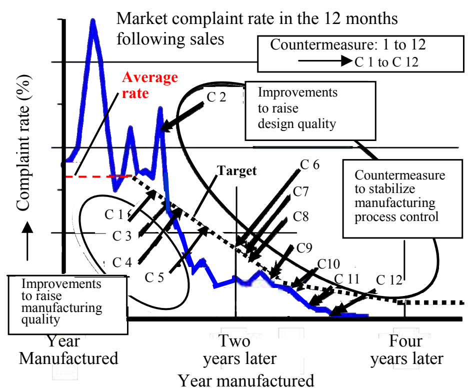

Figure 16: Reduction in Market Complaint Rate.

6. Application to Similar Problems

With its effectiveness verified, the author was able to apply the Optimal CAE Design Approach Model to critical development design technologies for automotive production, including predicting and controlling the special characteristics of automobile lifting power, anti-vibration design of door mirrors (Amasaka, 2010b), urethane seat foam molding (Amasaka, 2010b), and loosening bolts (Yamada and Amasaka, 2011).

In each of these cases as well, discrepancy was 3–5% *versus* prototype testing. Based on the achieved results, the model is now being used as an intelligent support model for optimizing product design processes.

6. CONCLUSION

In this paper, the author constructed an Optimal CAE Design Approach Model by utilizing High Quality Assurance CAE Analysis Model for predictive evaluation method in design work is expected to contribute a great deal to shortening development design time and improving quality. The model primarily used numerical simulation to clarify the technological mechanism generating oil leaks as a result of metal particles entering oil seals in the transaxle.

ACKNOWLEDGEMENTS

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CHAPTER 13

Strategic QCD Studies with Affiliated and Non-Affiliated Suppliers Strategic Development of Science TQM - 3

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Abstract: This paper analyzes and proves the significance of strategically implementing “Science TQM”, which combines the “Strategic task team model”, “Global partnering model”, and “Simultaneous Fulfillment of QCD (Quality, Cost, and Delivery) approach model” verified at Toyota. Studies were conducted by developing Science TQM not only at affiliated suppliers, but also at non-affiliated companies, and aims to achieve harmonious coexistence between these suppliers. The studies successfully achieved simultaneous QCD fulfillment, which is a global management challenge in production.

Keywords: Science TQM, strategic task team model, global partnering model, simultaneous QCD fulfillment, affiliated and non-affiliated suppliers, toyota.

1. INTRODUCTION

This paper proposes “Science TQM, New Quality Management Principle” of next generation management technology that contributes to corporate management (Amasaka, 2004a, 2008a). Science TQM consists of a hardware system founded on three core elements (TMS - Total Marketing System, TDS - Total Development System, TPS - Toyota Production System, TIS - Total Intelligence Management System and TJS - Total Job Quality Management System), and a software system “TQM-S” (Total Quality Management utilizing “Science SQC”) that enables the application of scientific TQM (Total Quality Management).

In previous studies, the effectiveness of Science TQM was successfully proven through its application in a leading Japanese company, Toyota Motor Corporation. In developing “Global Marketing” to win the global competition in quality and cost, the key for domestic and foreign companies is to successfully achieve “Global Production” that enables simultaneous production startup (the same quality and production at optimal locations) all over the world.

Today’s management challenge is to provide high QCD products ahead of competitors through “Market Creating” activities, with priority given to customers.

This is the mission of Science TQM. In the implementation stage, strategic QCD studies are needed to strengthen core technologies and mutually link them as a whole. Above all, manufacturers endeavoring to become global companies are required to collaborate with not only affiliated suppliers, but also with non-affiliated suppliers to achieve harmonious coexistence among them based on cooperation and competition. In other words, a so-called “federation of companies” is needed.

This paper analyzes and proves the significance of strategically implementing Science TQM at Toyota. To realize manufacturing of excellent quality for customer, the author (Amasaka, 2008b) proposes a management technology strategy model consisting of three core models: “Strategic task team model”, “Global partnering model”, and “Simultaneous Fulfillment of QCD approach model”. Studies were conducted by developing Science TQM not only at affiliated suppliers but also at non-affiliated suppliers, with the aim of achieving harmonious coexistence between them.

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Kakuro Amasaka (Ed)

The studies successfully achieved "simultaneous QCD fulfillment" through the solution of the worldwide technological subject, which is a global management challenge for production.

2. TODAY'S MANAGEMENT TECHNOLOGY PROBLEM

2.1. Needs for the Reform of Japanese-Style Management Technology

The top priority issue of the industrial field today is the "new deployment of global marketing" for surviving the era of "global quality competition" (Kotler, 1999: Amasaka, 2004b). The pressing management issue particularly for Japanese manufacturers to survive in the global market is the "uniform quality worldwide and production at optimum locations" which is the prerequisite for successful global production. To realize manufacturing that places top priority on customers with a good QCD and in a rapidly changing technical environment, it is important to develop a new production technology principle and establish new process management principles to enable global production.

Furthermore, a new quality management technology principle linked with overall activities for higher work process quality in all divisions is necessary for an enterprise to survive (Burke and Trahant, 2000: Amasaka, 2004b). The creation of attractive products requires each of the sales, engineering/design, and production departments to be able to carry out management that forms linkages throughout the whole organization (Seuring *et al.*, 2003: Amasaka, 2000, 2004a). From this point of view, the reform of Japanese-style management technology is desired once again. In this need for improvements, Toyota is no exception (Goto, 1999: JUSE TQM Committee, 2000: Amasaka, 2004b).

2.2. Importance of Strategic QCD Studies with Affiliated and Non-Affiliated Suppliers

IT development has led to a market environment where customers can promptly acquire the latest information from around the world with ease. In this age, customers select products that meet their lifestyle and have a sense of value on the basis of a value standard that justifies the cost. Thus the concept of "Quality" has expanded from being product quality, which is oriented to business quality, to becoming corporate management quality-oriented.

Customers are strict in demanding the reliability of enterprises through the utility values (quality, reliability) of their products (Evans and Dean, 2003: Amasaka, 2004a). Advanced companies in countries all over the world, including Japan, are shifting to global production. The purpose of global production is to realize "uniform quality worldwide and production at optimum locations" in order to ensure company's survival amidst fierce competition (Doz and Hamel, 1998: Amasaka, 2004b).

For the manufacturing industry, the key to success in global production is systematizing its management methods when modeling strategic SCM (Supply Chain Management) for its domestic and overseas suppliers. In-depth studies of the Toyota Production System called JIT (Traditional Just in Time) and Lean Production System (Ohno, 1977: Roos *et al.*: Jones and Womack, 1994: Amasaka, 2002), TQM (Total Quality Management), partnering, and digital engineering will be needed when these methods are implemented in the future.

Above all, manufacturers endeavoring to become global companies are required to collaborate not only with affiliated companies, but also with non-affiliated companies to achieve harmonious coexistence among them based on cooperation and competition. In other words, a so-called "federation of companies" is needed (Hamel and Prahalad, 1994: Amasaka, 2004a, 2004b).

3. SCIENCE TQM STRATEGY

3.1. Traditional Japanese Production System and Quality Management: JIT

One of the greatest contributions that Japan made to the world is JIT. JIT is a production system that enables provision of what customers desire when they desire it. JIT is also introduced in a number of enterprises in the United States and Europeans a key management technology (Taylor and Brunt, 2001: Amasaka, 2000).

The Japanese-style production system represented by the current Toyota Production System, called JIT, is a production system which has been developed by Toyota. Implementing TQM in the production process, this production system aims to achieve the simultaneous of quality and productivity in pursuit of maximum rationalization while recognizing the principle of cost reduction.

This is the essential concept of JIT and therefore, these have been positioned as a core part of Toyota's management technology and often likened to the wheels on both sides of a vehicle. However, Toyota production system, which is representing the Japanese-style production system today, has already been developed as an internationally shared system, known as a Lean System and is no longer an exclusive technology of Toyota in Japan. In the Western countries also, the importance of quality control has been recognized through the studies on the Japanese TQM.

As a result, TQM activities have been increasingly popular. Therefore, the superiority in quality of Japanese products assured by the Japanese-style quality control has been gradually undermined in recent years (Amasaka, 2004a).

3.2. Significance of Science TQM, New Quality Management Principle

Having said the above, it is the author's conjecture that it is clearly impossible to lead the next-generation by merely maintaining the two Toyota management technology principles, TPS and TQM. To overcome this issue, it is essential to renovate not only TPS, which is the core principle of the production process, but also to establish core principles for marketing, design and development, production and other departments.

The next-generation new quality management principle, Science TQM, which the author (Amasaka, 2004a, 2008a) has proposed through theoretical and systematic analyses as shown in Fig. **1**, is the Just in Time system for not only manufacturing, but also for customer relations, sales and marketing, product planning, R&D, design, production engineering, logistics, procurement, administration and management, for enhancing business process innovation and introduction of new concepts and procedures.

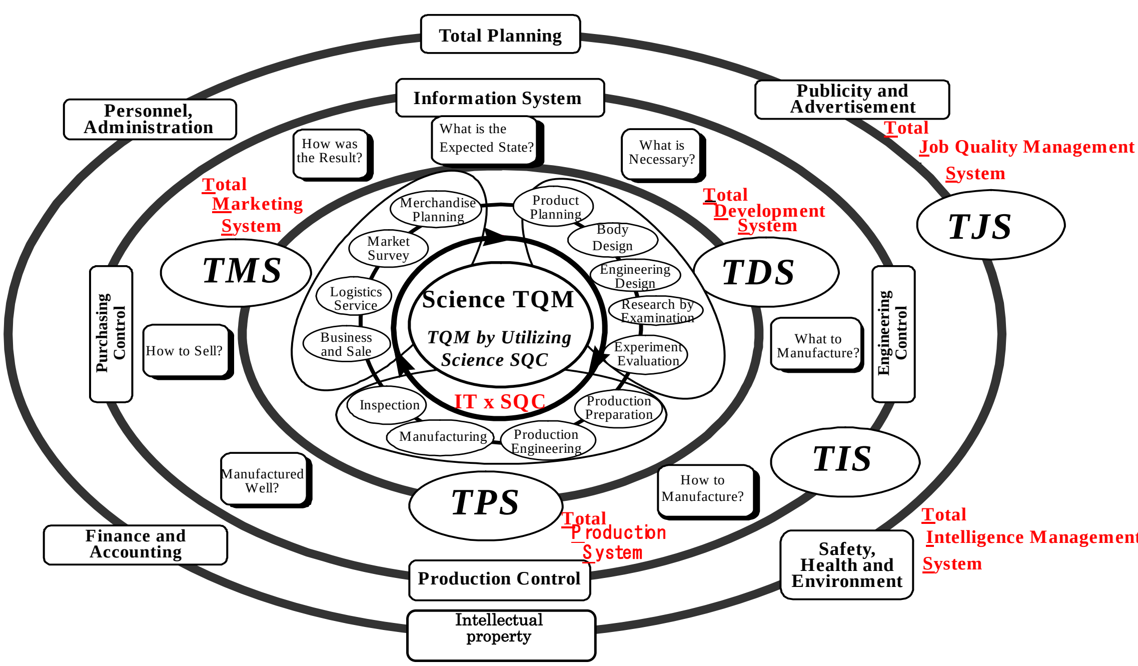

Figure 1: Science TQM, New Quality Management Principle.

Science TQM contains hardware and software systems as the next generation technical principles for accelerating the optimization (high linkage) of work process cycles of all the divisions. The first item, the hardware system, consists of the TMS, TDS, TPS, TIS and TJS which are the three core elements required for establishing new management technology principles for sales, R&D, design, engineering, and production, among others.

The expectations and role of the 1st core principle TMS include the following: (i) Market creation through the gathering and use of customer information, (ii) Improvement of product value by understanding the elements essential to raising merchandize value, (iii) Establishment of hardware and software marketing system to

form ties with customers and (iv) Realization on the necessary elements for adopting a corporate attitude (behavioral norm) of enhancing customer value and developing customer satisfaction (CS), customer delight (CD) customer retention (CR), and networks.

The expectations and role of the 2nd core principle TDS are the systemization of design management method which is capable of clarifying the following: (i) Collection and analysis of updated internal and external information that emphasizes the importance of design philosophy, (ii) Development design process, (iii) Design method that incorporates enhanced design technology for obtaining general solutions, and (iv) Design guideline for designer development (theory, action and decision-making).

The expectations and new role of the 3rd core principle TPS comprise the following: (i) Customer-oriented production control systems that place the priority on internal and external quality information, (ii) Creation and management of a rational production process organization, (iii) QCD activities using advanced production technology and (iv) Creation of active workshop capable of implementing partnership.

The expectations and role of the 4th core principle TIS comprise the following: The required technological elements are (i) the product management system, in which the pre-process and post-process are integrated, (ii) the intelligent information management system, which combines the dealers and suppliers, (iii) the knowledge-intensive type total business process management system, which connects the congested off-line, in-line, and on-line process systems, and (iv) the communication management system, which improves human management as the basis for the integration of the cooperative activities participated in by the top line staff.

The expectations and role of the 5th core principle TJS comprise the following: The behavioral code for the office related department, involving the "corporate philosophy, corporate behavior, and business process management attitude" has been designed to totally link the four sub core elements of (i) coexistence with the society, (ii) global partnering (iii), intelligent management, and (iv) customer-in. This code will then be turned into a model and put into effect.

For the second item, the strategic quality management system, the author is proposing "Science SQC, New Quality Control Principle" (Amasaka, 2003a, 2004c) in Toyota as a software system for improving the "business process quality" of the 13 departments shown in the diagram as shown in Fig. **1**.

3.3. Platform-type Partnering Chains by means of a Structured Model of Stratified Joint Task Teams

Concretely speaking, the author believes that a company has to (1) join forces with domestic suppliers to enhance the intellectual productivity of plant divisions, and (2) succeed in "Global Production" to promote overseas operations and develop local production. In the implementation stage, first, (A) the quality management theory of Science SQC will be applied, as the figure shows, as the methodology for scientifically solving problems through the strategic linkage of these 3 core elements.

Second, as Fig. **2** shows, (B) the structured model of stratified joint task teams formed from partnering linkages will be developed systematically and organizationally to promote the strategic development of Science TQM. This model will consist of Task 1 to Task 8 teams involving the group, section, division, category, company, affiliated companies, non-affiliated companies, and overseas affiliates.

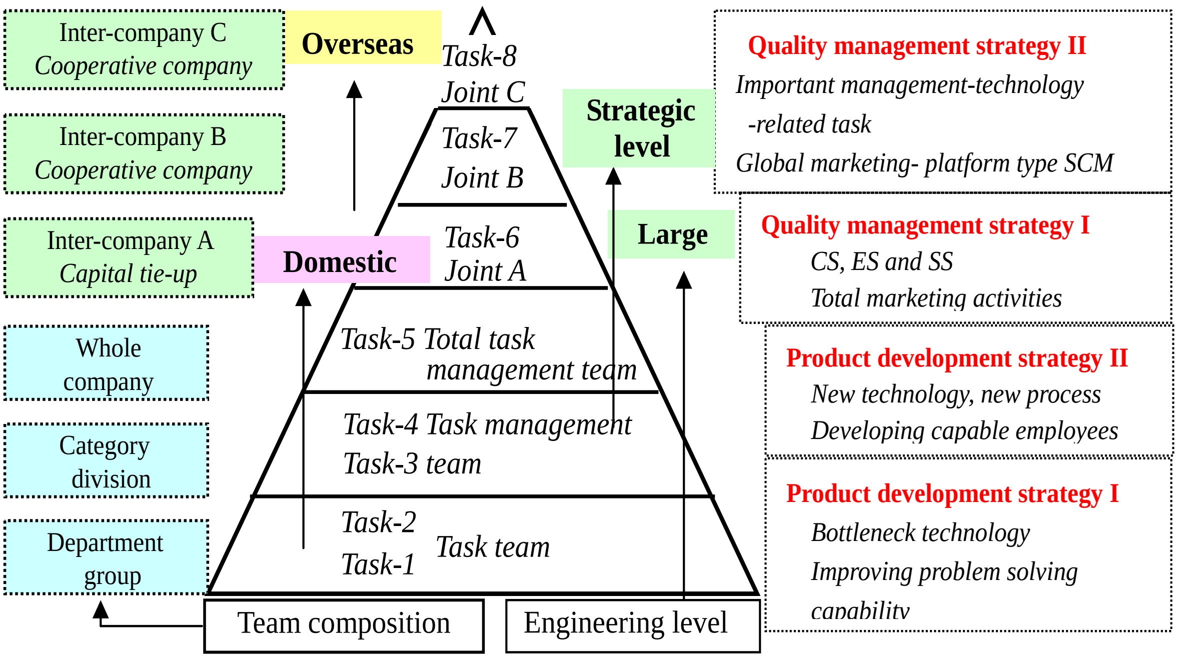

Figure 2: A Structured Model of Strategic Stratified Joint Task Team.

As indicated in the figure, the level of problem-solving technology rises strategically to product development strategy I and II through joint task teams of intra-company departments and divisions (Task-1 to Task-5, Task team, Task management team, and Total task management team) in proportion with the improvement of the stratified task level. This technology is further expanded to quality management strategy I to II through the domestic joint task teams of affiliated and non-affiliated companies and overseas counterparts (foreign groups: affiliated/non- affiliated) (Task-6 to Task-8, Joint A to Joint C).

4. PROPOSAL OF MANAGEMENT TECHNOLOGY STRATEGY MODEL FOR DEVELOPING SCIENCE TQM

Today's management challenge is to provide high QCD products ahead of their competitors through "Market Creating" activities, with priority given to customers. This is the mission of Science TQM. To realize manufacturing that provides excellent quality to the customer, the author proposes: (i) a management technology strategy model that utilizes the "Strategic Task Team Model" between the manufacturer and affiliated/non-affiliated suppliers. (ii) A "global partnering model" for strategically implementing Science TQM, and (iii) "Simultaneous QCD Fulfillment Approach Model" for developing Science TQM.

4.1. "Strategic Task Team Model" between the manufacturer and Affiliated/Non-affiliated Suppliers

The author believes that the key to successful global production is joint task activities between the manufacturer and affiliated/non-affiliated suppliers (Amasaka, 2004b) as stated above. In other words, it is important for the companies involved to work hard together in world markets under the principle of "harmonious coexistence through cooperation and mutual competition" in order to establish improved management technologies.

An example of concrete measures for development is shown in Fig. **3** ("Strategic Task Team Model between the manufacturer and Affiliated/Non-affiliated Suppliers"). To purchase the necessary parts, it will be important for the manufacturer to mutually cooperate with (a) Supplier I (in-house parts maker (own company)), (b) Supplier II, affiliated manufacturer (capital participation), (c) Supplier III, non-affiliated manufacturer, and (d)

Supplier IV, manufacturer with foreign capital. In the stage of actual implementation, it is important to strategically organize the stratified task teams from the following viewpoints and by setting the objective to be continual improvement of management technologies: (i) Product strategy, (ii) Engineering strategy, (iii) Quality strategy, (iv) QCD effect, (v) Value of the task teams, and (vi) Human resource strategy.

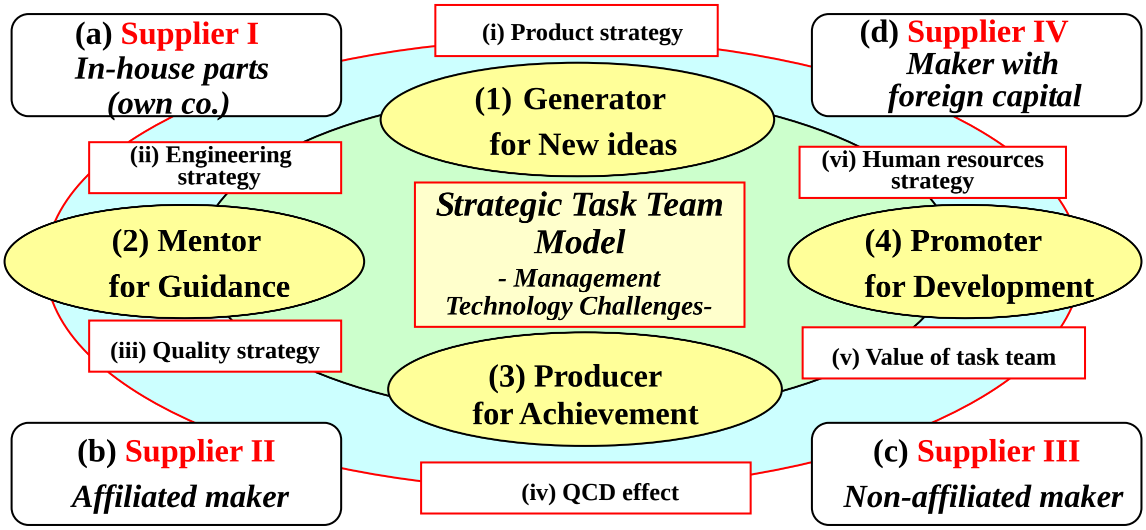

Figure 3: Strategic Task Team Model between Maker and Affiliated/Non-affiliated Suppliers.

After solving the most important management technology challenges at the beginning, the important job for the manufacturer's general administrator is to select jointly from his own company and suppliers: (1) "Generators" gifted with a special capacity for creating ideas, (2) "Mentors" having the ability to give guidance and advice, (3) "Producers" with the capability to achieve and execute, and (4) "Promoters" capable of implementing things as an organization.

4.2. "Global Partnering Model" for Strategically Implementing Science TQM

Understanding the need for strategically implementing Science TQM by applying the aforementioned strategic task team model between the manufacturer and affiliated/non-affiliated suppliers, the author proposes the 4-core structured "Global Partnering Model (GPM)" in Fig. **4** that implements the quality management principle of Science SQC. This principle has been proven effective in strategically solving management technology problems in this author's previous studies.

Non-affiliated Suppliers

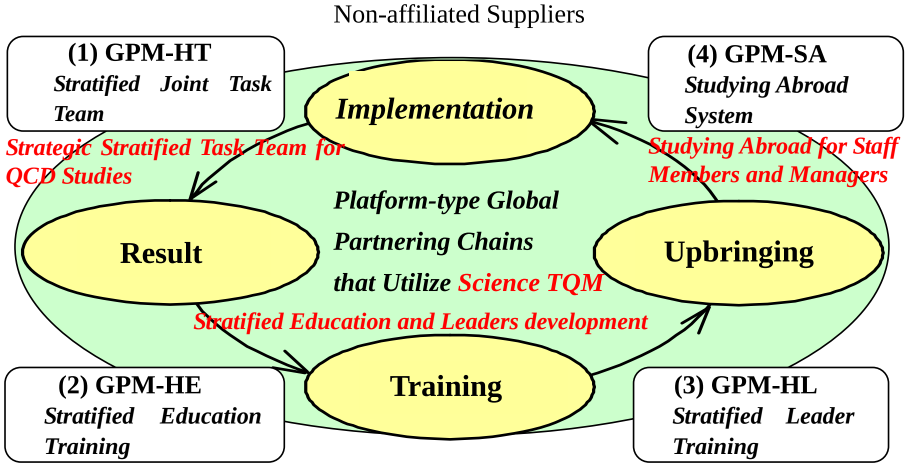

Figure 4: Global Partnering Model for Strategically Implementing Science TQM.

As shown in the figure, GPM is composed of four cores, namely (1) Stratified joint task team (GPM-HT, Task-1 to Task-8) in mutual cooperation with affiliated and non-affiliated suppliers, (2) Stratified education training for improving the skills of staff and managers (GPM-HE, the Hierarchical Education), (3) Stratified leader training (GPM-HL, the Hierarchical Leaders Growth) and (4) Overseas study system (GPM-SA, the Studying Abroad System).

To render the proposed “Global Partnering Model” effective in the implementation stage, it is important to adopt the hardware system with five core elements (TMS, TDS, TPS, TIS and TJS), and the software system “Science SQC”.

5. APPLICATION EXAMPLES: STRATEGIC JOINT TASK TEAM ACTIVITIES BY TOYOTA AND AFFILIATED/NON-AFFILIATED SUPPLIERS

This section describes the development of Science TQM and the results of strategic QCD studies by joint task team activities at “Toyota and Affiliated/Non affiliated suppliers”.

5.1. Global Development of Science TQM between Toyota and a group of Cooperative Companies

Toyota’s quality management, “SQC Renaissance” (Nikkei Mechanical, 1994: Amasaka, 1998), which is the administrative staff’s activity for improving quality management technology by utilizing Science SQC (1988 onward), became popularized and expanded through joint task team activities with affiliated and non-affiliated suppliers. In addition, the author drew up the “Toyota SQC Studying Abroad System” (1990 onward) for adopting Science SQC.

The system for training all Toyota “SQC leaders” (called senior SQC specialists) is being promoted as planned. Similarly, the author (Amasaka and Osaki, 1999) succeeded in strengthening “Senior SQC Leaders” (senior SQC advisors) among the manager strata as a result of the propagation and expansion of “Management SQC” (1994 onward), the core method of Science SQC.

Fig. **5** shows an example of a joint task team formed between Toyota and an overseas company. This is the promotion system for “Science SQC in Toyota Motor Thailand” (Amasaka *et al.*, 1999) (1996 onward). The system has been globally developed in Europe, North America, Canada, and developing countries and found effective as a strategic QCD study (Amasaka, 2004a: Sakai and Amasaka, 2006). As thus far described, “Science SQC education” (Amasaka and Osaki, 1999) and “Stratified Task Team” (Amasaka, 2004a, 2004b) activities have raised the administrative staff’s problem-solving skills with excellent business results being subsequently achieved.

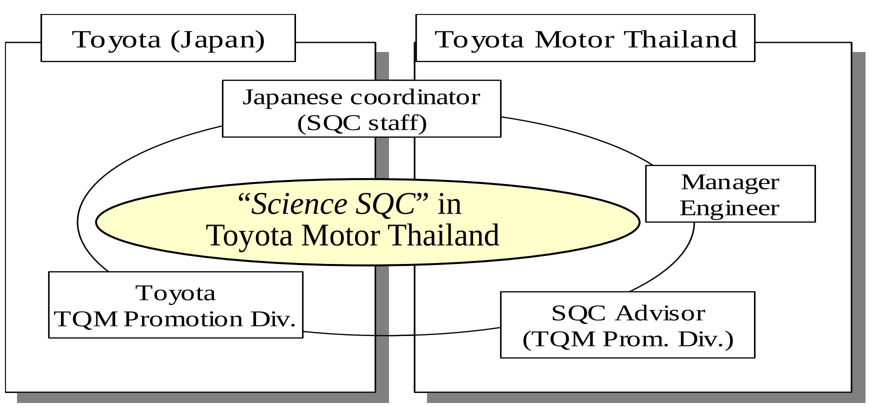

Figure 5: *Science SQC* by Toyota Motor Thailand.

As the next section describes, these activities and their achievements were attributable to the effective activities of stratified joint task teams formed with line, staff, management, administrative and indirect operational divisions, and related companies of affiliated and non-affiliated suppliers during the planning and implementing phases. Similarly, the activities are presently being implemented to improve the quality management technologies at overseas companies and local production plants. The activities have become a strategic arrangement of measures for the so-called "All Toyota Science TQM Global Development" (2000 onward).

5.2. Strategic Science TQM Study "Simultaneous Fulfillment of QCD" and its Effects

This Section discusses examples (A) through (D) of a strategic QCD study for the "Simultaneous Fulfillment of QCD" made jointly by Toyota and affiliated/non-affiliated suppliers to realize the strategic implementation of Science TQM.

5.2.1. Improving the market strength of automotive chassis parts — A global initiative to achieve simultaneous fulfillment of QCD

The first example (A) is a case where the quality of appearance and paint corrosion resistance (resistance to SST, Salt Spray Test) were improved without increasing cost, in order to improve the market strength of automotive chassis parts (front and rear axles). Making a global initiative to achieve simultaneous fulfillment of QCD, Toyota formed joint task teams (Task-6 and -7) with Aisin Kako Co., an affiliate, and Tokyo Paint Co., a non-affiliate. Fig. **6** shows an example where the joint task team of Toyota and Tokyo Paint raised the product value (VA= performance/cost) of the front axle (Amasaka, 2004b).

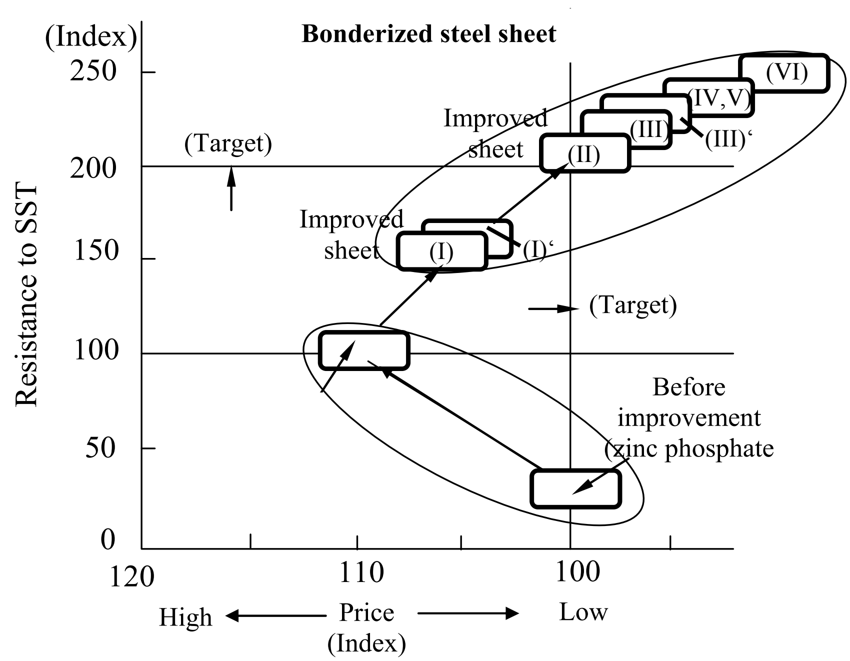

Figure 6: Improved Product Value for Front Axle.

The task team of both companies produced 11 patents. It improved the painting material, conversion treatment material, and facilities for conversion treatment, painting, and drying in this order (the first improved version (I) to final improved version (VI) in the figure). As a result, after 10 months, the team realized (a) a 15 times higher rust prevention (index) as compared to conventional products in the final improved version (VI), (b) a 5 times higher appearance quality (index) with uniform paint film thickness, (c) the development of quick drying paint, and (d) the adoption of room temperature drying and subsequent discontinuation of drying equipment. These improvements achieved (i) a reduction of inventory in process of 1/3 and (ii) a reduction of paint cost to 85% of the conventional amount (15% cost reduction). Using a similar approach, Toyota and Aisin Kako realized identical achievements of simultaneous QCD.

5.2.2. Improving the operating ratio and stabilizing the quality of the welding process — A long-time bottleneck process in manufacturing

The second example, (B), is a case of simultaneous fulfillment of QCD in the welding process (Amasaka, 2004a). For example, arc welding of automotive parts (manual and robot work) requires periodical cleaning of spatter from the welding nozzle and replacement of worn welding tips. Thus the stabilization of the operating ratio and quality was a long-time bottleneck for this technology. Toyota formed task teams (Task-7) with Noritake Co. and Toshiba Tungaloy Co. respectively, both non-affiliates. For example, the ceramic coating of (B) to (G) for all surfaces of the conventional (A) Cr-Cu alloy welding tip (base material A), as shown in Fig. **7**, improved the wear resistance of the copper alloy welding tip by using a surface quality improvement technology.

Furthermore, the attachment of spatter was eliminated by developing a 100% ceramic welding nozzle in place of the conventional copper alloy nozzle. During about one year of joint task team activities, both companies obtained 19 patents. They developed welding nozzles that require no cleaning and welding tips with a longer service life at an identical quality level. As a result, they improved the operating ratio of the welding process by 8% (from 80% to 88%) and also obtained a sharp improvement in productivity. Thus the welding process achieved an operating ratio at an identical level to the machining process, and subsequently developed “*JIT*” for the manufacturing process.

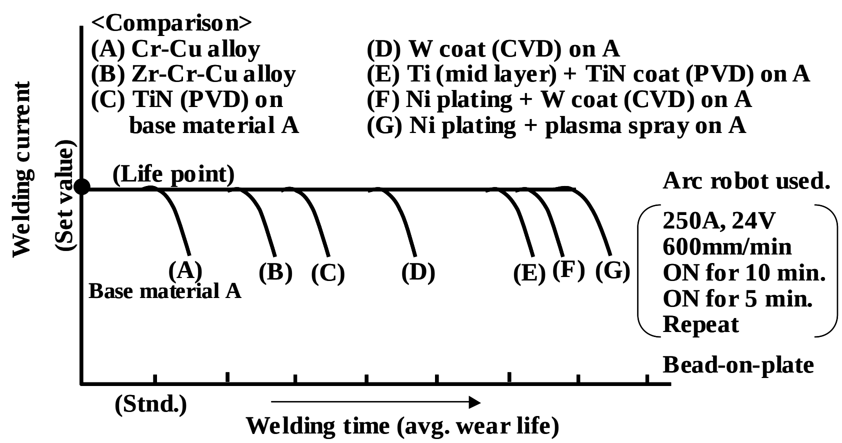

Figure 7: Welding Nozzle Wear Life Comparison by Ceramic Coating.

5.2.3. Improving the reliability of the oil seal for transaxles by utilizing the Science SQC approach —Clarifying the oil seal leak mechanism through visualization

The third example, (C), looks at “strategic QCD studies” (Amasaka, 2003b), to explain the “oil leak mechanism” of the oil seal in the drive system unit. This remains an unsolved problem on a global basis. Here too, Toyota and the non-affiliated NOK Co. implemented joint task team, “Dual Total Task Management Team” activities (Task-8), for about a year in world markets. The author developed the world’s first visualization device for an oil leak in the oil seal as shown in Fig. **8**.

Using this device, the author observed the motion and contact between the oil seal lip and the drive shaft connected to a drive gear turning at a high speed. As a result, it was found that metal chips are generated at the contact point between the drive shaft, which makes a slightly eccentric turn, and the sealed portion of the oil seal lip. These metal chips bond to one another and increase in size, causing the oil seal lip wear.

The author performed a multivariate analysis in order to analyze the cause, as shown in Fig. **9**, and identified oil seal lip hardness as the cause. Based on these findings, to improve the sealing performance between the oil seal and the drive gear, the task team improved: (i) the design quality (improved oil seal material, contour, and gear material for the drive unit). It also improved (ii) the processing equipment and oil seal assembly process. Subsequently NOK achieved a major reduction of the in-process defect ratio (by 90%) and an improved the operating ratio by 20%.

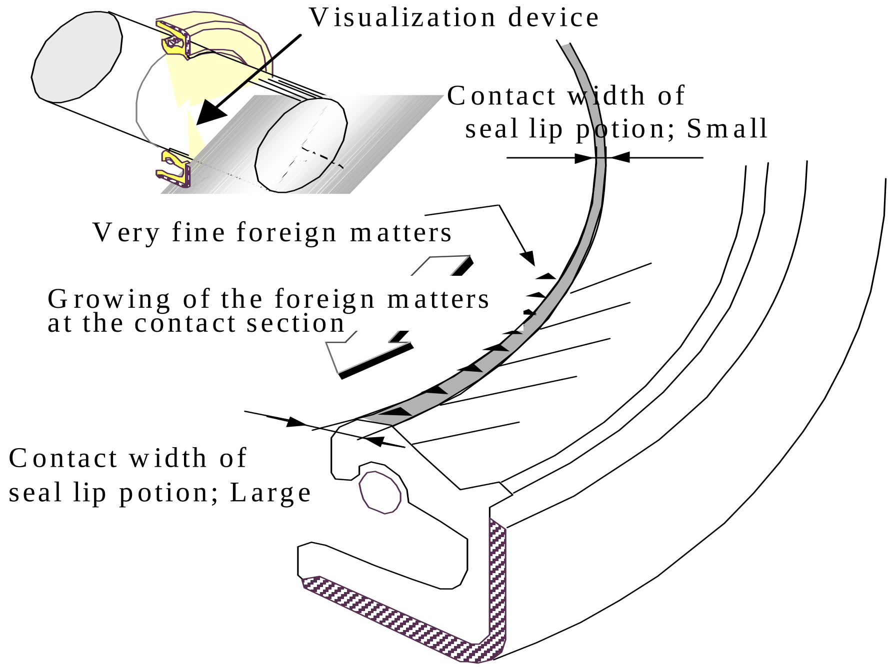

Figure 8: Clarification of the Oil Leakage Mechanism.

As the result, the running life for B10 (cumulative failure rate 10%) was improved 4 times (from 100,000 km to 400,000 km). NOK realized a sharp reduction in market claims (down to 1/16) and also achieved strategic QCD simultaneously.

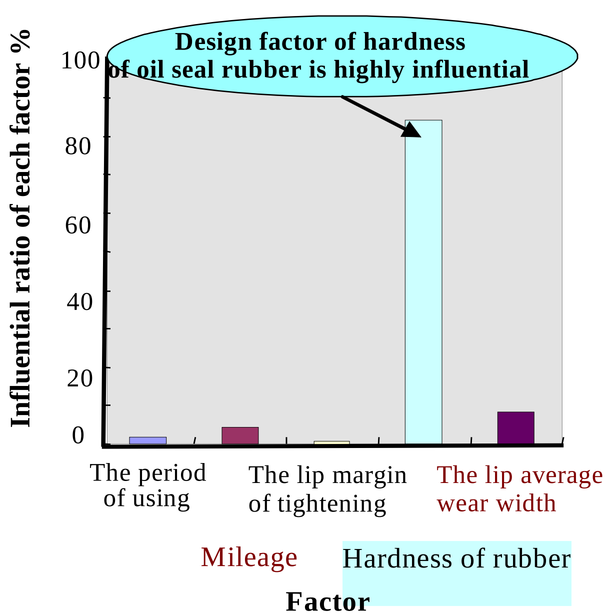

Figure 9: Influential Effect of Each Factor.

5.2.4. Developing New JIT through Strategic Stratified Task Team Activities to Japanese Advanced Companies

As mentioned above, each example of "QCD studies" indicates that Toyota and the affiliated/non-affiliated suppliers put their sales, service, development design and production divisions together to carry out joint task activities. In the implementation stages, they obtained targeted results smartly and correctly by adopting Science SQC. These examples contributed to the strengthening of the hardware system with three core elements (TMS, TDS, TPS, TIS and TJS) and the software system "Science SQC", and demonstrated the effectiveness of strategic "All Toyota's Science TQM" activities (Amasaka, 2004a).

Being in charge of promoting strategic quality management for Toyota and the Toyota group, the author organized and led task teams. The task teams tackled various engineering issues. The author's reference (Amasaka, 2004b) shows the progress of activity themes undertaken and accomplished by the task teams (Task-1 to Task-8). From 1988 to 2000, about 15,000 staff and 5000 managers carried out 4000 task team activities, part of which were presented to Japanese and overseas academic organizations in the thesis - Developing New JIT through Strategic Stratified Task Team Activities.

At present, furthermore, spread and expansion of the Science TQM are progressing as a "global production strategy model" of a Japanese advanced company (Fuji-Xerox Corp., Sanden Corp., Daikin Industries Ltd., NHK Spring Corp., JFE-Steel Corp., NEC Corp., Yanmar Corp. and others) (Shimakawa. et al, 2006: Baba, *et al.*, 2006: Fujii, *et al.*, 2006: Suzuki, *et al.*, 2006: Minomiya, *et al.*, 2006).

In the future, Science TQM will be positioned as a management technology strategy model and applied to solving various practical problems. And with the accumulation of demonstrative studies, "next-generation manufacturing" designed to improve the principle of world wide production management will hopefully be established.

6. CONCLUSION

Today's challenge in business management lies in providing customers with products of excellent QCD performance based on the "Customer First" concept, and doing this ahead of your competitors in "Market Creation" activities. This is the mission of Science TQM. This paper analyzed and proved the significance of strategically implementing Science TQM at Toyota. To realize manufacturing of excellent quality for the customer, the author proposed a management technology strategy model composed of three core models - "Strategic task team model", "Global partnering model", and "Simultaneous Fulfillment of QCD approach model" from the viewpoint of "Global Production". By applying the proposed model, the author could illustrate through strategic QCD studies on the "Simultaneous Fulfillment of QCD", the effectiveness of global implementation of Science TQM as demonstrated by Toyota, an advanced corporation and its affiliated/non-affiliated suppliers.

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KEY TERMS AND DEFINITIONS

Structured Model of Strategic Stratified Joint Task Teams:

Structured model of stratified joint task teams by forming partnering links will be developed systematically and organizationally to promote the strategic development of Science TQM. This model will consist of Task 1 to Task 8 teams involving the group, section, division, category, company, affiliated companies, non-affiliated companies, and overseas affiliates.

A Management Technology Strategy Model:

To realize manufacturing of excellent quality for the customer, the author proposes a management technology strategy model that utilizes the “Strategic task team model” between the manufacturer and affiliated/non-affiliated suppliers, the “Global partnering model", for strategically implementing Science TQM”, and the “Simultaneous QCD Fulfillment approach model”, for developing Science TQM.

Strategic Task Team Model between the Manufacturer and Affiliated/Non-affiliated Suppliers:

In the stage of actual implementation, it is important to strategically organize the stratified task teams from the following viewpoints by setting the objective to be continual improvement of management technologies: (i) Product strategy, (ii) Engineering strategy, (iii) Quality strategy, (iv) QCD effect, (v) Value of task team, and (vi) Human resource strategy.

Global Partnering Model for Strategically Implementing Science TQM:

GPM consists of four cores, namely, the Stratified joint task team (GPM-HT, Task-1 to Task-8) in mutual cooperation with affiliated and non-affiliated suppliers, the Stratified education training for improving the skills of staff and managers (GPM-HE, the Hierarchical Education), the Stratified leader training (GPM-HL, the Hierarchical Leaders Growth), and the Overseas study system (GPM-SA, the Studying Abroad System).

CHAPTER 14

Developing a Strategic Advertisement Method: Case Studies in Science TQM - 1

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Abstract: In this paper, the authors develop the "Video Unites Customer behavior and Maker's designing Intentions, VUCMIN" as a new strategic advertisement method designed to enhance the desire to visit dealers in the automobile industry. The proposed method uses video advertisement, and was developed based on scientific approaches and analyses that focus on the standard behavioral movements of customers who visit dealers when choosing an automobile. This method, which is based on the different approaches identified in target customer profiles, aims to increase the desire of customers to visit dealers. After creating this video advertisement, customers were verified as having a positive opinion towards visiting dealers with a plan to purchase the vehicle featured in the video.

Keywords: VUCMIN, a new strategic advertisement method, desire of customers, visiting dealers, automobile industry, video advertisement, AIDA model.

1. INTRODUCTION

In the 21st century, one of the important issues in the industrial world is how to create desirable and influential products. The last century was concerned with the important issue of how to implement uniform production in the industrial world. But in today's world, customer desires have diversified, and it is getting harder to meet the expectations of each customer in production. That is why it has become necessary to design and develop products that grasp the heart of customers and impress them deeply.

In this paper, the authors develop the "Video Unites Customer behavior and Maker's designing Intentions, VUCMIN", as a new strategic advertisement method designed to enhance marketing and the desire to visit dealers in the automotive industry. The proposed method uses development of a video advertisement based on scientific approaches and analyses that focus on the standard behavioral movements of customers who visit dealers in automobile industry.

Using a statistical data analysis of customer behaviors, the basis of different customer segments, their priorities, and preferences during personal visits can be clarified and linked with an advanced marketing strategy "AIDA" model using a short, internet video–oriented advanced advertisement method. This method, which is based on the different approaches identified in target customer profiles, aims to increase customer desire to visit stores.

2. NEED FOR A NEW ADVERTISING APPROACH IN THE AUTOMOBILE INDUSTRY

Advertising expenses in the Japanese automotive industry are trending to around 6 trillion Japanese Yen (Dentsu, 2003). Despite these high advertising expenses, the number of vehicle sales is stagnant (JAMA, 2005). Further, it is thought that retaining existing customers and gaining new customer profiles will be difficult unless researchers construct a new advertising policy: therefore, the authors propose a new advertisement approach (Amasaka, 2007).

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Kakuro Amasaka (Ed)

From the manufacturers' perspective, new designs must be created to grasp the heart of customers and find out how sale advertisements can deal with new customer intentions in the future. When looking at media-based advertising expenses, there has been an increase in internet advertising expenses recently (Dentsu, 2003). The automobile industry has also been expected to use internet video as a new advertising method.

2.1. Application of the AIDA Model in Advertising

The AIDA model, introduced by E. St. Elmo Lewis in 1898 (Lewis, 1985), is used to evaluate the effects of an advertisement. The model percieves levels of physiologically diversified behaviors, from when a person comes in contact with an advertisement until engaging in actual purchase of the intended product. The AIDA model is the prototype of today's advertising information processing model, and it categorizes the psychology of purchasing behavior in customers into 4 steps: A (Attention), I (Interest), D (Desire), and A (Action).

2.2. Actual Application of the AIDA Model in Advertising Automobiles

The author shows the AIDA curve from the new sale advertisements of Toyota's newly-released Funcargo model (Amasaka, 2009: Refer to Fig. **6** of Chapter 6). From this figure, one can see that in terms of advertisements, vehicles are generally promoted in the following order: television commercials (TVCM), newspapers, radio, fliers, posters, direct mail (DM), and direct hand (DH).

The results of this can be seen in the current status of customers visiting the dealers. The A curve in the figure shows the effecs of TVCMs after the advertisements, when 1.7% of customers make an actual dealer visit. The B curve confirms that the Media-Mics (newspaper advertisements, fliers, DM, and DH) result in a 7.3% increase in dealer visits. However, the effects of the Media-Mics are insufficient as advertisement tools, therefore the authors consider the need to promote new advertisement media (Melewar and Smith, 2003: Kimura, *et al.*, 2007: Smith, 2009).

In the next chapter, the authors propose "VUCMIN", which looks at establishing a new stategic advertisement method using internet interface.

3. APPOACH OF THE VUCMIN STUDY

The purpose of the "Video Unites Customer behavior and Maker's designing Intentions, VUCMIN" study is to effectively generate fascination with a product, resulting in an increase in the desire of customers to visit dealers and growth in the number of vehicle sales. The authors generated the following solution to the current situation outlined in chapter 2: distribution of a video 1 to 2 minutes in length to a particular age group and gender segment. The video takes customer preferences and the intentions of the product planning and design departments into account.

Fig. **1** represents the steps (Step 1–Step 4) of the VUCMIN study, utilizing the specific concept methods outlined in "SQC Technical Methods" (Amasaka, 1999, 2004, 2007). These steps cover preparation of internet video distribution, which unites customer preferences and behaviors with the manufacturer's design intentions.

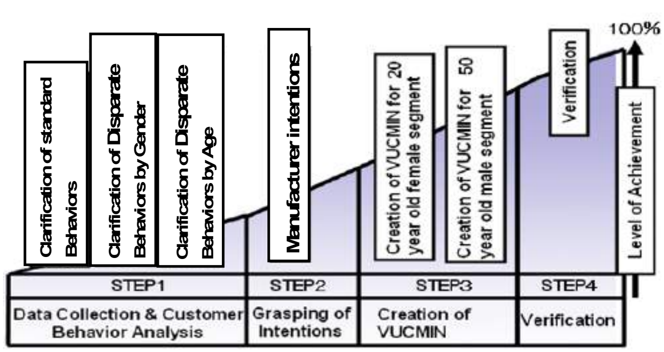

Figure 1: The Process of VUCMIN Video Creation.

3.1. Analysis of Customer Behavior and Data Collection (Step 1)

This step aims to provide an up-to-date inquiry as to deep-seated customer wants in terms of customer behavior analysis (James, *et al.*, 2006). Disparate behaviors by gender and age segment will be clarified in the analysis of standard behaviors.

3.2. Perception of Intentions (Step 2)

In this step, the intentions of the product planning department and designers are scientifically analysed in terms of product design. Identifying which aspects of the vehicle the designers and manufacturer want to express to customers is an important step in preparing the video.

3.3. Creation of the VUCMIN (Step 3)

An advertising video is created, targeting females in their 20s and males in their 50s using the results of Step 1 and Step 2. With this final step, the authors try to reach a solution based on the above research.

3.4. Verification (Step 4)

Using the data results from Steps 1 through 3, the authors verified the validity of the VUCMIN internet video that was created.

4. FRAME OF VUCMIN MODEL

Based on the research approach outlined in the previous chapter, the framework of the VUCMIN model is established as in Fig. **2**. In this figure, i) standard behaviors and ii) disparate behaviors by gender are identified and classified. After classifying the subjects by age, the details of disparate behaviors are identified mainly in terms of the front seat of the vehicle (driver's seat tools, passenger rearview mirror, *etc.*) and the rear seat (not shown in figure).

This knowledge of customer behaviors and knowledge of the parts that product plannning and designers wish to show to customers are taken into consideration as the basis for the VUCMIN model framework.

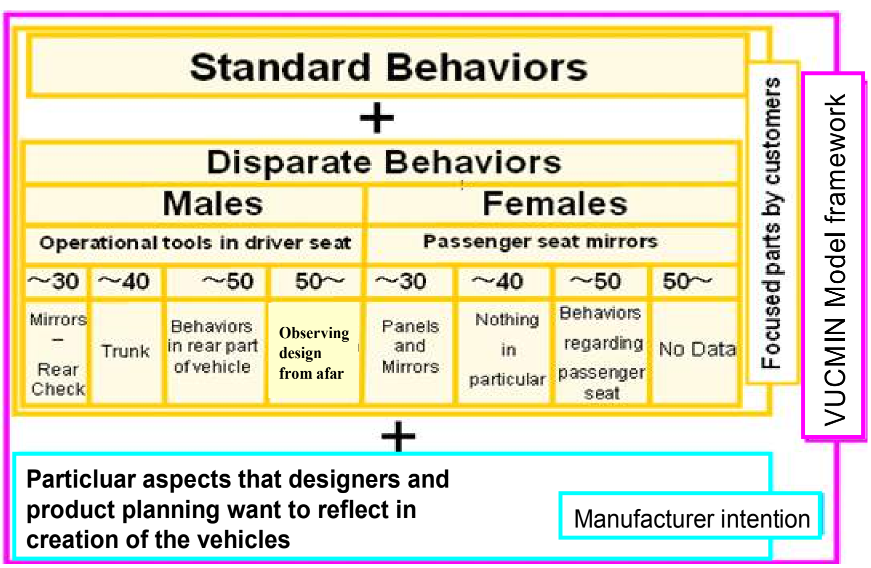

Figure 2: Frame of VUCMIN Model.

5. THE PROCESS OF VUCMIN CREATION

In this chapter, the authors explain the process of video creation using VUCMIN.

5.1. Data Collection from Customer Behaviors

In this section, customer behaviors are analyzed while customers are facing the vehicle from the front. This allows collection of customer information used to create the video. It is thought that customers' desire to visit the dealer can be increased *via* video distribution when the customer is in the stage "prior to dealer visit".

The authors therefore conducted the following survey in order to investigate customer behaviors. The authors prepared the survey table in Fig. **3**. The survey item categories were decided as follows:

In the survey table, the target vehicle model is 1, gender 2, age 3, standing positions 4, and vehicle part focused on is 5. Among those items, standing positions are categorized as in Fig. **4**. Front is 1, front fender (driver seat) 2, rear fender (driver seat side) 3, trunk is 4, rear fender (passenger seat side) 5, front fender (passenger seat) 6, handle 7, shift lever 8, near passenger seat is 9. In total, all customer behaviors (standing positions, getting in and out, operation, walking time, *etc.*) are categorised into 85 distinct types of behaviors.

The survey was conducted on customers visiting the Toyota Exhibition Hall in the 2 months from August 2006 to September 2006 between 12:00 and 17:00 p.m., according to age and gender group. 316 data items were collected.

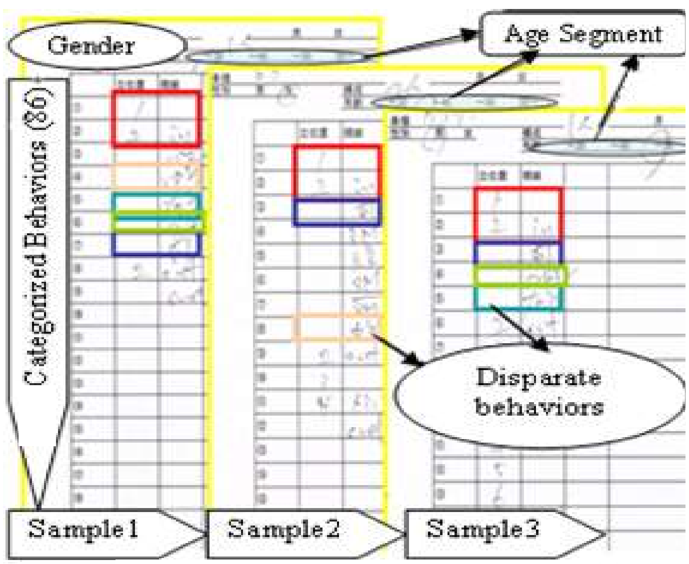

Figure 3: Survey Samples.

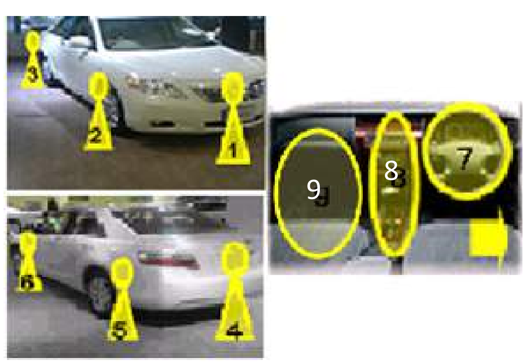

Figure 4: Sample Customer Standing Positions.

5.2. Data Analysis of Customer Behaviors

As a result of the behavioral analysis of how customers observe vehicles outlined in chapter 3, the following (i〜iv) conclusions were drawn:

i) In general, when customers visit vehicle galleries (dealers) they pay special attention to the first vehicle and focus on some parts with interest. However, they start to loose interest by the second and third vehicles, which they observe casually and for a shorter period of time.

ii) When movment time is excluded, customers spend only 1-2 minutes to determine the value of each vehicle.

iii) Regardless of gender and age, heading for the driver's seat and getting in and observing the interior, steering wheel, gagues, and other items was common standard behavior.

iv) Nevertheless, there were disparities in standard behaviors by both gender and age.

5.3. Detailed Analysis for Creation of VUCMIN

5.3.1. Standard Behaviors for Creating the Video

Toyota's Mark X was the vehicle model used in creating the video, and analyses regarding standard behavior were conducted as follows. As seen in Fig. **4** above, survey sheets are taken on each customer sample while they are observing the vehicle. Sample 1 is a 20 year old male, sample 2 is a 30 year old female, and sample 3 is a 40 year old male. Samples of each of the three customers are different according to their age and gender.

For further analysis, TMS (Text Mining Studio) is conducted on all categorized customer behaviors and the results are shown in Fig. **5**, numbers 1 to 86. The numbers in the inner circle of the figure (1, 9, 12, 16, 22, 29, 31, 32, 85) represent the nine standard behaviors (I) (observing front area → sitting in the driver's seat → driver operation system (control system) → leaving the driver's seat, *etc.*). Element resolution of the standard behaviors are also shown in Fig. **6**.

Next, the numbers in middle circle of the figure (17, 35, 40, 49, 53, 59, 73) represent the seven standard behaviors (II) (observing rear seat from driver's seat → moving to rear seat → leaving driver's seat and observing side of trunk → getting into rear seat of passenger seat → moving into passenger seat).

Furthermore, the remaining 70 attached behaviors from the outer circle of Fig. **6** specify individual behaviors. For example, 2 through 8 are looking at the vehicle entirely from behind, tires, and engine: 18 to 28 are passenger seat storage, side mirror, and lights: 42 to 48 are looking at vehicle diagonally from a 45 degree angle, looking under the vehicle, *etc.*

Finally, as a result of detailed anaylses, a pattern of standard behaviors was identified regardless of age or gender. Front → moving to driver's seat → entering driver's seat → looking out the front viw → observing steering operation systems and instrument panel → looking to passenger seat side → looking at operation systems on driver's side and checking side mirrors → leaving the vehicle.

5.3.2. Disparate Customer Behavior by Gender and Age for Creating Video

In this section, the following analyses of disparate behavior are conducted regarding age and gender.

1. Explanation of Disparate Behaviors by Gender

On the basis of the data collected above, a Correspondence Bubble Analysis was then conducted as seen in Fig. **7** to identify disparities in behavior by gender. Correspondence Bubble Analysis is an analysis technique generally known as correspondence analysis. This method distributes area maps related to attributes (gender, age) and texts (customer behaviors). Items with stronger relationships are closely distributed. In Fig. **7**, the difference in distributed texts (behaviors) by age and gender can be seen. (The blue line in the figure shows behaviors by gender, and the green line shows behaviors by age). Moreover, the authors identified male and female behaviors as follows.

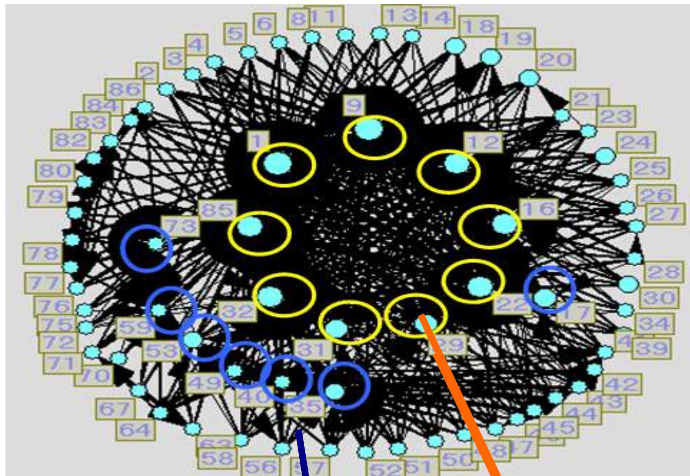

Figure 5: TMS Analysis of Standard Behavior.

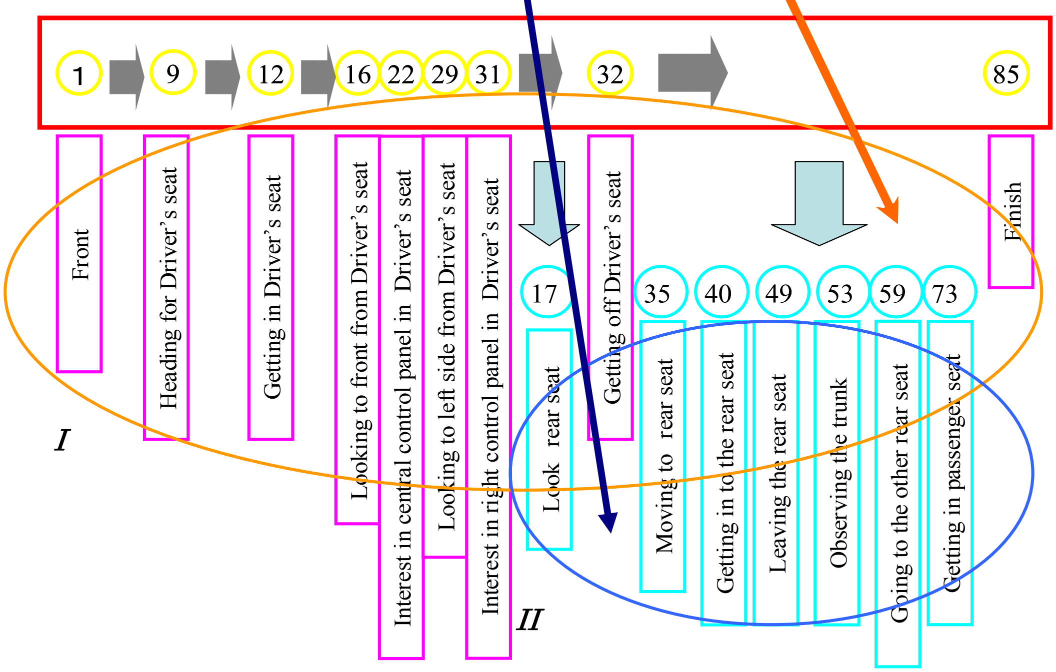

Figure 6: Standard Customer Behaviors.

-1) Female Behaviors

According to the results of the Correspondence Bubble Analysis, female customer behaviors indicate that they are especially concerned with the area around the passenger seat in addition to the front fender and rear-view mirror, door opening and closing, the dashboard, sun visor (make-up mirror), *etc.*

-2) Male Behaviors

However, males do not show concern the with passenger seat, and instead were focused on the driver seat position, shift lever, door switches, air conditioner, operating tools, and switches around the driver seat such as audio parts.

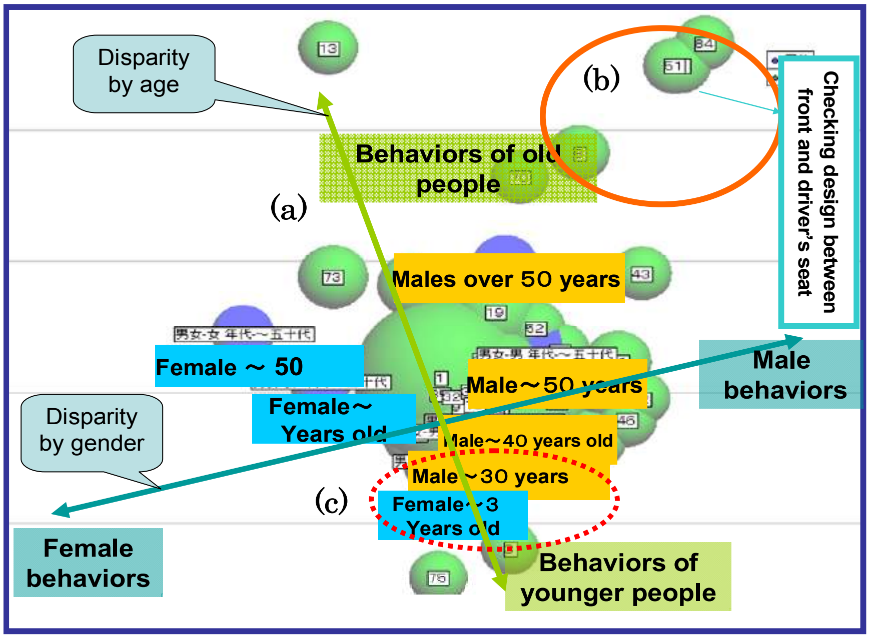

Figure 7: Disparate Customer Behaviors by Age and Gender.

2. Explanation of Disparate Behaviors by Age

In this section, disparate behaviors are investigated by conducting a Correspondence Bubble Analysis, on both gender and age attributes. For example, the following behaviors are seen for (a) males over 50 years old (the numbers from orange areas (b) in the figure, 8, 51, 84: (i) looking towards the driver's seat from far behind, (ii) observing the design between the front and driver's seat, (iii) looking to the driver's seat from a distance, *etc.*).

In particular, disparate behaviors are not evident until (c) the age of 30 for both male and female profiles. Moreover, males in their 20s look at (i) rear seats from the driver's seat, (ii) the rearview mirror, and (iii) the side mirrors. Similarly, profile behaviors of females in their 20s are looking at (i) the side mirror on the opposite side, (ii) the rearview window, (iii) the instrument panel, (iv) the dashboard, (v) and lastly, focusing on the operation and sound of the passenger seat door while opening and shutting.

The creation of VUCMIN the basis of this knowledge will be explained in the next chapter.

6. THE CREATION OF VUCMIN

6.1. Indentifying the Intentions of Product Designers

This chapter will explain the influence of product planning and designer intentions in VUCMIN creation. The Mark X is used as a target vehicle in design inquiries. According to common opinions from designers and product planning at Toyota Motor Corporation, the parts that are focused on to be demonstrated to customers are:

i) Front Proportions

ii) Streamlined Side Proportions

iii) Tri-Beam Headlamps (Lenses)

iv) Widened Console Box

v) Sharpened Rear

6.2. The Creation of VUCMIN for Males in Their 50s and Females in Their 20s

In this section the video created for the target profile of males in their 50s will be explained using the timetable in Fig. **8**.

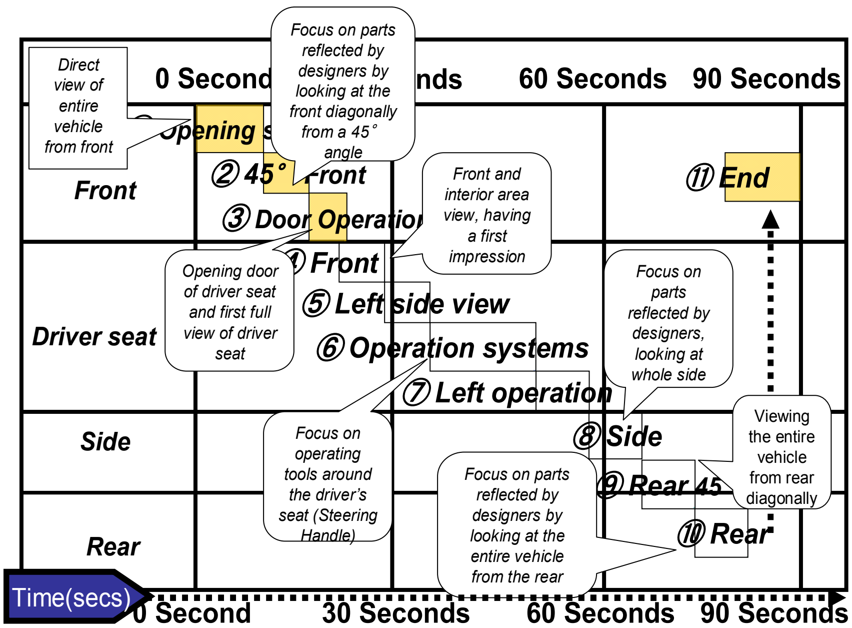

Figure 8: VUCMIN (Males in their 50s, Mark X) Creation Timetable.

The timetable figure indicates that video time is set at 90 seconds. Video shooting order is composed specifically of scenes from 1 to 11 starting from the front, driver's seat, side, and rear of the vehicle. Scenes are 1. direct front scene, 2. diagonally front view scene, 3. door opening scene of the driver's seat, 4. entire driver's seat view scene, 5. console box and shift lever scene, 6. Steering handle scene, 7. Operation tools of driver's seat scene, 8. side view scene from driver's seat, 9. rear side view scene, 10. entire view of vehicle from rear, and lastly, moving back to front, 11. entire view of the vehicle scene.

The composed scenes form the VUCMIN video on the basis of the standard and disparate behaviors of customers. Example photos representing these scenes (1 to 11) are shown in Fig. **9**. Using the same approach, VUCMIN is created regarding age and gender.

7. VERIFICATION

In this chapter, customer surveys are executed in order to test the validity of VUCMIN. This is done by asking customers, "After seeing the Mark X video, approximately when do you plan to purchase one by visiting a Toyota dealer?" to verify their desire to visit dealers (high, low). According to the survey results, the desire to visit dealers (early stage consideration of Mark X purchase) is not only increased for current Toyota vehicle owners but also for customers who own vehicles from other manufacturers.

The authors are currently promoting the results of this research as part of the strategic advertising method VUCMIN, which utilizes internet interface with the collaboration of universities and industries.

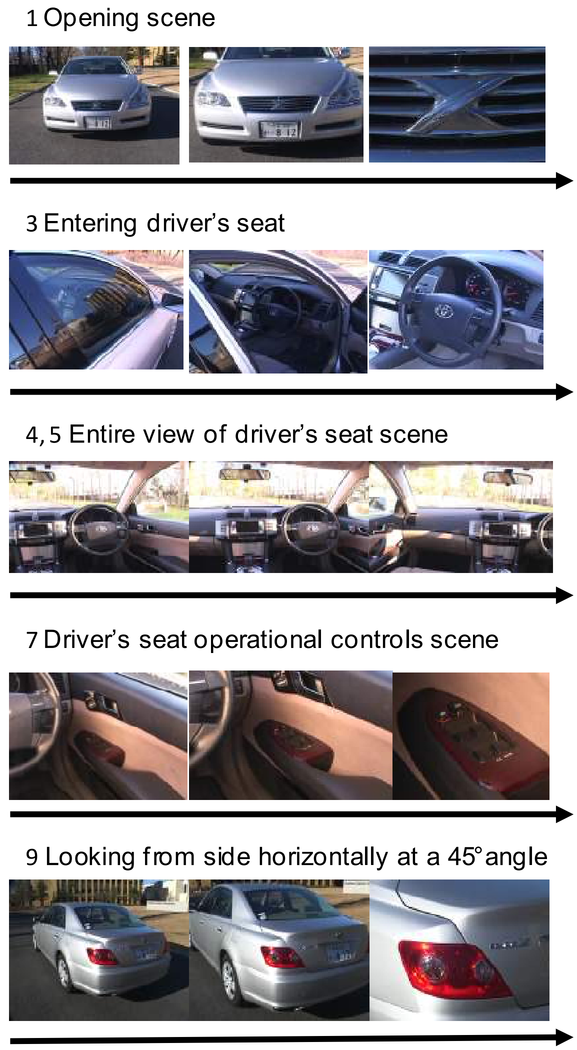

Figure 9: Example of Representative Photos for VUCMIN Video.

8. CONCLUSION

In this study, the authors developed VUCMIN as a new strategic advertising method in order to enhance the desire to visit stores in the automobile industry. The proposed VUCMIN uses video advertisements, developed based on the scientific approaches and analyses that focus on the standard behaviors of customers visiting stores in the automobile industry. VUCMIN aims to increase customer desire to visit stores based on target customer behavior approaches.

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CHAPTER 15

Effectiveness of Flyer Advertising: Case Studies in Science TQM - 2

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Abstract: In this paper, the author shows the effectiveness of flyer advertising utilizing as a core technology "Total Marketing System, TMS". TMS is part of "Science TQM", which contributes to constructing a "Toyota Sales Marketing System, TSMS". This new TSMS is key to scientific automobile sales innovation at Toyota group dealers in Japan. This study describes the "flyer advertising effect", the "day of the week effect", and the "new car effect". Employing the "Science SQC" approach, these effects are acknowledged among those on the front lines of automobile sales as having a high level of investment efficiency and resultant customer traffic.

Keywords: Flyer advertising effect, science TQM, TMS, science SQC, TSMS, automobile sales innovation, toyota.

1. INTRODUCTION

In the light of recent changes in the marketing environment, the author believes it is now necessary to develop innovative business and sales activities that adequately take into account the changing characteristics of customer's who are seeking to break free from convention. If they are to be successful in the future, those involved in global marketing must develop an excellent quality marketing system that is impressive to users and that will enable the consistent and timely provision of excellent quality products through corporate management.

With this in mind, the author has recently touched on the development of the "Science TQM", and its validity as a new quality management principle for 21st century manufacturing (Amasaka, 2004a, 2008). Science TQM offers a renewal of each division's business processes. The system encompasses sales, development design, and production. In particular, a marketing management system must be established so that the divisions responsible for the development and design of appealing products (Business, Sales, and Service divisions), which are also the ones closest to customer, can easily acquire information on customer needs and preferences through the consistent application of objective data and scientific methodology.

In this paper, therefore, the author (Amasaka, 2009) shows the effectiveness of flyer advertising utilizing as a core technology Total Marketing System "TMS". TMS is part of Science TQM, which contributes to constructing a "Toyota Sales Marketing System, TSMS". This new TSMS is key to scientific automobile sales innovation at Toyota group dealers in Japan. This study describes the "flyer advertising effect", the "day of the week effect", and the "new car effect". Employing the "Science SQC, New Quality Control Principle" (Amasaka, 2004b), these effects are acknowledged among those on the front lines of automobile sales as having a high level of investment efficiency and resultant customer traffic.

2. BACKGROUND

Full-scale marketing in Japan began in the 1950's when the father of quality control, Dr. W. E. Deming, visited Japan to give lectures. The lectures led to the widespread introduction of Statistical Quality Control (SQC) in the field of market research (Kaneko, 1998). Although Deming's aim was the permeation of business science into corporate management, the main development resulting from his lectures was Total Quality Control (TQC), which mostly applied to manufacturers' production activities. This was partly due to underlying influences at the time.

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Kakuro Amasaka (Ed)

Thus, TQC and SQC have not been adopted as widely in sales and product planning as in production, development and design. This has caused tension in customer-oriented quality management. In the light of the above, quality control has recently undergone a transformation, and is now referred to as Total Quality Management (TQM) (TQM Committee, 1998).

Recent research conducted by the author (Amasaka, 1999a) has revealed that scientific marketing and system construction in sales and sales-related organizations remain inadequate. The research was aimed at surveying the circumstances of major Japanese enterprises in order to gain an understanding of problem areas in the promotion of TQM, in the hope that rapid progress could be made in these areas in the future.

The above research suggests that it is necessary to promote scientific activities involving sales and sales-related departments. That is, close observation of recent changes in the field of marketing by the author (Amasaka, 2001a, 2007) and other researchers (Kotler, 1999: Niiya and Matsuoka, 2001: Okada, *et al.*, 2001: Ikeo, 2006) has led us to the conclusion that it is necessary to place more emphasis on communicating with customers in order to gain an adequate understanding of their changing characteristics, unbiased by established concepts.

This new understanding should form the basis of business and sales innovation. In particular, the author (Amasaka, 2001b) believes that a better quantitative understanding of the effect of publicity and advertising in automobile sales will enable more effective sales activities. Although experience shows that, of the various types of advertising media, flyer advertising has been very effective in attracting customers, this has not yet been analyzed quantitatively (Gary and Arvind, 2003: James and Mona, 2004: Jeffrey and Bernard, 2005).

3. SIGNIFICANCE OF SCIENCE TQM

Developing appealing products and supplying them to customers is the mission of all enterprises and the basis of their existence. As mentioned above, the author has recently touched on the development of a new version of the "Science TQM, New Quality Management Principle" (Amasaka, 2004a, 2008), which offers a renewal of each division's business processes.

This Science TQM includes hardware and software systems developed according to new principles to enable the companywide coordination of all activities, as shown in Fig. **1**. The hardware system comprises five core elements: Total Marketing System "TMS", Total Development System "TDS", Total Production System "TPS", Total Intelligence Management System "TIS" and Total Job Quality Management System "TJS". The software system is the application of TQM-S (TQM utilizing Science SQC, New Quality Control Principle (Amasaka, 2000, 2008).

Fig. **1** illustrates a typical organization chart. As shown, there are a total of 13 departments: five departments are concerned with development and design (Product planning, Profile design, Engineering design, R&D and Evaluation by examination), four departments are engaged in production (Preparation for production, Production engineering, Manufacturing and Inspection) and four departments are related to sales and planning (Sales, Service, Market research and Product management). Jobs generally span multiple departments and staff are required to carry out timely and speedy Quality, Cost and Delivery (QCD) activities. In this sense, the principles of Total Marketing are consistently applied companywide (Amasaka, 1999b).

In order to develop a Science TQM that is customer-oriented, the author (Amasaka, 2003a, 2004b) has proposed "Science SQC, New Quality Control Principle", shown in Fig. **2** below. With its four principles, this scientific method serves as a common language for the five core systems (TMS, TDS, TPS, TIS and TJS) that form the basis of the organically linked Science TQM. Science SQC is a new systematized SQC application for creating technologies that seeks general solutions which can serve as quality control principles for the industry as a whole.

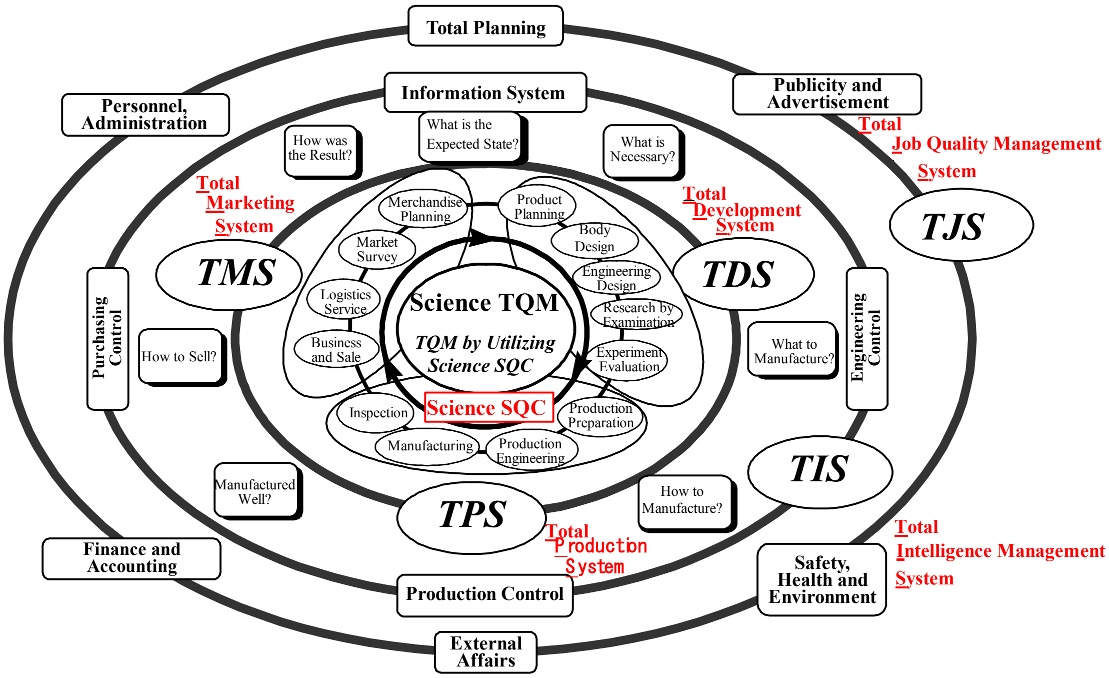


Figure 1: Science TQM, New Quality Management Principle.

The survey indicates the need for such a system across the whole automobile industry, including Toyota. This has led the author (Amasaka, 1999a, 2000) to the conclusion that a core system consisting of three technologies should be employed, where the TMS and TDS are added to the conventional core technology of Toyota Production System. In particular, the establishment of TMS (which involves the application of Science SQC) is expected to be a key factor in promoting Science TQM.

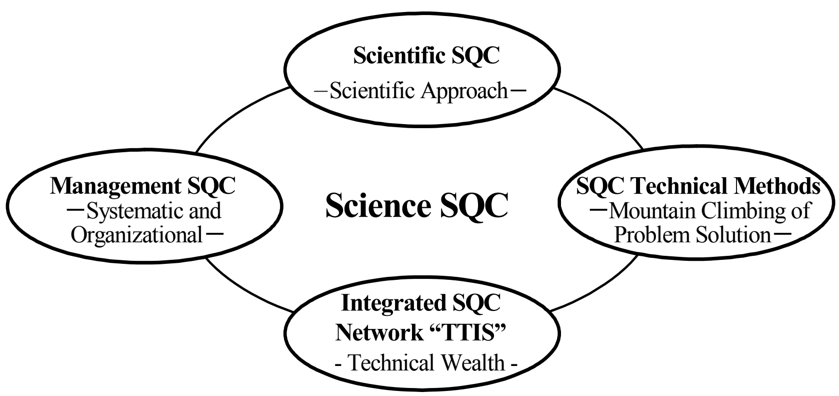


Figure 2: Science SQC, New Quality Control Principle.

4. NEED FOR AUTOMOBILE SALES INNOVATION THROUGH TMS

The author (Amasaka, 2004a, 2007) has previously proposed the TMS, which includes the four main axes (a)-(d) contained in the core system as shown in Fig. **3**.

a) Market creating activities making full use of customer information gathered by linking sales, product planning, design, development and production.

b) Product value improvement through the strengthening of product competitiveness, reflecting all factors constituting product value (QCD, reliability and brand).

c) Building ties with customers through the firm establishment of the Toyota Sales Marketing System. This system involves three key factors: Shop appearance, Merchandise and Service.

d) Customer value improvement through practical company activities focusing on all three requisite factors: Customer Satisfaction (CS), Customer Retention (CR), and Customer Delight (CD).

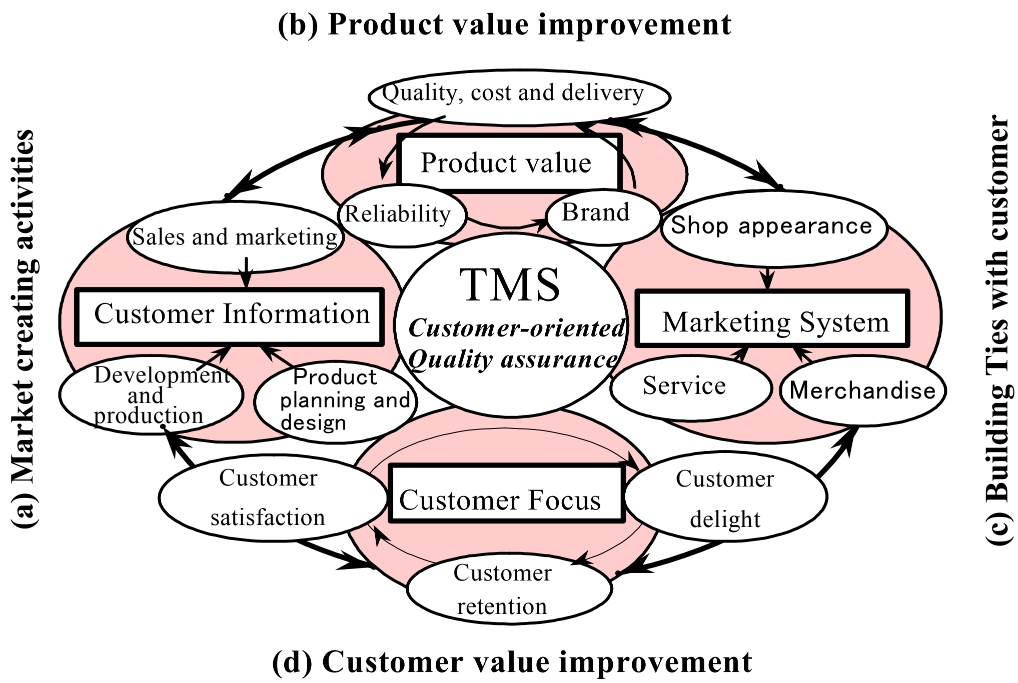


Figure 3: Total Marketing System "TMS".

In order to verify the effectiveness of the proposed TMS, the author (Amasaka, *et al.*, 1998, Amasaka, 2001a) has constructed the "Toyota Sales Marketing System, TSMS" as shown in Fig. **4***,* as a way to aid sales marketing through *"*innovative bond building with the customer" (Amasaka, 2003b).

This system combines information technology and statistical science to make practical use of customer data in order to (i) increase the rate of customer retention, and (ii) acquire new customers. In order to increase the rate of dealer visits and vehicle purchases by current loyal users, customers are stratified into "High-Probability Customer, HPC", "Medium-Probability Customer, MPC" and "Low-Probability Customer, LPC" customers, and a sample is then taken of the marketing, sales, and service items demanded by these customers, and the level of customer satisfaction achieved (Amasaka, 2001a).

The system then uses this data to enhance daily marketing, sales, and service activities. The system can also be employed when visiting customers, and to help acquire new customers when they visit dealers. By using this system, "Netz Chiba", a Toyota dealer in Chiba Prefecture, has successfully improved its customer retention and new customer acquisition ratios. The system is now in use at Toyota dealers nationwide (Nikkei Business, 1999).

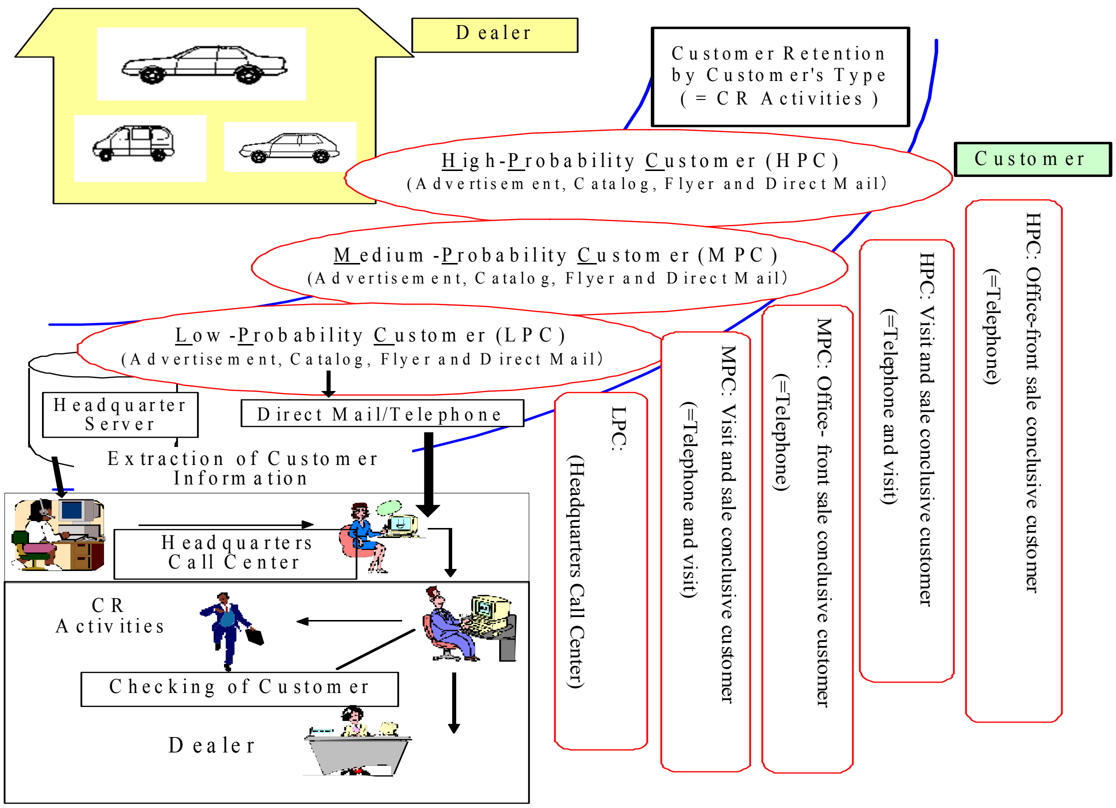


Figure 4: Outline of Toyota Sales Marketing System, TSMS.

5. NEED FOR SCIENTIFIC AUTOMOBILE SALES INNOVATION THROUGH TMS

5.1. Publicity and Advertising as Automobile Sales Promotion Activities

For many years, dealers have been employing various publicity and advertising strategies in cooperation with automobile manufacturers in order to encourage customers to visit their shops. Fig. **5** shows a graphical representation of the relationship between publicity and advertising media that contributes to drawing customer traffic to dealers. Area A represents multimedia advertising (internet, CD-ROM, *etc.*), Area B represents direct advertising (catalogs, handbills, direct mail, telephone, *etc.*) and Area C, represents mass media advertising (radio and TV broadcasting, newspapers, magazines, flyers, *etc.*).

There appear to be few cases where scientific research methods have been used to study the ways in which such sales activities actually draw customers to dealers (Kubomura and Murata, 1969). As part of an organization's market creation activities, it is important to gain a quantitative understanding of the effect of publicity and advertising, which are the principal methods involved in sales promotion and order taking, in order to aid the development of future business and sales strategies. The author believes that this will lead to innovations in dealer business operations (Amasaka, 2001a).

5.2. Dynamics of the Effect of Publicity and Advertising

The kind of information dealers need to know in order to continuously increase the number of customers attracted following the launch of a new model is (i) how many months the effect of the new model introduction lasts, (ii) the best timing (day of the week) and volumes for the most effective flyer advertising, (iii) the ratio of HPC customers who show an interest in purchasing a new car, (iv) the percentage of HPC customers who actually purchase new cars, and (v) variation among dealers. It is preferable to know the actual causes and effects involved.

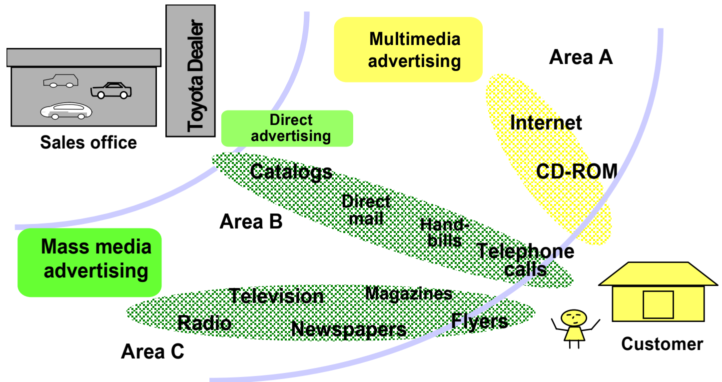


Figure 5: Graphical Representation of Customer Motives for Visiting Dealers.

Analytical methods have not been established for analyzing the dynamic effect of publicity and advertising due to the large scale and level of difficulty of market experiments for obtaining quantitative information in time series. Therefore, there are few reports on this subject relating to automobile marketing (Tauchi, 1977). For this reason, the author presents in the next section factorial analysis conducted using Science SQC, in the hope that it will assist readers in strengthening their information-based marketing, and promoting the Toyota Sales Marketing System.

6. EFFECTIVENESS OF FLYER ADVERTISING IN AUTOMOBILE SALES

This section demonstrates the effectiveness of the “flyer advertising effect”, “day of the week effect”, “new car effect” (Amasaka, 2001a). These effects are acknowledged among those on the front lines of automobile sales as having a high level of investment efficiency and resultant customer traffic, achieved through Science SQC, the so called Marketing SQC (Amasaka, *et al.*, 1998).

6.1. Publicity and Advertising Media and Sales Activities

Fig. **6** shows a graphical representation of the causal relationship between sales and order taking activities (dealer visit → HPC → order placement), and publicity and advertising media. The diagram indicates that the dealer’s publicity and advertising activities (causal system: X1 to Xn) attract customers’ interest in purchasing, encourage them to visit the dealer (result system: Y0), and ultimately lead to the purchase of a vehicle (HPC:Y1→order placement:Y2).

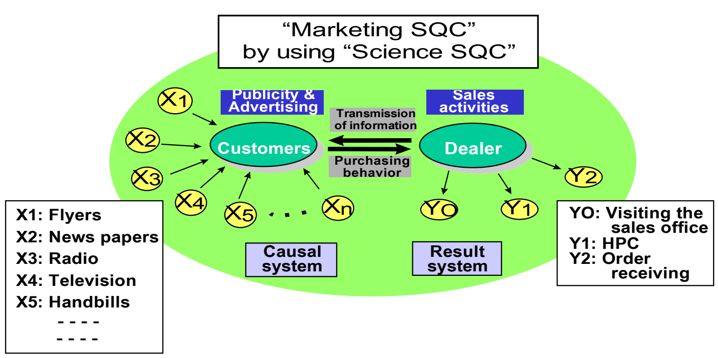


Figure 6: Relationship between Sales Activities and Publicity and Advertising.

6.2. Importance of Flyer Advertising

Next, we will comparatively evaluate the importance of the factorial effect of publicity and advertising on the basis of the subjective criteria (evaluation point: median) of representative sales staff from Toyota group dealers A and B. Table **1** indicates the extent of the effect gained from each of the respective media used to promote customer visits to dealers.

The table suggests that the effect of flyer advertising delivered together with newspapers is expected to be significant, which agrees with the empirical knowledge (sales people's experience) fostered through years of sales activities.

Table 1: Comparison of Publicity and Advertising Media

	Flyer ad	News paper	Television	Radio	···
Information capacity	○	○△	△	×	···
Information quality	○	○△	△	×	
Frequency of acquiring information	○△	○△	△	○△	
Ease of acquiring information	○	○	△	△	
Residual effect	○	○	△	×	
Total point	174	144	60	30	···

Rating	
◎	5 points
○	4 points
○△	3 points
△	2 points
×	1 point
××	0 point

6.3. Survey on the Effects of Flyer Advertising and Factorial Analysis

6.3.1. Survey on What Prompts Customers to Consider Buying a Car

In order to verify the points made in Section 4, analysis has been carried out on what customers say prompted them to consider buying a car at Toyota group's representative dealers A and B. Fig. **7** shows that flyer advertising is a significant factor in influencing a customer's decision to purchase a new car.

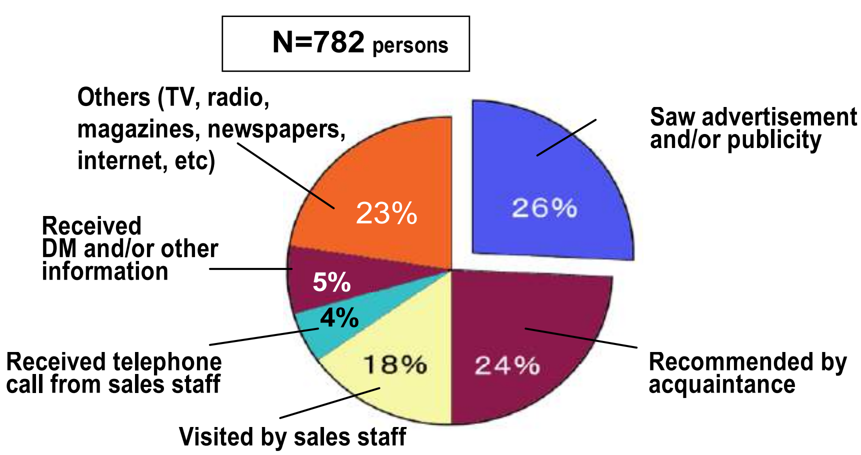


Figure 7: Survey on What Prompts Customers to Consider Buying a Car.

6.3.2. Factorial Analysis of the "Flyer Advertising" Effect

1. Content of the Field Survey

A field survey was conducted as follows by designating six sales offices of Toyota group's dealer B, which is located in an urban area.

a) A visitor questionnaire was used to determine customers' motives for visiting the dealer's sales office, and to create a customer profile (age, desired vehicle type, timing of purchase, budget, *etc.*)

b) Analysis was carried out based on the results of the study in time series of distribution of the flyers (quantity, *etc.*) over the nine-month period starting before and ending after the latest introduction of a new car, and covering the order taking activities at the respective dealers (number of visitors → number of HPC customers → number of cars sold).

2. Science SQC Approach

The core techniques of Science SQC, SQC Technical Methods are used to objectify (modeling: explicit knowledge) the subjective evaluation (empirical knowledge: implicit knowledge) of the "flyer advertising" effect. Here, the Science SQC approach shown in Fig. **8** is applied to conduct a factorial analysis on the effect of flyer advertising in the sequence of Step 1 (survey) and Step 2 (analysis). The author intends to report on Step 3 (demonstration) at a later time.

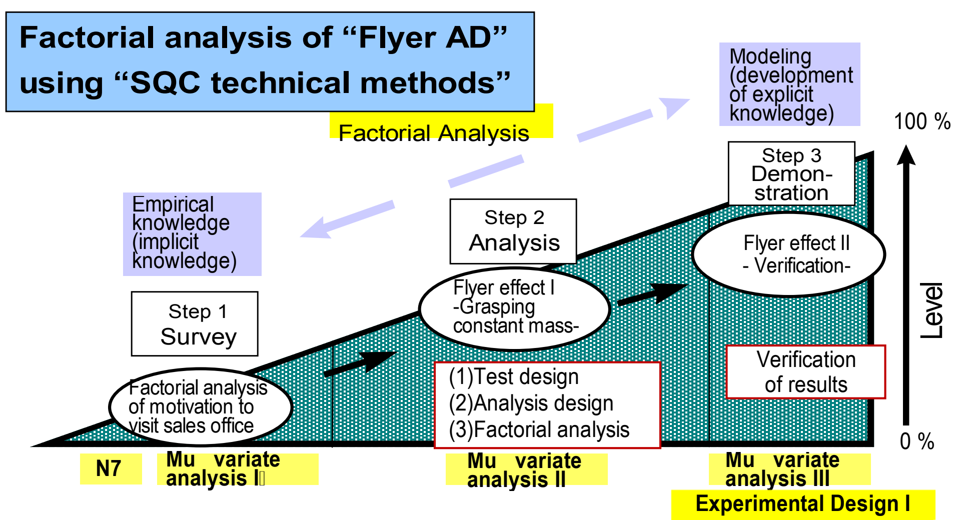


Figure 8: Factorial Analysis of the Effect of Flyer Advertising.

3. Analysis of Customer Motives for Visiting Dealers

Fig. **9** represents graphically an analysis of customer motives for visiting dealers. This analysis was carried out on the basis of Quantification Class III in order to objectify subjective evaluations. The categorical quantities of publicity and advertising media such as flyers, newspapers and magazines shown in the diagram, lead us to the conclusion that those customers prompted by flyers to visit dealers are likely to at some time need to replace their old car, and will be on the lookout for a bargain.

With other media, comparatively younger male customers may, for example, visit a dealer upon seeing some new RVs featured in a magazine. These results corroborate the information on publicity and advertising media shown in Fig. **6** and Table **1**, and the results analysis of their respective effectiveness. This enables us to acquire useful knowledge for developing future business and sales activities.

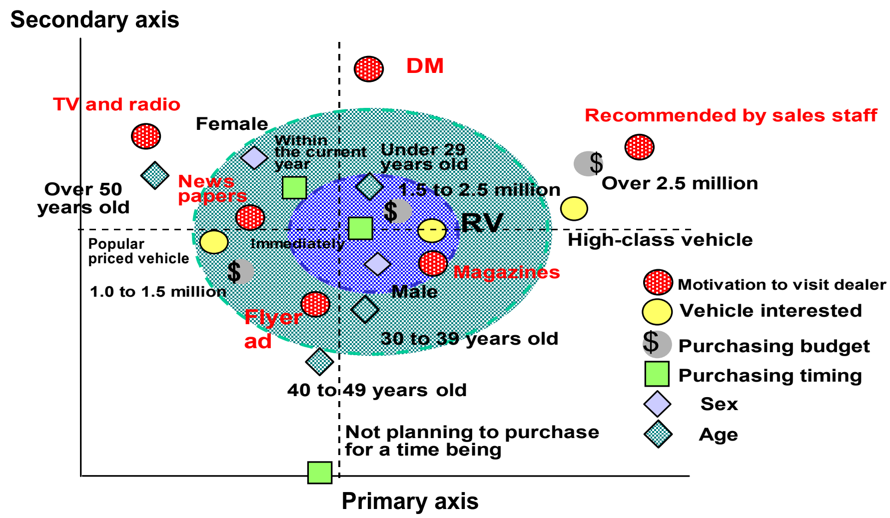


Figure 9: Analysis of Motives for Visiting Dealers (Quantification Class III Scatter Diagram Showing Category Quantities.

4. Analysis of Sales Activities in Time Series

Fig. **10** shows an overview of the number of visitors to the shop (Y0), the number of HPC customers (Y1) and actual orders received (Y2) in the two months following the start of a new car sale within the total nine-month period of the field survey. The chart gives an outline of the distribution effect (↓) of flyer advertising.

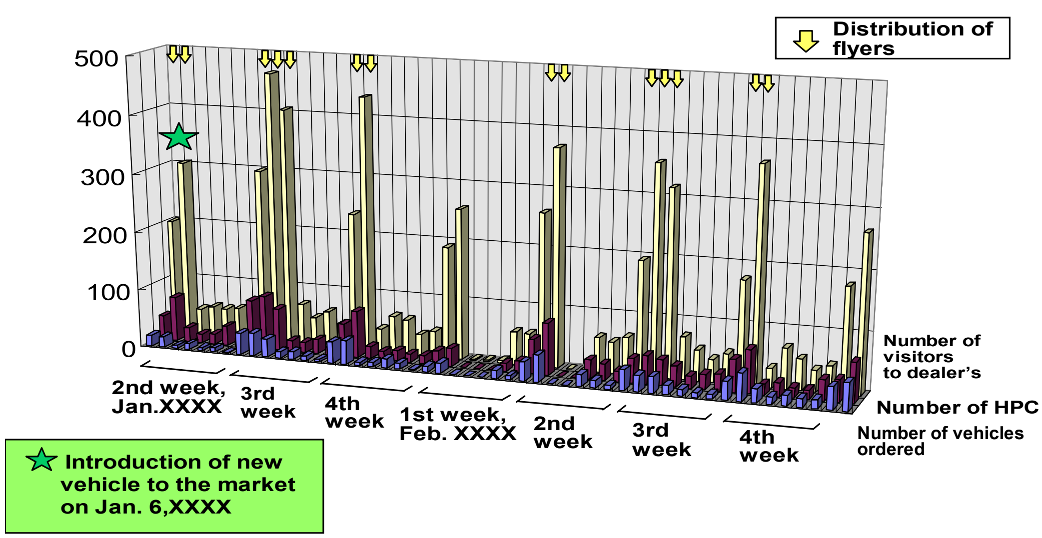
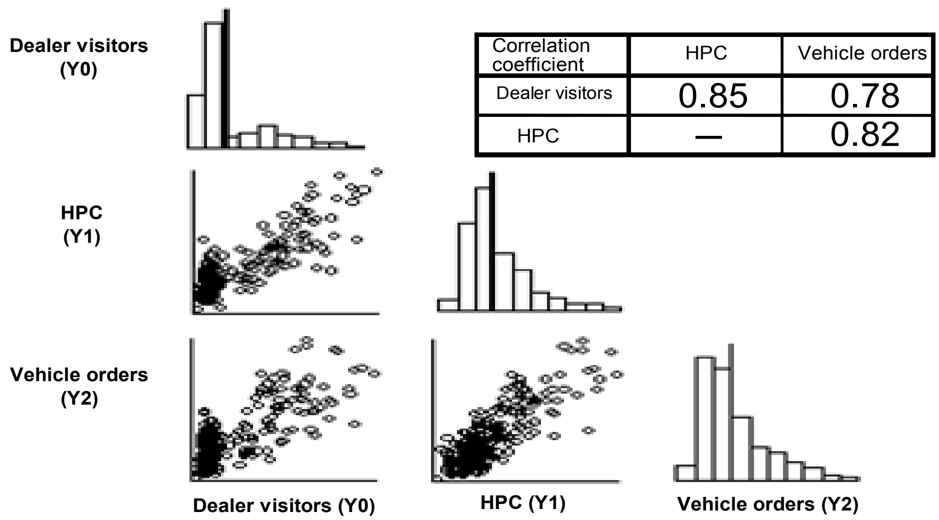


Figure 10: Example of the Records of Sales Activities.

Moreover, we can assume from the multivariate association diagram in Fig. **11**, which covers the total nine-month survey period, that the number of visitors (Y0) is the principal factor in increasing the number of purchases (HPC (Y1) to order placement (Y2)).



Correlation coefficient	HPC	Vehicle orders
Dealer visitors	0.85	0.78
HPC	—	0.82

Figure 11: Relationship Between the Number of Dealer Visitors, HPC, and Vehicle Orders Placed.

Now let us look at the relationship between the number of visitors, number of HPC customers and the number of units sold, as shown in Fig. **12**. This diagram shows that (i) as the number of visitors (Y0) increases, the number of HPC (Y1) and the number of units sold (Y2) also increase on a regression slope of the respective exponents a 1 and a 2.

Also, the diagram confirms that (ii) the ratio of the number of units sold is about one-half of the number of HPC customers. Further, we can assume from the information in the diagram that (iii) due to the considerable dispersion in the data from the regression line, there is also a considerable dispersion in the ratios of the number of HPC customers and units sold to the number of customers visiting the respective sales offices.

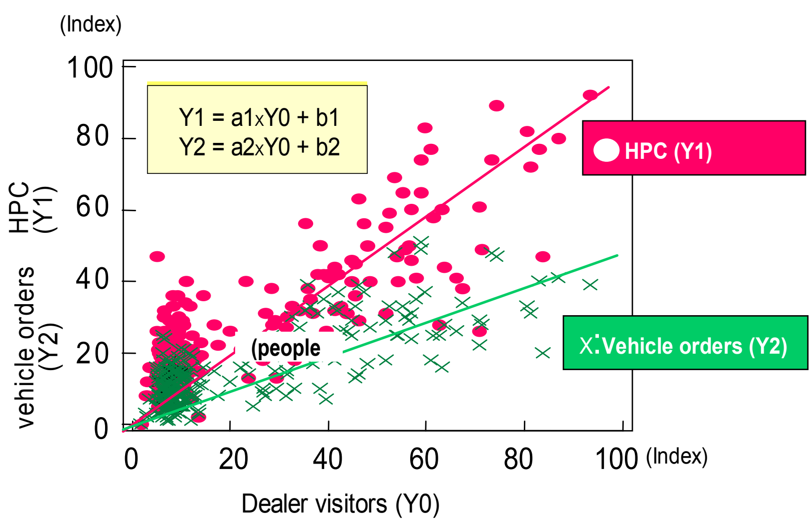


Figure 12: Scatter Diagram Showing the Number of Dealer Visitors, HPC, and Vehicles Orders Placed.

In this connection, a survey and analysis were carried out to determine whether such dispersion factors in the data are dependent on the characteristics of each sales office. Six representative sales offices were selected from dealer B and analysis was carried out on differences in flyer distribution, the number of visitors to each of the sales offices, the number of HPC customers, and the number of orders received for each office. The results of this analysis are summarized in Fig. **13**.

This figure indicates that there is considerable variation in the exponents of orders received among the sales offices. For example, in comparing the exponents of orders received (η= number of units ordered/number of HPC) between the main sales office located in an urban area and the Maizuru sales office located in an outlying area, the figure shows that the exponent for the Head Office is 0.48, while that for Maizuru sales office is 0.71.

Although it goes beyond the scope of this discussion, the author is able to obtain new activity guidelines for formulating new sales strategies by gaining an understanding of the data dispersion among the sales offices on the basis of such analysis.

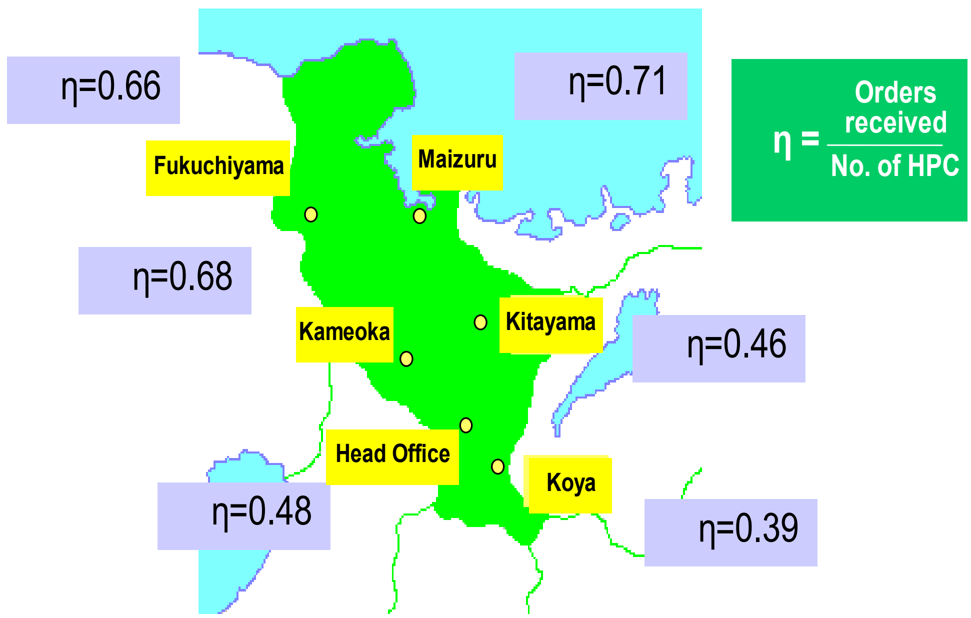


Figure 13: Map Showing Location of Toyota Dealer B Sales Office.

5. "Flyer effect", "Day of the week effect", and "New car effect"

Due to time constraints in the object period for analysis, the author used quantification class I for the current factorial analysis of the survey data in time series. Fig. **14** shows the "flyer effect", the "day of the week effect", and the "new car effect", which influence the number of visitors (Y0) to the sales office.

Confining the discussion to the current range of investigation, the following can be observed from Fig. **14**: (i) Item 1 shows that the greater the number of flyers distributed, the more customers visit the dealer. (ii) Item 2 shows that the effect is greater on Saturdays and Sundays, while the number of visitors is more or less constant on weekdays. (iii) Item 3 shows that the "new car effect" continued for two months in the current analysis, including the first month the new car went on sale. The effect converged in the period from three to five months after the new car went on sale.

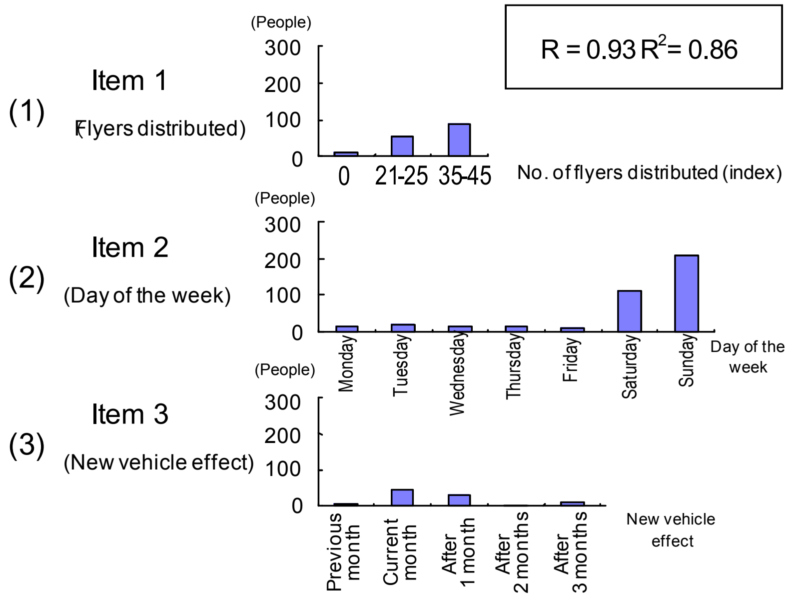


Figure 14: Quantification Class I (Graph of the category quantities).

6. Considerations

As a result of the survey and analysis conducted thus far, the author has been able to quantitatively clarify the acknowledged opinions of sales staff (empirical knowledge) on the "flyer effect", the "day of the week effect" and the "new car effect". Based on this information the author believes that, in order to efficiently enhance the effectiveness of flyer advertising, it is necessary to carry out demonstrative research (Fig. **8**: Step 3 Demonstration) to determine the saturation point of flyer advertising (limit the number of flyers distributed), optimal timing (best days of the week for distribution), the elements of effective flyer design (layout and impact), and the location and scale of dealers.

Furthermore, the author intends to carry out a new demonstrative study on the effectiveness of similar mass media such as TV advertising, direct mail, and the internet, so that they can be applied as strategic steps in developing the Toyota Sales Marketing System (TSMS). The deployment of TSMS, which involves strategic developments in the effective use of flyer advertising and other publicity media, has recently contributed to an increase in the sales share of Toyota vehicles in Japan (From 40% in 1988 to 46% in 2005) (Nikkei Business, 1999).

7. CONCLUSION

This paper has aimed to clarify the publicity and advertising activities of automobile sales organizations in order to quantitatively assess the causes and effects of flyer advertising and other advertising methods, utilizing Science SQC to promote the strategies of the Toyota Sales Marketing System (TSMS). Specifically, the author demonstrates the "flyer advertisement effect", the "day of the week effect", and the "new car effect". Through this study, the author has demonstrated the effectiveness of flyer advertising utilizing as a core technology Toyota Marketing System (TMS), part of the New JIT system.

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CHAPTER 16

Highly Precise CAE Analysis Approach Method: Case Studies in Science TQM - 3

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Abstract: In this paper, the authors propose a "Highly Precise CAE Analysis Approach Method", which is intended to contribute to the regeneration of development and design. This model has been applied with significant results in making proposals for bolt tightening behavior analysis, which continues to be an area of concern.

Keywords: Highly precise CAE analysis approach method, development design, CAE analysis of bolt tightening behavior.

1. INTRODUCTION

Japan's automotive industry is currently aiming to achieve worldwide uniform quality and production at optimum locations in order to ensure survival in today's harsh economic climate. Amidst the rapidly changing management technology situation and worldwide quality competition, it is now imperative for automobile manufacturers to take the initiative in offering highly reliable leading-edge products to enhance customer value if they are to prevail in the global market.

Specifically, it is considered necessary to change over from conventional repetitive evaluation-based development involving a prototyping and testing process (confirmation of actual products for improvement) to predictive evaluation-based methods employing CAE (Computer-Aided Engineering), which is capable of accurately producing equivalent evaluations through numerical simulation (CAE, computer aided engineering) by using statistical science (Amasaka, 2007, 2008, 2010: Yamaji and Amasaka, 2008).

Thus, in this paper, the authors propose a "Highly Precise CAE Analysis Approach Method", which is intended to contribute to the regeneration of development and design. In order to demonstrate its effectiveness, the model has been applied with significant results in making proposals for bolt tightening behavior analysis, which continues to be an area of concern (Ueno, *et al.*, 2009: Takahashi, *et al.*, 2010).

2. RESEARCH

2.1. Highly-Reliable CAE Analysis Technology Element Model

In order to create intelligent CAE software for realizing quality assurance independent from prototyping and experimental evaluation, the following must be fully clarified, as shown in Fig. **1** (Amasaka, 2007): (1) Has the problem been properly confirmed with the actual product? (2) Has the theory needed for solving the problem been established? (3) What type of numerical simulation model should be applied? (4) What type of calculation method should be adopted? (5) What type of calculator needs to be selected? For realization of highly reliable CAE analysis, solutions to problems such as the following must be found: (i) How to match the results of simulation and data of the actual vehicle, (ii) How to conduct DR without the actual machine on hand, and (iii) How to prevent errors and omissions in evaluation. Without overcoming

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these problems, reform in the development design process from "development through real object confirmation and improvement" to "prediction evaluation oriented development" will not progress (Amasaka, 2008, 2010).

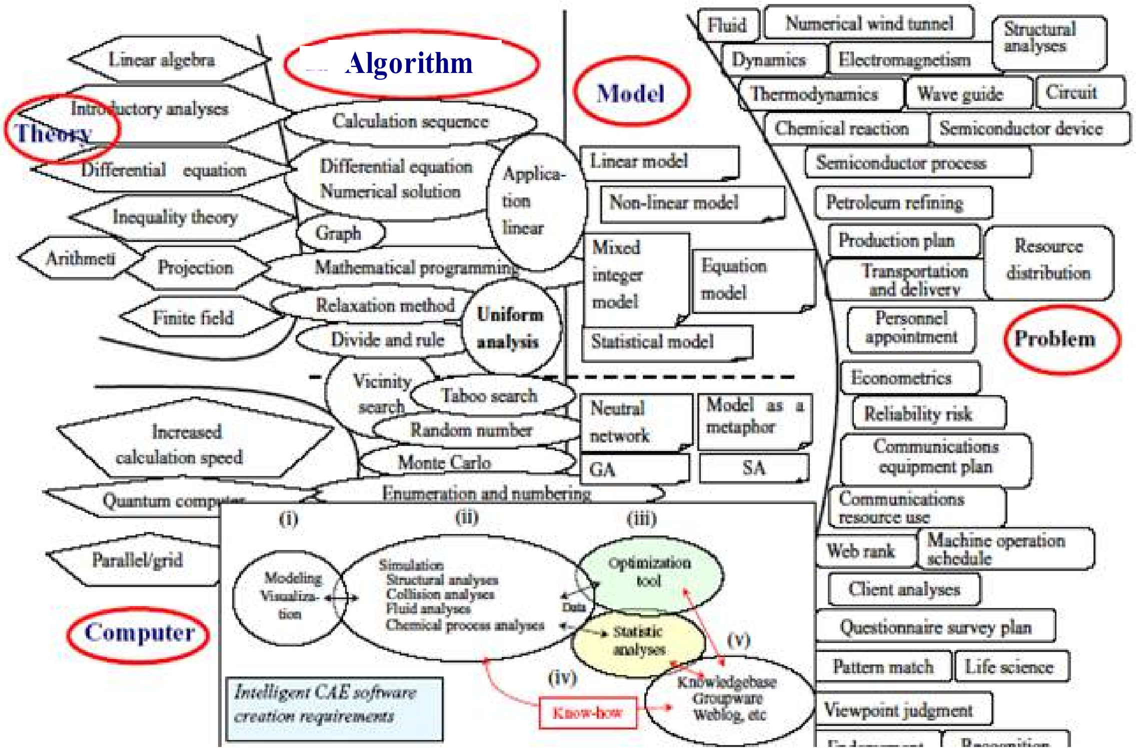


Figure 1: Highly-Reliable CAE Analysis Technology Element Model.

2.2. Total Intelligence CAE Management Model and Intelligence CAE Management System Approach Model

Following the above, the author proposes for Establishment of "Total Intelligence CAE Management Model" (Amasaka, 2008, 2010) shown in Fig. **2**, which contributes to high quality assurance as well as QCD simultaneous achievement in automobile development design. As shown in this Fig. **2**, 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 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 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.

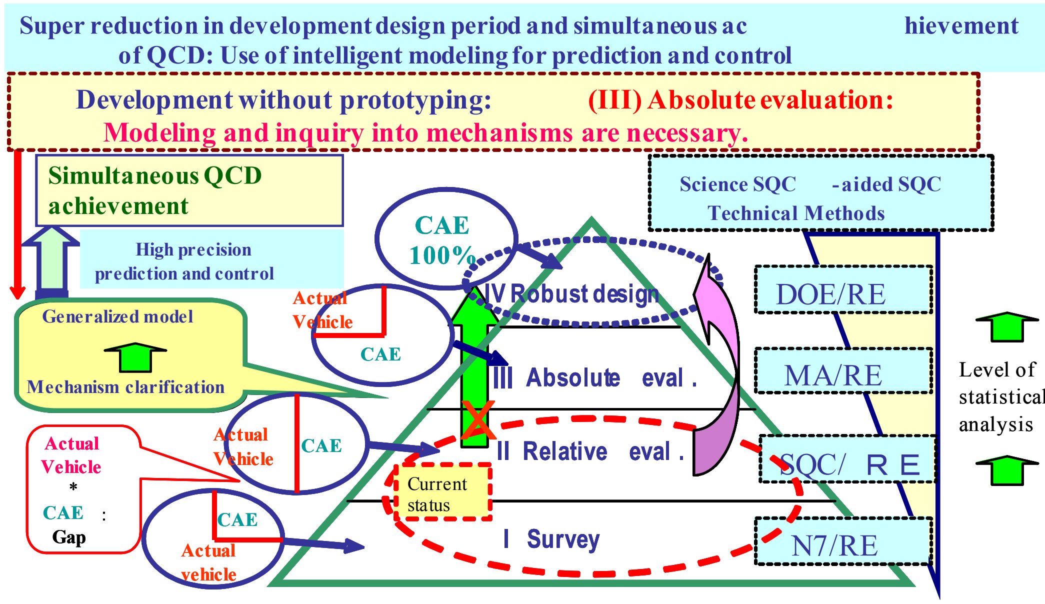


Figure 2: Total Intelligence CAE Management Model.

Against the above background, as a fundamental solution to the automotive development and designing problem, the authors created "Intelligence CAE Management System Approach Model" (Amasaka, 2008, 2010), as indicated in Fig. **3**. As seen in the figure, first, the (A) actual vehicle and experiment (meaning bench evaluation tests using actual vehicles and parts) visualizes the dynamic behavior (tricky mechanism) of the problems. Next, by means of the (B) factorial analysis in which the unique technology and empirical technology are combined together with N7, RE, MA, and DE, the latent factors which induce oil leakage are investigated using actual vehicles and experiment procedures in an effort to clarify the mechanism (Amasaka, 2010: Yamaji and Amasaka 2008).

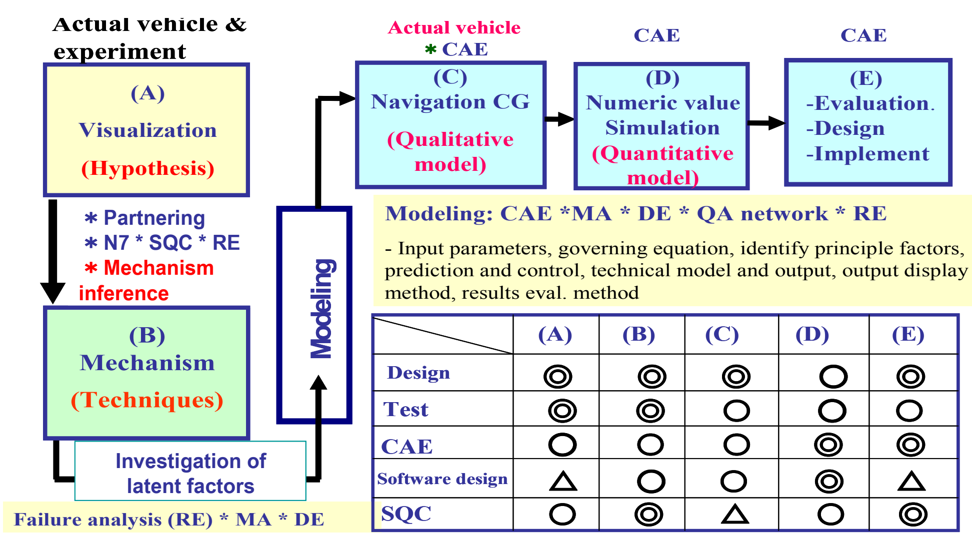


Figure 3: Intelligence CAE Management System Approach Model.

Based on the knowledge obtained through the above steps, as well as the navigation process using Computer Graphics (CG) created by a combination of (C) experiments and CAE, qualitative modeling of problems was conducted. Furthermore, for the purpose of accurately reproducing the mechanism, which has been grasped by an inductive approach of visualization experiments, quantitative modeling is conducted by means of (D) numeric value simulation. In the final stage, the (E) differential (gap) between the evaluation results of actual vehicles and experiment procedures (absolute value) and those of the CAE analysis (simulation value) was confirmed.

The target of the differential ratio of analysis precision is between 1% and 2%. To achieve such a target, an all-out, collective partnering is indispensable among the chief engineers (◎), collaborating engineers (○), and assistants (△) who are involved in the design, testing, CAE analysis, CAE software development, and SQC throughout the process stages from (A) to (E) indicated in the figure. Thus, this study uses visualization technology at the absolute evaluation stage to clarify the mechanisms involved in current technical problems and proposes a model for a highly reliable CAE analysis approach to enable absolute evaluation through the creation of generalized models.

3. PROPOSAL OF A HIGHLY RELIABLE CAE ANALYSIS APPROACH METHOD

In order to minimize discrepancies in results obtained from testing of actual products and CAE, it is necessary to properly formalize the expertise of many technical analysts required for CAE analysis. The authors proposed a “Highly Reliable CAE Analysis Approach Method” to enable highly precise absolute analysis as shown in Fig. **4** (Takahashi, *et al.*, 2010).

The following four steps are proposed in order to achieve a high level of reliability in development and design: ① surveys, ② relative evaluation, ③ absolute evaluation, and ④ robust design. Issues remain concerning ③ absolute evaluation if CAE analysis is to guarantee high quality development and design and help enable the simultaneous achievement of QCD (Quality, Cost, and Delivery). Functional failures are a recurring cause of market claims in automotive development and design, making it necessary to clarify relevant technical issues such as the reasons and mechanisms by which such failures occur. This should be done according to the following steps.

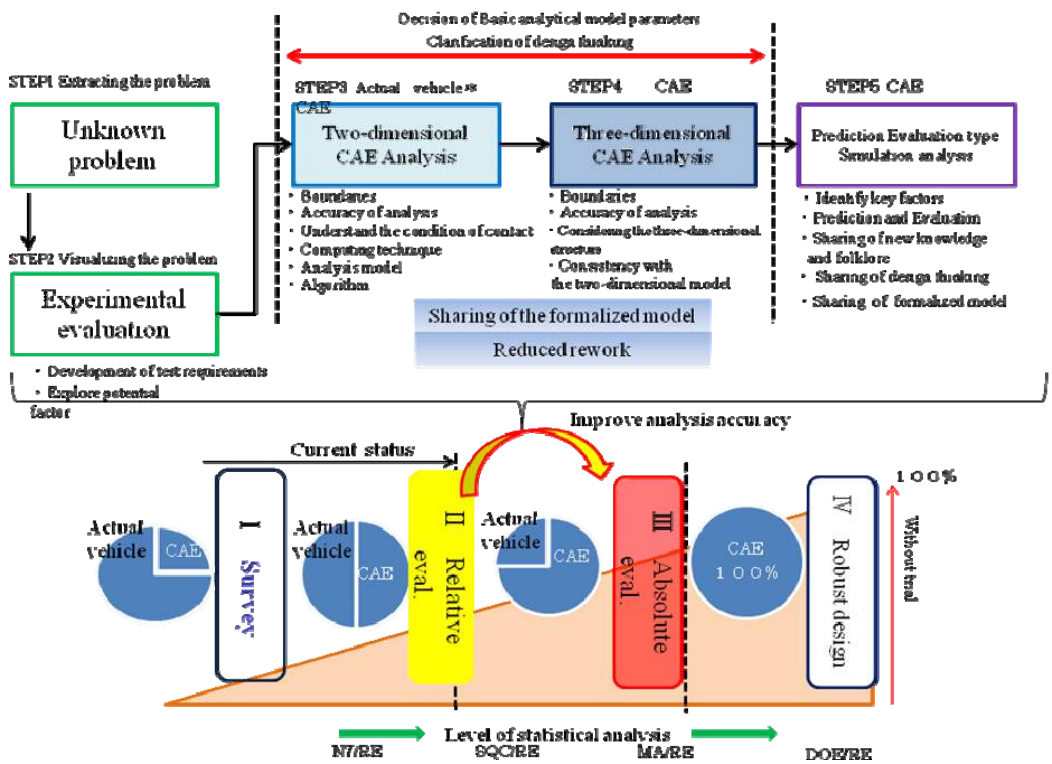


Figure 4: Highly Precise CAE Analysis Approach Method.

Step 1: Extracting the problem: Investigate and analyze the causal relationships that become apparent and infer the mechanisms through which failures occur, employing the latest SQC (Statistical Quality Control) methods backed up by expertise accumulated through the cooperative efforts of internal and external specialists.

Step 2: Visualizing the problem: Test actual products demonstrating the failure mechanisms to visualize the dynamic behavior of the problem. In order to accurately analyze the failure and its causes, it is necessary to uncover any underlying factors that were not evident from previous findings and may have been overlooked. A logical reasoning process must be applied to demonstrate the mechanisms of the failure, employing tools and principles such as the seven New Seven tools (N7), Statistical Quality Control (SQC), Reliable Engineering (RE), Multivariate Analysis (MA), and Design of Experiments (DE).

Step 3: Testing & CAE analysis: Consolidate the findings and apply statistical simulation to create a two-dimensional model integrated on a qualitative level where the visualization produced through actual testing can be reproduced. When creating this two-dimensional model, it is necessary to conduct tests to produce a model (qualitative modeling) of the causal relationships involved in undefined failure mechanisms. Precise calculation methods, analysis models and algorithms must be properly selected in order to clarify boundary conditions and contact situations and enable highly accurate statistical simulation. It is essential to use such tools to minimize discrepancies between actual testing and CAE absolute evaluation. The findings from such analysis should then be used for more detailed three-dimensional analysis.

Step 4: Highly reliable CAE: Conduct accurate testing of actual products based on the findings from step 3 to gain a more explicit understanding of the failure mechanisms. Consolidate the findings from the processes involved and conduct statistical simulation (quantitative modeling) with a high level of credibility to enable the prediction and control of absolute values.

Step 5: Predictive evaluation CAE analysis: In this final step, identify the primary factors from the results of the statistical simulation in step 4 to be used for prediction and evaluation. The new findings obtained, design concepts, and formulation models should be shared and disseminated. Utilizing models with a higher level of analytic accuracy enables an advance from relative evaluation to absolute evaluation of analysis results in the actual development process. The authors believe that this will lead to the future establishment of design frameworks involving predictive evaluation.

4. BOLT TIGHTENING EXPERIMENT AND CAE ANALYSIS OF BOLT TIGHTENING BEHAVIOR

This section illustrates a case where a "Highly Precise CAE Analysis Approach Method" was used in the CAE analysis of bolt tightening behavior (Ueno, *et al.*, 2009: Takahashi, *et al.*, 2010).

4.1. Step 1: Extracting the Problem and Technological Elemental Analysis of Bolt Tightening

The "Technological Elemental Analysis of the Bolt Tightening Simulator" as shown in Fig. **5** indicates the following. Relevant issues for conducting simulation of physical chemical phenomena (i) are: (1) the relationship between axial force and torque, (2) the dynamic friction coefficient and static friction coefficient, and (3) contact surface pressure on the threaded portion and bearing surface. Models for solving these issues (ii) are: (1) the dynamic elemental model, (2) the elastic-plastic model, (3) the contact model, and (4) the material component rule model, Useful algorithms (iii) are: (1) the finite element method and (2) the dynamic analysis method. (iv) Suitable theoretical equations are: (1) structural mechanics, and (2) equation of equilibrium. Finally (V) examples of creative solutions for ensuring precision and realistic time calculation are: (1) the temporal integration method, (2) the matrix function, (3) the penalty method, and (4) the Lagrange multiplier method. These are to be utilized to compose a highly reliable CAE analysis model (Baggerly, 1996: Gamboa and Atrens, 2003: Leea, *et al.*, 2005).

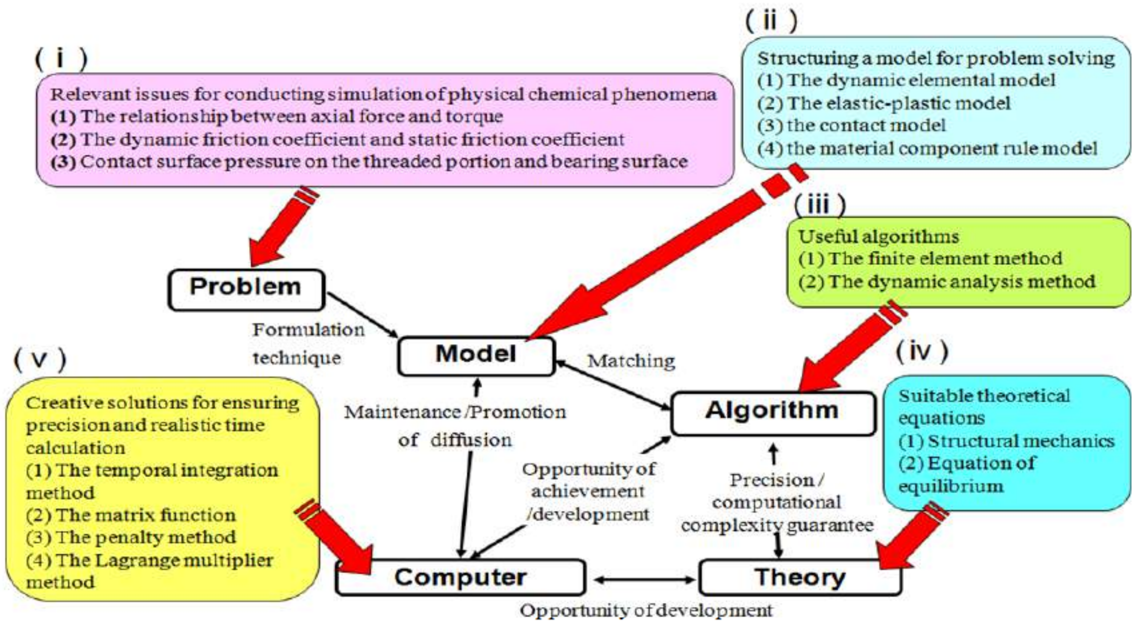


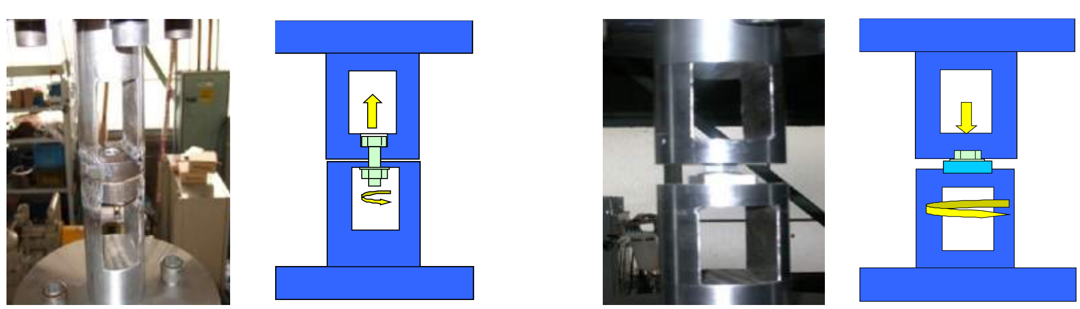
Figure 5: The Technological Elemental Analysis of the Bolt Tightening Simulator.

4.2. Step 2: Visualizing the Problem and Bolt Tightening Experiment

A strain gauge is attached to the material to which hexagon flange bolts are tightened, and an experiment was conducted as shown in Fig. **6** (measuring the friction coefficient to tighten bolts) in order to confirm an important parameter of the friction coefficient based on the dynamic behavior of “angle * torque * axial force” of (1) the threaded portion and (2) bearing surface (Izumi, *et al.*, 2004: Aragóna, *et al.*, 2005).

The bolt tightening experiment was conducted using “hexagon flange bolts and hexagon nuts with flange,” which are actually used in the automotive industry for commercial use. The friction coefficient of the threaded portion (1) was measured using a 2-axial fatigue testing machine, which is capable of applying axial force and twist force at the same time.

The bolt head was pulled with the force of 20KN, 40KN and 60KN, conducting the experiment for each tensile force five times in total, while torque and axial force were measured. The friction measurement for coefficient of the bearing surface (2) was similarly conducted using the 2- axial fatigue testing machine, applying a compression load of 20KN, 40KN and 60KN onto the substrate while rotating the nut so as to confirm the torque and axial force.



(1) Measuring the friction coefficient of the threaded portion

(2) Measuring the friction coefficient of the bearing surface

Figure 6: Measuring the Friction Coefficient to Tighten Bolts.

Based on the results of the friction coefficient measurement of (1) the threaded portion and (2) the bearing surface, torque and axial force were obtained. Applying theoretical equations to these experiment results, the friction coefficients were calculated. As an example, the friction coefficients of the threaded portion and bearing surface when the tensile force and compression load in the axial direction are both 60KN at the angle of 40° are shown in Table **1**. Using these calculated friction coefficients, bolt tightening simulation was conducted and the relationship between simulative axial force and torque was confirmed (Sakai, 2000: Suzuki, 2005: Tanaka, *et al.*, 1981).

Table 1: The Friction Coefficients

The Friction Coefficient of the Threaded Portion			**The Friction Coefficient of the Bearing Surface**		
Angle (deg)	Torque (Nm)	The friction coefficient	Angle (deg)	Torque (Nm)	The friction coefficient
40	18.63	0.02	40	215.26	0.35
40	23.05	0.03	40	221.63	0.37
40	35.30	0.06	40	198.09	0.33
40	28.44	0.04	40	208.39	0.34
40	32.85	0.05	40	226.53	0.37

4.3. Step 3: Statistical Simulation Using a 2D Finite Element Model

This analysis utilizes the axis symmetry two-dimensional model. The analysis parameters are the same as the experiment parameters. Regarding the analysis parameters, axial force is applied to part of the upper substrate and the bolt bounded from all directions in the same way as it is applied to part of the bolt head and lower substrate.

The friction coefficient was calculated by conducting experiments on parts of the contact bearing surfaces and the contact surface of the threaded portions, and then inputted into CAE simulation software. In addition, the authors compared the relationship between torque and axial force using the results from the experiment and simulation analysis. As can be seen in a "2D finite element model" as show in Fig. **7**, (i) the high stress exists at the nut and the base metal boundary. In addition, (ii) the high stress exists part of the helical structure.

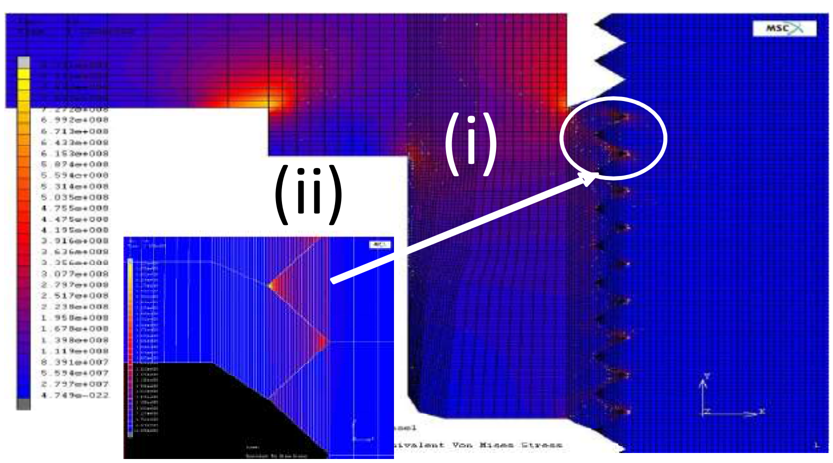


Figure 7: Analysis Result of 2D Finite Element. model

4.4. Step 4: Statistical Simulation Using a 3D Finite Element Model

Figs. **8** and **9** show a "3D finite element model" simulating the helical structure of the threaded portion. In the diagrams, the area around the bolt and nut and the contact sections are represented by a fine mesh compared to the 2D finite element model (Fig. **7**). The analysis process involves the following steps: ①

Place parts to be clamped (2 substrates) between the bolt and nut, ② Apply axial force to the bolt and determine the distribution of stress during contact, ③ Fix the edge of the lower substrate and apply upward perpendicular force (axial force) to the upper substrate, and ④ Determine the pressure on the contact surface (bolt/nut bearing surfaces and between the bolt crest and nut).

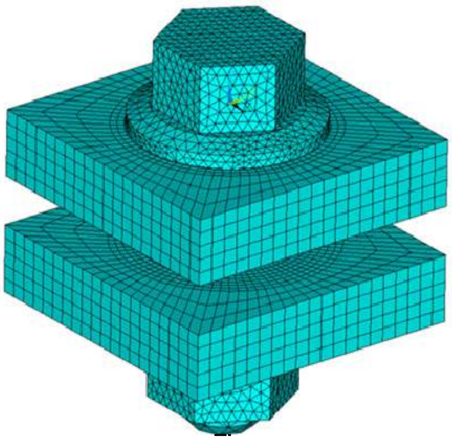


Figure 8: 3D Finite Element Model.

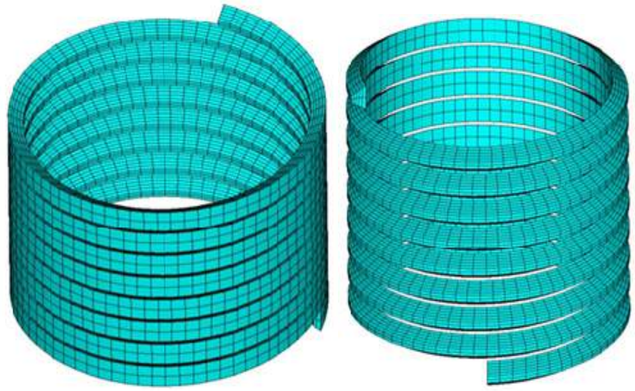


Figure 9: 3D Finite Element Model of the Helical Structure**.**

4.4.1. Analysis of the Area around Bolt Flanges

The results of analysis when axial force was applied to the upper substrate in a perpendicular direction are shown in Figs. **10** and **11**. The diagrams show that there is a greater degree of stress on the surface of the substrate in contact with the bolt flange than the periphery of the substrate. This stress distribution shows that stress is concentrated in the perpendicular section between the bolt head and the flange, making it possible to examine more thoroughly the results of analysis conducted using the 2D axial symmetry model in 4.3 (Fig. **7**).

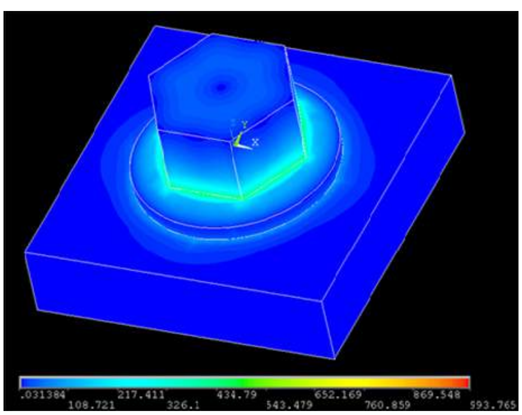


Figure 10: Stress of the Surface of the Substrate.

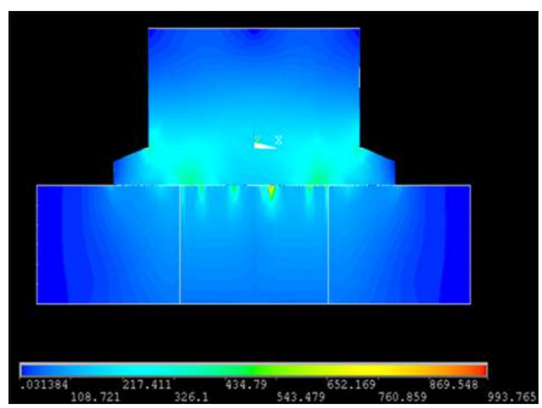


Figure 11: Stress of the Surface of the Substrate(Cross-Section).

4.4.2. Analysis of the Area around Thread Contact Points

Fig. **12** shows a stress diagram (cross-section) with the thread contact section enlarged. It can be seen from the diagram that the lower section has a higher stress value than the upper section.

1. Comparison of 2D and 3D CAE analysis

The results of three-dimensional CAE analysis show inconsistent crest stress values (higher stress values at the top of the threaded section than the bottom) in contrast to the stress distribution (mostly consistent stress values for each thread crest) obtained from a 2D axial symmetry model.

The helical structure and trapezoidal shape of the threaded section is likely to be a contributing factor. Analysis using 3D model takes into account the helical structure and models are constructed so that the trapezoidal shape of the threaded section conforms to JIS standards. Such models show that stress probably occurs in the lower part of the nut's threaded section because a perpendicular axial load is applied to the upper substrate and force therefore acts upon the bolt in the same direction.

2. Comparison of actual product testing and 3D CAE analysis

The results from actual product testing and 3D CAE analysis shown in Fig. **13** illustrate the relationship between torque and axial force. As can be seen in the diagram, the largest discrepancy between the two sets of results is 5%. These results demonstrate the accuracy of CAE analysis, and show that it is possible to reproduce almost the same results as those obtained from the testing of actual products.

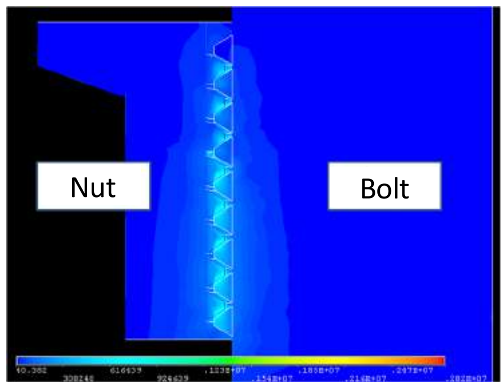


Figure 12: Stress of the Thread Contact Section.

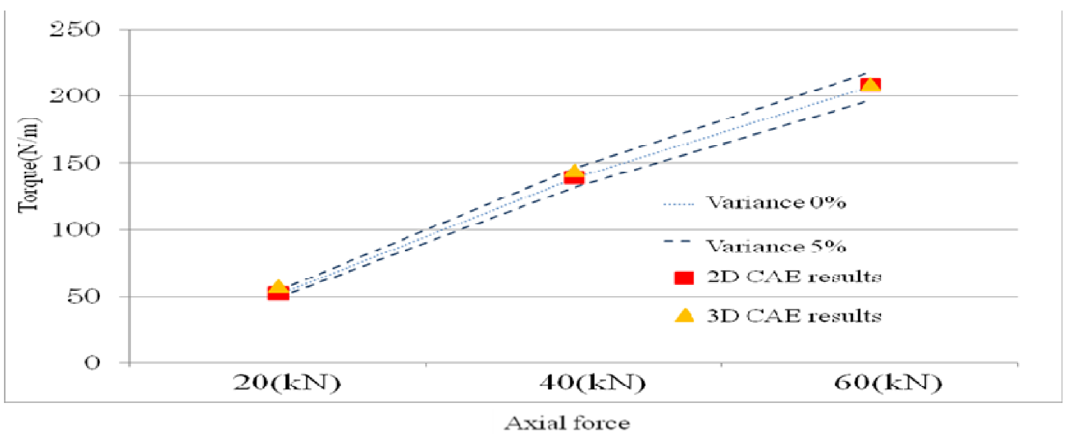


Figure 13: Measuring the Friction Coefficient to Tighten Bolts.

5. CONCLUSION

The authors believe that the use of statistical simulation technology in the form of CAE can contribute significantly to the regeneration of development and design processes, which is considered vital to the survival of Japan's automotive industry in the current situation. Thus, in this paper, the authors propose a changeover from the conventional prototyping and testing approach to a predictive evaluation process based on "Highly Precise CAE Analysis Approach Method".

This approach method has been used to clarify issues related to the behavior of bolts during tightening through actual testing, and elements such as modeling, algorithms, reasoning, and calculation methods have been applied to establish the essential factors involved in bolt tightening analysis.

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CHAPTER 17

Patent Value Appraisal Model in the Corporate Strategy: Case Studies in Science TQM - 4

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Abstract: This paper proposes "TJS-PVAM" (Total Job Quality Management System-Patent Value Appraisal Model) that contributes to corporate strategy by utilizing "Science TQM". Improvement of "patent value" signifies engineers' value creation at work (invention). The author established a "high performance business model" which raises patent quality. This model consists of several elements each for "inventive technique" and "patent right" in order to explain the indispensable elements of inventive technique and patent right for a strategic patent, and verified the validity of the model at major enterprises such as Toyota. Furthermore, standardization has been carried out in order to spread the effectiveness of TJS-PVAM, and "A-PPM" (Amasaka's Laboratory Patent Performance Model) has been created and its effectiveness investigated through trial application at major enterprises.

Keywords: Science TQM, high performance business model, patent quality, TJS-PVAM, A-PPM.

1. INTRODUCTION

Looking to attain a high performance business model for corporate management technology in Japanese companies, the author proposes and verifies the validity of the next-generation quality management principle, "Science TQM, New Quality Management Principle" employing the five core technologies "TDS, TPS, TMS, TIS, and TJS". Among these, the intellectual property divisions are the think tank of corporate strategy and play a key role in acquiring patent rights. They assume roles to reinforce "TJS" (Total Job Quality Management System*"* and enhance the intellectual productivity of the company through collaborative activities.

This paper proposes application of the patent value appraisal model, "TJS-PVAM*"* (Total Job Quality Management System - Patent Performance Model), to corporate strategy. It is generally stated that a "good patent" refers to an invention and/or a right that is useful for the entity that owns it for retaining their main business, while affecting the business of others. What is available in this field, however, is mere analysis of simple metrical statistics that are available from patent information. In other words, no qualitative analysis is available of the engineers' level of consciousness about the depth of "what is a good patent?" for them, the patent inventors.

Therefore, the author undertook the task of formulating measures to define the concept of the "*patent value appraisal model"* and defined it by grasping individual engineers' recognition of the present status of their patents as linguistic information and understanding it quantitatively by using TJS. Improvement of "patent value" signifies engineers' value creation at work (invention). The author established a "patent performance model" that consists of several elements each for "inventive technique" and "patent right" in order to explain the indispensable elements of inventive technique and patent right for a strategic patent. In recent years, the author continued to apply the TJS-PVAM successfully and proved the validity of the proposal with 12 major enterprises such as Toyota.

Furthermore, standardization has been carried out in order to spread the effectiveness of TJS-PVAM, and "A-PPM" (Amasaka's Laboratory Patent Performance Model) has been created and its effectiveness will be investigated through trial application at leading corporations. This study provides new insight that contributes to the quality patent creation process for innovating the intellectual property function and enhancing engineering strategy.

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2. SIGNIFICANCE OF PATENT ACQUISITION IN CORPORATE STRATEGY

2.1. Patent Application in Japan

Patent application by companies accounts for a large percentage of total applications and is growing annually (Japan Patent Office, 2005). Japan had the highest share of global applications in 2005, with approximately 500,000 patent applications filed, which is about 10% of the total number of global applications. However, only 30% of the patent technology was utilized and the remaining 70% are so-called "sleeping patents".

In fact, over 40% of patent applications are "defensive patents" which does not assume any practical use of the patent. The present state, in which approximately 150,000 patents are registered annually, signifies an approximately 1 trillion yen deficit between patent maintenance costs and royalty income from patent utilization. On the other hand, although total patent application in the United States is only half that of Japan (second largest share in the world), its trade balance in the past ten years has resulted in a 17.5 trillion yen surplus. Compared with the 4.1 trillion yen deficit of the Japanese technical trade balance, the US surplus implies remarkably high patent quality (Amasaka, 2003).

2.2. Corporate Innovation and the Significance of Patent Acquisition

The observation above confirms that the recent propagation of "Corporate innovation through competitive patents" is a matter of course (Nikkei, 2002). The current task for a company's technological strategy is to promote development of epoch-making innovative technology that will lead to quality patents and the acquisition of competitive, unique patents. A patent must be innovative and original.

Engineers should therefore develop strategic technology with epoch-making ideas (originality), which naturally necessitate the enhancement of the engineer's creativity. An engineer's pursuit of new technology toward the creation of "patent technology" encourages individual growth and corporate innovation and development (Amasaka, 2003b). As white-collar intellectual productivity also increases, "invention and acquisition of patent right" will serve as a core of the corporate strategy.

3. CORPORATE INNOVATION THROUGH "SCIENCE TQM"

3.1. Science TQM, the Key to Innovating Management Technology

The author (Amasaka, 2004, 2008) has proposed a next - generation quality management principle "Science TQM" with the aim of innovating management technology. This principle is underpinned by five core principles: "TMS" (Total Marketing System), "TDS" (Total Development System), "TPS" (Total Production System), "TIS" (Total Intelligence Information System) and "TJS" (Total Job Quality Management System).

These principles are organically linked by the "Science SQC, New Quality Control Principle" (Amasaka, 2003a) in order to realize "Customer Science" (Amasaka, 2005) — quality management that positions customers as the first priority. The author (Amasaka, ed., 2007) applied the Science TQM to the quality management activity of leading corporations, Toyota and others, and verified the validity of the Science TQM through observation of engineers' enhanced intellectual productivity. The most important current issue is the establishment and execution of strategic patent acquisition measures in order not to fall behind other companies.

3.2. "TJS", the Core of Corporate Strategy

The administration/indirect divisions located on the outer circle in Fig. **1** are the think tank of the corporate strategy. TJS, also located in the outer circle, strategically integrates the TMS, TDS, TPS, and TIS cores, and plays the role of enhancing intellectual productivity through the cooperative and creative activities of all divisions. As shown in the conceptual diagram in Fig. 2, TJS consists of 4 core elements.

Specifically, those divisions first transform external information (domestic and international) into valuable management and technological resources. They are therefore, expected to perform strategic internal management. In collaboration with purchasing control, engineering control, production control, and information systems, these administrative divisions should promote a commercialization strategy that relates to sales, and production of the thirteen divisions positioned on the inner circle.

At the implementation stage, the company must ensure high reliability of corporate actions through (c) intellectual management through business process quality improvement and (b) global partnering. Secondly, these administrative divisions must carry out collaborative activities with the engineering divisions for external management by developing the management technology information of the individual engineering divisions into a corporate strategy. At the implementation stage, (a) coexistence with society and (d) customer-in management attitude is essential.

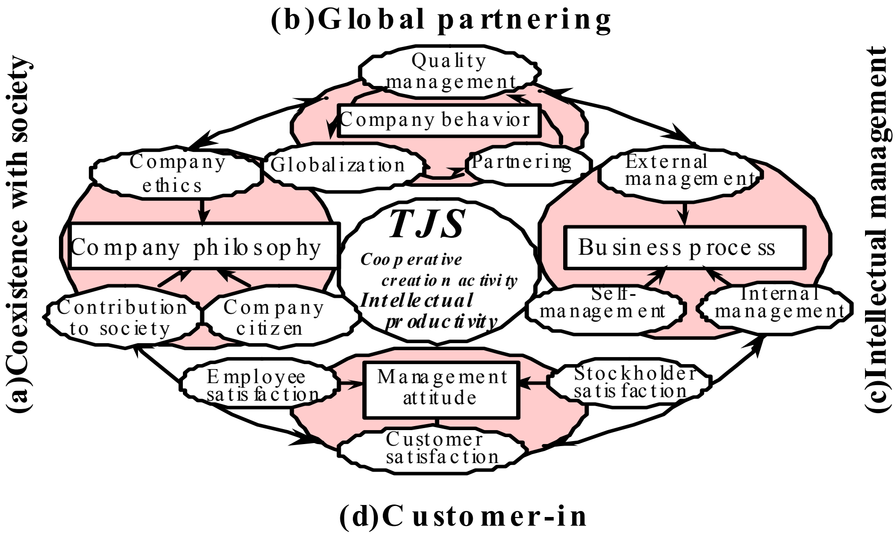


Figure 1: TJS, Total Job Quality Management System.

4. NEED FOR PATENT VALUE APPRAISAL MODEL

4.1 Past Study of Qualitative Patent Value Appraisal

Generally, a “good, strategic patent” is an invention and right that advances the main business of the company, influences other companies and benefits the company itself (Amasaka *et al.,* 1996). To the author’s knowledge, no study has been presented for qualitative patent value appraisal (Kusama, 1992: Taketomi *et al.* 1997: Umezawa, 1999: Kevin and David, 2000: Ueno, 2003: Japan Patent Office, 2005). In many cases, evaluation of the patent application only involves statistical analysis, mainly classification and stratification of the technological development contents and characteristics of the company or inventor. There was one case of intellectual property value (cash flow) appraisal, but it only covered qualitative theory.

According to interviews (Japan Patent Attorneys Association, “Patent collateral value appraisal”, 7major enterprises: Toyota, Fuji-Xerox, JFE Steel, Daikin Kogyo, NEC, Sanden and NHK Spring) and research (Japan Patent Office, “Patent evaluation index”) by Ishigaki and Niihara (2004), most appraisal cases rely on intuitive and subjective evaluations and the results are likely to deviate. From this background, establishment of a consistent “patent value appraisal model” is strongly desired.

4.2. The Challenge for Intellectual Property Divisions: “Qualitative Evaluation of Patent Value”

As already explained, the intellectual property divisions positioned on the outer circle play a key role in acquiring patent rights. The author (Amasaka, 2003a, 2003b) researched and analyzed the example of a leading company, Toyota (97 engineers and managers from 7 divisions: 1 development, 1 design, 2 production engineering, 1 machinery, 1 research and 1 control) by using a questionnaire as shown in Table **1** and multivariate analysis.

Table 1: Questionnaire on "What is a good patent?"

(Question A): What is a good patent for you? What do you routinely place priority and/or importance on to the patents?

* Please circle a number out of 1 to 6 in the following questions. (Questions may be similar to each other, but please answer them all. For any question, contact ______ .)

If you have any other items than stated below you routinely feel the need for some action or measure, please state it in the space given to ⑫ and ㉔.

[1] The following are questions concerning the "Content of Inventions."

Item	Very important	Considerably important	Important	Neither important nor unnecessary	Not necessarily needed	Not needed at all
① Practicality (for the present and future)	6	5	4	3	2	1
② Cost (inexpensive, makes good profit)	6	5	4	3	2	1
③ Overthrowing established technologies (unexpectedness)	6	5	4	3	2	1
④ Merchandizability (sellable, marketable with high added value)	6	5	4	3	2	1
⑤ Can make good PR on our engineering capabilities	6	5	4	3	2	1
⑥ Performance (product performance, productivity)	6	5	4	3	2	1
⑦ Epoch-making (new, and much valuable)	6	5	4	3	2	1
⑧ Advancedness (ahead of competitors)	6	5	4	3	2	1
⑨ Idea and conception (not necessarily having to implement)	6	5	4	3	2	1
⑩ Uniqueness (differentiate others, pioneer)	6	5	4	3	2	1
⑪ General-purpose, developable and applicable	6	5	4	3	2	1
⑫ State your free opinion ( )	6	5	4	3	2	1

[2] The following are questions concerning the "Right."

Item	Very important	Considerably important	Important	Neither important nor unnecessary	Not necessarily needed	Not needed at all
⑬ Conceptual range of patent application and simple expression (unlimiting and can be widely interpreted)	6	5	4	3	2	1
⑭ Large system (combination of subsystems)	6	5	4	3	2	1
⑮ Rich with concrete cases and examples (many cases of embodiment)	6	5	4	3	2	1
⑯ Elementary technology (system component)	6	5	4	3	2	1
⑰ Coverage of patent right with multiple inventions (including improvements and peripheral points)	6	5	4	3	2	1
⑱ Possible prompt embodiment (early license fee receivable)	6	5	4	3	2	1
⑲ Toyota's embodiment technologies (confined to Toyota products)	6	5	4	3	2	1
⑳ Basic idea (nucleus of multiples, principle and rule)	6	5	4	3	2	1
㉑ Other companies are eager to acquire (others unable to bypass)	6	5	4	3	2	1
㉒ Internationally applicable (possible development overseas)	6	5	4	3	2	1
㉓ Embarrassing to others (effective in suppressing their development will)	6	5	4	3	2	1
㉔ State your free opinion ( )	6	5	4	3	2	1

This was done to discover the "expectations and roles of the intellectual property divisions", which are held by the managers and engineers of administrative divisions that create business model patents, and the engineering divisions that create technological patents for new technology, materials, production engineering and manufacturing methods

To clarify the question of "What is a good patent?" and how engineers and managers carry on their patent activities (what do they place priority on?) the authors conducted a questionnaire to study their consciousness. The authors mainly divided questions into the "content of invented technology" and the "content of patent right". The questionnaire is based on a multiple choice reply form (marking method, 6 points: very important – 1 point: not needed at all) of eleven questions and one free opinion each. Each question consisted of a hearing conducted with the staff in charge of the intellectual property, the engineers, and the managers.

As done previously, the author (Amasaka, 2003a) surveyed Toyota engineers who had acquired patents in the past in order to find out "what makes a strategic, good patent at a company". From the analysis of collected language data (cluster analysis and factor analysis), the author clarified the necessary factor structures. In general these consist of (1) Group (A): Realist (profit-minded), (2) Group (B): Advance (pioneer-minded) and (3) Group (C): Future (innovative-minded) as shown in Fig. **2**.

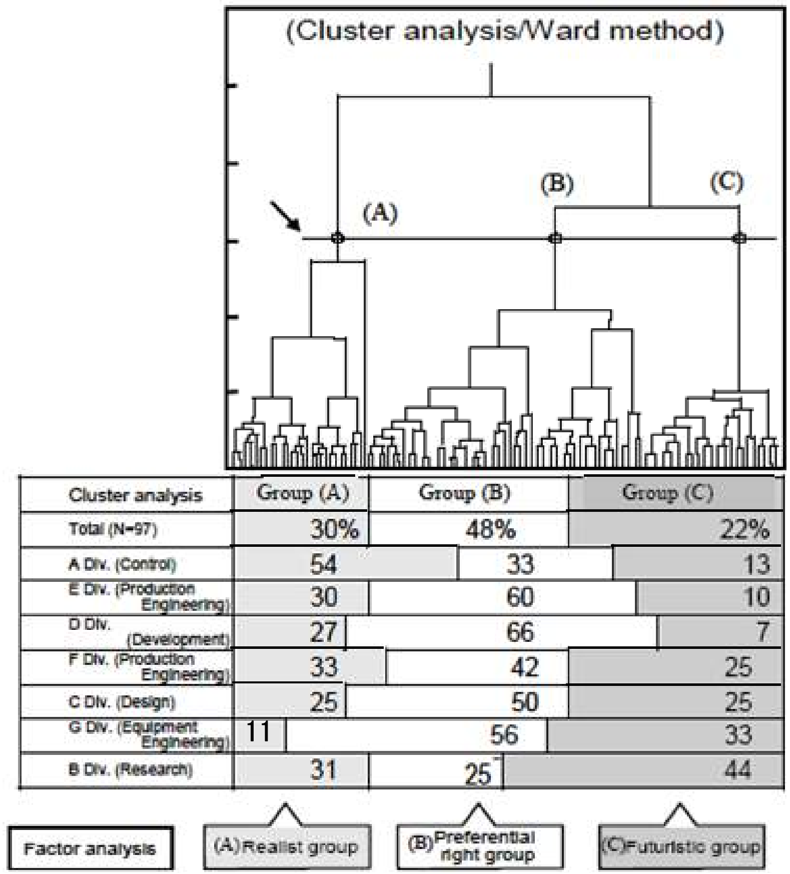


Figure 2: Grouping to Common Recognition of Strategically "Good Patent" (Cluster Analysis and Factor Analysis).

Furthermore, depending on the divisions that the engineers belong to (R&D, production engineering, manufacturing) and also their job history (practicality, competitiveness, advancement), engineers' value (awareness) of patents differ. This new insight served as a stepping-stone to establish the "patent value appraisal model".

In order to achieve a breakthrough on these issues, TJS will be strategically incorporated. To be specific, the Intellectual Property Division and the engineers and managers of other indirect divisions will cooperate to (i) establish rational "patent value appraisal methods" utilizing a rule of thumb that can be shared by both divisions. As a result, the expected effect would be the establishment of a strategic patent acquisition process model to reduce the number of sleeping patents and the mistaken rejection of inventions filed by engineers and managers.

5. PROPOSAL OF THE PATENT VALUE APPRAISAL MODEL "TJS-PVAM"

Based on the finding of the above analysis, the author proposed and verified the patent value appraisal model, "TJS-PVAM" which assists creation of strategic patents as a core of the corporate strategy. In order to implement the method, the author (Amasaka, 2003b) performed research and analysis by the same methods stated in chapters 3 and 4 above, targeting 248 engineers and managers of 16 divisions including research, development, design, production technology, production, and intellectual property, at 7 companies from a group of leading enterprises (Toyota, Fuji-Xerox, JFE Steel, Daikin Kogyo, NEC, Sanden and NHK spring).

5.1. Grasping the Relationship between Good Invention and Good Patent Right

A patent is comprised of inventive technique (X) and patent right (Y). In order to identify the relationship between X and Y that is necessary for "strategic patents", the author extracted and summarized the necessary elements (explanatory variables: x_1 to x_{22}) from the language data obtained in the above survey and created a 6-point scale survey (6: extremely important, 5: very important, 4: important, 3: medium, 2: slightly unimportant, 1: unimportant) as shown in Table **1**.

Aiming to understand the relationship between inventive technique (x_1: "practicality" to x_{11}: "expansive") and patent right (x_{12}: "scope of right is conceptual and simple" to x_{22}: prevent other companies), the author conducted a survey for Toyota engineers and managers (total 97 people from 7 divisions) and obtained the canonical correlation analysis results shown in Fig. **3**.

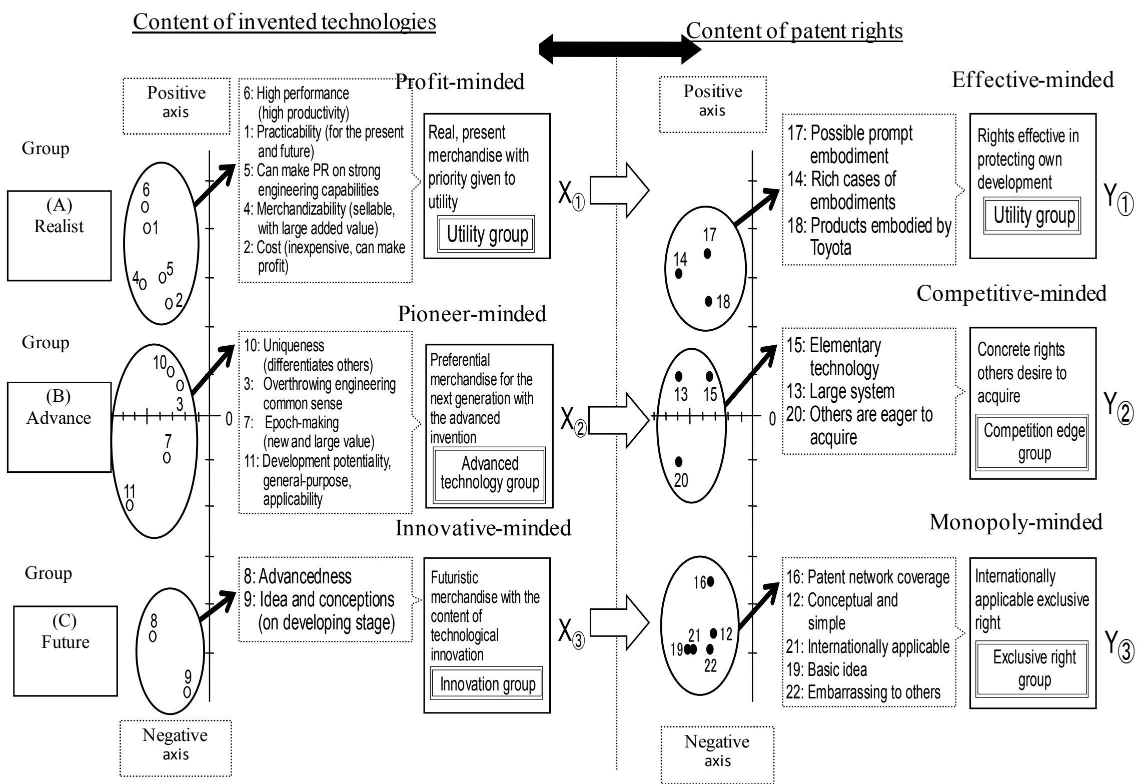


Figure 3: Correlation Between the Contents of Invented Technology and the Patent Right (Canonical Correlation Analysis: Scatter Diagram of Correspondence Between Components).

From the main component relation scatter diagram of the figure, "inventive technique" is classified into "Profit-minded: $X_{①}$ (prioritize profit with actual products at hand: x_1, x_2, x_4, x_5, x_6)", "Pioneer-minded: $X_{②}$ (prioritize advanced technology with next-generation products: x_3, x_7, x_{10}, x_{11})", and "Innovative-minded: $X_{③}$ (prioritize technical innovation with high-potential products: x_8, x_9)".

Corresponding to these groups, "patent right" is similarly classified into "effective-minded: $Y_{①}$ (effective right that protects company development: x_{14}, x_{17}, x_{18})", "competitive-minded: $Y_{②}$ (practical right that attracts competitors: x_{13}, x_{15}, x_{20})", and "monopoly-minded: $Y_{③}$ (exclusive right that is globally applicable: x_{12}, x_{16}, x_{21}, x_{22})". These findings were consistent with the experiences and techniques of the inventors, managers, patent evaluators, and patent attorneys.

5.2. Proposal of Strategic Patent Appraisal Model, "TJS-PVAM"

The appraisal model obtained from the canonical correlation analysis enabled qualitative patent value evaluation through an overall evaluation of inventive technique and patent right and also typifying the two elements into three clusters as follows:

(1) Overall evaluation of inventive technique:

$X=X_{①}+X_{②}+X_{③}$

(Standardization：Perfect score is 6)

"Profit-minded":

$X_{①}=0.25x_1+0.22x_2+0.24x_4+0.20x_{5+}0.19x_6$

"Pioneer-minded":

$X_{②}=0.30x_3+0.32x_7+0.18x_{10}+0.20x_{11}$

"Innovative-minded":

$X_{③}=0.52x_8+0.48x_9$

(2) Overall evaluation of patent right:

$Y=Y_{①}+ Y_{②}+Y_{③}$

(Standardization：Perfect score is 6)

"Effective-minded":

$Y_{①}=0.28x_{14}+0.35x_{17}+0.37x_{18}$

"Competitive-minded":

$Y_{②}=0.40x_{13}+0.38x_{15}+0.22x_{20}$

"Monopoly-minded":

$Y_{③}=0.20x_{12}+0.19x_{16}+0.18x_{19}+0.23x_{21}+0.20x_{22}$

Therefore, the author considered diffusion of the patent value appraisal model gained through the Toyota study and made revisions to the appraisal model in an approach similar to the above in cooperation with the 3 major enterprises (240 staff members in 16 divisions of Toyota, Xerox, and Daikin).

The example shown in Fig. **4** is the evaluation by inventors at Xerox, JFE Steel, and Toyota (Evaluators: a, b, and c) of the inventive techniques and patent rights, expressed by radar chart. All of the inventions investigated possessed features of the contents of inventive techniques and patent rights, and received sufficient favorable comments from the inventors of the 3 enterprises.

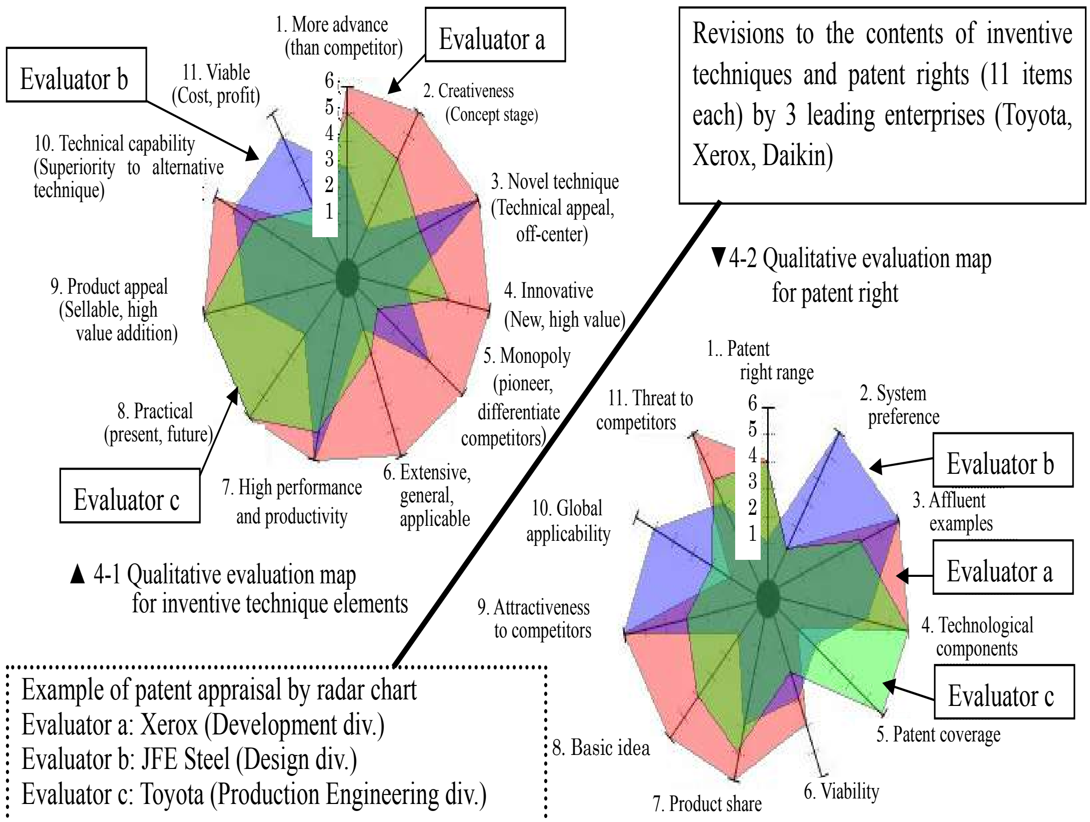


Figure 4: Example of the Qualitative Evaluation Map for Visualized Inventive Technique/Patent Right Using "TJS-PVAM".

5.3. Verification of "TJS-PVAM" Validity

Therefore, the author (Amasaka, 2003b) will validate the effectiveness of TJS-PVAM with Toyota. Patent value evaluation can be strategically visualized from the appraisal model using TJS-PVAM as shown in Fig. **5**. Similarly, Fig. **6** indicates an example of patent right evaluation. When the inventor applied the patent, the qualitative value of the patent had only a clearly above-average value for monopoly and competitive.

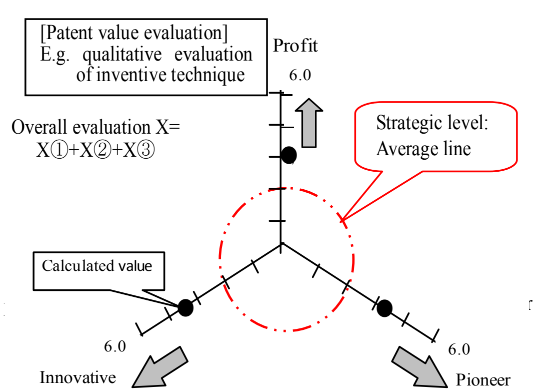


Figure 5: Patent Value Appraisal Model "TJS-PVAM" (Ex. 1 Visualization of Inventive Technique).

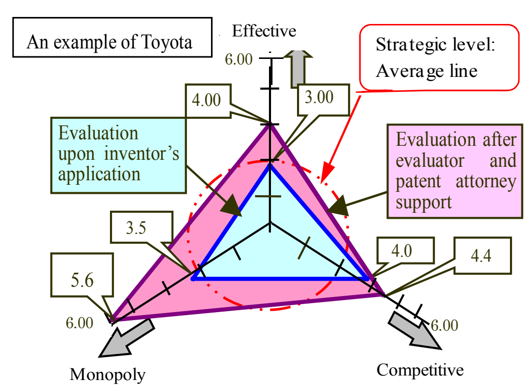


Figure 6: Improved Strategic Value of Patent Right Using "TJS-PVAM" (Ex. 2 Visualization of Patent Right).

In order to raise the strategic value of the patent, the inventor revised the patent content with the support of the patent evaluator (intellectual property division) and patent attorney. Consequently, the patent's strategic value significantly increased.

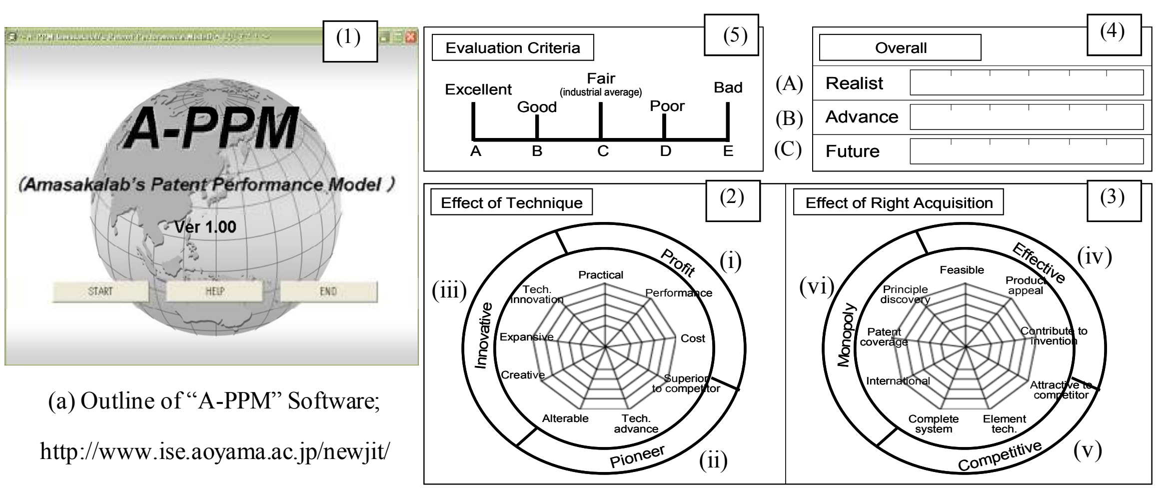
6. APPLICATION

This chapter contains a study carried out on the effectiveness of creating software for standardized "A-PPM" (Amasaka's Laboratory Patent Performance Model) at leading enterprises, as a means of effectively spreading the TJS-PVAM proposed by the authors (Amasaka, 2003b, Ishigaki and Niihara, 2004, Kaneta and kuniyoshi, 2005).

6.1. Summary of the "A-PPM"

TJS-VAM was further expanded and applied in an industry-academy collaboration study group "Quality Management in the Manufacturing Industry" (Amasaka, 2007) led by the author, and 12 leading enterprises (Toyota, Fuji-Xerox, JFE Steel, Daikin Kogyo, NEC, Sanden, NHK Spring, Yanmar, Yokogawa-Electric, NTT-Docomo, Nissan and others). At this time, further revision was made in consideration of versatility and convenience.

A proposal was made, as shown in Fig. **7**, and (1) standardized as A-PPM software. Its structure and features are clearly expressed. Reflecting the effectiveness stated previously, the contents of inventive techniques and patent rights are summarized and visualized in the combination of outer and inner circles as shown in the Figure. For example, (2) the general evaluation of the "Effect of Technique" is specified in 3 representative items: (i)"Profit" is subcategorized as "Practical, Performance and Cost" and, in a similar manner, (ii) "Pioneer" is subcategorized into "Superior to competitor, Technique is advance and alterable," and (iii)"Innovative" is subcategorized into "Creative, Expansive, and innovation of Technique" and represented in a radar chart accordingly.



(a) Outline of "A-PPM" Software;

http://www.ise.aoyama.ac.jp/newjit/

(b) "A-PPM" Patent Performance Evaluation Sheet.

Figure 7: Outline of "A-PPM, Amasaka's Laboratory Patent Performance Model".

Similarly the general evaluation of (3) "Effect of Right Acquisition" is also expressed in 3 representative items: (iv) "Effective" is subcategorized into "Feasible, Product appeal, and contribution to innovation," (v) "Competitive" is subcategorized into "Attractive to competitor, Element technology, and Complete system," and (vi) "Monopoly" is subcategorized into "International, Patent coverage, and Principle discovery."

The 6 representative categories (i) to (vi) are appropriately placed under 3 well-balanced elements, which enhance the versatility and convenience of the A-PPM evaluation model. As shown in Fig. **3**, (4) the 3 groups; namely (A) "Realist," (B) "Advanced", and (C) "Future," evaluated the contents of inventive techniques and patent rights, which are then totaled and their features (age aspect) visualized in a scale as shown in the figure. "Realist" is the total of (i) Profit and (iv) Effective scores; "Advance" is the total of (ii) "Pioneer" and (v) "Competitive scores; and "Future" is the total of (iii) Innovative and (vi) Monopoly scores. Furthermore, these evaluations by the 3 groups were then totaled as (5) "Evaluation criteria," which is then placed on a 5-level scale (A: Excellent, B: Good, C: Fair, D: Poor and E: Bad). Rank C is the industrial average for patent application.

The A-PPM established in this manner automatically tabulates evaluation scores and expresses them in a radar chart, offering convenience to users. As a result, it is now possible to perform an appraisal of patent value for each invention in approximately 20 minutes.

6.2. Validation of "A-PPM" Effectiveness

The authors applied the established A-PPM and investigated its effectiveness at the previously mentioned 12 leading enterprises. Fig. **8** shows the example of Fuji-Xerox. It shows in the figure that (a) evaluation upon inventor's application was later (b) supported by a patent attorney in the intellectual property division, thereby strategically enhancing the contents of inventive techniques and patent rights.

Similarly, the authors are able to illustrate this effectiveness at other leading enterprises, confirming the results obtained.

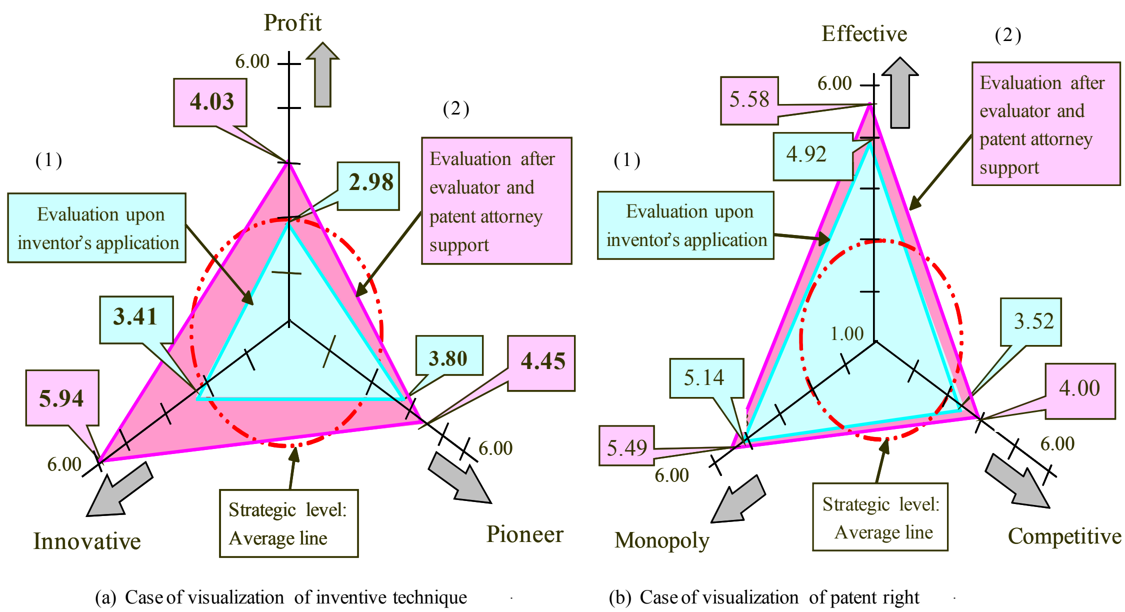


Figure 8: Example of Improved Strategic Value of Inventive Technique and Patent Right. Using "A-PPM" by Fuji-Xerox.

7. CONCLUSION

This paper proposed TJS-PVAM, a model that contributes to corporate strategy by utilizing Science TQM. In recent years, the author has continued to apply the TJS-PVAM successfully and proved the validity of the proposal at leading enterprises such as Toyota. Furthermore, in order to spread the effectiveness of TJS-PVAM, the author standardized A-PPM as software and validation of its effectiveness was made at 12 leading enterprises. This study provided a new insight that contributes to the quality patent creation process for innovating the intellectual property function and enhancing engineering strategy (Amasaka, 2007).

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AFTERWORD

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Advanced corporations—who by all rights should be leading global production—are seeing an increase in recalls, and they seem to be losing their grip on the scientific quality management methods that were once an exclusive feature of Japanese quality management practices. These are warning signs that existing quality management technology must be reinforced. As we enter a new era of remarkably competitive technological innovation, figuratively referred to as the "global quality competition", there is a strong desire to overhaul Japanese management techniques once again. Executives and managers are concerned with generating rational management outcomes through "Customer-first Quality Management".

Thus, the author established "Science TQM, new quality management principle" in response to the urgent need to create a next-generation management technology. This world-leading uniquely Japanese quality management principle is vital in ensuring that Japanese manufacturing does not fall behind in the advancement of technology. Science TQM aims to contribute to producing globally consistent levels of quality and simultaneous production worldwide, which is the key to success in global production.

More specifically, Science TQM consists of the following core technologies: Total Marketing System (TMS), Total Development System (TDS), Total Production System (TPS), Total Intelligence Management System (TIS), and Total Job Quality Management System (TJS). These systems are then effectively linked to rationally achieve strategic quality management using the driving force in developing Science TQM: Science SQC, New Quality Control Principle, Strategic Quality Management—Performance Measurement Model, and Partnering Chains as the Platform for Strategic Quality management.

First, the author verified the significance of the Strategic Marketing Development Model, High Quality Assurance CAE Analysis Model, and Partnering Performance Measurement Model as the Innovation Models utilizing Science TQM.

Second, the author developed the Change in Marketing Process Management, Evolution of Development Design Process Management, and Strategic QCD Studies with Affiliated and Non-affiliated Suppliers as the Strategic Development of Science TQM.

Third, the author demonstrated its effectiveness using case studies in Science TQM: Developing a Strategic Advertisement Method, Effectiveness of Flyer Advertising, Highly Precise CAE Analysis Approach Method, and Patent Value Appraisal Model in the Corporate Strategy.

It is hoped that this eBook will contribute to the evolution of quality management, thereby creating an opportunity to establish a global model for strategic quality management. In recent years, Science TQM has been applied at many leading Japanese companies where its effectiveness has been verified, and it is now known as New Japan Model—Science TQM [1].

The theory is covered in more detail in the author's other theses mentioned below. It is hoped that the reader will find it useful to also refer to these other works.

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