Management for Quality Improvement

The Seven New QC Tools

Management for Quality Improvement

THE SEVEN NEW QC TOOLS

Edited by

Shigeru Mizuno

Foreword by Norman Bodek, President
Productivity, Inc.

Productivity Press
Portland, Oregon

Transferred to Digital Printing 2010

Original Japanese edition, *Kanrishi to Sutaffu no Shin-QC-nanatsu-dogu*,
edited by Shigeru Mizuno, published by JUSE Press, Ltd., Tokyo, Japan,

Productivity, Inc.
P.O. Box 13390
Portland, OR 97213-0390
Telephone: (503) 235-0600
Telefax: (503) 235-0909
E-mail: service@productivityinc.com

Library of Congress Catalog Card Number: 88-042625
ISBN: 0-915299-29-1

Cover design: Bill Stanton
Typeset by Publication Services, Boston, MA

Library of Congress Cataloging-in-Publication Data

Management for quality improvement.

Translation of: Kanrisha to sutaffu no shin QC nanatsu-dōgu.
Includes index.
1. Production management — Quality control.
I. Mizuno, Shigeru, 1910- . II. Title.
TS156.K35413 1988 658.5'62 88-42625
ISBN 0-915299-29-1

Publisher's Note

The publisher has gone to great lengths to ensure the quality of this reprint but points out that some imperfections in the original may be apparent.

Contents

Publisher's Foreword vii

Preface ix

Introduction xv

A Note on Japanese Names xix

PART ONE **AN OVERVIEW OF THE SEVEN NEW TOOLS FOR QUALITY CONTROL** 1

1

Total Quality Control and The Seven New QC Tools 3

2

Seven New QC Tools 23

3

Applying the Seven New QC Tools 55

PART TWO **DETAILS OF THE SEVEN NEW TOOLS FOR QUALITY CONTROL** 85

4
Relations Diagram 87

5
KJ Method: Affinity Diagram 115

6
Systematic Diagram 143

7
Matrix Diagram 171

8
Matrix Data-Analysis 197

9
Process Decision Program Chart (PDPC) 217

10
Arrow Diagram Method 249

11
Education to Introduce the Seven New QC Tools 283

Conclusion 293

Index 297

Publisher's Foreword

Productivity Press is pleased to present *Management for Quality Improvement: The Seven New QC Tools.* This book introduces the latest advances in tools for quality management—tools that promote a new, more creative and effective approach to quality planning and project management. *The Seven New QC Tools* are used by top executives for strategic planning as well as at all levels of management for planning, goal-setting, and problem-solving.

Most of us are familiar with the original seven tools used in statistical quality control: the cause-and-effect diagram, pareto chart, histogram, check sheet, control chart, bar graph, and scatter diagram. These are used in data-gathering and analysis to solve specific QC problems while total quality control (TQC), as the name implies, involves problem-solving companywide. TQC marshals the skills, information, and efforts of many people—across different departments and over extended periods of time—to address quality problems that go beyond manufacturing into such areas as design,

delivery, and service. Total quality control demands that we build quality into our products; the seven new QC tools were designed to help us build quality into every single management decision.

How can we assure quality in planning and management?

Lately, we have been hearing more and more about the hidden "software" of the Japanese—the management techniques that permit the most productive companies to plan and successfully implement wide-ranging and detailed TQC objectives. *The Seven New QC Tools* are at the heart of this management "program for success." Look at almost any Japanese book published in the last ten years on achieving manufacturing excellence: You don't have to understand Japanese to see that these new graphic QC management tools are essential to the Japanese quality improvement effort. Over and over, we see them used both to analyze information and to communicate it graphically and effectively.

For example, the affinity and relations diagrams introduced in this book are widely used during the planning stage to identify problems by organizing diverse forms of verbal data and clarifying complex causal relationships. Once problems are identified, the systematic diagram and the matrix diagram methods facilitate the search for appropriate solutions and organize the steps toward achievement of quality objectives. Finally, the arrow diagram (used in PERT) and the process decision program chart (PDPC) assist in planning and controlling actual implementation.

Our mission at Productivity Press is to make available the ideas and tools that have revolutionized manufacturing in Japan. We are especially proud to introduce the first book dealing with this important new approach to total quality management.

We extend our special thanks to Mrs. Haruko Mitsuaki, Managing Director of JUSE Press, Ltd. (Japanese Union of Scientists and Engineers) for her help and cooperation in bringing this book to America. Thanks also to Connie Dyer who supervised the project and to the staff of Editorial Services of New England, Inc., who helped produce the book.

Norman Bodek

Preface

The meetings of the Society of QC Technique Development, part of the quality control basic course sponsored by the Japanese Federation of Science and Technology, served as the birthplace of this book. The Society's first meeting was held on April 26, 1972. Now, nearly seven years later, it gives us great pleasure to observe the publication of this book. The authors would like to take this opportunity to briefly note the main points of *Seven New QC Tools*.

The general consensus remains that the main objective of company-wide promotion of quality control is achieving the company's business goals through basic reform in the following five areas:

1. *Distinguishing potential future development projects.* Merely finding out what sells and then trying to produce it less expensively than competitors is not enough. Instead, development of technology and systems capable of competing in the world market must be found. It is necessary to transform potential market needs into future development projects.

2. *Planning seriously for the future.* Simply "putting out the fire" once trouble has begun is not sufficient. Anticipating likely trouble spots before problems occur is much more important.
3. *Paying strict attention to processes.* Increased profit is not always an indicator that systems are functioning well. If that were the only criterion, recessions would indicate a poorly operating system. Processes need to be continually evaluated to facilitate needed improvements.
4. *Prioritizing and focusing attention on problems.* Efforts should be made to achieve business objectives within set resource and expense limits. From all the problems a company faces, being able to distinguish those which must be dealt with first is necessary in order to meet the corporate goals.
5. *Focusing attention on the corporate system.* Individuals working alone, even though they are doing their best, cannot compete with a company in which members cooperate in a closely interrelated system.

In order to promote these basic reforms, every employee of a business should be thoroughly familiar with the philosophy of "thinking quality management." The need for managers and staff to "think quality management" has increased dramatically in recent years as a result of the continually changing social and economic atmosphere.

The tools used in the past for quality management include the former seven tools, various statistical methods, experimental design methods, etc. These tools have been used effectively in all fields of company-wide quality control by managers and QC circle members. But now, to meet the demands that social change requires, managers and staff must supplement the traditional tools of quality control with new techniques. This served as the motivating factor when the Society for QC Technique Development was originally organized.

Managers and staff who promote company-wide quality control should not place heavy emphasis only on data collection and analysis. More appropriately, their duty lies in identifying problems, establishing plans, and supporting interdepartmental coordination. Managers and staff must assimilate diverse verbal as well as technical information and develop it into specific plans with innovative

flair. The tools they need are those which can be most useful now. Some of these new techniques have already been used in various ways by QC "pioneers" with considerable success. Hoping to promote these new methods, the Society for QC Technique Development presents *Seven New QC Tools*.

Since April of 1972, the Society for QC Technique Development has held monthly study meetings for the purpose of putting together the seven new tools. The Society's activities consisted of identifying and evaluating various management-control techniques used in areas such as operations research (OR) and value engineering (VE), diverse creativity techniques, and other company-wide QC techniques, looking for those which have proven most effective. Each technique was investigated through applications and outcome. In addition, each technique was also tested in companies not affiliated with Society members. *Seven New QC Tools* is based on the cumulative results of these investigations and other experimental trials.

The proposed seven new tools are as follows:

1. Relations diagram
2. KJ method (affinity diagram)
3. Systematic diagram
4. Matrix diagram
5. Matrix data analysis
6. Process decision program chart (PDPC)
7. Arrow diagram

The rationale for designating these techniques as the seven new tools is based on the collective experience of Society members that an outcome is assured and success is heightened when the techniques are applied to all aspects of company-wide quality control in a closely coordinated manner. It is further believed that these techniques in no way contradict or detract from earlier QC techniques; they actually complement each other, thus contributing to the promotion of total quality control.

The Society for QC Technique Development finished its research late in 1976. Starting in January of 1977, the Society devoted

itself to the refinement and promotion of its ideas through lectures, conferences, seminars, and symposia. In 1978, the Society invited Mizuno Shigeru, professor at the Tokyo Industrial University and Kondo Yoshio, professor at Kyoto University to act as advisors. For nine months, monthly meetings were held under the name the Research Society for the Seven New QC Tools. These meetings contributed enormously to the development of a conceptual framework and techniques for the *Seven New QC Tools*. At the same time, a large number of applications of these principles began to pour in from various companies.

As our promotional activities progressed, we received many requests from different people in diverse fields asking us to teach more about the theory, use, and application of the seven new tools. In addition, many people whose opinions we value advised us to make this material on the seven new tools more widely available. In response to these demands and this advice, we have compiled the present book.

The book consists of two parts. Part I describes the background and rationale behind the seven new tools, provides an outline of each technique, examines the relationship of each tool to other QC techniques, and discusses the graphic and linguistic basis of the new tools. We also introduce examples of systematic application in policy management, hoping that the reader will be able to grasp fairly quickly not only the main features, but also a few of the different types of applications.

Part II provides a detailed discussion of the conception, construction, and use of each one of the seven new tools. A variety of examples to which these methods can be applied is given so readers will be able to modify and apply the tools to their respective companies and situations. We hope our readers will apply these techniques and inform us of their experiences in order for us to improve on any weak points that might surface.

We gratefully acknowledge the guidance and advice of Professors Mizuno and Kondo. In spite of his busy schedule, Dr. Mizuno agreed to take on the role of editor-in-chief and has written a gracious foreword. He has also been my lifelong mentor, for which I am extremely thankful.

We are indebted to Chizumi Shizuo, professor at Keio University, who provided guidance on relations diagrams to the committee

members of the Society, and to the numerous executives and managers of various companies for their encouragement and assistance. Unfortunately, space will not allow all of them to be mentioned here.

Messrs. Aima and Tanaka of the Osaka Office of the Japanese Federation of Science and Technology have made personal sacrifices in supervising the Society for QC Technique Development since its inception in 1977, and they have provided continuing assistance to us. We would like to express our extreme gratitude to them.

Finally, we are indebted to Mr. Tahara and his colleagues at JUSE Press, Ltd. for helping us with the graphs and other complicated tasks inherent in publishing this type of book. It would be impossible to imagine this book ever being completed without the assistance and guidance of these people. We are indeed fortunate to have had their assistance, and accordingly, we are very much indebted to them.

Nayatani Yoshinobu
President
Society for QC Technique Development
April 1979

Contributors (in alphabetical order)

Futami Yoshiji (Osaka Electro-Communication College)
Kato Shoichi (Nippon Paint Co.)
Kurabayashi Mikihiko (Mitsubishi Electric Co.)
Nayatani Yoshinobu (Osaka Electro-Communication College)
Sano Motohiko (Sekisui Chemical Co.)
Yagi Juichi (Mitsubishi Electric Co.)

Introduction

It probably goes without saying that the quality of Japanese products, such as automobiles, home appliances, and cameras, is far above the quality of similar foreign-made products. These products were originally designed and manufactured overseas, but the recent superior quality level of Japanese products has resulted in massive exports, giving rise to a growing chorus of objections to the further expansion of Japanese manufacturing, which supposedly deprives workers in foreign markets of their jobs. Japan's future options appear limited to either manufacturing at foreign plants that draw from the local work force, manufacturing products that do not compete with foreign products, or developing creative new products that meet the needs of foreign markets.

As Dr. Juran pointed out at the International Conference on Quality Control held in October of 1978 in Tokyo, the quality of Japanese products in the 1950s was so poor that it seemed that Japanese industry would not survive unless it could improve its

products enough to be able to export to foreign markets. Since that time, Japanese industry's efforts for improved quality control, fueled by survival instincts, have brought about splendid results, and now Japan faces the new challenge of searching in new directions for the future. Even prior to Dr. Juran's comments, the Japanese business sector had been expanding the application of quality control (QC) from traditional areas such as manufacturing to planning, development, and design and even extending it to include postmanufacturing areas such as sales and service. In other words, the scope of quality control had been expanded companywide. As part of these promotion activities, efforts were made to improve the fundamental company culture, for example, through companywide participation in quality control activities from top management to the basic quality control circles.

There are seven traditional tools of quality control, including the well-known pareto chart, the cause-and-effect diagram, and the control chart. These tools have been used as an effective means of analysis and control, and they have contributed significantly to quality improvement. The seven tools have been the favorites of QC staff as well as of QC circle members, largely because the tools are easy to understand. No one doubts that these tools will continue to be used extensively. Quality control has entered a new era of development, however, and there is no room for complacency with the present tools. A new era demands new tools.

In this new era of quality control, the boundaries for QC involvement are limitless: Activities of managers and staff are expanding to include resolving major quality problems, developing products with new levels of quality, and setting up and managing the systems necessary for attaining goals such as these.

Management for Quality Improvement: The Seven New QC Tools is designed to meet the needs of this new QC era. This book is the result of the tireless efforts of Dr. Nayatani and his colleagues with the Kansai QC Leadership Group. Although designation as the "seven new tools" runs the risk of creating what may become a passing fad in facing the new era, and although the designation may impart the impression that the seven new tools are better than the original tools, the seven new tools are new techniques not intended to replace the original tools, but to aid in coping with the problems that the new era poses.

In varying degrees, these tools have been used in other fields; however, they have almost never been used for quality control. It is significant that recognizing the need for these tools in quality control, the Kansai group has named them the seven *new* tools.

Although an editor-in-chief might typically be involved in all the details of a book's production, my role was limited to offering suggestions I felt might be useful based on my experience. I wish to emphasize the limited nature of my contribution, lest I be given any undue credit simply because of the title editor-in-chief.

Management for Quality Improvement presents tools that lend themselves to an approach that is forward-looking. This is worthy of special note. In this sense the new tools may provide momentum for new directions in this new era. The practical examples enhance this potential. The many examples reflect actual applications that were of major importance to the companies involved and which, in fact, were candidates for the respective company's President's award. For reasons of privacy and to prevent premature disclosure, some information and a few names had to be changed. Nonetheless, these tools have great promise and potential for immediate results.

I sincerely hope that the seven new tools will be adopted by managers and staff and will contribute to the establishment of a new era for quality control.

Mizuno Shigeru

A Note on Japanese Names

In Japan, the family name appears first. Thus, the famed inventor of the Toyota production system is known in Japan as Ohno Taiichi, and not Taiichi Ohno as usually written in the West.

In Productivity Press books we try to follow the Japanese practice of placing the surname first, in part, to make the representation of Japanese names uniform but primarily out of common courtesy. The reader therefore will find contributors and authors referred to surname first in the text and notes.

Management for Quality Improvement

The Seven New QC Tools

PART
ONE

An Overview of the Seven New Tools for Quality Control

1

Total Quality Control and the Seven New QC Tools

Expanding the promotion of total quality control

The basic objective of total quality control (TQC) consists of bringing about company reforms in the following areas: (1) distinguishing potential future development projects, (2) planning seriously for the future, (3) paying strict attention to processes, (4) prioritizing and focusing attention on problems, and (5) focusing attention on the corporate system. Concerted efforts to improve in these areas make it possible to expect progress in fulfilling corporate duties to society as well as to develop better management systems.

In order to promote and fulfill the basic objectives of total quality control, the following four elements are extremely important:

1. Ideals and viewpoints concerning quality control. What are the company's management goals? What are the company's viewpoints concerning the promotion of total quality control? What is the

company's long-range plan for the promotion of total quality control? What are the social responsibilities connected with the business?

2. Specifying and attaining policy directives. What needs to be done to attain corporate ideals? Are the goals stated clearly? Are expected levels of achievement clearly defined?

3. Establishing management systems. Are the quality assurance system, cost-control system, and other necessary systems in place? Are the systems functioning effectively?

4. Tools for quality control. Are the seven tools for quality control and other statistical methods being utilized? Are new ideals, goals, policies, systems, and QC tools being researched?

Because these four things are interrelated and complement each other, if a company is willing to attempt to implement them effectively, then that company can expect the practical results from their application to soar. Essentially, then, the true purpose in desiring reform in the five areas listed in the first paragraph is for all employees of a company, including managers and staff, to develop the talent of "better thinking." This is exactly the expectation of every business manager and the goal of TQC human-resource development. A wise manager once commented that he wished his employees would bring their minds to work, not just their bodies. From this perspective, the adoption of "thinking total quality control" and "thinking quality management" is necessary for expanding the promotion of total quality control.

The seven new QC tools are presented with the conviction that they are the QC techniques that offer the best methods for the stimulation of thinking.

Background behind "thinking total quality control"

In the past several years, dramatic changes in TQC thinking and promotion have taken place. The major social and economic factors that have helped bring about these changes can be summarized as follows:

Continuation of stable economic growth

Even though an era of stable economic growth started in Japan at the end of the 1973 oil crisis, it is unlikely that a growth rate equivalent to the Jinmu-Iwato boom* will ever be experienced again. It is now necessary to reinforce the business systems that must be adopted in order to maintain stable economic growth.

Shift to multiple economic indicators

In the past, countries were concerned merely with their own economic welfare, but recently, the interrelationships among countries in terms of the world economy have become increasingly evident. Countries have realized that GNP alone does not suffice as an adequate economic indicator. A comprehensive evaluation of industrial activities and economic prosperity must now be made on the basis of a variety of indicators such as business trends within other countries, financial market trends, relative trade balances among countries, and the trade of specific products. Many nations need to reevaluate policies designed to simply boost their own GNP.

When only one indicator was used, the obvious goal was to maximize that indicator's value. Presently, however, with the use of multiple indicators to measure an economy, it is neither feasible nor permissible to obtain the highest values for every indicator. A careful, balanced selection of individual indicator levels must be made in terms of overall merits and demerits. This is an era of searching.

Conservation of energy and resources

After surviving the confusion of the oil crisis, the worldwide availability of energy has stabilized. However, many observers forecast a shortage of oil resources again in the 1980s. Although alternate energy plans, such as the "sunshine plan," the "moonlight plan," and nuclear fusion research geared toward the twenty-first century have

*The Jinmu-Iwato boom was a post-World War II period of extreme economic growth for Japan in the 1950s.

been promoted, the prospects for a practical substitute for petroleum are not bright.

While exhaustion of the world oil supply during this generation may not be realistic, our obligation to future generations to pass on all the natural resources possible remains. These considerations highlight the task of businesses to conserve resources in product design and production.

Environmental and public hazards

Viewed from the standpoint of improving the quality of life and respecting human dignity, protecting the environment and avoiding situations that might prove hazardous to the public become increasingly important. Systems for the production, delivery, circulation, use, and disposal of products must be evaluated to confirm that they have no adverse effects on the environment. These are important constraints that relate to all business activities.

Product liability

Judging from recent trends in the United States and the rising awareness of human rights in Japan, the importance of product liability will continue to increase. This also will act as a large industrial constraint, along with the environmental and public concerns just mentioned.

Awareness of customer needs

Despite the various constraints under which businesses must operate, consumers are demanding increasingly sophisticated and advanced products that complement their diverse lifestyles and values. Businesses that want to remain competitive both nationally and internationally, must research and develop products that will maintain a certain level of exportability despite the reduced export competitiveness of Japan caused by the present yen-dollar exchange rate.

Reduced prospects for technology import

Postwar economic development of Japan was based on the import of new technologies from foreign countries. The present situation is drastically different from the 1940s: New and radical technologies are emerging constantly. Fewer technological "seeds" can be developed into giant industries, the foreign ideas that might become these "seeds" are next to impossible to import. The advancement of developing countries has narrowed the technological gap in a number of industries and products. These technological constraints further emphasize the need to promote total quality control for the development and refinement of new products.

A new era for quality

The "new era for quality"[1] proposed by Professor Mizuno could have been anticipated if thoughtful consideration had been given to the economic and social factors discussed above. The first requirement of the new era for quality is the creation of an "added value" over and above consumer needs. It is necessary to first uncover latent customer needs and then, in response, not only meet those needs, but also to discover an added value that will surpass them. The new era for quality expects the generation of new ideas.

The second requirement inherent in the new era for quality is the ability to cope with varying limitations, hopefully without missing any necessary items: In other words, the key is to prevent failure in meeting customer needs. The constraints businesses must work around are numerous: environmental pollution, product liability, efficient use of resources, cost, and productivity, just to mention a few. In the future, business activities will undoubtedly be subject to additional constraints and limitations. In this sense, as Professor Kigure proposed, the major task facing businesses is to shift "from defensive QC to offensive QC."[2] It is important to solidify defenses against constraining factors while at the same time emphasizing an aggressive posture toward new product development.

The book *Quality Deployment*, edited by Professors Mizuno and Akao, represents an outstanding achievement as a quality system for new product development, responding to the needs of the new era.[3] Hopefully, a wide adoption of this system in industry will help businesses to march through this new era for quality.

This is the true objective of the *Seven New QC Tools*.

Highlights of "thinking total quality control"

Based on the background presented earlier, when the four elements of total quality control are applied company-wide in a comprehensive manner, the roles of managers and staff increase dramatically in company reform. In order to promote "thinking total quality control," seven items that highlight this way of thinking are listed and explained below.[4]

Conducting multidimensional evaluations

Managers and staff should always keep multidimensional characteristics and their evaluation in mind, even when pursuing a single objective. In the early stages of importing total quality control, concern frequently centered on reducing the rate of defective products or reducing costs. Now, however, desired outcomes would be difficult to obtain if quality is pursued as a single issue. Disruptions in other related functions often accompany any improvement in quality. Simply put, improvement in one function must be carried out while at the same time considering the constraints it might place on other functions and characteristics.

Thinking that "cost is cost and quality is quality" is no longer sufficient; these concepts are not exclusive of each other. An awareness of functional interrelationships is necessary: "Does the lowered cost bring about irregularities in quality?" "Is there a firm basis to back up the guarantee for product longevity?" Unless one is fully prepared to answer related questions, there will be unexpected claims later. The pressures associated with lowering costs have often

created unexpected accidents after shipping that ultimately brought near disasters to businesses. Thus multidimensional evaluation refers to looking at a problem in its context and totality.

Eliminating the phrase "recurrence prevention"

An important point in the current promotion of total quality control is forbidding the use of the phrase "recurrence prevention." Promotion should proceed with the firm conviction that failure is unacceptable from the beginning. Previously, the phrase "recurrence prevention" was used frequently, and it was sometimes said that "in quality control, the first mistake is acceptable, although its recurrence is not." However, this is an era in which even an initial failure or mistake in the design or development of a new product is simply not permissible. It is crucial to deliver a product to the market as planned and therefore to ring up sales as planned.

Such failures as lower profit because of higher production costs and unanticipated claims after shipment cannot be afforded. When faced with the problem of environmental pollution or product liability, it is totally inconceivable for anyone to maintain the naive posture that "It was a design mistake. Quality control now only has to prevent it from recurring."

In this era, failure is unacceptable from the very beginning. Merely "putting out the fire once it has started" is not sufficient. In the promotion of total quality control, preventing mistakes is necessary. Moreover, to prevent mistakes and errors during the promotion of total quality control, it is important to list all the correlated items.

Consider this issue from the standpoint of problem solving. A current problem causing a malfunction must be corrected as soon as possible. A secondary problem, however, is a situation which, left unattended, has the potential to create malfunctions in the future: It is necessary to be able to predict such malfunctions and introduce corrective measures now. The former type of problem is sometimes called an "emergent" problem; the latter is known as a "prognostic/predictive" problem.[5] Stating that recurrence prevention is not a permissible approach to quality control reflects an emphasis on the predictive type of problem.

Specifying a desirable condition

Understanding the statement "Specify a desirable condition and move toward achieving it" is easier than actually dealing with a situation within the framework of a predicted problem. There are several reasons for this. First, after talking with someone, a person may admit that there is a problem and strive toward a desirable condition. Second, in improving predictive ability, experience shows that thinking in terms of striving for a more desirable condition is more likely to produce interesting and creative ideas than talking only in terms of the problem.

In striving for a "desirable condition," it is important to note that desirable conditions, products, and systems all vary from one type of business to another. Even within a specific type of business, desirable conditions may differ depending on the size and scope of the business. To illustrate this point, consider that some taxis in metropolitan areas are painted yellow or orange, while others have sober colors such as black. Both companies believe they have the right color.

Further, an interview was held with the executive officer of a small taxi company that uses a bright color for its taxis. This company prefers a bright color because it is easier to detect from a distance. Since it changed from black to a brighter color, revenues have increased. Because there is a greater ability to identify the company, the drivers are less likely to refuse customers, and this has resulted in a reduction of complaints. As secondary effects, job stability among drivers is up and their attitudes toward customers have improved as well. The executive concluded that choosing the bright color has been very beneficial. There are some drawbacks, however. For example, the bright-colored taxis cannot be used for funeral services.

Another larger company prefers black because its cars are often hired by large corporate customers and the sober color is more fitting to their tastes and status. Owing to the large number of cars in operation, there is a high risk of minor accidents. In cases of minor accidents, the sober color makes the taxis indistinguishable from private automobiles, which is to the company's advantage. However, the sober color shows dust and dirt easily. For these reasons, these cars are probably not as suitable for operating as taxis.

Although the preceding example is mundane, it illustrates the importance of "thinking total quality control." In other words, this is an era in which simply copying other companies' quality control will not suffice. Each business must establish its own "desirable condition."

As is clear from the preceding example, a "desirable condition" may not be the best one for every evaluative dimension. Both advantages (merits) and disadvantages (demerits) must be considered, various means of achieving the objectives must be compared, and the solution that maximizes merits over demerits must be selected. This is similar to the importance of multidimensional evaluation explained earlier.

Making a truly prioritized effort

As described earlier, total quality control entails the task of prioritizing efforts. Probably foremost in prioritizing efforts is the allocation of resources. This refers to allocating the limited resources of a nation or a business (i.e., human, material, and financial resources, as well as facilities) to those objectives with the most merits. It is particularly important to place emphasis on investment in research and development.

Although the phrase "prioritized effort" has long been emphasized in the field of quality control, the reality of TQC promotion in the business world reveals that the principle of overall harmony, a typical Japanese trait, prevails. In order to determine the relative importance of suggestions made by the subordinates, it is critical for the manager to be decisive and able to distinguish the important from the unimportant.

The second task of the prioritized effort is to assign relative importance to the various steps and processes in promoting reform. Generally speaking, a single project is comprised of many tasks that have to be implemented. In evaluating a project after the passage of a certain amount of time, to cite an extreme example, one may find that 95 percent of the tasks have been completed, but that the overall result is nil. Upon closer examination of such a case, the remaining 5 percent of tasks frequently are discovered to be technically quite difficult. There is a natural human tendency to start with easy tasks and postpone difficult ones. Although the number of tasks to be

implemented may be large, usually it is only a small portion that poses any real difficulty. Yet without executing the difficult tasks, the desired objective can never be obtained. In executing long-range plans, an efficient manager identifies the difficult tasks at the beginning and works gradually toward completing them.

For this reason, it is necessary at the inception of a project to list all items or tasks that need execution and to assess the level of ease or difficulty of each by attaching as much technical detail as possible.

Encouraging system-wide promotion

The system-wide promotion of total quality control requires that every member of a company or team cooperate fully. A system functions like a human body. The entire organization of a business should act in organic harmony. For this purpose, it is essential that the function of information transmission, like the brain function in the human body, be performed faithfully. Professor Oba proposed a method called the "theory of QC hearing"[6] which articulates the need for each project director to develop and maintain a close relationship with other project directors or counterparts. It is an excellent idea that attempts to get everyone who is involved in a project to the same level of awareness and knowledge.

In addition to transmitting simple information, it is necessary to study information pertaining to other fields or projects, including their complex language, so that information can be transmitted accurately. For example, suppose that a business planning department's top directive is to "secure x new users." Under such circumstances, those in charge of field operations would naturally endeavor to secure the designated number of new users. In the process of securing new users, however, it often happens that old users are lost to competitors. Unknown to the directive's audience, though, the idea of securing a designated number of users presumed certain unstated preconditions. Among these, for example, may be that the existing users be retained or that limits be set on the types of orders received, the suggested price, or the quantity per customer. Directives usually do not spell out such details, but managers and staff are expected to grasp the underlying presumptions, as well as

how they relate to other departments or projects, rather than simply to carry out the directives blindly and literally.

In the example just described, the desired result can be obtained only when there is system-wide cooperation among the planning department, the plant, and the field office. In gaining the cooperation of other departments, it is not sufficient to resort only to official channels. It is nothing more than an excuse if one has to say, "We have talked to them, but they just wouldn't do it." It is clear that unless the related sectors are mobilized, any system-wide reform is hard to achieve. What is important here is to think of ways that encourage one's counterparts to *want* to work. Helpful in this connection are ideas that motivate one's counterparts and provide incentives.

The education of subordinates emerges as an important problem in executing system-wide management. Managers and staff need to meet with subordinates at least once a month to share thoughts, perspectives, and progress. In other words, it is necessary to lead one's subordinates with words and theory and at the same time let them possess the same information. Here the problem of transmitting complex information in a way that is simple to understand is encountered.

Actively making changes

One of the important ideas permeating the present concept of total quality control is that of change. In order to create products with "added value" and to avoid not meeting consumers' needs, previous methods will undoubtedly have to be changed somewhat. Basically, change is the essence of reform. No one could reasonably suggest that drastic reductions in a product's fraction defective rate or a significant lowering of cost could occur if, as in the past, the same employees in the same organization use the same system with the same equipment and the same methods. At any rate, change is critical. It would not be overstating the point to say that managers and staff need only to think of "What should we change?"

Change is important not only in terms of results, but it is also necessary in terms of avoiding becoming entrenched in routines: Through change, people are able to avoid job stagnation. People

often tend to become invigorated when they join a new company, change job locations, or get promoted. Managers and staff should constantly introduce changes in their TQC activities to prevent the organization from becoming lifeless and stale.

Looking at the other side, however, failures also tend to occur at the time of change. Trouble might occur when systems change or operators change as a result of personnel transfers, yet without constant change, improvement and reform are hopeless. This is a time when companies cannot afford not to change. In this new era for quality, one of the prime responsibilities of managers and staff is to actively promote change based on a balanced grasp of the various merits and demerits entailed in that change.

Anticipating and predicting the future

As an idea about adjusting to the new era for quality, one last comment is necessary: A smooth and quick rotation through the PDCA (plan, do, check, act) cycle is invaluable. Stated another way, it is better not to waste time rotating through PDCA cycles that will be useless. Therefore, it is important to try to anticipate and predict the expected outcomes. In the future promotion of total quality control, managers and staff will be required to be able to predict and be prepared for future events.

Concerning the problem of prediction, even QC specialists have voiced their concern about whether it is possible to "predict what has not yet happened." However, such predictions are made unconsciously every day. When people play "Go" or chess, they anticipate what their opponents will do during the next two or three moves. Players will at least predict what their opponents will do in response to this move or that move. Professional players can think through various contingency outcomes for a number of moves ahead. QC personnel are professionals in design, production, research, development, business operations, and sales. Unlike the situation when amateurs play "Go" or chess, QC personnel should be able to consider a multitude of factors and contingencies and take action with a certain degree of seasoned prediction. This opinion probably results from the belief that predictive potential has not been fully utilized.

In order to be able to predict, one must be able to assimilate the relationships between potentials, such as verbal information and likely outcome.

QC techniques designed to encourage thinking

As discussed in the preceding section, riding through the new era for quality requires the promotion of total quality control with a new frame of mind and a new perspective. Therefore, it is necessary to introduce new QC techniques which are appropriate to the demands of the new era.

The seven well-known tools of quality control[7] are as follows:

- Cause-and-effect diagram
- Pareto chart
- Checksheet
- Histogram
- Scatter diagram
- Control chart
- Various graphs

These constitute fields of company-wide QC activities. Results from using these tools have proven to be most effective when they are used comprehensively throughout companies, from managers to TQC circle members. However, managers and staff need special techniques in order to utilize the tools mentioned here and elsewhere.

In addition to the seven tools listed above, the tools used in quality control include a number of statistical methods, experimental design methods, and multivariate analysis methods. These tools, however, are used for obtaining data and analyzing available data after the objectives of the investigation have been decided. Although statistical quality control is based on these methods, as a practical matter, not all managers and staff can become proficient enough with statistics to use these tools.

Hopefully, managers and staff will consider the complex relationships among technical details and between departments and then organize and systematize this information as they initiate the phases of their QC activities. In order to accomplish this, managers and staff need new tools to help sort the confusing elements, uncover the underlying problems, and devise a measure of the extent of implementation. This need has long been recognized by authorities in the field of quality control, and the development of a partial solution has been advocated for some time now (see the first section of Chap. 3). It is important to think about how to treat previous problems rather than to simply gather more data. Of the original seven tools, only the cause-and-effect diagram appears to accommodate this need. However, expectations for the seven new tools run high.

Basically, there are seven desirable prerequisites for any tools or methods designed to be of use in the new era. The following subsections illustrate these prerequisites.

The ability to process verbal information

In general, the problems confronting managers and staff involve more verbal data. This is usually data involving both in-house and out-of-house matters, i.e., dealing with technological as well as market information. Managers and staff have a high-level ability to make use of this information. In the promotion of total quality control, it is important to transform language data into either graphs or some other quantitative form so that everyone in the company has equal access to it.

In other words it is hoped that any new techniques will be useful in helping managers and staff consolidate complex and varied verbal information. Such new techniques do not necessarily have to be quantitative or computational. In fact, if possible, computational techniques should be avoided. Rather, techniques that develop and express complex phenomena in terms of graphs and diagrams and uncover underlying problems clearly are sought. An appropriate new technique would be able to identify and adjust problematic elements when quantitative data do not exist, and it would specify the types of quantitative data needed for future analyses.

The ability to generate ideas

In the future, no one could contest the need to consistently promote total quality control using new ideas (see preceding section). New techniques should generate new ideas. Therefore, with this in mind, two needs surface.

The first is that any new technique should make managers and staff feel that they are utilizing their intellectual capabilities. The generation of ideas starts with the use of brainpower. In addition to this "thinking" process, thoughts and ideas need to be expressed in clear statements and diagrams. Through repetition of this process, ideas are transformed into sentences and diagrams that can serve as the starting point for ensuing rounds in the thinking process.

Methods of generating ideas also vary greatly from person to person. New techniques also should be capable of yielding results in proportion to the user's ability. In addition, new techniques should have some positive effects by virtue of having been utilized. For example, anyone can construct a cause-and-effect diagram, brainstorming and listing ideas to be sorted according to their relative importance. However, frequently it is merely the drawing of this cause-and-effect diagram that contributes to a better articulation of problems.

The second need for new techniques in terms of the generation of ideas is that there should be an orderly procedure for the construction and use of cause-and-effect diagrams, while at the same time leaving room for improvement. Because there are numerous ways of drawing these diagrams, any method should be flexible enough to accommodate new ways to utilize these diagrams.

The ability to complete tasks

When a directive is received to proceed with or complete a certain task, one should take into consideration the directive's relationship with other tasks. Any new technique brought to bear should incorporate ways to dissect tasks and assist in forming a step-by-step work schedule.

One of the important aspects of completing a task closely relates to the problem of prediction (see the preceding section). For example,

QC activities in research and development aim at completing constantly changing themes and objectives. An important element here is the establishment of a hypothesis designed for problem resolution based on various kinds of verbal and technical information. QC methods in research and development quickly and thoroughly test such hypotheses. Such hypotheses are evaluated from a theoretical perspective and examined for potential value; then a detailed test is designed based on the resulting predictions. It is commonly believed that the quality of plans cannot be evaluated. In specific instances, this is probably due to the fact that there has not been sufficient appreciation of either the problem-solving hypothesis or its predicted outcome.

This situation is not restricted to research and development applications. Since the new era for quality aims to improve conditions across the board in industry, this concept deserves serious consideration in all departments, including the QC activities for high-level products. Hopefully, new techniques will be responsive to these requirements.

The ability to eliminate failure

When quality improvement is suggested in a department and, accordingly, reform plans are implemented, complex problems surface relating to cost, payment period, and facilities. Reform plans can rarely be implemented at the upper levels of management alone; they have to be coordinated with the production process, outside clients, supervisors, and subordinates. It is necessary to promote improvement and consolidate efforts on all fronts while at the same time working to prevent failures or eliminate slippage that might occur during the transition period. New techniques should be useful here as well.

The ability to assist in the exchange of information

As explained earlier, research, design, and development in total quality control, along with QC development in such new fields as atomic power plants, shipbuilding, and building construction, require a higher degree of information sharing between the departments

concerned. In order to achieve this, several things are required: Information should be made accessible to everyone involved. Departmental relationships should be well-defined. Each manager or supervisor should list all the tasks for which they are responsible, as well as the specific tasks inherent to their project. Efforts should be made to merge company-wide technical forces. Presumably, new techniques should be responsive to these needs.

The ability to disseminate information to concerned parties

Since TQC activities are aimed at merging company-wide intellectual power, new techniques should provide a process whereby individuals' ideas can be clearly communicated to others who could benefit from that information. As long as reform is a group activity, ideas and thoughts need to be expressed in an easy to understand manner. The essential aim of this prerequisite, then, is for all the information contained in the group to become the possession of the entire group, and this, in turn, leads to the generation of new ideas.

The ability to use "unfiltered expression"

Quality control materials often suggest "resorting to unfiltered expression," in other words, saying things as they are. This is the equivalent of encouraging an uncensored, unfiltered, lively expression of successful results, the troubles endured during the process of some improvement, or the birth or death of a new idea.

Essentially, "unfiltered expression" correlates closely with another well-known saying in quality control: "Evaluation of the process is more important than the outcome." When one listens to the history of quality improvement in another department in one's company, it is very helpful if the changes in deficiency rate and values of characteristics have been recorded over the years. However, people rarely go so far as to record implementation details over the course of several years of reform. Practically speaking, however, it is hopeless to expect to rouse the interest of the younger generation of employees by sharing with them only tales of trials and hardships.

Preferably, new techniques should encourage an unfiltered, lively, and truthful expression of the promotion process, as well as

presenting the information obtained in a manner that is accessible to succeeding generations.

As an attempt to fulfill these prerequisites, seven new QC tools are advocated and promoted here. Details of these tools are provided generally in Chapter 2 and more specifically in Part II. At this point, let us just list the seven tools briefly:

1. Relations diagram method
2. KJ method (affinity diagram method)
3. Systematic diagram method
4. Matrix diagram method
5. Matrix data-analysis method
6. PDPC (process decision program chart) method
7. Arrow diagram method

These methods have all been used in other fields, but an attempt has been made to avoid simply importing these techniques. Each method was assessed in terms of its potential effectiveness in quality control or in terms of previous experience with the techniques in QC applications, especially in areas that pose QC problems. These new methods do not have to be newly invented ideas; if they were techniques that had not previously existed, their utility would be rather suspect.

These seven new tools are being promoted in the belief that they can be used most efficiently when they are combined in an interrelated manner. It also needs to be made clear that the seven new QC tools do in no way contradict or replace the existing tools; the new tools are simply meant to supplement and complement the previous tools (see the second section of Chap. 2).

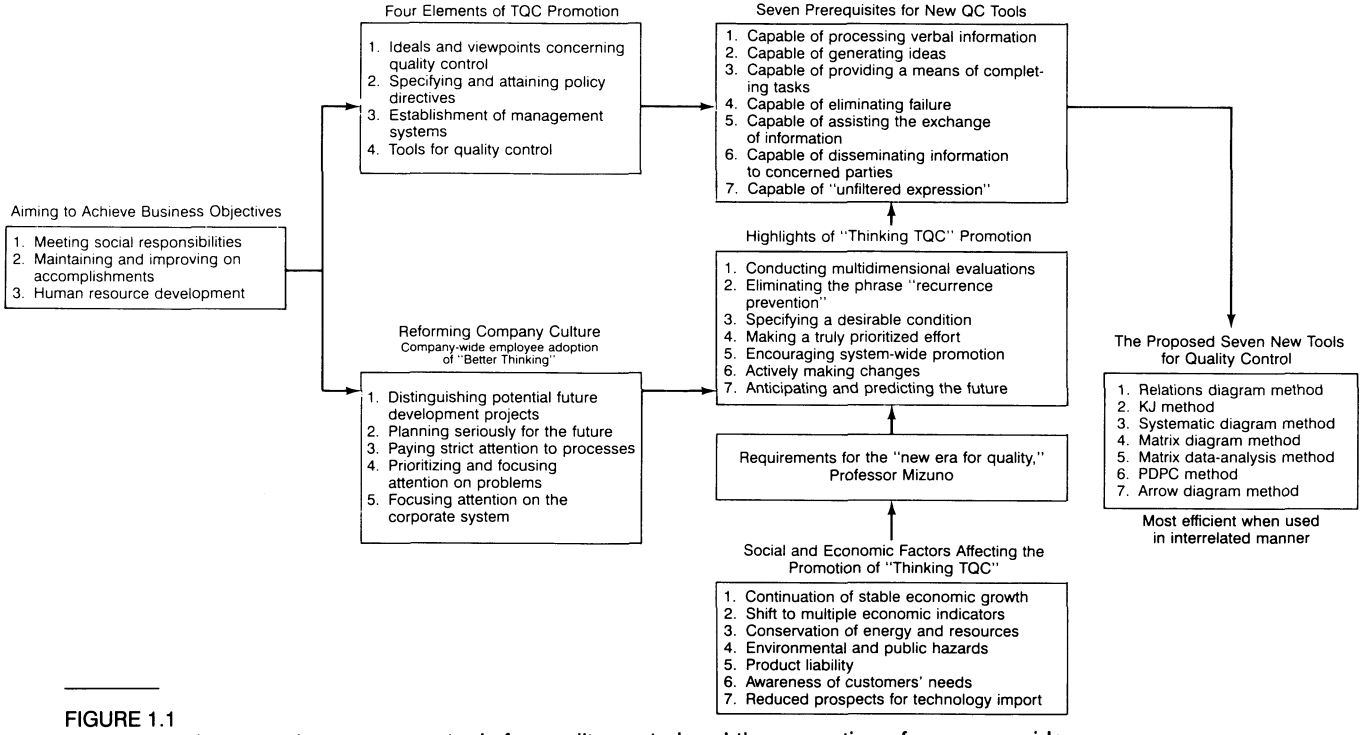

FIGURE 1.1
Relationship between the seven new tools for quality control and the promotion of company-wide quality control

Notes

1. Mizuno Shigeru and Akao Yoji, *Hinshitsu Kino Tenkai* (JUSE Press, Ltd., 1978). See Chapter 1 by Dr. Mizuno; he coined the phrase "new era for quality" at the 1972 Quality Control Convention.
2. Kigure Masao, "Quality Control in an Era of Reduced Quantity," *Hinshitsu Kanri* (*Quality Control*), vol. 29 (July 1978), p. 44.
3. Mizuno Shigeru and Akao Yoji (Eds.), *Hinshitsu Kino Tenkai* (*Quality Deployment*) (Nikka Giren Publishing Co., 1978).
4. This section benefits from the following sources, and the writer gratefully acknowledges them: Asayoshi T., "Strengthening of Company Culture in TQC," *Standardization and Quality Control* (Sept. 1978); Asayoshi T., "Suggestions to Managers — Coping with a Low-Growth Stable Economy," *Monthly Quality Text*, vol. 78 (1975); and Ishikawa T., "Riding Through Turbulent Periods with Quality Control," *Monthly Quality Text*, vol. 71 (1974).
5. Sato Mitsuichi, "How to Structure and Solve a Problem," *Diamond Harvard Business*, vol. 3, no. 3 (May-June 1978), p. 49.
6. Oba Koichi, "Problems in Introducing and Planning QC — A Few Examples and Practical Advice," *Hinshitsu Kanri*, (*Quality Control*), vol. 20, Supplement (November 1969), p. 5–8.
7. There is no fixed or definitive theory regarding the seven tools of quality control. This section relies on *Techniques for On-Site Improvements* by Imazumi. In other lists of the seven tools, control charts are replaced by stratification.

1. Kondo Jiro, *Operations Research* (Tokyo: JUSE Press, Ltd., 1973), pp. 128–136.
2. This section relies heavily on information in Chaps. 2 and 3 of *Computer Graphics Theory*, by Yoshikawa Hiroyuki, published by JUSE Press in 1977. Grateful acknowledgment is due.
3. Yoshikawa Hiroyuki, *Computer Graphics Theory* (Tokyo: JUSE Press, Ltd., 1977).

1. Mizuno, Asaka, and Ishikawa (eds.), *Dai Ikkai Hinshitju Kanri* (*The first quality control symposium*) (Tokyo: JUSE Press, Ltd., 1965).
2. A number of Japanese authors have considered the important issue of promoting policy control, for example, Ishihara Katsuyoshi, "Procedures for Establishing Quality Control Policy," *Hinshitsu Kanri* (*Quality Control*), vol. 27 (October 1976), pp. 8–12; Ikazawa Tachuo, "Managing Quality Control Policy," *ibid.*, pp. 13–15; Tamura Shoji, "Promoting Management Policy," *ibid.*, pp. 16–19.
Mizuno Shigeru has also addressed the related problems involved in planning and programming in "Planning and Programming in Business," *Quality Control*, vol. 20 (November 1969), supplement pp. 1–4. Koura Kozo has studied the relationship between objectives control and the QC team in "Examples of QC Teams," *Quality Control*, vol. 19 (October 1968), pp. 32–37.
Finally, a number of studies have been done on policy setting, implementation and promotion at different companies, for example, Ishihara Katsukishi, et al., "Staff's Role in Developing QC Policy and Plans (Nos. 1–4)," *Quality Control*, vol. 21 (November 1970), supplement, pp. 68–86; Yamamoto Mitsuo, "Examples of Policy Management in 1976," *Quality Control*, vol. 28 (June 1977), supplement, pp. 9–13.
3. Matsuda Takehiko, *Keikaku to Joho* (*Planning and Information*) (Tokyo: Nippon Hoso Kyokai Publishing Co., 1969).

4. In the field of quality control, the relations diagram was first introduced in Senmochi and Mizuno, *Hinshitsu Kanri no tameno Keizaikeisan* (Economic calculations for quality control) (Tokyo: JUSE Press, Ltd., 1971).
5. For more on evaluation *see* Shigeru Mizuno and Yoji Akao (eds.), *Hinshitsu Kino Tenkai* (Development of quality and function) (Tokyo: JUSE Press, Ltd., 1978).
6. Eguchi, Kagoyama, and Kishimoto, "On Reducing Nitrogen Oxide in LPG Boiler," in *Hin QC Nanatsu Togu Katsuyo irei Happyokai Jireihsyu* (Applications of the seven new QC tools) (Tokyo: JUSE Press, Ltd., 1978).
7. This chapter is based on research reported in Nayatani Yoshinobu, "Applying QC Techniques in Policy Management: *Hinshitsu* (*Quality*), vol. 8, no. 4 (1978), pp. 25–31.

1. Senju Toshio and Mizuno Yukiichi, *Hinshitsu Kanri no tame no Keizai Keisan* (Economic planning for quality control) (Tokyo: JUSE Press, Ltd., 1971); Senju Toshio and Fushimi Michio, *Keizaisei Kogaku* (Economic engineering) (Tokyo: Japan Management Association, 1967).
2. Yagishi Seichi and Kurabayashi Mikihiko, "Kanri Shihyokan no Renkan Bunseki Shuho" (Management indicator relational analysis), *Quality Control*, vol. 26 (May 1975), special issue, pp. 213–217.
3. Senju and Mizuno, *Economic Planning*, 1971; Senju and Fushimi, *Economic Engineering*, 1967.

1. Ko Takahashi, "Lecture Notes of the Kansai Self-Study Group — Luthe Research Society of Creativity and Development" (recorded by Kago), 1977.
2. See Kawakita Jiro, *Thought Method II* (Tokyo: Chuo Koronsha, 1970); Kawakita and Makajima Shiniichi, *Science of Problem-Solving—KJ Method Workbook* (Tokyo: Kodansha, 1970); Japan Management Association, eds., *Introduction to KJ Method for Management—A Practical Approach to a Creative Technique* (Tokyo: Japan Management Association, 1974).
3. Material in this section and the following sections on card sorting and labelling, drawing diagrams, and making written and oral presentations is drawn from Kawakita, *Thought Method II*, 1970; Kawakita and Makajima, *Science of Problem-Solving*, 1970; and JMA, eds., *KJ Method for Management*, 1974.
4. Mita and Ishizaki, "What Will Happen to QA?" in *Summary of Tasks* 3, *4, and 6 — Seven New QC Tools Study Group* (Tokyo: JUSE Press, Ltd., 1978).
5. Mita and Ishizaki, *Summary of Tasks*, 1978.

1. Editorial Board for Quality Control (Ed.), *Understanding and Promoting Quality Design* (Tokyo: JUSE Press, Ltd., 1967).
2. Futami Yoshiharu, "Analysis of Quality Characteristics Using the Function Analysis Technique," *Hinshitsu Kanri* (Quality Control), vol. 26, Supplement (May, 1975), pp. 208–212; Tsutsuya Yutaka and Futami Yoshiharu, "Technique to Sustain Management During Low Growth Periods — The Technique and Implementation of Value Engineering," *Kojo Kanri* (Factory Management), vol. 21, no. 4 (1975), pp. 6–63.
3. For more on the development of quality and quality functions see Mizuno Shigeru and Akao Yoji (Eds.), *Hinshitsu kino Denkai* (Development of quality and function) (Tokyo: JUSE Press, Ltd., 1978).
4. Futami, *Quality Control*, pp. 208–212; Yutaka and Futami, *Factory Management*, pp. 6–63.
5. Futami, *Quality Control*, pp. 208–212.

6. *See* Mizuno Keizi, *Jishyu Gijutsu Kaihatsu* (Do-it-yourself technology development) (Tokyo: Sanno Publishing Co., 1971) and Makino Noboru, *Gijutsu Nyumon* (Technology forecasting for beginners) (Tokyo: Nikkan Kogyo Shimbunsha, 1969).
7. Makino, *Technology Forecasting*, 1969.
8. *See* Saito Yoshihiro, "An Approach Toward Decision (1): Rationale and Technique," *Operations Research*, vol. 12, (August 1967), pp. 16–21; Saito Yoshihiro, *Kettei no Hanashi* (Decisionmaking) (Tokyo: JUSE Press, Ltd., 1969); R. V. Brown, A. S. Carl, and C. Peterson, *Decision Analysis; From Introduction to Application* (translated by Fujita Tsuneo) (Tokyo: Sanno Publishing Co., 1974).
9. Shiomi Hiroshi, *Kosaiseki to Shindan* (Breakdown analysis and diagnosis) (Tokyo: JUSE Press, Ltd., 1977); Japanese Union of Scientists and Engineers, Division of Machine Reliability, eds., *FMEA and FTA Explained* (Tokyo: JUSE Press, Ltd., 1978).
10. Yabiki Seiichiro, *Handan to Kettei no Kagaku* (Science of judgment and decision) (Tokyo: Japan Management Association, 1975).
11. *See* Mizuno Keizi, *Genjo Daha no Shikoho* (Getting to breakthrough) (Tokyo: Dobunkan, 1973).
12. Tamai Masatoshi, *Kinobunseki* (Function analysis) (Sanno Publishing Co., 1967); Futami Yoshiharu, *VE Manual*, 1978; Tsutsuya and Futami, *Factory Management*, pp. 6–63.

1. Futami Ryoji, "Uses of Matrix," *Kojo Kanri* (Factory Management), vol. 24, No. 9 (1978), pp. 6–15.
2. *Ibid.*
3. *Ibid.*
4. *Ibid.*
5. Yada Hiroshi, "A Quality Development System Applied at Sumikoto Joint," in *Proceedings of Regular Meeting of the Society for Study and Use of the Seven New QC Tools* (Tokyo: Japanese Union of Scientists and Engineers, 1978), pp. 3–22.
6. *Ibid.*, Futami, "Uses of Matrix," pp. 6–15.
7. Futami, "Uses of Matrix," pp. 6–19; *Proceedings*, 3–22.
8. Futami, "Uses of Matrix," pp. 6–19.
9. Makino Noboru, *Introduction to Technology Forecasting* (Tokyo: Nikkan Kogyo Shimbunsha, 1970).
10. Editorial Board for Handbook Study and Development, *Handbook on Research Development* (Tokyo: JUSE Press, Ltd., 1973).

1. *See* for example, Okuno, Kume, Haga, Yoshizawa, *Tahenryo Kaisekisuho (Multivariate Analysis Method)* (Tokyo: JUSE Press, Ltd., 1971).
2. Takabatake Kunihiko, "Tokei Kaiseki no Suishin" (The advancement of statistical analysis), *Hinshitsu Kanri (Quality Control)*, vol. 29 (May 1978), special issue, pp. 194–196; Nakaso Nobutada, "Tahenryo Kaiseki no Taikenteki Donyu ni tsuite" (Concerning the experienced introduction to multivariate analysis), *Hinshitsu Kanri (Quality Control)*, vol. 29 (May 1978), special issue, pp. 197–202.
3. Noya, Kurioka, Shokugaki, "Enshokusei to Metamerizumu ni Kansuru Kenkyu, Sono 3" (Research on performance and *metamerizumu, Shomei Gakkai Zasshi* (Lighting Study Group), vol. 27 (1968), p. 190.
4. Toda Tanaka, "Shokuhin no Shiko Chosa" (Study of Food Preferences), *Dai 9 Kai Kanno Kensa Daikai Hobunshu* (Report on the 9th Sensory Inspection Conference), vol. 10 (1968), JUSE; Tanaka Toda and Jinbo, "Shiko kara mita

Shokuhin Bunrui" (Categorization of food by preference), *Takeda Kenkyu Sho Nenpyo* (Yearly report of the Takeda Research Center), vol. 27 (1968), p. 190.
5. Noguchi Hiroshi, "Shinsozai Yoto Tansaku no Giho" (Method for investigating new material applications), in *Nippon Hinshitsu Kanri Gakkai Dai 10 Kai Kenkyu Happyo Kai, Kenkyu Happyo Yoshishu (Proceedings of the 10th Japan Quality Control Conference)* (Tokyo: JUSE Press, Ltd., 1977), p. 20; and Noguchi Hiroshi, *Kansai Tahenryo Kaiseki Semina — Tekisuto, Jishirei* (Kansai multivariate analysis seminar — text and case studies) (Tokyo: JUSE Press, Ltd., 1978), p. 37.
6. Mizuno, Nagae, Kamisugi, "Shitsugobyo no Sogoteki Hyoron Chi 0-1 score — Shuseibun Seki o Ooyoshite" (Aphasia evaluation 0-1 score — application of the principal-component method), *Gyodokeiryogaku* (Behavior measurement), vol. 3, No. 2 (1976), p. 1.
7. See note 3.
8. Kawasaki Kentaro et al., "Fashion Dynamics 3" *Seni Seihin Shohi Kagakkaishi*, (Textile product study group newsletter), vol. 17, no. 14 (1976).
9. Tamanaka Kiroki, *Kansai Tahenryo Kaiseki Semina — Tekisuto, Jishirei* (Kansai multivariate analysis seminar — text and case studies), (Tokyo: JUSE Press, Ltd., 1975).
10. Sumimoto and Kamimura, "Jidosha no Seizokotei ni okeru Tahenryo Kaisetsu Ooyorei" (Application of multivariate analysis in automobile manufacturing processes), *Hinshitsu* (Quality), vol. 6, No. 2 (1976), p. 59.
11. W. H. Lawton and E. A. Sylvester, Self-Modeling Curve Resolution, *Technometrics*, vol. 13 (1971) p. 617.
12. For example, Iguchi Haruhiro, *Tahenryo Kaisetsu to Komputa Purogramu* (Multivariate analysis and computer programming) (Tokyo: Nikkan Kogyo Shimbunsha, 1972), p. 61.

1. Kondo Jiro, *Introduction to Mathematics for the Social Sciences* (Tokyo: Toyo Keizai Shimposha, 1973).
2. Kondo Jiro, *Operations Research* (Tokyo: JUSE Press, Ltd., 1973).
3. Division of Machine Reliability (Eds.), *FMEA and FTA Explained* (Tokyo: JUSE Press, Ltd., 1978).
4. Mizuno Shigeru, (Ed.), *Prevention Plan for Product Responsibility* (Tokyo: JUSE Press, Ltd., 1975).
5. Yagi Juichi and Naya Yoshinobu, "Application of PDPC in Quality Control Systems," Japan Quality Control Academy, 10th Research Presentation Conference, 1976; – – –, "PDPC Method," in *The Seven New QC Tools Summary for Managers and Staff* (Tokyo: JUSE Press, Ltd., 1978).
6. Eguchi, Kagoyama, and Kishimoto, "Nitrate Oxide Reduction Operations for LPG Boiler," from *Seven New QC Tools: Case Study Presentation Meeting* (Tokyo: JUSE Press, Ltd., 1978).

1. *See*, for example, Mori Tatsuo, *PERT — The New Way to Consolidate Jobs* (Tokyo: Japan Management Association, 1964);_____, *PERT II–Effective Application* (Tokyo: Japan Management Association, 1965); Sekine Tomoaki, *PERT/CPM Introduction* (Tokyo: JUSE Press, Ltd., 1965); Tone Kaoru (Ed.), *PERT Lecture I: Basics* (Tokyo: Toyo Keizai Shimposha, 1966); Kato Shokichi, *New Techniques for Planning and Management—Theory of PERT/CPM and Its Application* (Tokyo: Industrial Engineering Association, 1964).
2. Mizuno Shigeru and Furukawa Yasushi, "PERT and QC," *Hinshitsu Kanri* (Quality Control) (special issue), vol. 14 (November 1963).

3. Tone Kaoru (Ed.), *PERT Lecture IV: Applications* (Tokyo: Toyo Keizai Shimposha, 1967); Mizuno and Furukawa (Tokyo Engineering University) and Suzuki, Numano, Takimura, and Sato (Toyota Motor Company), "PERT and QC — Practical Examples in the Automobile Industry (2nd Report)," *Hinshitsu Kanri* (Quality Control), vol. 15 (fall, 1964), special issue, pp. 198–201; Mizuno and Furukawa (Tokyo Engineering University) and Mitsubishi Heavy Industries, Inc. and Mihara Manufacturing Corporation, "PERT and QC — Practical Examples in the Field of Industrial Machinery (2nd Report)," *Hinshitsu Kanri* (Quality Control), vol. 15 (fall 1964), pp. 201–206; Mizuno, Furukawa, and Oba (Tokyo Engineering University) and Watase (Suzuki Motor Corporation), "PERT and QC — Quality Evaluation in the Development of New Automobile Models," *Hinshitsu Kanri* (Quality Control), vol. 15 (fall 1964), special issue, pp. 207–211.

Additional references

Nagao Seigo, *Sangyo Renkan Bunseki Nyumon* (Introduction to industrial relational analysis) (Tokyo: JUSE Press, Ltd., 1970).

Nagao Seigo et al., "Relational Analysis," *Operations Research*, vol. 17 (September–December 1972).

Nagatani Shotaro and Shinohara Ko, "Zensha teki Hinshitsu no Donyu to Suishin" (Companywide quality control: introduction and advancement), *Quality Control*, vol. 28 (June 1977), special issue, pp. 5–9.

Fujita Shinji, *Kanri Gijutsu Koza* (Lectures on management methods) (Tokyo: Japan Standards Association, 1975).

Kumatani Tomoe, "Toyota Seisan Hoshiki no Tokushitsu" (Special characteristics of the Toyota production system), *Kojo Kanri* (Factory Management), vol. 24, no. 13 (1978), p. 155.

Japanese Union of Scientists and Engineers — QC Methods Development Division, *Proceedings of the QC Methods Development Division Conventions — Seven New QC Tools* (Tokyo: JUSE Press, Ltd., 1978).

———, *Introduction to Seven New QC Tools for Management and Staff* (Tokyo: JUSE Press, Ltd., 1978).

Futami Ryoji, *VE Manual* (Tokyo: Sogogiken Publishing Co., 1978).

Motoaki Hiroshi, "Science Illustrated #2: Psychology of Perception," in *Betsatsu Science* (Tokyo: Japan Economic Journal, 1976).

Tsukada Yuzo, "Science Illustrated #4: Brain," in *Betsatsu Science* (Tokyo: Japan Economic Journal, 1977).

Takahashi Hiroshi, *Training of Creativity* (Tokyo: Japan Industrial Training Association, 1970).

Kawakita Jiro, *Study of Party* (Tokyo: Shakai Shiso Sha, 1964).

———, *Teamwork* (Tokyo: Kobunsha, 1966).

———, *Exploration of Knowledge* (Tokyo: Kodansha, 1977).

Umezao Tadao, *Technology of Intellectual Production* (Tokyo: Iwanami Shoten, 1969).

Nakayama Masakazu, *All About NM Method* (Tokyo: Sanno Publishing Co., 1977).

Tokinori Norihiko, *Story of the Brain* (Tokyo: Iwanami Shoten, 1962).

Mizuno Shigeru and Akao Yoji, *Development of Quality and Function* (Tokyo: JUSE Press, Ltd., 1978).

Futami Ryoji, "Using the Matrix to Come Up with Defect Causes and Countermeasures," *Kojo Kanri* (Factory Management), vol. 24, no. 3, (1978), pp. 15–19.

Sano Motohiko, "PDPC Method and Technology Development," from *Hinjitsu Kanri* (Quality Control), vol. 29 (November 1978), special issue, pp. 167–171.