

1 Introduction to Statistical Quality Control

- The material contained in the introduction has been taken from the following sources:

Farnum, N.R. (1994), *Modern Statistical Quality Control and Improvement* (Chapter 2), Duxbury, NY.

Montgomery, D.C. (2009), *Introduction to Statistical Quality Control* (Chapter 1), Wiley, NY.

Snee, R.D. (1999), “Why Should Statisticians Pay Attention to Six Sigma?”, *Quality Progress*, September, pages 100-103.

Wadsworth, H.M., Stephens, K.S., and Godfrey, A.B. (1986), *Modern Methods for Quality Control and Improvement* (Chapters 1,2), Wiley, NY.

1.1 The Meaning of Quality and Quality Improvement

- *Quality is conformance to requirements or specifications.*
 - This is the definition used by Crosby who suggests that in order to manage quality adequately, we must be able to quantify and measure it.
- *Quality is fitness for use.*
 - This is a more general definition attributed to Juran. It places emphasis on the consumer aspect of quality. It emphasizes that requirements and specifications translate fitness for use into measurable quantities.
- *Quality is inversely proportional to variability.*
 - This definition of D. Montgomery (your textbook author) implies that if the variability in a product’s important characteristics decreases, the quality of the product increases. Thus, *quality improvement* is the reduction of variability in processes and products.
- *Quality is the totality of features and characteristics of a product or service that bear on its ability to satisfy given needs.*
 - This definition was the 1978 consensus definition in ANSI/ASQC Standard A3. If you replace the word given with stated or implied you have the ISO definition.
 - It implies that quality is an attribute of a product. A product is a quality product if it meets all the requirements established for it; that is, it is a defect-free product.
- The quality of a product can be evaluated in many ways referred to as *dimensions of quality*. Therefore, it is important to differentiate among these dimensions:
 1. Performance: Will the product do the intended job?
 2. Reliability: How often does the product fail?
 3. Durability: How long does the product last?
 4. Serviceability: How easy is it to repair the product?
 5. Aesthetics: What does the product look like?
 6. Features: What does the product do?
 7. Perceived quality: What is the reputation of the company or its product?
 8. Conformance to standards: Is the product made exactly as the designer intended?

- **Quality improvement** is the reduction of variability in processes and products. One goal of this course is to learn how to implement statistical tools that can be used to improve quality.
- For every product, the user or consumer defines certain properties of perceived quality referred to as **quality characteristics**.
- Quality characteristics are often related to **specifications**. For a manufactured product, specifications define a range of acceptable measurements for the quality characteristics of the product components.
- The desired value for a quality characteristic is called the **nominal** or **target value**. A target value is typically bounded by an acceptable interval of values that will not impact the performance of the product if the quality characteristic value is in that range.
- The largest allowable value for a quality characteristics is called the **upper specification limit (USL)**, and the smallest allowable value for a quality characteristics is called the **lower specification limit (LSL)**.
- A quality characteristic may only have one specification limit (USL or LSL, but not both).
- A **nonconforming product** is a product that fails to meet one or more of its specifications. A specific type of failure is called a **nonconformity**.
- A nonconforming product is not necessarily unfit for use. For example, a cosmetic nonconformity (like color irregularity) will not effect the fitness of the product for use.
- A nonconforming product is considered **defective** if it has one or more **defects**. A defect is a nonconformity that is serious enough to significantly affect the proper usage of the product.

1.2 History and Evolution of Quality Control and Improvement (Supplemental)

- The need for inspection of manufactured products has been around as long as processes and factories that generate these products have existed. Before industrialization, individual workers or artisans inspected their own work.
- Industrialization made goods available to the masses, but introduced a basic change in commerce by separating the workers who made products from the customers who received them. This depersonalization introduces the need for producers to develop new means to monitor and control the quality of their products.
- Inspectors were now employed to inspect the work of others. Defective products would presumably be found by the inspector and removed or repaired before shipment. Thus, the early focus of quality control was on inspection to identify faulty products and prevent them from being shipped to customers.
- As factories became larger, this burden became too much for the inspector and, consequently, quality control tools and techniques were developed to assist the inspector. Because it was recognized early that variation in measurements is a statistical phenomenon, many of the quality control tools and techniques are statistically based.
- Although the area of experimental design is a major statistical quality method, it will not be included in the following discussion.

Earliest Developments

- With the industrial revolution, there were suddenly thousands of unskilled workers involved in high-speed manufacturing operations. Managers usually did not understand the manufacturing process and had little or no experience running large operation. In 1875, Frederick Taylor introduces management principles referred to as “Scientific Management”.
 - He advocated breaking each process into smaller, more easily completed steps and then have procedures written which detailed how each of these steps should be carried out. Managers should manage the system and workers should do as they are told.
 - The focus was on productivity. Productivity improved but quality remained a problem.
- In the early 1900s, the utilization of the assembly line was pioneered by Henry Ford in the automobile industry. Ford developed automated assembly concepts, self-checking, and in-process inspection.
- Much of the earliest work in quality control was centered in the Bell Telephone System. The need for some methods that could generate confidence in the quality of the system’s instruments was recognized early in the development of this company. Thus, the building of a national communications network created a need for rigorous inspection for assuring the quality of a product being supplied to other companies.
- Instead of having each company that receives the products do redundant inspections, the growing AT&T company (in 1907) reorganized and directed the Western Electric Co. to provide inspection and testing for the various Bell Operating Companies under the direction of the Engineering Department of AT&T. This inspection and testing was extended by 1908 to manufactured products, installed products, and purchased materials.
- Although very few statistical techniques existed in 1908, sampling was used extensively and efforts were made to judge conformity to requirements and to assess durability and reliability.
- By the 1920s, quality assurance was applied to all phases of quality: design, manufacture, and installation. Introduction of the panel switching machine (then a very complex electromechanical device) led to the necessity for a large number of inspectors. The burden was on making the product right with the mantra of “Do it right the first time.” To the current day, many industries have adopted this philosophy to increase productivity and to lower costs.
- In 1925, the members of the Inspection Department were transferred to the newly formed Bell Telephone Laboratories. This department contained Walter Shewhart, Harold Dodge, George Edwards, and others. These men were to become the founders of modern quality control methods. As their work proceeded to develop the art and science of inspection engineering, they coined the name Quality Assurance. The department evolved with Edwards as Director of Quality Assurance, Shewhart responsible for theory, and Dodge in charge of methods.
- From 1925 to 1941, the development of statistical quality control methodology was remarkable. The concept of monitoring a production process to determine if it was stable over time and capable of producing quality products was introduced. The focus shifted from inspection of a final product to studying the process that is used to make the product.
- In *JASA* (1925), the Shewhart paper “The Application of Statistics as an Aid in Maintaining Quality of a Manufactured Product” introduced the control chart. Within 25 years, the control chart was a basic manufacturing quality control tool used around the world.

- Also in 1925, Dodge introduced the basic concepts of sampling inspection by attributes and the concepts of consumer's risks and producer's risks. These concepts led to the risks of Type I and Type II errors in the testing of statistical hypotheses.

Developments in the World War II Era

- At the beginning of American involvement in WWII, there was an immediate need for large quantities of war materials – everything from guns to radar equipment to shoes. American industry rapidly expanded at the same time as the armed forces expanded.
- Many people who had never worked in manufacturing were now employed in those new or expanding factories. Thus, the quality of manufactured goods suffered from lack of skilled personnel. Training programs which emphasized the use of control charts and acceptance sampling plans were then established by companies and government organizations. For example, the War Department engaged Bell Telephone Laboratories to go to manufacturing plants and teach employees simple QC methods. Other instructors were selected from local universities.
- In 1940, the War Department published a guide for using control charts to analyze process data. Between 1940-1943, Bell Laboratories developed the forerunners of the military standard sampling plans for the U.S. Army. One of the best-known individuals working with the War Department was Dr. W. Edwards Deming who developed statistical techniques and taught QC courses.
- Another development during this period was the establishment of two groups of statisticians and engineers to do research in the use of statistics in quality control. One of these was the Aberdeen Proving Ground in Maryland. This group was formed by Walter Shewhart and included Harold Dodge. Their work resulted in standards for statistical control of quality.
- The second group was the Statistical Research Group at Columbia University. Results from this group included the development of sequential analysis and the use of multivariate analysis in quality control with the introduction of the T^2 statistic by Harold Hotelling.
- In 1944, the first journal devoted to scientific advances in statistical quality control, *Industrial Quality Control*, was published. (In 1969, it was replaced by two journals: *Quality Progress* and *Journal of Quality Technology*).
- At the end of the WWII, groups of faculty and graduate students in the training centers formed local quality control societies. In 1946, many of these societies were combined to form the American Society for Quality Control (ASQC).
- Much of the manufacturing capability in Europe and Asia had been destroyed. American manufacturing capabilities, which had grown as part of the war effort, were ready to be converted to peacetime production. There was an insatiable demand worldwide for manufactured products.
- Thus, immediately following WWII, the guiding rule was that if you could make it you could sell it. U.S. manufacturers could sell whatever they produced, so the emphasis was now on *quantity* of production and not on product quality.
- Many of the wartime quality lessons were forgotten or ignored, and customers did not seem to care because jobs were plentiful, wages were good, and if something broke, you could always replace it. That is, the U.S. developed into a “throw-away” society: one bought a product and when it failed to perform satisfactorily, threw it away, and bought another.

- Postwar Japan faced an entirely different situation. Food and shelter was scarce, and the factories were in ruins. Japan seemed unable to produce manufactured products at a level of quality acceptable to the rest of the world. In short, “Made in Japan” meant junk.
- Japan assessed and corrected the causes of their failure. The Japanese Union of Scientists and Engineers took the initiative to deal with this problem that threatened Japan’s economic existence. In 1950, they invited Deming to explain his ideas for quality improvement to leaders of Japanese industry. Dr. Deming had been preaching quality management in the U.S., but no one was listening because everyone was too busy making money.
- The Japanese listened to Deming and others (e.g., Juran) and soon mastered the inspection and process control concepts and turned their industries around. In 1951, in his honor, the top Japanese named the individual and plant quality awards the Deming Awards.
- The Japanese went on to develop their own quality improvement techniques (e.g. Taguchi and Ishikawa). By the 1970s, they had achieved world leadership in quality.

Modern Developments

- One of the earliest techniques developed was the control chart. Its use in Shewhart’s original form is still widespread. When employed this way, it is commonly called a Shewhart chart.
- Other control charts have subsequently been developed. These include the cumulative sum (CUSUM) chart and the exponentially weighted moving average (EWMA) chart which use past history in the decision-making procedure. As a result, both charts have the ability of detecting small parameter changes quicker than the Shewhart chart. CUSUM and EWMA charts were introduced, respectively, by E.S. Page in 1954 and S. Roberts in 1959.
- Many acceptance sampling standards and procedures were originally developed as military standards by the War Department (United States Department of Defense). Although many are still commonly known by their military names, in the U.S. most standards are currently published by the American National Standards Institute (ANSI) and are called voluntary standards. ANSI is responsible for overseeing the quality control standards in the U.S..
- Since WWII, the subject of reliability has developed rapidly. Much of the early work in this field was in the aerospace and electronics industries. From the reliability field, concepts of life testing of products has evolved. This will be discussed later in the course.
- One of the earlier ideas (1951), called “Total Quality Control”, was suggested by A.V. Feigenbaum of General Electric. He stressed that responsibility for quality control involved all departments and not just the quality control department.
- An outline of the entire scope of managing quality, often called “Total Quality Management (TQM)”, was presented by J.M. Juran. His pioneering work in postwar Japan led to much of Japan’s quality successes. Juran stresses the necessity for leadership by top management, extensive training programs to make basic QC techniques available to every worker, and a dedication to quality at every step: market research, product design, vendor relations, manufacturing, delivery, and service.
- Kaoru Ishikawa made significant contributions to Japanese quality. He stated that to achieve company-wide quality control the stress is to be placed on the participation of all in quality control work from the president downward to foremen and operators.

- It is interesting to note that many of the pioneers of the quality movement (including Shewhart, Deming, Juran, and Ishikawa) were trained as physical scientists or engineers. Statistical methods provided the tools needed to perform their jobs as scientists or engineers.
- In the late 1970s and early 1980s, a number of major changes began to take place in American industry. The automotive sector was in a serious slump and thousands of workers lost their jobs. The ripple effect into other parts of the economy triggered a worldwide recession. It was in this same era that the Japanese quality efforts of 25 years, began to pay off. By the mid-1980s, the balance of trade was the worst it has ever been in the history of the U.S..
- Many U.S. companies then developed quality programs and training courses. Unfortunately, these occurred at the end of the manufacturing process – after the product was manufactured. The R&D (Research and Development) groups were excluded from QC activities. American industries were treating the symptoms but ignoring the root causes for poor quality.
- Eventually, many U.S. industries began to adopt Japanese strategies (which were often based on earlier U.S. strategies) to improve product quality.
- ISO (International Organization for Standardization) was founded in 1946 to establish a series of international standards for products and production processes. Currently, over 90 countries are members.
- In 1987, ISO published the ISO 9000 series of generic standards for quality management and quality assurance. These standards apply to companies of every size and to all industrial sectors – goods, services, and information. Various extensions of the original ISO 9000 standards have been introduced since 1987.
- ISO 9000 standards provide guidance for suppliers to implement effective quality systems. They can also be used by customers to evaluate the adequacy of a supplier’s quality system. To avoid the need for each customer to check each supplier, a system of registration was established. ISO audits a supplier and certifies if it is or is not in compliance with ISO standards. Registration gives the customer an assurance that the supplier will provide quality products.
- In 1988, the Malcolm Baldrige National Quality Award was established by the U.S. Congress.
- More recently, the focus of quality expanded beyond production industries to service industries (which deal with the performance of labor for the benefit of another). Thus, greater emphasis is placed on human factors and their impact on service quality. Examples: food services, health care, building services, transportation, education, finance, and government.
- In 1997, many companies begin to adopt Motorola six-sigma approach to quality.

1.3 Statistical Methods for Quality Control and Improvement

These will be discussed throughout this course.

1.4 Management Aspects of Quality Control

Quality Planning

- **Quality planning** is the development of strategic activities designed to improve the quality of a product. The planning will include both statistical and management activities.

Quality Assurance

- Another term related to an overall approach to quality control is *quality assurance*. It is designed to include checks and controls on the quality control procedures in use.
 - For a specific product or service, this may involve verification audits and the evolution of the quality factors that affect the specification, design, production, procurement, installation, test and inspection, sales, marketing, and use of the product or service.
 - Quality assurance makes sure that quality control is doing what it should be doing. Such an effort should be organized within a factory, company, or corporation and motivated by management.
- **Quality Assurance** is a system of activities whose purpose is to provide an assurance that the overall quality control is in fact being done effectively.

Quality Control

- *Quality control is the regulatory process through which we measure actual quality performance.*
 - This is the definition given by Juran (1974). It puts quality into an action mode that makes use of standards and measurements.
- *Quality control: The operational techniques and the activities which sustain a quality of product or service that will satisfy given needs; also the use of such techniques and activities.*
 - This is the ANSI/ASQC Standard A3 definition (1978).
- *The Statistical Control of Quality is application of statistical principles and techniques in all stages of design, production, maintenance and service, directed toward the economic satisfaction of demand.*
 - This definition was given by Deming (1971) emphasizes the statistical applications, and it also makes explicit the economic objectives of quality control.
- Statistical process control (SPC) can be considered as statistical quality control applied to a process or to a product resulting from a process. The DuPont Co. definition of SPC is:
 - *SPC is the totality of all process activities directed at improving process consistency through detecting changes in measured characteristics, identifying causes of changes, and preventing recurrence of those causes.*

Benefits of Quality Control in Industry

- Improving the quality of products.
- Increasing the productivity of manufacturing processes.
- Reducing manufacturing and corporate costs.
- Determining and improving the marketability of products.
- Reducing consumer prices of products.
- Improving and/or assuring on-time deliveries and availability.

Design Quality vs Manufactured Quality

- *Design quality* refers to the quality of those product characteristics that will appeal to potential customers. It takes into account what it will cost to produce the product and what the customers are willing to pay for the product. It can be considered as the potential for achieving manufactured quality.
- After the manufacturing process has begun, the process does not always produce a unit in conformity with the design. For example, defects arise in materials, parts, subassemblies, assemblies, and in the final product. When these defects are not related to the design, but are related to an inadequate, poorly planned, poorly controlled manufacturing process, we are concerned with *manufactured quality* (which is also known as the ‘quality of conformance to design’).
- Any defective or nonconforming materials, parts, assemblies, and finished products that are discarded or reworked during the manufacturing process result in increased cost and customer dissatisfaction. The lost time and effort in producing the defective or nonconforming product, the loss of business resulting from delays in delivery, and other associated costs attributable to a poorly manufactured product are the consequence of manufactured quality.
- Higher design quality usually means higher cost, but higher manufactured quality usually means lower cost. Because the goal should be to provide good quality at low cost, both aspects of quality need to be considered simultaneously.
- At the corporate level, insufficient preproduction testing or design qualification may result in the necessity to recall (e.g. automobiles, food products) and repair or replace the product. Thus, quality is also part of corporate attitude.
- Understanding of quality concepts contributes to correct implementation and management of product quality, and the entire production enterprise benefits. A manufacturer must be aware of the physical, cultural, and operational environment in which the product will be used.
- If quality is understood, great reductions in cost may be possible.

The Deming Philosophy

- W. Edwards Deming is the most recognized name in quality management. He believed that the primary responsibility for quality lies with management. He often stated that most of quality-related problems can only be solved by management and not the workforce. This is the key to the Deming philosophy. The following summarizes his recommendations to management (known as Deming’s 14 points for management).
1. Create a constancy of purpose toward improvement of products and services with the aim to become competitive, stay in business, and to provide jobs. This can only be achieved if requisite resources and effort are devoted to this end.
 2. Adopt the new philosophy. That is, a company should reject old beliefs about quality that some defectives, poor workmanship, and service are to be tolerated. The company must sincerely strive to put quality as a prime objective.
 3. Cease dependence on inspection to achieve quality. Eliminate the need for mass inspection by building quality into the product in the first place. Wherever possible, seek to replace inspection for defects with statistical process control methods for prevention of defects.

4. Vendors should be chosen based of ability to supply quality products, and not solely on ability to supply low-cost products. Eliminate the practice of giving contracts to the lowest bidder without regard to quality. Take advantage of building long-term supplier relationships.
5. Seek continuous improvement everywhere to improve quality and productivity, and thus constantly decrease costs. Continuous improvement is to be sought in all the company's activities, from marketing, accounting, and manufacturing to payroll, engineering, and procurement.
6. Institute training on the job. Train the workforce in the tools, both statistical and nonstatistical, that are needed to improve quality.
7. Improve supervision, empower workers to make decisions about a process, and require management to make necessary process changes and exhibit leadership in quality improvement. The aim of supervision should be to help people and technology to do a better job.
8. Eliminate employees' fear of asking questions about processes and procedures so that everyone may work effectively for the company.
9. Break down barriers between departments. Departments should become familiar with one another's operations and take advantage of this knowledge to improve products and processes.
10. Numerical goals, productivity targets, quality targets, and so on should be eliminated. Instead, emphasize continuous improvement. Stressing targets will not increase quality, but stressing quality will achieve such goals. Stressing targets often creates adversarial management/workforce relationships because the majority of causes of low quality and low productivity belong to the system, and thus like beyond the power of the workforce.
11. Work standards and quotas are another form of numerical target and should be eliminated. Instead, substitute improvement aids and helpful supervision.
12. Remove barriers that rob the hourly worker of his/her right to pride of workmanship. Give workers the power to control their particular process or operation. Similarly, remove barriers that rob people in management and engineering of their right to pride of workmanship. Eliminate performance reviews and merit systems for promotions and salary.
13. Everyone should be trained in quality techniques. In particular, the quality department (if one exists) is no longer solely in charge of determining quality or using statistical methods.
14. Only top management can create an atmosphere and structure to make these points work.

Deming's philosophy requires great change in management style for many companies. Under his system, managers are required to be leaders and facilitators, not merely authority figures. They must play an active role in changing systems to improve quality, and not play the passive role of creating targets that the workforce is required to meet.

Juran's Organizing for Improvement

- Joseph Juran was a quality pioneer whose activities paralleled that of Deming. Like Deming, Juran was also invited by the Japanese. He conducted quality control seminars beginning in 1954, and had consistently been at the forefront of quality improvement.
- Unlike Deming who emphasizes statistics and the role of management, Juran's strengths are in the implementation and organization for change. He describes his steps for solving quality problems as a "breakthrough sequence" which are summarized below:

1. Establish the existence of a problem. That is, present data and arguments that prove to others, especially management, that a problem exists and is worthy of study.
2. Pare down the list of possible projects to the ‘vital few’ whose solution will provide the greatest impact. Pareto charts are used at this stage.
3. Organize for change. Obtain agreement on the project’s aim, obtain necessary permissions and authority, obtain necessary diagnostic skills, establish time horizons, and plan for implementing the solution.
4. Collect and analyze the data. Statistical tools are used at this stage.
5. Ascertain the effect (on people as well as on processes) of proposed changes and try to limit resistance to these changes.
6. Make the changes.
7. Put controls in place to maintain the improvements (referred to as “foolproofing” by Juran).

Juran’s breakthrough sequence is more of a problem-solving technique than it is a list of management objectives. From a management viewpoint, Juran (like Deming) subscribes to the view that the majority of quality problems can only be fixed by management and not by the workforce.

The Six-Sigma Approach

- The goal of the six-sigma approach to business improvement is to find and eliminate causes of mistakes or defects in business processes. To achieve this goal, the focus is placed on outputs that are of critical importance to customers resulting (hopefully) in enhanced process performance, improved customer satisfaction, and increased savings and revenues.
- Six sigma is strategic approach designed to work across all processes, products, and industries. The principles not only apply to manufacturing and electronics (where it originated at Allied Signal, Motorola, and General Electric), but to any type of business (e.g., banking and financial services, chemicals, pharmaceuticals, utilities, health care, etc.).
- While many six sigma tools are not new, the approach and deployment of the tools are unique (especially to those accustomed to using traditional statistical methods).
- Six sigma utilizes a standard deviation (sigma) which is a measure of the capability of the process to achieve defect-free performance where a defect is defined as anything that results in customer dissatisfaction.
- The ability to produce products and services with only 3.4 defects per million is described as ‘six sigma’ and is considered as world-class performance for many processes.
- The six sigma approach combines statistical methodology with quality processes to create a new methodology. This knowledge is applied to process improvement projects with the goal of increasing bottom-line numbers and customer satisfaction.
- The following are 3 aspects of the six-sigma method not emphasized in other approaches:
 1. Integrating the human element of improvement (e.g., bottom line, management leadership, sense of urgency, customer focus, project teams, culture change) and the process elements of improvement (e.g., analysis of process variation, statistical methods, process management).

2. Focusing on the bottom line. (No six sigma project is approved unless the bottom line impact has been identified.)
 3. Linking improvement tools into an overall approach. (The five-phase improvement process — design, measure, analyze, improve, control (DMAIC) — is the template.) This is reviewed in Chapter 2 of the text.
- From a statistical point of view, consider the properties of the normal distribution in terms of ppm (parts per million) defective. The following table summarizes the expected number of defective items when LSL and USL are set at target $\pm k\sigma$:

Specification Limits	Percent Inside Specs	ppm Defective
± 1 sigma	68.27	317300
± 2 sigma	95.45	45500
± 3 sigma	99.73	2700
± 4 sigma	99.9937	63
± 5 sigma	99.999943	0.57
± 6 sigma	99.999998	0.002

- At first look, this table seems reasonable for quality performance. However, this corresponds to a *single quality characteristic*. What happens if a product has multiple quality characteristics and each one has to meet specifications. If the characteristics are independent of each other, and if any one of them is outside of specifications, then the ppm defective will be much higher than the table values.
- Example: If a product has n independent components, then the probability all n components meet specifications is $.9973^n$. For $n = 100$, this would equal $.763$ which is unacceptably high.
- To address this problem, Motorola decided to adopt **six-sigma quality**. That is, they adopted $\pm 6\sigma$ limits which is ≈ 2 parts per billion defective. In the case with $n = 100$ components, the probability that a unit is nondefective is $\approx .999998$ or $\approx .2$ ppm.

2 The DMAIC Process

- The objective of the **design (D) step** is to identify opportunities and to verify/validate the potential for improvement.
- The objective of the **measure (M) step** is to evaluate and understand the current state of the process. This includes collecting data on measures of quality.
- The objective of the **analyze (A) step** is to use the data from the measure step to determine cause-and-effect relationships in the process and to understand the different sources of process variability.
- The objective of the **improve (I) step** is to use the results of the measure and analyze steps to determine specific changes to implement to improve the process.
- The objective of the **control (C) step** is to control the improvements made until future improvements can be made.
- A detailed discussion of each of these five steps is given in Chapter 2 of the text.