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Basic Principles of Total Quality Management, Just in Time, Computer-Integrated Manufacturing, and Continuous Improvement

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ABSTRACT: This paper is divided into four major sections. The first section deals with total quality management (TQM). The second section is concerned with just-in-time (JIT) systems. The third section considers computer-integrated manufacturing (CIM). Finally, the fourth section addresses continuous improvement (CI). After defining TQM, the first section outlines its basic principles, followed by a short discussion of Deming's 14 Points. The section then discusses several TQM issues. The second section talks about JIT. JIT is defined, and then its elements are highlighted, ranging from flexible resources to supplier networks. The advantages and disadvantages of JIT are also summarized. The third section depicts CIM. It too is defined, followed by an examination of its basic functions. The fourth section discusses CI, where it is defined and its purpose is described. Shiba's WV Model is then presented as an example of continuous improvement. The paper concludes by stating that the four topics are related to each other, and by appreciating their interconnections, one can gain a better understanding of how they fit together.

KEYWORDS: • Computer-Integrated Manufacturing •Continuous Improvement •Deming's 14 Points •Just-In-Time •Lean Manufacturing •Total Quality Management • WV Model

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LIST OF ABBREVIATIONS

Abbreviation	Description
CAM	Computer-Aided Manufacturing
CI	Continuous Improvement
CIM	Computer-Integrated Manufacturing
FMS	Flexible Manufacturing Systems
JIT	Just-in-Time
MRP	Materials Requirements Planning
PDCA	Plan-Do-Check-Act
SQM	Strategic Quality Management
TQM	Total Quality Management

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INTRODUCTION

This paper is divided into four major sections. The first section deals with total quality management (TQM). The second section is concerned with just-in-time systems. The third section considers computer-integrated manufacturing (CIM). Finally, the fourth section addresses continuous improvement. After defining TQM, the first section outlines its basic principles, followed by a short discussion of Deming's 14 points. The section then discusses several TQM issues. The second section talks about JIT. JIT is defined, and then its elements are highlighted, ranging from flexible resources to supplier networks. The advantages and disadvantages of JIT are also summarized. The third section depicts computer-integrated manufacturing (CIM). It too is defined followed by an examination of its basic functions. The fourth section discusses continuous improvement, where it is defined and its purpose is described. Shiba's WV Model is then presented as an example of continuous improvement. The paper concludes by stating that the four topics are related to each other, and by appreciating their interconnections, one can gain a better understanding of how they fit together.

TOTAL QUALITY MANAGEMENT

In this section, TQM is discussed. First, TQM is defined. Second, the basic principles of TQM are discussed. Third, W. Edwards Deming's 14 points are outlined. Fourth, the problems with TQM are highlighted. The section concludes by observing that traditional organizational design assumes that bigger is better and products should be put together correctly. Traditional organizations are in some sense static, whereas TQM are alive and dynamic. This is the value of TQM.

Definition of Total Quality Management

What is TQM? According to the American Society for Quality, the Naval Air Systems Command coined the term to describe the Japanese management approach to quality improvement.[1] It is a holistic approach to management that employs the principles and techniques of the behavioral sciences, as well as quantitative and qualitative analysis, to continuously improve the activities and relationships of a business.[2] Juran and Gryna stated that TQM is a system of activities that aims to delight customers, empower employees, achieve higher revenues, and obtain lower costs.[3] Evans and Lindsay observed that TQM is a total, companywide effort that involves the entire workforce to achieve customer satisfaction through continuous improvement.[4]

Total Quality Management has several aliases that should be mentioned. Feigenbaum talked about total quality in terms of control.[5] In other words, the organizational impact involves the managerial and technical implementation of customer-focused quality activities whose main responsibility lies with general management and the main-line actions of marketing, engineering, production, industrial relations, finance, and service, as well as the quality control function.[6] On the other hand, Juran viewed total quality in terms of its strategic importance for establishing long-range goals at the senior management level.[7] Juran adopted the term Strategic Quality Management (SQM) since quality management is an all-inclusive term that is related to all of the processes of the Juran Trilogy, namely, quality planning, quality control, and quality improvement.[8] SQM is used because of the convergence of responsibility for these three processes at the upper management level.[9]

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[1] ASQ STAFF, THE CERTIFIED QUALITY MANAGER HANDBOOK (American Society for Quality 1999).
[2] *Id.*
[3] JOSEPH M. JURAN. & FRANK M. GRYNA, QUALITY PLANNING AND ANALYSIS (McGraw-Hill Publishing 1993).
[4] JAMS R. EVANS, & WILLIAM M. LINDSAY, THE MANAGEMENT AND CONTROL OF QUALITY (South-Western College Publishing 4th ed. 1999).
[5] ARMAND. V. FEIGENBAUM, TOTAL QUALITY CONTROL: FORTIETH ANNIVERSARY EDITION, (McGraw-Hill Publishing 3rd ed. rev. 1991).
[6] *Id.*
[7] JOSEPH M. JURAN, JURAN ON QUALITY BY DESIGN: THE NEW STEPS FOR PLANNING QUALITY INTO GOODS AND SERVICES (The Free Press 1992).
[8] *Id.*
[9] *Id.*

Basic Principles of Total Quality Management, Just in Time, Computer-Integrated Manufacturing, and Continuous Improvement

Basic Principles of TQM

According to Evans and Lindsay, the principles of total quality are simple and involve:[10]

1) Focus on the customer;
2) Participation and teamwork; and
3) Continuous improvement and learning.

The difference between the principles of total quality, as stated by Evans and Lindsay, and traditional management is that the companies in the past did little to understand their customers, promote employee participation and teamwork, and relentlessly work to improve their processes.[11] The focus on the customer is centered on the idea that the customer is the principal judge of quality. This includes selling existing products and designing new products that delight customers and respond to rapidly changing customer and market demands. This strategic perspective is just as crucial for external customers as it is for internal customers, for this perspective ensures that the firm is an exemplary corporate citizen and a world-class organization.

The act of participation by employees uses the full knowledge and creativity of a firm's workforce.[12] Empowering employees to make decisions without the constraint of bureaucratic rules demonstrates a significant level of trust. By encouraging employees to work in teams, total quality ensures that the workforce solves systematic problems, possibly across functional areas. Imai aptly observed that using cross-functional teams, also known as quality circles, can reduce corporate tensions by focusing on solving problems rather than specific individual behavior.[13] This activity is quite beneficial for organizations that have suffered internal strife, where quality is adversely affected.

Continuous improvement has its roots in the Industrial Revolution, where in the early 1900s, Frederick Taylor, the father of scientific management, believed that management was responsible for finding the best way to do a job and training the workers accordingly.[14] It should be noted that continuous improvement of both an incremental and breakthrough nature enhances the value to the customer, reduces errors and defects, and improves productivity and effectiveness while increasing cycle time performance.[15]

Russell and Taylor listed a set of eight principles of total quality, similar to the three principles noted by Evans and Lindsay, and includes:[16]

1) The customer defines quality;
2) Top management provided leadership for quality;
3) Quality is a strategic issue;
4) Quality is the responsibility of all employees at all levels;
5) Corporate functions need to focus on continuous improvement to achieve strategic goals;
6) Quality problems are solved through cooperation;
7) Continuous quality improvement employs statistical control methods; and
8) Training and education are the basis for continuous improvement.

Upon examination, Russell and Taylor's total quality principles appear similar to Evans and Lindsay's three principles. This is readily apparent if the eight principles are mapped to the three more general principles above.

Evans and Lindsay's Principles	Russell and Taylor's Principles
#1 Focus on the customer	#1, #4
#2 Participation and teamwork	#2, #6, #8
#3Continuous improvement and learning	#3, #5, #7

The table above reveals that the two lists of principles are the same, although Evans and Lindsay's principles are more general. The fact that Russell and Taylor's principles are approximately evenly distributed suggests that both classifications are equivalent.

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[10] Jams R. Evans, & William M. Lindsay, *supra*, note 4.
[11] *Id.*
[12] *Id.*
[13] Masaaki Imai, *supra*, note 4.
[14] Jams R. Evans, & William M. Lindsay, *supra*, note 4.
[15] *Id.*
[16] ROBERTA S. RUSSELL, & BERNHARD W. TAYLOR III, OPERATIONS MANAGEMENT: FOCUSING ON QUALITY AND COMPETITIVENESS (Prentice-Hall Publishing 1995).

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Deming's 14 Points

One of the obvious problems with both sets of principles is that they are not operational. In other words, the principles may be difficult to implement. Deming developed a series of 14 points, or guidelines, to transform American business.[17] They include:[18]

1) Create constancy of purpose toward improvement of product and service;
2) Adopt a new philosophy;
3) Cease dependence on mass inspection;
4) End the practice of awarding business based on price tag;
5) Improve constantly and forever the system of production and service;
6) Institute training on the job;
7) Institute leadership;
8) Drive out fear;
9) Break down barriers between departments;
10) Eliminate slogans, exhortations, and targets asking for zero defects and new levels of productivity;
11) Eliminate work standards that prescribe numerical quotas by substituting leadership;
12) Remove barriers that rob hourly workers of their right to pride of workmanship;
13) Institute a vigorous program of education and self-improvement; and
14) Everybody in the company must work to accomplish the transformation.

Deming's 14 points are the most detailed of the three sets of total quality principles specified and occur in chronological order. Deming created these points with the intent of helping to solve the problems, big or small, faced by American industry.

The first principle deals with the fact that there are two problems that all companies face on an ongoing basis – the problems of today and the problems of tomorrow. It is very easy for a firm to become so enmeshed in the problems of today that future issues are ignored, where innovation and the resources for long-term planning are put on hold. Deming firmly believed that resources should always be allocated for research and education so that constant improvements are likely to occur.[19]

The second principle addresses that the American management style impeded competitive behavior in the late 1970s and early 1980s. Companies from other nations, particularly Japan, were stealing market share from U.S. companies by providing the American consumer with outstanding choices. According to Deming, a transformation was required, or American industries would inevitably die.[20]

Dependence on inspection to improve quality is both ineffective and costly. Deming observed that the quality of a product comes from improving production processes rather than finding the mistakes after the fact. Rework is expensive, workers are loathe to do it, and inspectors can disagree, resulting in parts that may not be repaired but used as is.[21]

On the surface, the fourth principle seems to contract the laws of economics, for it states that business should not be rewarded solely based on price, where the lowest price usually gets the business. However, suppose all the information about an input is contained in its price. In that case, higher-priced inputs may have more value, thereby lowering the total costs of the production processes.[22]

To achieve significant economies, Deming believed that managers must be taught to look beyond price and develop long-term relationships with suppliers to foster the innovative activities of that supplier. The idea is to reduce lot-to-lot variations by reducing the number of suppliers so that a manufacturer can work effectively with the selected suppliers. Deming firmly believed that single-sourcing suppliers were essential to ensuring that the products purchased meet the needs of the company's customers.[23]

The sixth point is simple: institute the training of employees. According to Deming, not only should managers be trained, but individual contributors should also be trained. Deming pointed out that people learn differently. Some have difficulty with written words, while others struggle with spoken words. Some people learn best by seeing pictures, while others learn by doing. The fact is that there is no best way to teach a human being, and by concentrating on one type of learning mechanism, firms are failing to optimize the abilities of their employees.[24]

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[17] W. EDWARDS DEMING, OUT OF THE CRISIS (Massachusetts Institute of Technology, Center for Advanced Educational Services 1982).
[18] *Id.*
[19] *Id.*
[20] *Id.*
[21] *Id.*
[22] *Id.*
[23] *Id.*
[24] *Id.*

The seventh principle is akin to the sixth one in that leadership is a critical trait that must be nurtured in all employees. The hourly worker should take pride in workmanship, and managers are responsible for ensuring this happens. Leaders must know the work they supervise so that upper management can be informed appropriately and that corrective action can be expediently taken. Years ago, a foreman could train their workers since they were familiar with the process, but today, only 1 out of 20 foremen have done the actual job their workers are performing.[25] This means that most front-line supervisors cannot gain their employees' trust.

The eighth point stated that fear must be driven out of the workplace. According to Deming, there is the fear of losing one's job, the fear that a supervisor may move to another company, the fear of expressing an idea, the fear of not receiving a raise, the fear of not knowing the answer when asked, the fear of admitting a mistake, the fear that comes from the mistrust of management, and the fear of starting another job. The problem with fear is that it reduces productivity and increases costs and rework.[26] Breaking down barriers between different functional areas is the ninth principle.

According to Deming, people in different areas of a company must understand the organization's functioning from the perspectives of engineering, accounting, marketing, finance, manufacturing, etc.[27] The issue is teamwork, where the strengths of another compensate for the weaknesses of one team member.

The elimination of slogans, exhortations, and targets must be directed towards managers rather than workers. The problem with appeals and posters is that they breed frustration and resentment. Without an effective strategy to increase productivity, become a quality worker, or take pride in workmanship, such slogans result in the things they are intended to correct.[28]

Eliminating numerical quotas for the workforce and numerical goals for management is the eleventh of Deming's 14 points. Numerical quotas for hourly employees are usually set to accommodate the average worker. With half of the workforce producing below the average, the result is a loss of productivity, dissatisfaction, and turnover.[29] Quotas are a barrier against increases in quality because pride in workmanship is lost. With quotas, the goal is to meet the quota, not necessarily to satisfy the customer. Without a plan, the mission is truly impossible.

Some barriers rob individual contributors of the pride of workmanship. According to Walton, when workers do not know what is expected of them from day to day, when standards are changed frequently, or when supervisors are arbitrary, the quality of the work suffers.[30] Deming observed that when people are treated as a commodity or as a resource, they rarely take the time to learn their job, resulting in a loss of pride in workmanship.[31] When managers are given production challenges that are too aggressive, there is a tendency to work long hours and cut corners, when necessary, again resulting in a loss of pride in workmanship.

Training and education are critical for empowerment and are Deming's thirteenth principle.[32] It is not sufficient to have good people in an organization; they must continually acquire new knowledge and skills to cope with an ever-changing marketplace.[33] According to Deming, there is no shortage of good people, but there has always been a shortage of individuals dedicated to continuous learning. One of the key purposes of a firm is to foster training and education to empower the workforce. The last principle states that companies must take action to accomplish the transformation. According to Deming, the practical steps that must be taken are:[34]

- Management will struggle to implement the first thirteen points;
- Management will take pride in adopting the new philosophy;
- Management will explain the new philosophy via seminars;
- Every job is part of the process;
- Start as soon as possible and work with deliberate speed;
- Everyone can take part in a team; and
- Embark on constructing an organization for quality.

These steps can be encapsulated into the Shewhart Cycle, the Deming Cycle as it is known in Japan, the PDCA Cycle, or the Plan-Do-Check-Act Cycle.[35]

[25] *Id.*
[26] *Id.*
[27] *Id.*
[28] *Id.*
[29] *Id.*
[30] MARY WALTON, THE DEMING MANAGEMENT METHOD (Perigree Books 1986).
[31] W/ Edwards Deming, *supra*, note 17.
[32] *Id.*
[33] Mary Walton, *supra*, note 30.
[34] W. Edwards Deming, *supra*, note 17.
[35] Mary Walton, *supra*, note 30.

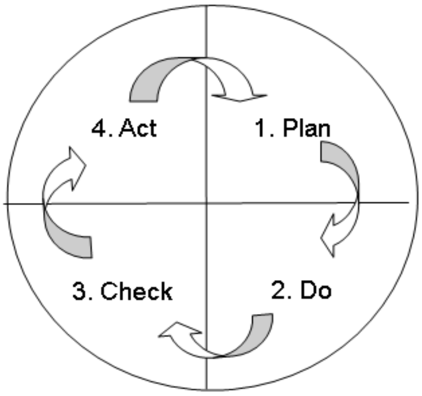

Figure 1. Plan-Do-Check-Act (PDCA) Cycle

In planning, the questions include what must be accomplished, the desirable changes, what new observations are needed, and how the observations will be used.[36] In doing so, there is the search for data to answer the questions in the previous step or collect data on a small scale to determine the effect of the change. The purpose of the third step is to observe the effect of the change, and the last step is to study the results and learn from what was done. The key to accomplishing the transformation is to help people think of their work as satisfying the customer's needs, whether the customer is inside or outside the organization.

Issues with Total Quality Management

According to Brown et al., companies that pursue TQM typically go through a start-up, alignment, and integration phase in that order.[37] TQM fails in the start-up phase because of the lack of management commitment, poor timing and pacing, wasted education and training, and the lack of short-term, bottom-line results. The key to management commitment is to train senior management before training the company. Timing is critical, and there are no shortcuts to obtaining quality. To ensure that education and training are not wasted, how much training is necessary and who will receive the training must be determined. According to Brown et al., training fails because of unrealistic expectations, the training is not tailored to the audience, it is irrelevant, the employees doubt the company's commitment to TQM, the training does not start at the top, or there is a lack of follow-up.[38]

The last reason why TQM fails during the start-up phase is because organizations focus on activities rather than results. Common mistakes include measuring the wrong indicators, focusing on behavior instead of accomplishments, emphasizing courtesy instead of competence, disguising cost control as TQM, concentrating on internal versus external improvements, failing to identify key process variables, and ineffective benchmarking. Thus, to prevent failure during start-up, there is a need to balance activities and results. The key is to focus on results, process controls, performance improvements, customer needs, and long-term strategies.[39]

During the alignment phase, a firm must establish a credible and manageable implementation strategy that combines seemingly divergent organizational systems. The four reasons why TQM fails in this phase are because many firms think of quality as separate from work, the appropriate measures are not selected, outdated appraisal methods are employed, and inappropriate rewards are given. If TQM looks like a program with a significant amount of hype and hoopla, then employees tend to classify TQM with previous programs that failed. The result is that TQM becomes isolated from the organization's workings, doomed to be stalled or even ignored. Data measurement can also prevent TQM from being successful. Compiling too much data, failing to base decisions on the data collected, and using unspoken, incomplete, or inconsistent measurements contribute to the failure to implement TQM successfully. Regardless of what a business is engaged in, companies must measure customer satisfaction, financial performance, product/service quality, employee satisfaction, operational performance, and public responsibility.[40]

The hierarchy of measurements should begin with top-level management and flow to the lower echelons of the organization. In appraising the effectiveness of an organization, Brown et al. reported that individuals should not be pitted against each other so that neither a bell-shaped nor an upright triangle is created, where feedback is constrained, and flexibility is lost. Fourthly, additional pay is probably the least effective form of compensation. This is not to say that money is not essential. According to Brown et al., of all the various mechanisms to reward quality improvement, gainsharing seems to have the most promise.[41]

[36] *Id.*
[37] MARK G. BROWN, DACEY E. HITCHCOCK, & MARSHA L. WILLARD, WHY TQM FAILS AND WHAT TO DO ABOUT IT (Irwin Professional Publishing 1994).
[38] *Id.*
[39] *Id.*
[40] *Id.*
[41] *Id.*

Although gainsharing can fail, it can succeed if it solicits the input of customers, users, and employees, the bonus is large enough and frequent enough to motivate employees, and it is based on team performance using indices that can be influenced by employee behavior.

As is expected, failure in the integration phase is just as critical as failure in the first two phases. TQM can fail in this phase because power is not transferred to the employees, outmoded management practices are retained, the organizational structure oscillates between centralized and decentralized, outdated business systems are not replaced, and management is unable to promote learning and the diffusion of innovation. When managers have all the power within an organization, employees tend not to participate in the quality process. However, when quality circles, or self-directed teams, are formed, employees feel they have a voice in the system, and continuous improvement becomes the order of the day. Managers who take on the role of coaches rather than bosses develop the skills to overcome resistance to change, including their own arrogance.[42]

Total Quality Management Conclusion

The problem with the traditional organizational design is the assumptions supporting it; namely, bigger is better, and products should be assembled correctly. The first assumption promotes centralization, while the second assumption encourages decentralization. According to Brown et al., firms must be flexible in searching for synergies, possess open boundaries, and develop explicit programs that create new ventures. Essentially, traditional organizations are sterile entities, and TQM proposes giving the organization the gift of producing life, a.k.a. new organisms called companies. The last reason why TQM may fail is because some firms cannot learn and do not evolve as dynamic innovations come to the forefront. To become a learning organization, a company must promote experimentation and be able to fail without incrimination. By empowering employees, firms allow their workers to take responsibility for their actions and promote their employees' ability to work through others. In other words, a firm can only progress if it promotes the efficacy of its people, allowing them to embrace change in much the same way as management does.[43] This is no mean feat.

JUST IN TIME SYSTEMS

In this section, the JIT philosophy of manufacturing is discussed. First, JIT is defined. Second, the elements of JIT are described, including flexible resources, cellular products, full production system, kanban production systems, small lot production, quick setups, uniform production levels, quality at the source, total productive maintenance, and supplier networks. The advantages and disadvantages are then highlighted. Finally, the section concludes by observing JIT manifests itself as Lean manufacturing. Although JIT has significant advantages, it is not for every business.

Definition of JIT

According to Schroeder, the JIT philosophy of manufacturing was developed at the Toyota Motor Company in Japan during the 1970s.[44] It was in response to the entire production efforts of the entire Japanese automobile industry that produced a mere 30,000 vehicles in the 1950s.[45] JIT manufacturing was popularized by Taiichi Ohno, a vice president at Toyota, and became popular in the United States when the technology was transferred to Kawasaki's plant in Lincoln, Nebraska.[46] Because capital was in very short supply in Japan during the 1950s and 1960s, the president of Toyota, Eiji Toyoda, mandated that the company eliminate waste.[47] The Japanese defined waste as "anything other than the minimum amount of equipment, materials, parts, space and time which are essential to add value to the product."[48] Examples of waste include watching a machine run, waiting for parts, counting parts, overproduction, moving parts over a long distance, storing inventory, looking for tools, machine breakdown, and rework.[49]

However impractical, the objective of JIT is to be able to produce parts where a single part constitutes a lot.[50] Although this may not be economically feasible, the JIT solution is to reduce waste by acquiring raw materials just in time to have them manufactured into parts, manufacturing parts just in time to be assembled into finished products, and assembling finished products just in time to be sold and consumed in the marketplace.[51] In an ideal JIT system, all inventory, not merely raw materials, is moving

[42] *Id.*
[43] *Id.*
[44] R. G. SCHROEDER, OPERATIONS MANAGEMENT: DECISION MAKING IN THE OPERATIONAL FUNCTION (McGraw-Hill Publishing 1993).
[45] ROBERTA S. RUSSELL, & BERNHARD W. TAYLOR III, OPERATIONS MANAGEMENT: FOCUSING ON QUALITY AND COMPETITIVENESS (Prentice-Hall Publishing 1995).
[46] R. G. Schroeder, *supra*, note 44.
[47] Roberta S. Russell, & Bernhard W. Taylor III, *supra*, note 45.
[48] KIYOSHI SUZAKI, THE NEW MANUFACTURING CHALLENGE (Free Press 1985).
[49] Roberta S. Russell, & Bernhard W. Taylor III, *supra*, note 45.
[50] R. G. Schroeder, *supra*, note 44.
[51] SANG M. LEE, & MARK J. SCHNIEDERJAMS, OPERATIONS MANAGEMENT (Houghton Mifflin Company 1994).

continuously and is not stored anywhere for any length of time. In a typical JIT system, inventory is pulled through the system by the demands of the market. Thus, firms employing JIT are usually placing minimal and frequent orders for inventory. Although it could be construed that the pricing of these products would be pretty flexible based on the nuances of demand, the Japanese typically sign long-term contracts with vendors that allow the price to float inside a prescribed interval.[52]

Because of the small incoming inventory, Japanese firms expect the inventory to be 100 percent free of defects. Once in the assembly area, inventory items are transformed, where workers along the assembly line are responsible for performing quality control checks on the inventory they are processing. If an inventory item is defective or a worker causes a defect, it is immediately returned to its source. Since orders set to a JIT organization tend to be minor, warehouses rarely store finished goods waiting for customers to buy them. Since JIT firms are demand-driven, retail stores can be small, where each store need not carry a significant amount of inventory.[53] In other words, with a large number of outlets, JIT companies can be closer to the customer, providing convenient service as the need arises.

Elements of JIT

According to Schroeder, in a JIT manufacturing system, workers are responsible for producing quality parts just in time to support the next production process.[54] A JIT production system is composed of the following elements:[55]

- Flexible resources;
- Cellular layouts;
- Pull production system;
- Kanban production system;
- Small-lot production;
- Quick setups;
- Uniform production levels;
- Quality at the source;
- Total productive maintenance; and
- Supplier networks.

Flexible Resources

Flexible resources and multifunctional workers are critical. When Ohno first came to work at Toyota, he asked his workers to operate two machines instead of one. The machines were located in parallel lines to ensure this was possible. Over time, Ohno further asked his workers to operate three or four machines simultaneously, where the machines were arranged in a U-shaped configuration.[56] Since the machines are not necessarily all the same, additional training is required. With labor flexibility came flexible machines that were generally purposed in nature, reducing the setting up of another machine and reducing waste and waiting times.

Cellular Products

Although manufacturing cells were first discussed in the 1920s, Ohno brought innovation to the world stage. Figure 2 demonstrates what a U-shaped cell would look like:[57]

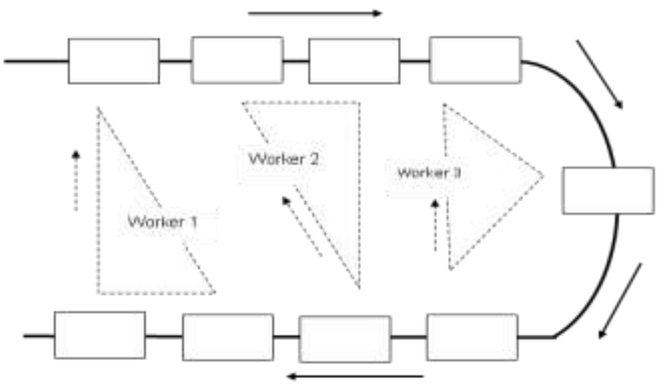

Figure 2. Manufacturing Cell with Worker Routes

[52] *Id.*
[53] *Id.*
[54] R. G. Schroeder, *supra*, note 44
[55] Roberta S. Russell, & Bernhard W. Taylor III, *supra*, note 45.
[56] *Id.*
[57] *Id.*

Because cells are producing similar items, setup times are small, and lot sizes are low. Movement of inventory is in small lots, or kanbans, which is a card that corresponds to a standard quantity of production.[58] Furthermore, cellular layouts facilitate pull production or, from an economic perspective, demand-driven production processes.

Full Production System

The reason that inventory exists is to cushion the firm against the nuances of coordination. Ohno got the idea for a pull inventory system by observing that Americans do not keep large food stocks in their homes. Consumers replenish food as needed, and supermarkets control their inventory by reordering items after they disappear. In most manufacturing facilities, each workstation pushes its completed work to the next station. In a pull system, workers return to previous stations and obtain the items they need; workers at these stations then replenish the items taken by the succeeding stations. Russell and Taylor noted that what is necessary to produce is not dictated by a schedule but is determined by successive workstations.[59] Since this methodology runs counter to the way that manufacturing organizations operate, Ohno found that introducing kanbans, or cards, permitted greater control over pull processes on a shop floor.

Kanban Production Systems

Kanban is the Japanese word for card. A kanban corresponds to a standard production quantity in a pull manufacturing system. A kanban contains basic information, may be color-coded, and can rotate back and forth between preceding and succeeding workstations. Kanbans are associated with fixed-quantity inventory systems, where a certain quantity is ordered when the stock falls below an item's reorder point. A reorder point is specified so that the demand for the item can be met and corresponds to the demand lead time. Inventory is continuously in transit, with only one bin and the card, or kanban, placed on top of the bin. There are many variations on a simple kanban system, including a dual kanban approach, a kanban square, a signal kanban, a material kanban, and a supplier kanban.[60] It is relatively easy to enhance a simple kanban system, but it should always be remembered that the purpose of the system is to reduce inventory levels and ensure that inventory flows smoothly through a production process.

Small Lot Production

The advantage of small lot production is that it requires less space and a small capital investment. By producing small numbers of products, small amounts of time are expended, which means that processes can be physically close to each other, problems are easy to detect, and workers are less likely to allow defects to proceed undetected. According to Imai, any worker at Toyota can stop the production process once a defect is discovered.[61] Then, a thorough adjustment is made to ensure it does not happen again. Thus, small lot production reduces the four components of lead time, including processing time, move time, waiting time, and setup time, and of these four, the biggest bottleneck is usually setup time.[62]

Quick Setups

Quick setups are critical. As a consultant for Toyota, Shigeo Shingo reduced setup times on a 1,000-ton press from six hours to three minutes by employing a system entitled SMED, or single-minute exchange of dies. There are essentially two types of setup: an internal setup performed when the machine is stopped and an external setup that occurs in advance while the machine is running. The key to reducing setup times is to convert internal setups to external setups while streamlining an external setup. Another way to reduce setup time is to add an extra person to the setup team, thereby taking advantage of increasing returns to scale since two people can perform a setup in less than half the time of a single person.[63]

Uniform Production Levels

To eliminate waste, JIT systems work towards maintaining uniform production levels by smoothing out the production requirements when assembling the final product. One way to accomplish this is to anticipate demand by making accurate forecasts. At Toyota, demand is estimated twice a year, and monthly product schedules are drawn up two months in advance. The plans are reviewed a month and 10 days in advance. Another mechanism to smooth out demand is to divide it up into small increments so that the same amount of an item is produced each day, and item production is mixed throughout the day in small quantities to take into account the variations in demand.[64] In other words, some amount of an item is produced every day, ensuring that some amount of an item is available to allow the firm to respond to variations in demand.

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[58] *Id.*
[59] *Id.*
[60] *Id.*
[61] Masaaki Imai, *supra*, note 4.
[62] Roberta S. Russell, & Bernhard W. Taylor III, *supra*, note 45.
[63] Roberta S. Russell, & Bernhard W. Taylor III, *supra*, note 45.
[64] *Id.*

Basic Principles of Total Quality Management, Just in Time, Computer-Integrated Manufacturing, and Continuous Improvement

Quality at the Source

According to Russell and Taylor, quality must be extremely high in a JIT system, since there is no inventory to buffer against defective items. Quality improvements accelerate as processes become streamlined. Workers must quickly and easily spot quality problems and be prepared to remedy the problem with minimum rework. At Toyota, the goal is zero defects so workers can ultimately stop the production line if quality problems are encountered. This is called judoka. Above every workstation are a series of lights: a green light indicating regular operation, a yellow light requesting help, and a red light indicating that the line has stopped. At Toyota, a line is stopped for about 20 minutes daily because of judoka.[65]

Other notions that are present in a JIT system are capacity scheduling, visual control, poka-yoke, and kaizen. Undercapacity scheduling occurs when extra time is allocated to a schedule for non-productive tasks, such as preventive maintenance, planning, training, problem-solving, and maintaining the work environment. Visual control concerns production systems where problems are visible, and workers have explicit expectations regarding performance. This time of quality control leads to poka-yoke, where there is a foolproof mechanism for detecting defects and preventing them from occurring. This includes machines that prevent too many items from being put in a package or detecting components that are not aligned correctly. The fourth quality of JIT is known as kaizen, which is the Japanese term for continuous improvement. The idea is to continuously look for ways to reduce inventory, speed up setups, improve quality, and quicken the reaction to customer demand. This involves the participation of every employee at every level and is known as total employee involvement (TEI). Thus, the essence of JIT is the willingness of workers to spot quality problems, stop production, if necessary, generate new ideas for improvement, analyze processes and perform different functions and routines.[66]

Total Productive Maintenance

Since machines cannot operate continuously without someone attending to them, some maintenance is always necessary. The first type is breakdown maintenance, where failed machines are operational. The second type is preventive maintenance, where a machine is periodically inspected to ensure it usually operates. According to Russell and Taylor, breakdowns can still occur, and so JIT demands total productive maintenance, where preventative maintenance is combined with total quality, or employee involvement, decisions based on accurate data, zero defects, and a strategic focus.[67] With TPM, management must take on a strategic view of maintenance, where products are designed that can be produced on existing machines, machines are designed for easy operation, changeover, and maintenance, workers are trained and retrained to operate machines properly, machines are purchased that maximize the company's productive potential, and preventative maintenance plans take into consideration the useful life of a machine.[68] The goal of TPM is clearly zero breakdowns.

Supplier Networks

A network of reliable suppliers is critical for JIT to work correctly. At Toyota, parts are delivered several times daily, whereas engines and transmissions are delivered every 15 to 30 minutes. To achieve this kind of frequency, suppliers encircled the Toyota plant within a 50-mile radius and also practiced JIT. The critical issues consisted of the following:[69]

- Locate near the customer;
- Establish small warehouses;
- Consolidate warehouses with other suppliers;
- Use standardized containers ;
- Ensure a precise delivery schedule;
- Become a certified supplier; and
- Accept payment at regular intervals rather than upon delivery.

According to Russell and Taylor, if these were practiced effectively, suppliers would be reliable, and JIT would become almost a certainty.[70]

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[65] *Id.*
[66] *Id.*
[67] *Id.*
[68] *Id.*
[69] *Id.*
[70] *Id.*

Advantages and Disadvantages of JIT

According to Russell and Taylor, the average benefits accrued over 5 years by implementing JIT include a 90 percent reduction in manufacturing cycle time, a 70 percent reduction in inventory, a 50 percent reduction in labor cost, and an 80 percent reduction in space requirements. Although not all companies can achieve such impressive gains, a list of JIT benefits includes:[71]

- Reduced inventory;
- Improved quality;
- Lower costs;
- Reduced space requirements;
- Shorter lead time;
- Increased productivity;
- Greater flexibility;
- Better relations with suppliers;
- Simplified scheduling and control activities;
- Increased capacity;
- Better use of human resources; and
- More product variability.

Just-in-Time Systems Conclusion

In implementing JIT in the United States, a new concept has come to the forefront, and it is called lean production. What has been learned over the years is that JIT is evolving and that it is not for everyone. To be successful, JIT must have some stability of demand with high volumes. Russell and Taylor aptly observed that JIT is not appropriate for low-volume items or unique orders.[72] Even so, it appears that more processes can benefit from JIT than there are those where JIT is not the correct manufacturing system to employ.

COMPUTER INTEGRATED MANUFACTURING

This section discusses CIM. First, CIM is defined. Second, CIM basic functions are described. Third, continuous improvement is defined. Fourth, the purpose of continuous improvement is evaluated. Fifth, Shiba's WV methodology is highlighted. Finally, the section concludes that any process possesses variation, of which some are acceptable and some are not. The whole point of CIM and continuous improvement is to control variation at the process level and at the points where the product is being made. The critical issues are to control variation and minimize its negative effects.

Definition of CIM

CIM defines computers directing a product's flow through a manufacturing process.[73] According to Russell and Taylor, CIM is often perceived as the ultimate in manufacturing processing, where there is no human interference. Even so, probably a more accurate definition is that CIM entails the use of computer technology to bind together the design, manufacturing, marketing, and delivery of a product into an integrated system.[74] According to Schroeder, CIM is the factory of the future, where a computer database is employed to help design products, control robots that perform the actual manufacturing with the aid of material requirements planning software, and provide timely data for marketing and delivery.[75] Juran and Gryna defined CIM as the process of using a computer in a planned fashion from design inception to the shipping of a product.[76]

Narayanan looked at computer integrated manufacturing in terms of the natural economies of scale that can be achieved through volume production, where the costs per unit are low, and fixed costs, no matter how high, are amortized over a large number of units.[77] With a desire by customers for essentially uniquely produced goods, and a rejection of mass marketing, came mass customization, where flexible manufacturing techniques are employed. This includes materials requirements planning (MRP) systems, just-in-time (JIT) systems and flexible manufacturing systems (FMS) that take blatant advantage of computer aided manufacturing (CAM). According to Hanna and Newman, computer integrated manufacturing allows computer systems to talk to one another so that design changes can be quickly tested for manufacturability, as well as manufacturing issues bridging the design

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[71] *Id.*
[72] *Id.*
[73] Sang M. Lee, & Mark J. Schniederjams, *supra*, note 51.
[74] Roberta S. Russell, & Bernhard W. Taylor III, *supra*, note 45.
[75] R. G. Schroeder, *supra*, note 44.
[76] Joseph M. Juran. & Frank M. Gryna, *supra*, note 3.
[77] V. K. NARAYANAN, MANAGING TECHNOLOGY AND INNOVATION FOR COMPETITIVE ADVANTAGE (Prentice-Hall Publishing. 2001).

and marketing gaps.[78] Thus, CIM is really a strategy for organizing and controlling a factory, rather than a specific technology to run the workings of a shop floor.

CIM Basic Functions

The keys to CIM are the databases that encompass both manufacturing and product data. According to Gryna, there are eight key functions to computer-integrated manufacturing. They include:[79]

- Design and drafting (CAD/CAM);
- Production scheduling and control;
- Process automation;
- Process control;
- Material handling and storage;
- Maintenance scheduling and control;
- Distribution management; and
- Finance and accounting.

Design and drafting are accomplished by using computer software that currently runs in a Microsoft Windows environment. Production scheduling and control is coupled with materials management and requirements planning, starting when raw materials are procured, and ending when the final products are shipped to the customers. Process automation is achieved through the direct control of production processes, inspection and testing, the utilization of robotics and flexible manufacturing. In contrast, process control is concerned with sensing the activities of the machinery, and reporting conditions that demand operator intervention, and is typically under the auspices of a programmable controller. Material handling and storage is automated in a computer integrated manufacturing system, where the retrieval of finished and purchased parts are predicated on selecting schedules and requisitions. This function is typically handled by servers specifically programmed for this activity. Preventative maintenance scheduling and reporting are accomplished to minimize downtime. This function controls spare parts inventory, managing and reporting usage. Distribution management deals with order processing, sales reporting and invoicing, together with warehousing and transportation. This function is usually reserved to a firm's main computers. Finally, the finance and accounting function is dedicated to reporting operating results, and forecasting future results. It is also concerned with analyzing costs, so that they may be minimized, or equivalently, profits maximized.[80]

Advantages and Disadvantages of Computer-Integrated Manufacturing

According to Russell and Taylor, technology, and in this case CIM, is not a panacea for regaining competitiveness or a source of competitive advantage. Technological decisions should consider technological readiness, design, selection, and integration.[81] Automation cannot grant exceptions, tweak a process, or modify a design. Products that are poorly designed or have inefficient processes are often exposed when automation is introduced. Remember that this can be an expensive learning experience for management.[82]

The advantage of automation is not its ability to mimic human behavior but to do things that humans cannot do. For example, humans find it difficult to return a tool to where they found it, but they can search for the correct spot. Machines are outstanding at repeating actions repeatedly, thus reducing the need for sensitive sensors. For example, the manual assembly of high-tech products is a thing of the past because robots can perform tasks with high quality, uniformity, and cleanliness.[83]

It is imperative that the selected level of automation match "the requirements of the manufacturing system, the product being produced, and the competitive environment."[84] Human work is preferred when sensing and intelligence are demanded, the environment changes frequently, or it is not cost-effective to program a machine. In making this statement, it should be remembered that technology changes over time and that activities that were once the exclusive domain of human work can be, at times, easily converted to automated production. On the other hand, if a market becomes too diversified, it is conceivable that once automated activities may return to the realm of human work.[85]

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[78] MARK D. HANNA, & W. ROCKY NEWMAN. (2001). INTEGRATED OPERATIONS MANAGEMENT (Pearson Custom Publishing Cust. Ed. 2001).

[79] Frank M. Gryna, F. M. (1988). Manufacturing Planning. In JOSPEH M. JURAN & FRANK M. GRYNA (EDS.), JURAN'S QUALITY CONTROL HANDBOOK (McGraw-Hill Publishing 4th ed. 1988).

[80] *Id.*

[81] Roberta S. Russell, & Bernhard W. Taylor III, *supra*, note 45.

[82] *Id.*

[83] *Id.*

[84] *Id.*

[85] *Id.*

It needs to be remembered that technology is usually quite expensive and that firms typically automate incrementally. According to Russell and Taylor, there needs to be a strategy for automation so that as different systems are purchased, they can be integrated into a whole.[86] As technology becomes more powerful, it needs to be more flexible, easier to use, more intelligent, and better integrated than its predecessors. Only then will CIM fulfill the dreams of its creators.

Computer-Integrated Manufacturing Conclusion

CIM is critical to maintain a pre-specified level of product quality. The purpose of the CIM features is to ensure that there are no significant deviations in product quality in the long term. The technology decisions should involve the readiness, design, selection, and integration of a manufacturing process. Because technology is typically expensive, CIM should likely be implemented incrementally so that a firm is not unduly financially burdened. As technology becomes more sophisticated, its flexibility makes it more desirable. Thus, along with technological developments, CIM should also promote reduced costs to ensure successful implementation.

CONTINUOUS IMPROVEMENT

According to Lee and Schniederjams, world-class organizations share some of the following characteristics:[87]

- Integrate management resources to meet customer satisfaction;
- Continually improving product quality;
- Developing competitive advantages;
- Avoiding waste in production systems to improve productivity;
- Possessing excellent manufacturing capabilities, including flexibility; and
- Always striving for improvements.

This list reveals that regardless of whether an organization is large or small, some improved technology is required for the firm to become world-class. These principles predicate a company continually improving its processes to ensure its success. Thus, it is entirely appropriate to discuss continuous improvement in some detail.

Definition of Continuous Improvement

What is continuous improvement? According to Shiba et al., continuous improvement is a problem-solving process.[88] Continuous improvement is based on the notions of systematic improvements and iterative improvements. Juran and Gryna stated that continuous improvement is an enduring effort to act upon chronic and sporadic problems to achieve better and better levels of performance year after year by reducing variation around a target value.[89] For Imai, continuous improvement is called *kaizen*, which means improvement in Japanese, but it occurs in small and gradual improvements.[90] Evans and Lindsey stated that Western management had perceived improvement in large and expensive innovations.[91] In contrast, Deming believed that continuous improvement is a transformation of how things are made and business is done, where best efforts are not sufficient, consistency of effort is paramount, short-term profits are not an index of success, and the support of top management is insufficient.[92] In other words, continuous improvement is a revolution in way products are designed, made, and how quality is built into a product as it is transformed from basic inputs to finished goods that are sold to a firm's customers.

Basic Principles of Continuous Improvement

According to Shiba et al., there are four (4) levels of quality; namely:[93]

- Fitness to standard;
- Fitness to use;
- Fitness to cost; and
- Fitness to latent requirement.

Fitness to standard means that a product is built according to specifications. The weakness of fitness to standard is that it assumes that quality can only be achieved through inspection and neglects the marketplace's needs. Fitness to use is the means to ensure that

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[86] *Id.*

[87] Sang M. Lee, & Mark J. Schniederjams, *supra*, note 51.

[88] SHOJI SHIBA, ALAN GRAHAM, & DAVID WALDEN, A NEW AMERICAN TQM: FOUR PRACTICAL REVOLUTIONS IN MANAGEMENT (Productivity Press 1993).

[89] Joseph M. Juran. & Frank M. Gryna, *supra*, note 3.

[90] Masaaki Imai, *supra*, note 4.

[91] Jams R. Evans, & William M. Lindsay, *supra*, note 4.

[92] W. Edwards Deming, *supra*, note 17.

[93] Shoji Shiba, Alan Graham, & David Walden, *supra*, note 88.

a product satisfies the market's needs. Like fitness to standard, fitness to use is achieved through inspection. The weakness of fitness to use is that any competitive advantage a company enjoys is only temporary.[94]

Fitness to cost means high quality and low cost and is the essential characteristic of Total Quality. To achieve this level of quality, a company must examine its production system and look for ways to improve its processes. These changes can be continuous improvement or fundamental reinvention. Fitness to latent requirements is a way of meeting a customer's needs before they know that the needs exist. A famous example is the Polaroid Land camera, which satisfied the latent need for instant pictures. A weakness for companies that meet fitness to latent requirements is that they may not be able to adjust quickly enough to market needs.[95] To achieve continuous improvement, all four levels of quality need to be emphasized to ensure that the processes involved in producing a product promote a competitive price in a rapidly changing global marketplace.

Shiba et al. postulated that since the world is rapidly changing, the notion of quality will also change in the future. The authors believed that the direction of the quality movement would encompass fitness to corporate culture and the societal and global environment. Companies increasingly make decisions and promote themselves to their customers based on their culture. For example, a firm may view itself as a company of computers and communication or an internet company. The purpose of fitness to corporate culture can be viewed as a way to flesh out a production stream from product inception to customer purchase and acceptance. There is also the ever-present pressure for firms to improve the quality of the work environment for employees, as well as an effort to adapt the products and manufacturing processes to the outside environment.[96] Although this could be construed as a variation on the fitness to latent requirements, it is becoming increasingly focused in customers' minds.

Purpose of Continuous Improvement

According to Shiba et al., the five basic principles that every manager should understand are:[97]

- Customer needs the desired output;
- The processes used determine the actual output;
- The actual output invariably possesses variance;
- Inspection is a poor control method; and
- To meet the desired output, reduce variance by removing the sources of the variation.

Since the goal of every business process is to satisfy a customer, either internal or external, it is the customer that determines the desired outputs. Thus, a firm must understand and know what customers care about. This is known as hearing the voice of the customer. The outputs come from the process and not the voice of the customer. For example, if a product is acceptable within specific tolerances, the process controls the output range and not the customer's desires.[98]

Shiba's WV Method

According to Shiba et al., the WV method of systematic improvement modifies Kawakita's W model. This model describes the problem-solving process as alternating from thought (rumination, planning, and analyzing) and experience (collecting data, interviews, experiments, and measurements). The name of the WV model comes from traversing between these two levels over time and is pictured in Figure 3:[99]

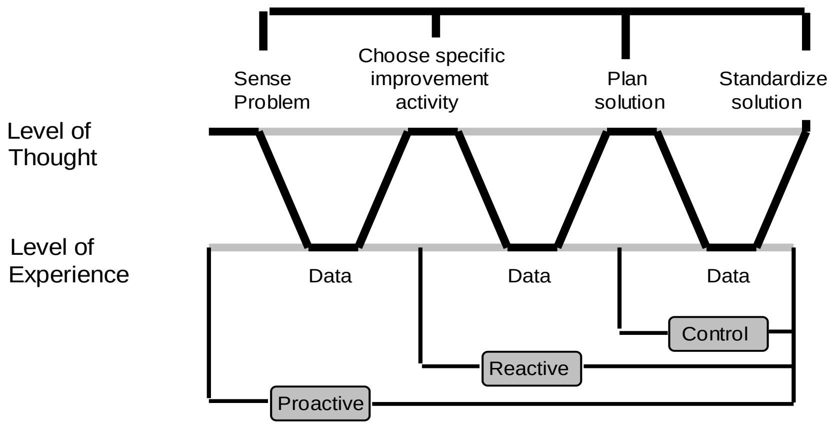

Figure 3. Problem-Solving Version of the WV Model

[94] *Id.*
[95] *Id.*
[96] *Id.*
[97] *Id.*
[98] Id.
[99] *Id.*

The WV model can also illustrate the different types of improvement: process control, reactive improvement, and proactive improvement. Process control means monitoring a process to ensure it works correctly and aligning it if necessary. Reactive improvement deals with a process that is not good enough or weak. Proactive improvement is about sensing a problem, exploring the situation, formulating the problem and then reactively improving the process. In other words, the WV model travels back and forth from the level of thought to the level of experience. It goes between:[100]

- Exploring the situation;
- Formulating the problem;
- Collecting and analyzing the data;
- Analyzing the causes;
- Implementing the solution; and
- Evaluating the effects.

The WV model is also known as the Plan-Do-Study-Act (PDSA) cycle, which appeared previously in Figure 1. It is an iterative problem-solving principle in which improvements are made step-by-step and the cycle is repeated many times.

The point of the WV model is to focus on the vital issues that can dramatically affect a business. If necessary, focusing on a few issues and using a Pareto chart maximizes the impact of the change since the use of a firm's limited resources is funneled to the appropriate paces. This notion is consistent with economic theory, where scarcity is the order of the day. In other words, a firm's perennial economic problem is employing limited resources to satisfy unlimited wants and desires. According to Shiba et al., an organization should work on only those critical improvements to a company's future and produce the most significant payback.[101] In other words, those activities that improve customer satisfaction are the ones that demand the most attention.

Continuous Improvement Conclusion

Any process possesses variation, some of which are acceptable and some of which are not. Historically, it has been controlled by inspection, but this is a poor mechanism to control variation since it comes into effect after the fact. The whole point of CIM and continuous improvement is to control variation at the process level and at the points where the product is being made. Thus, the critical issue in continuous improvement is to reduce variation by removing the sources of the variation.[102] If the source of the variation does not exist, then the variation cannot occur. It is that simple.

CONCLUSION

This paper sought to examine the basics of total quality management, just-in-time, computer-integrated manufacturing, and continuous improvement. The idea was to define each one of these four topics, and then briefly outline their characteristics, thereby giving a student a fundamental understanding of what each topic involves. For TQM, its principles were discussed, followed by a short description of Deming's 14 points, and then talk about its issues. In the second topic, just-in-time systems were described and defined. The elements of JIT were highlighted, where anything from flexible resources to supplier networks were outlined. The advantages and disadvantages of JIT were then reviewed. Computer-integrated manufacturing was briefly highlighted. Here, CIM was defined and its basic functions were assessed. Finally, continuous improvement and its basic principles were examined. Shiba's WV Model was discussed, along with the purpose of continuous improvement.

It is critical to encapsulate these four areas of study with the idea of showing how they are interrelated to each other. By appreciating their interconnections, one can come to realize their cohesive value. The hope is that a student will gain a better awareness of their integral importance, thereby being better able to go forward and apply these subject areas in their professional lives.

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[100] *Id.*
[101] *Id.*
[102] *Id.*

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