Total Quality Management Journal, Vol. 9, No. 6, Dezembro, 1998.

QUALITY CONTROL METHODS: TOWARDS MODERN APPROACHES THROUGH WELL ESTABLISHED PRINCIPLES

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Abstract: *Zero Defect Quality Control (ZDQC) is a result of the interaction of source inspection, "poka-yoke" devices applied as 100% inspection, and immediate corrective action after detecting abnormalities in processing. The aim of ZDQC is to ensure that a manufacturing system is able to produce defect-free products consistently through identification and control of the causes (errors) of defects. ZDQC has source inspection as its most important component. The identification and control of causes which generate defects are the main points of this inspection method. The effective utilization of source inspection depends on the acknowledgment of the existence of a cause-and-effect relationship between errors and defects, identification of incidental errors, and implementation of suitable techniques to counteract them.*
The improvement of the inspection process is often mistaken for the improvement of quality control and assurance. Therefore one might think sampling inspection is always preferable over 100% inspection. However, 100% inspection performed under ZDQC environment has proved to be superior to the sampling inspection for achieving the goal of zero-defect.

Key words: quality control; inspection; "poka-yoke" device; Toyota Production System; zero-defect

1. Introduction

It is incredible how much discussion there is about Just-In-Time, "kanban", lean production, "andon", "jidoka", and other Japanese management techniques when improvement of productivity and competitive capacity are required. It is strange that Zero Defect Quality Control (ZDQC) does not attract equivalent attention, since it is undoubtedly an important support to the superior performance of Japanese companies like Toyota Motor Corporation and Matsushita Electric Company.

There are likely two reasons which might justify this lack of interest:

1. The simplicity of ZDQC may not convince the western companies of its effectiveness as a process-control tool. Since some companies use statistics and other tools with some success, the existence of a simpler, more accurate technique seems ludicrous.

2.The name Zero Defect Quality Control brings to mind the Zero Defect Programswhich were popular in the 60s. These programs used mainly motivational appeals to attain zero-defects while the real causes of defects were not eliminated.

Regardless of what it is called, the ZDQC performed by some Japanese companies has three common components:

1. source inspection;
2. poka-yoke (100% inspection);
3. feed back and immediate action;

This tri-partite system should be emphasized rather than the name given to the process. It is this same sinergistic combination that enables the Toyota Motor Corporation to have the lowest defect rate among automobile manufacturers.

2. Zero Defect Quality Control (ZDQC)

“For reducing defects within production activities, the most fundamental concept is to recognize that defects are generated by work and all inspections can do is to discover those defects. Zero defects can never be achieved if this concept is forgotten. The idea it expresses, moreover, is the cornerstone which the Zero Quality Control system is built on.”[1]

The expression “zero defects” was not coined by Japanese. It originated in America in 1962 as an improvement program of Martin Company (now Martin-Marietta Corporation). This company manufactured Pershing missiles for the United States army and was requested by the government to reduce delivery time.[2]

Martin Company’s executives realized that the request would be accomplished only if ordinary errors and defects could be eliminated from all manufacturing stages. In other words, “zero defect” would be demanded as a performance standard for all production activities. Everyone should make constant effort “to do right the first time”. This slogan was popularized by Philip Crosby, an executive of the Martin Company in the 60’s.[3]

Since the Martin Company successfully employed a zero-defect program, the U.S. Army, enthusiastic about the results (drastic reduction of defects and delivery time), has undertaken to popularize and promote it among other suppliers.

Juran and Gryna have analyzed the contents and results of the programs first adopted by companies engaged in Zero Defect Quality Control. Those programs consisted of the following:[4]

1. A motivational “package” which encouraged workers to decrease defects. Tools such as performance board, bulletin board, and motivational meetings were employed within this

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[1] Shingo, Shigeo, 1986, p. 39.

[2] Ishikawa, Kaoru, 1985; Garvin, David, 1988; Hernandez, Arnaldo, 1993; Juran, Joseph M. & Gryna Jr., F., 1978; Schonberger, Richard J., 1982; Ohno, Taiichi & Mito, Setsuo, 1988.

[3] Garvin, David, 1988.

[4] Juran, Joseph M. & Gryna Jr, F., 1978.

package.

2. A preventive package which helped to reduce defects caused by management. This package focused on employee suggestions which were then analyzed by managers.

However, the race towards ZDQC resulted in disappointment for several companies. Many of those companies falsely assumed that having a zero-defect program would automatically guarantee defect-free products.[5] Too much confidence was placed on the assumption that employees would manufacture error-free products because of motivational techniques.[6]

Schonberger pointed out that the only changes in the organizations were the appointment of ZD program's coordination and committee; regarding the techniques the only change consisted of a different approach to eliminate the causes of defects.[7] Ishikawa has also emphasized that zero-defect programs have become a willingness movement without any scientific method.[8]

In fact it is clearly understood that zero-defect programs rely exclusively on philosophy, motivation, and conscientiousness, thereby relegating problem-solving technical approaches to a secondary position.[9]

At Toyota Motor Corporation the expression "Zero Defects" has a very different meaning from that of Westerners. Zero Defects Quality Control (ZDQC) is not a program but a rational and scientific method which is able to eliminate defects through identification and control of causes. Unlike western programs, Toyota's ZDQC emphasizes operational tools. The method is based on a scientific approach (5 W1H, 5W's, ...[10]) to identify the causes of defects, the application of devices to detect abnormalities in the operations and immediate corrective action.

There are four fundamental points which support ZDQC as follows:[11]

1. Utilization of source inspection. This inspection method is preventive in nature and therefore is capable of eliminating defects since the control function is applied at the source not on the results;
2. Utilization of 100% inspection contrary to sampling inspection;
3. Reduction of time between abnormality detection and application of corrective action;
4. Acknowledgment that workers are not infallible. Utilization of mistake-proof devices ("poka-yoke") performing the control function together with the execution.

Figure 1 indicates the importance of defect detection at the source for cost reduction. At Toyota, error detection and prevention are goals, the ultimate goal being the reduction of unnecessary costs created by defective products.

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[5] Hernandez, Arnaldo, 1993.

[6] Juran, Joseph M. & Gryna Jr., F., 1978.

[7] Schonberger, Richard J., 1982, p. 44.

[8] Ishikawa, Kaoru, 1985, p. 158-9.

[9] Garvin, David, 1988; Oakland, John, 1990.

[10] 5 W's: Ask "Why" systematically until finding out the fundamental causes of the problems.
5W1H: "Why", "Where", "Who", "When", "What" and "How?"

[11] Shingo, Shigeo, 1986.

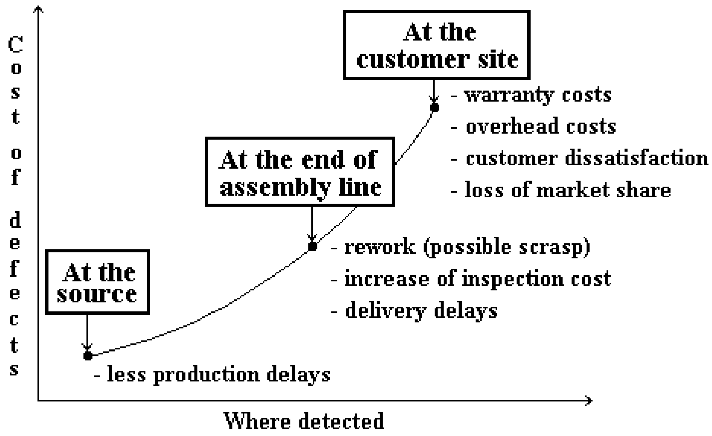


FIGURE 1 - COSTS OF DEFECTS
SOURCE: Lynch, 1989

Schonberger and his colleagues consider the attainment of zero-defects as intangible. From their viewpoint, zero-defect is valid only as a motivational tool but not as a real aim. Perhaps this conclusion resulted from observations of western companies where zero-defect has not yet been realized. In fact in some instances, disasters have occurred.

Shingo, on the other hand, believes that is feasible to attain zero-defect, not as a result of some miraculous program but as an outcome of a scientific approach which involves as a continuous improvement process striving for the elimination of all sort of wastes.

The goal of ZDQC is not only production of defect-free products but actually ensuring that a system will manufacture defect-free products *continuously*. This concept is applied to all processes and operations in such a way that each is designed with every possibility of failure considered and counter-balanced. This preventive approach avoids execution under abnormal conditions (errors) which would produce defects.

Manufacturing a complex product like a car that is absolutely free of any defects is a difficult task. However, when ZDQC is carried out in all stages of production cycle (all processes and operations[12]), it is reasonable to expect a considerably better end product. As a matter of fact, the assembly defect rate[13] of Toyota (Takaoka plant) compared to G.M.'s rate (Framingham plant) shows that Toyota has a rate that is three time better than that of G.M. Since continuous improvement is an essential component of ZDQC, it is reasonable to assume that this difference falls in Toyota's favor.

[12] One production might be represented as a net of process and operations which intersect each other in orthogonal flows. Process is a flow of materials or products from one worker to another on the different stages where one may observe its gradual changing into finished products. Operation, in its turn may be observed by focusing one (or a combination) of the agents of production (worker, machine, devices, etc.). In that case, the interest is on activities performed by agents. (Ghinato, 1994, pp. 71-7).

[13] According to Womack et al. (1990, pp. 71,73), in 1986, the accumulated average sum of defects detected by inspection of 100 cars after assembly was 45 for Toyota Takaoka and 130 for G.M. Framingham. In 1987, that index was kept the same at Toyota and rose up to 135 at G.M.

Shingo relates an account of a successful example of ZDQC application in the washing machine division of Matsushita Electric at Shizuoka. In this example, the assembly line of a drainpipe subset which produced 30,000 units monthly had reached a record mark of one month without any defects. Shingo verified that this perfect performance resulted from the utilization of source inspection, self-inspection, successive inspection, and “poka-yoke” devices. This perfect record was kept for another 6 months, clear evidence that the zero defects goal is entirely possible.[14]

2. The Inspection Operation

“Inspection is a process of measuring, examining, testing,... or any other comparison between unit [of product] and proper requirements.”[15]

According to Garvin, inspection has become an informal activity performed together with execution in order to ensure high quality products.[16] Mass production, interchangeability of parts, and the increasing complexity of production cycles as well as products have set inspection apart from execution activities.[17] In addition, the principles of scientific management formulated by Taylor have set inspection as an external responsibility from the execution function.[18] In the Western, the Christian belief that Man is nately evil because of original sin has strongly influenced the separation of inspection from execution, suggesting that people are not trustworthy.[19]

Thus, it is possible to realize why inspection activities were assigned to people (inspectors) who are independent from the execution, and who are empowered to check, assess, interrupt, and even punish.

According to Ishikawa, Japanese managers place much more confidence in workers than their American peers. The number of quality control inspectors in some American manufacturers reaches 15% of the total workers compared to the less than 1% in Japanese factories with Total Quality Control.[20]

Although there has been significant improvements in production factors, control methods and even on the quality of goods, inspection operation is still performing a fundamental role in the production mechanism.

The quality of products has evolved as a result of the change of focus on quality assurance.[21] At first it was believed that quality could be assured through rigorous inspections. About World War II, at the time of the advent of the

[14] Shingo, Shigeo, 1986.
[15] American Society for Quality Control -ASQC, 1983, p. 3.
[16] Garvin, David, 1988, pp. 3-6.
[17] Garvin, David, 1988, pp. 4-5.
[18] Taylor, Frederick Winslow, 1985.
[19] Ishikawa, Kaoru, 1985, p. 32.
[20] Ishikawa, Kaoru, 1985, p. 32.
[21] Ishikawa, Kaoru, 1985, pp. 78-83.

Statistical Process Control (SPC), it was realized (the Japanese were the first to conclude this) that the quality of products could be guaranteed through the control of manufacturing processes. Recently - but as early as the end of the 1950's for some Japanese companies - the focus of control changed from process to design phase. According to this approach, high-quality products result from the output of every stage; from market research through planning, to selling and market services. Therefore, all these activities have to be planned and specified from the start, with the goal of zero defects in mind.

Nevertheless, if the focus is kept on the product design stage, it does not mean the process control and inspection are negleted.[22] A company which seeks quality assurance from the product design stage needs to maintain its processes under control. It is also necessary to keep 100% inspection on processes which are still producing defective products.

Despite rigorous efforts devoted towards product design, there will still exist possibilities for failures of execution stages which might result in damage to the object (product), to the agents of production (workers, machines, facilities, etc.), to the schedule (time, quantities, etc.), or even to the external customer and/or environment, the latter being the worst-case scenario.

Besides well-performed design complete elimination of defects requires working on the execution phase in order to avoid processing under abnormal conditions. "Defects create the need of inspection."[23] On the other hand, although it is "non-value-added activity", inspection is an effective tool for the continuous improvement and elimination of defects, once its "feedback" attribute is properly used.

At Toyota Motor Corporation, the worker who executes the processing is also in charge of inspection not so much due to the influence of Confucian principles,[24] but especially because of a decisive and planned step towards the "complete elimination of wastes". The next step is the elimination of inspection operation itself. Thus workers can afford the time to perform necessary and value-added operations.

From the viewpoint of production function mechanism,[25] inspection is an activity which supplements processing, transportation, and waiting. This is easily understood since the aim of inspection is to reveal and prevent defects along the progress of work (processing), transportation, and waiting, ensuring an smooth flow of production.[26] Although inspection might be recognized as secondary to the transportation and waiting processes, it is primarily connected with processing.

While from the viewpoint of operation it is important to perform inspection under maximum efficiency, from the viewpoint of process an effective inspection is nothing but a well-performed waste. Processes always take precedence over operations, especially when introducing improvements. First of all, it is absolutely essential to question why inspection has been performed and

[22] Ishikawa, Kaoru, 1985, p.83.

[23] Ishikawa, Kaoru, 1985, p. 32.

[24] See Morishima, Michio. *Why Has Japan Succeeded? Western Technology and the Japanese Ethos*. 1982.

[25] From viewpoint of production function mechanism, processes may be classified in processing, inspection, transportation, and waiting (between processes and for lots formation) (Shingo, 1981, pp. 7-8).

[26] Shingo, Shigeo, 1986, p. 18.

try to eliminate or reduce it before improving the inspection operation. Therefore, the best way to improve the inspection operation is to use a processing method which eliminates the very necessity of inspection. This is what Shingo calls a process-oriented improvement approach.[27, 28]

3. Inspection operation and control function

According to Shingo, management process is comprised of three distinct functions: planning, control, and monitoring. Execution is not considered as a real managerial function. However, it is linked to control in such a way that this association brings about what is called "controlled execution". This conceptual approach to managerial functions is in fact practiced in reality, as control is performed through inspection function.

Inspection plays an important role in the production function mechanism since it keeps the control as a real managerial function. In other words, by allowing the control function to be performed concurrently with execution, inspection operation changes from its traditional goal of detecting defects to preventing and thus eliminating them completely.

4. Objectives and methods of inspection

Since inspection is essentially a comparison between product/service and proper requirements, any deviation from these requirements might be considered an abnormality. Characterizing these abnormalities is important for clear identification of purposes and assignment of appropriate inspection methods.

Abnormalities detected by the inspection process might be considered errors or defects. A defect is "a deviation of one quality feature from its level or desired status which occurs with severity enough to lead a product or service far from requirements of use usually desired or reasonably predicted."[29] A defect, therefore is usually understood as an imperfection of an object of production (product/service). An error in turn might be defined as an imperfect execution of some activity which may lead to damage the object, the agents of production, or the planning.

There is a strong cause-and-effect relationship between errors and defects. Usually defects are the results of improper utilization of one or several agents of production. Therefore an error is a "potential defect". The overwhelming majority of errors and consequent defects in any manufacturing process are human

[27,] Shingo, Shigeo, 1988, p. 315.

[28] It is operationally what one might call "controlled execution", namely inspection operation is embodied by processing itself.

[29] *Glossary and Tables for Statistical Quality Control* - ASQC, 1983, p. 13.

generated mistakes.[30] Although human errors arise from different sources, it is possible to identify at least ten kinds of errors and classify them:

Kind of error	Characteristics	Example	Prevention
1. Forgetfulness	occurs when one is not concentrating	the stationmaster forgets to lower the crossing gate	alerting operator in advance or checking at regular intervals
2. Error due to misunderstanding	jump to the wrong conclusion before being familiar with the situation	a person not used to a car with automatic transmission steps on the brake, thinking it is the clutch	training, checking in advance, standardizing work procedures
3. Error in identification	misjudjement of a situation due to not clear observation	a $1bill is mistaken for a $10 bill	training, attentiveness, vigilance
4. Amateurism	lack of experience	a new worker doesn't know the operation	skill building, work standardization
5. Willful error	one ignores rules under certain circunstances	crossing a street against the red light because there are no cars in sight at moment	basic education and experience
6. Inadvertent error	one makes error because he/she is absentminded	someone crosses the street without noticing that the light is red	attentiveness, discipline, work standardization
7. Error due to slowness	slow down actions due to delays in judjements	a person learning to drive is slow to step on the brake	skill building, work standardization
8. Error due to lack of standards	there are no suitable instructions	measurement executed according to an individual worker's discretion	work standardization and work instruction
9. Surprise error	equipment runs differently than expected	machine malfunctions without warning	total productive maintenance
10. Intentional error	one makes mistake deliberately	crime and sabotage	fundamental education and discipline

FIGURE 2 - TYPES OF ERRORS
SOURCE: Adapted from Poka-yoke: Improving Quality by Preventing Defects, 1988

Inspection may be conducted according with the following purposes:

- Discovering defects;
- Reducing defects;
- Eliminating defects.

The objective of inspection is closely related to the nature of abnormality to be detected. Inspection for discovering defects is designed to identify defects resulting from abnormal processing. Inspection for eliminating defects in turn depends on detecting errors during processing and taking immediate corrective action in order to avoid such error-originated defects.

When inspection methods are designed to discover or reduce defects, it is usual to have defects classified according to severity of damage. Military Standard 105-D, for instance, classifies defects as ‘critical’, ‘major’, and ‘minor’.[31] The essence of this classification conveys the idea that some defects might be tolerable depending on the severity.

When inspection methods are to eliminate defects, it seems unnecessary to classify defects since they are not to be tolerated. However, a classification of errors is necessary in order to identify the type of defect and to propose a suitable

[30] *Poka-Yoke: Improving Quality by Preventing Defect*, 1988, p. 10.

[31] *Military Standard 105D*, 1963, p. 2.

counter solution.

According to Shingo, each inspection method has a different objective, namely (see figure 3):[32]

- Judgment inspection is used to discover defects;
- Informative inspection is used to reduce defects;
- Source inspection is used to eliminate defects.

4.1 Inspection to discover defects: Judgment inspection

Inspection operation is considered a waste from the viewpoint of process function. However, inspection almost always exists and is in fact necessary in most manufacturing processes. It is thus important to keep inspection operations to a minimum. A reevaluation of objectives should therefore be the primary consideration.

In fact, changing the objective is essential when inspection is to detect defective units after processing. Inspection is conducted in such a way that the products are judged as either ‘defective’ or ‘non-defective’, with the latter not being sent to subsequent processes or even to the customers.

Although this method might be effective for discarding defective products, it exerts a very limited impact upon wastes arising from producing defective goods.[33] Judgment inspection method is based solely on detecting defects in the products rather than detecting errors during processing. It concentrates on effects instead of causes.

One drawback of judgment inspection is the inefficiency of the feedback function; the execution of counter measures take a long time. It is common to have this method applied to batches (by 100% or sampling) soon after the processing. Therefore in case of detecting defects, information is transferred to the person in charge of processing when there is no chance to correct it anymore or when corrective action can no longer avoid large amount of defectives. This inspection method concentrates its efforts on detection of defects instead of errors, thus it may be compared with an autopsy and the issuing of a death certificate.[34] It is reasonable to state that judgment inspection should be substituted by a method capable of eliminating defects completely in order to implement Zero Defect Quality Control (ZDQC).

[32] Shingo, Shigeo, 1986, p. 57.

[33] Producing defective products is one of the seven great wastes proposed by Ohno and Shingo (Ghinato, 1994, pp. 57-71).

[34] Shingo, Shigeo, 1981, p. 18; idem, 1986, p. 57; idem, 1988, p. 315.

objetive of inspection	inspection method		inspection technique		feed back			focus of inspection	
			sampl-ing	100%	long	short	imme-diate	effect (defects)	causes (errors)
inspection to discover defects	judgement inspection		☆	☆	☆	—	—	☆	—
inspection to reduce defects	inform-ative inspection	statistical methods	☆	—	—	☆	—	☆	—
		successive inspection	—	☆	—	—	○	○	—
		self inspection	—	☆	—	—	☆	☆	—
inspection to eliminate defects	source inspection		—	★	—	—	★	—	★

Poka-Yoke

Zero Defect Quality Control (ZDQC)

FIGURE 3 - CHARACTERISTICS OF QUALITY CONTROL METHODS
SOURCE: Adapted from Shingo, 1986

4.2 Inspection to reduce defects: informative inspection

The second type of inspection process is informative inspection, so called because as soon as a defect occurs all relevant information is transmitted to the person in charge of that particular process and immediate corrective action is adopted. This inspection method suggests that continuous correction and improvement of processing lead to a gradual decrease of defect rate.[35]

Though informative inspection is superior to judgment inspection in its ability to reduce defects, it is important to recognize that it is still ineffective for implementing and functioning of zero defects. This is due to the fact that informative inspection is designed for detecting defects in products after processing is complete rather than during processing. However effective the inspection method is, at least one defect must occur before corrective action is started.

Shingo prefers presenting informative inspection methods divided in three classes:[36]

- Statistical Quality Control (SQC);
- Successive Inspection System (SuIS);
- Self-Inspection System (SIS).

[35] Shingo, Shigeo, 1986, pp. 58-9.
[36] Shingo, Shigeo, 1986, p. 59.

4.2.1 Statistical Quality Control (SQC)

Industrial applications of statistics began in United States about World War II, focusing on purchased materials and process quality control. In post-war Japan, it was promoted and popularized by Deming. In hopes of becoming a major competitor in the global market, Japan fully implemented the teachings of Deming, Shewart and Juran. Through its determination, Japan has arisen as an economic world leader.

The statistical methods have not only been used in Japan. Since World War II, it has been used as a process control tool all over the world. However, it has been wrongly employed as a means of monitoring instead of controlling. This characteristic, mainly observed in western approaches, makes a great difference on the process performance as the counteraction speed is sharply reduced.

Statistical process control (SPC) has satisfied the need of process predictability and provided opportunity for corrective action before sequential occurrence of defectives. The theory of probability and normal frequencies distribution, which properly represent the overwhelming majority of events that take place during the production of standardized goods, were taken as conceptual bases.

This approach assumes that there does exist a probability of occurrence of a certain level of defects resulted from random variation in the production factors which can not be controlled. It is common in the manufacturing industry to have process control limits of +/- 3 or +/- 4 standard deviations. Thus, an acceptable probability of defectives resulting from special causes not detected by control charts would be 0.27% and 0.0063% respectively.

These defect rates, as insignificant as they seem, negatively impact the market. For example, at Matsushita, the television division might manufacture a few defective sets in a week. Those defective sets in turn will create dissatisfied consumers. Even this handful of unhappy customers is intolerable according to Matsushita's policy.[37] Thus, process control methods based on statistics are not appropriate when the purpose is defect-free production. New methods with control devices which ensure error-free production must be developed.

Shingo's criticism of the applications of statistics is not focused on statistics itself but its implementation in the West as a monitoring tool while ignoring its planning potential. On the other hand, the criticism might be a bit harsh, as off-line-quality-control techniques as design of experiments (DOE) were used in planning stage by a restricted number of companies in the early 1980's.

Shingo uses the defective rate control chart **p** to criticize processes that are statistically controlled.[38] In this method, the process is controlled through monitoring the defective units percentage of each inspected sample. The worker in charge of the process does not take any corrective action unless the percentage of defective units is above a pre-determined limit, or if there is evidence of existence of any other special cause. This demonstrates that SPC may be used without

[37] Shingo, Shigeo, 1988.

[38] Shingo, Shigeo, 1986, pp. 62-3.

preoccupation with continuous improvement. Namely, the process itself is considered fair, and no change is promoted since the defective rate is within acceptable limits.

As Dr. Eisaburo Nishibori reconfirmed in 1955, "it is clear that it [control chart] serves essentially as nothing more than a mirror. Everything it does is to reflect present conditions."[39]

Shingo points out that the time it takes for a defect (randomly distributed in the population) to appear in one specific sample, plus the time elapsed between detecting abnormality and applying corrective action, is mainly responsible for delaying improvements of quality levels through utilization of statistical control methods.[40]

Theoretical and conceptual principles of statistical quality control have been exceedingly valued to the detriment of the ultimate objective that should be reduction of defects. Quality control has become an activity performed by "experts" on statistics, who are very often completely disconnected from shop-floor reality. Shingo suspects that that is one of the reasons why quality control in Japan was slow in identifying zero-defects as its real aim.[41]

4.2.2 Successive Inspection System (SuIS)

About 1960, Shingo suspected that there should be an inspection method that is more effective than statistical quality control. He concluded that sampling inspection should be replaced by 100% inspection, and that improvement of the feedback function would provide faster corrective action as well.[42] The best way to improve the system is for the worker performing the processing to execute 100% inspection. Thus, action would be immediately after detecting any abnormality. However, it is possible that a worker might neglect the quality standards and approve defective units. A logical choice seemed to be inspection by the worker of the following process. Since this inspection mode is spread through all processing stages, each worker inspects products received from previous processes before executing processing himself.

SuIS generically unfolds according to the following sequence:

1. Worker A finishes processing and transfers the product to worker B of the following stage;
2. Worker B inspects the product received from A, executes the processing and transfers it to worker C of the next stage;
3. This sequence of events is repeated until the last processing stage;
4. When any worker detects a defective unit he/she immediately returns it to the previous processing stage in

[39] Nishibori, Eisaburo quoted by Shingo, Shigeo, 1986, pp. 63-4.
[40] Shingo, Shigeo, 1986, p. 65.
[41] Shingo, Shigeo, 1986, p. 67.
[42] Shingo, Shigeo, pp. 67-8.

order to have corrective action taken as soon as possible.

It is preferable that the time between occurrence of defect and detection should be limited to seconds or minutes, so as to avoid large amounts of rework and material waste.[43]

SuIS has been developed based on the following principles:[44]

1. 100% inspection;
2. The person independent of the particular process is capable of performing more objective evaluation;
3. Immediate feedback and instantaneous corrective action;
4. Execution of inspection prior to the processing prevents it from generating defects.

SuIS is effective and cost-efficient due to the following features:[45]

1. Inspection performed by the following worker is automatic and free. It does not require additional and sophisticated resources for pre-processing inspection.
2. The rate of defects which occur due to the lack of attention of the first worker decreases vertiginously when 100% inspection is executed by worker of the following process.
3. Usually defects originated from previous processes interfere in positioning, assembling, and processing at subsequent stages, what ensures a compulsory and costless appraisal.
4. Inspection performed by people independent of the particular processing stage is more effective and reliable.

For best results Shingo recommends that the number of features to be assessed should be no more than two or three for each process.[46]

SuIS application requires immediate line stoppage should a worker detect any defect in the units of a previous process. As the worker begins to feel responsible for line stoppages, he/she becomes more mindful of the effect of his/her performance over the production flow. In addition, as line stoppage aims to eliminate root causes, likely defects are avoided, and thus the time-consuming stoppage itself is compensated for.

4.2.3 Self-Inspection System (SIS)

[43] Harmon, Roy L., 1992, p. 273.
[44] Shingo, Shigeo, 1986, p. 76.
[45] Harmon, Roy L., 1992, p. 272.
[46] Shingo, Shigeo, 1986, p. 71.

The third and most effective informative inspection method is self-inspection system (SIS). Through this method, inspection is performed by the worker him/herself. The effectiveness of the system is due to instantaneous feedback; the detection of abnormality performed by worker is immediate, and corrective action is quickly applied. Moreover, people seem to prefer self-inspection to inspection performed by an independent agent. Also, corrective action tends to be better applied when workers observe, assess and resolve self-generated errors.

SIS is preferable to SuIS. The only limitation appears when it depends on the worker's sensibility. Subjectivity inherent to sensorial detection methods is a restrictive factor to SIS implementation. In this case, either higher and more reliable discrimination ability, or physically-measurable operational conditions should be adopted (this latter choice should always be pursued).

Physical detection permits the utilization of automatic inspection devices (poka-yoke) which then automatically stop the process when an abnormality is detected. In this case, 100% inspection is easily implemented, preventing the process from producing likely serial defects.

It is important to note that the implementation of informative inspection methods in general, and SuIS and SIS in particular, depends on an awareness of the internal customer-supplier relationship, inspection techniques, and standards.

4.3 Inspection to eliminate defects : source inspection

The third of Shingo's inspection methods is source inspection, and according to Shingo it is the most important component of zero defect quality control. Indeed, the importance of source inspection in the implementation of ZDQC is established by the following classification:[47]

source inspection 60%
100% inspection (poka-yoke) .... 30 %
immediate action 10%

It should be noted that the purposes of ZDQC and source inspection are the same: to prevent and eliminate any defects.

Essential to the method of source inspection is the identification and control of the causes of defects. Human errors, are quickly detected and corrected, and thus the conditions for occurrence of defects are eliminated.[48] Therefore, effective utilization of source inspection depends on acknowledging the existence of cause-and-effect relationship between errors and defects, the identification of errors, and the application of counteractive techniques.

The main differences between source inspection on the one hand and informative and judgment inspections on the other are better understood from the viewpoint of the control function.

[47] Shingo, Shigeo in *Poka_yoke: Improving Quality by Preventing Defects*, 1988, p. x.
[48] Shingo, Shigeo, 1981, p. 25-6; idem, 1986, p. 82; idem, 1988, p. 317.

A control cycle (feedback loop) of judgment and informative inspection methods unfolds according to the following steps (see fig. 4):

- An error (cause) happens but it is not noticed;
- A defect (effect) consequently occurs and is then detected;
- Feedback is prompted;
- Corrective action is implemented.

In source inspection, the control function occurs as a smaller loop, focusing on cause rather than effect (see fig. 4):

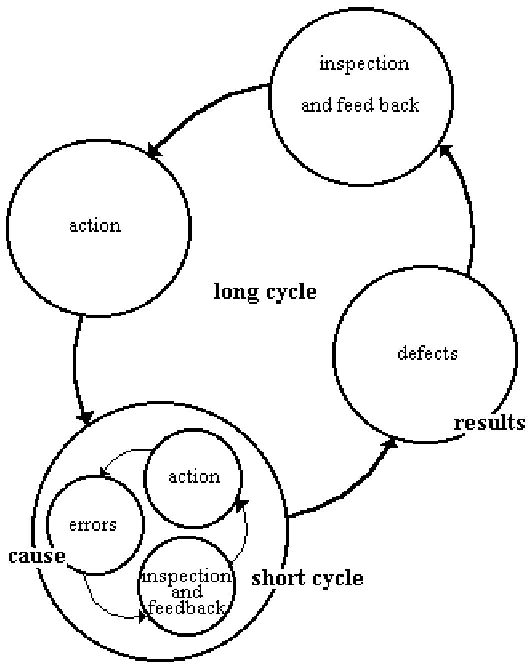
- Error (cause) takes place and it is detected;
- Feedback is promoted at the error stage;
- Proper corrective action is then implemented.

Therefore, putting the focus of control on the cause of abnormalities, the corrective actions are always directed to processing (agents) rather than to product (subject of production) as it occurs in long control cycles of judgment and informative inspections. This strategy makes it possible to accomplish zero defects.

Defects might have been caused by errors of previous processes. In this case, product quality is ensured by applying control to previous processes conditions. This method is known as vertical source inspection.

Inspection for the elimination of defects is also practiced by identifying the source (causes) of defects within the process itself, as well as detecting and correcting those errors.[49]

Shingo assents that it is necessary to evaluate the impact of previous processes, especially when those processes significantly influence later ones. This is compatible with the principles of process function.[50]



[49] Shingo, Shigeo, 1981 p. 26; idem, 1986, pp. 85-6; idem, 1988, p. 317.
[50] Shingo, Shigeo, 1986, p. 86.

FIGURE 4 - CONTROL FUNCTION AND INSPECTION METHODS
SOURCE: Shingo, 1986; 1988

5. Improvement of inspection

Improvement of inspection is often misunderstood as the improvement of quality assurance and control. Derived from the increasing application of statistical techniques as control tools, inspection methods were improved to be more effective, reliable, and above all cheaper.

100% inspection performed by either operator or inspector was known to be very expensive, tedious, time consuming, and inefficient. Sample plans supported by statistics was expected to take over the 100% inspection, with more efficiency, less time consumption, and especially more resources savings.

Undoubtedly, sampling inspection has achieved important status as a control technique, bringing some valuable advantages. However, it is necessary to understand that the contribution of statistics theory, particularly applied to the development of sampling plans, only makes sense when inspection is to discover or reduce defects. In other words, statistical sampling is an essential component for judgment and informative inspections, but it is not suitable for source inspection which aims to eliminate defects completely.

When the purpose is to eliminate defects, statistical sampling is not suitable since it is not 100% reliable in detecting defects. This method assumes that defects are randomly distributed in the population, and could be adequately represented by a sample. However, there exists some risk that some defects might go undetected by sample inspection.

A better choice would be an inspection method which would ensure the 100% detection of abnormalities. 100% inspection would be an apt candidate if its disadvantages were eliminated. The introduction of automatic-detection mechanisms (poka-yoke), which perfectly adapt to manufacturing processes, made possible the elimination of those disadvantages. Thus, the 100% inspection process was salvaged.

Shingo asserts that sampling inspection is an improvement of the inspection operation, but not of quality control itself.[51] From the viewpoint of process function, greater improvement of inspection is its own elimination, which is often attained by merging inspection and processing.

ZDQC is undoubtedly superior to sampling inspection when complete elimination of defects is warranted.

6. Conclusions

[51] Shingo, Shigeo, 1981, p. 22; idem, 1986, p. 93; idem, 1988, p. 317.

Zero Defect Quality Control performed by Toyota is very different in nature than the movement by the same name utilized by several western companies.

Under the scope of ZDQC, the inspection operation assumes a new and enlarged dimension, from a mere defect-detection mechanism of end products to a preventive tool which detects abnormalities (errors) during the manufacturing process. The key for attaining zero defects lies in that very differentiation. Moreover, it is essential to reformulate the utilization of statistics since poka-yoke systems conjugated with source inspection can be applied advantageously as control instruments on manufacturing processes. However, it is not intended to deny the usefulness of statistics as an auxiliary tool for process controlling. In fact, few other utilized alternatives exist that consist in combining poka-yoke systems and statistics, which appear as a promising and powerful instrument for performing process control.

It is also important to emphasize that ZDQC has recovered 100% inspection as a control method. In fact, the utilization of automatic detection mechanisms (poka-yoke) has integrated 100% inspection into the processing itself.

Poka-yoke systems and devices themselves will be the topic of a successive paper.

Acknowledgments

I would like to express my gratitude to Professor Dr. Katsuo Syoji from Department of Mechatronics and Precision Engineering of Tohoku University and Professor Dr. Susumu Fujii from Department of Systems Engineering of Kobe University. I would also like to thank the Ministry of Education, Science and Culture of Japan (Monbusho) for the financial support.

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