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Causal Relationship Model and Comprehensive Procedure for Quality Management As A Tool for Quality: Agile Strategy in Asian Network

Dr. Noriaki KANO
Professor
Tokyo University of Science
Tokyo, Japan 162-8601
Kano_n@ms.kagu.tus.ac.jp

SUMMARY

Activities for Quality Management can be categorized by current status quo maintaining, problem solving and task achieving and the standardized procedure for each of them are given as SDCA cycle, problem solving QC Story(PS-QCS), task achieving QC story(TA-QCS). PS-QCS is utilized for solving a problem of a current system while TA-QCS is done for breaking through current system as well as creating a new system. In this paper, first, discuss the causal relationship model as a basis for all the activities of quality management and the model behind those procedures and review the steps of each of the above three procedures, relate them with each other and then develop comprehensive procedure for quality management, namely, comprehensive quality management procedure(CQMP). In addition, study their historical development Moreover, propose whether DMAIC of Six Sigma is essentially equivalent with PS-QCS or not and request Six Sigma professionals to clarify how DMAIC was born.

1. Thee Activities of Quality Management

Quality Management in a standardized process consists of three activities for a quality characteristic as shown in Fig. 1 such as:

Maintenance: Activity to observe standards, prevent outliers and then maintain a quality characteristic within its control limits.

Problem Solving; An activity to identify factors causing the discrepancy between the present level and targeted level within the framework of an current system and to eliminate the discrepancy by removing such factors,

Task Achieving: a) An activity to achieve an aim by establishing a new system, or

b) An activity to achieve an aim by breaking through from the current conditions, not sticking to the framework of the current system

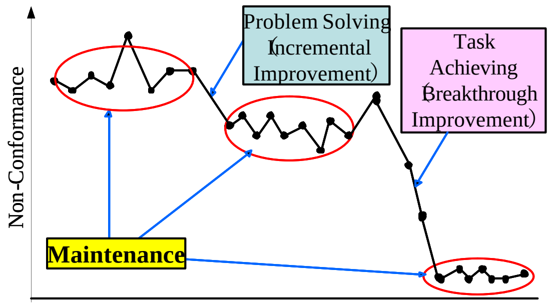

Fig. 1 Three Activities for Quality Management: Maintenance, Problem Solving and Task Achieving

2. Model Behind Quality Management

2.1 Causal Relationship Model and Process Standardization

On setting up the framework (mechanism) for producing a product, we can consider the factors for a quality characteristic. The relation between a quality characteristic and its factors is called as causal relationship. Let **"y"** denote a quality characteristic and let "$x_1,x_2,x_3,\dots,x_p,x_{p+1},\dots$" denote factors influencing the fluctuation of "**y**" where the number of the factors are infinite. And the relationship between the quality characteristic "**y**" and these variables "$x_1,x_2,x_3,\dots,x_p,x_{p+1},\dots$" can be expressed in the following equation.

$$y=f(x_1,x_2,x_3,\dots,x_p,x_{p+1},\dots) \qquad (2.1)$$

In this paper, the formula above is called as *causal relationship model*.

In order to produce a product within specification limits about a quality characteristic "**y**", first, we need to select, from among an infinite number of variables, a finite number of variables which are considered to give big impact on "**y**" which can be indicated as:

$$\mathbf{x_1,x_2,x_3,\ldots,x_p}.$$

Second, we try to control each factor "$\mathbf{x_i}$" at a specified value "$\mathbf{a_i}$".

For example, let "x_i" denote reaction temperature and let it be controlled at 70 degree C, where we cannot control it at 70.0000….degree but we can control it around 70 degree C with a certain tolerance, let's say, ±5 degree C.

In general, let "$\mathbf{A_i}$" denote a random variable "$\mathbf{x_i}$" which is controlled within a tolerance "$\pm ?_i$" with a standardized value "$\mathbf{a_i}$" at its center, that is,

$$\mathbf{A_i = a_i \pm ?_i} \quad \mathbf{(2.2)}$$

and control each factor "$\mathbf{x_i}$" as a random variable "$\mathbf{A_i}$". The set [$\mathbf{A_1,A_2,A_3,\ldots,A_p}$] is called a *process standard* of [$\mathbf{x_1,x_2,x_3,\ldots,x_p}$] and the conversion from [$\mathbf{x_1,x_2,x_3,\ldots,x_p}$] into [$\mathbf{A_1,A_2,A_3,\ldots,A_p}$] is called *process standardization*. Under the standardized process, the quality characteristic "**y**" is given as:

$$\mathbf{y=f(A_1,A_2,A_3,\ldots,A_p,x_{p+1},\ldots)} \quad \mathbf{(2.3)}$$

In a process where the process standard is observed, variables:

$$\mathbf{x_1,x_2,x_3,\ldots,x_p}$$

are considered to fluctuate in the neighborhood (tolerance) of each standardized value

$$\mathbf{a_1,a_2,a_3,\ldots,a_p}$$

and therefore, by applying Taylor expansion, quality characteristic "**y**" can be expressed approximately by the following equation of the first degree:

$$\mathbf{y=b_0(a_1,a_2,a_3,\ldots,a_p)+[b_1\,(A_1-a_1)+b_2(A_2-a_2)+\ldots+b_p\,(A_p-a_p)]+e(x_{p+1}\ldots)} \quad \mathbf{(2.4)}$$

Here, the first term is a constant determined by the standardized value of variables adopted in the standard, the second term is variation within tolerances of variables adopted in the standard, and the third term is variation by variables not adopted in the standard. However,

$$\mathbf{E[e(x_{p+1}\ldots)]=0}$$

holds true. (Otherwise, it can be incorporated into the first term.) . Moreover, applying Taylor expansion to $\mathbf{e(x_{p+1}\ldots)}$, it is expressed approximately as a linear combination of the variables $\mathbf{x_{p+1}\ldots}$. Suppose each variable is independent of each other, we can say that $\mathbf{e(x_{p+1}\ldots)}$ is approximately normally distributed owing to the central limit theorem. Therefore, the quality characteristic "**y**" is normally distributed with the mean of the first term of (2.4) and the variance due to:

- the dispersion of "$\mathbf{A_1,A_2,A_3,\ldots,A_p,x_{p+1},\ldots}$" which the tolerance "$\mathbf{\pm ?_1,\pm ?_2,\ldots,\pm ?_p}$" brings about
- the dispersion of variables not adopted in the standard such as "$\mathbf{x_{p+1}},\ldots$"

In the process where the process standard is observed, the range of "**y**" can be controlled within a certain range, which can be explained by so-called *three sigma rule*. This range is called as *process capability*.

2.2. Model for Maintenance

As described in 2.1, in a standardized process whose process capability for a quality characteristic satisfies the specification limits, the quality characteristic is distributed as shown in Fig. 2 in a case that the standard is observed. On the other hand, in another case that the standard is not observed,

for example, it is that $x_i = b_i \pm ?_i$ although it should be that $x_i = A_i = a_i \pm ?_i$,

this brings about outliers to the state where the standard is observed as shown in Fig. 3.

Applying the above, it is called as *maintenance* that standard is set up and implemented, confirm with control charts or the likes whether the standard is observed or not, and if any outlier is detected, it is investigated which parts of the standard is not observed and an action is taken to observe it.

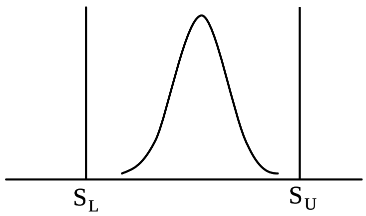

Fig. 2 Favorable Pattern

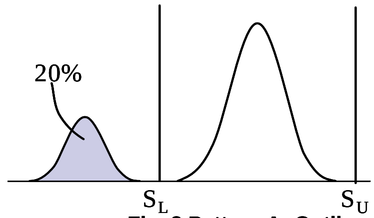

Fig. 3 Pattern A: Outlier Patterns of Non-Conformances

S_L: Lower Specification Limit

S_U: Lower Specification Limit

2.3 Model behind Problem Solving

In case that non-conformance to the product specification is happening despite observing the standard, we have two patterns such as biased as shown in Fig. 4 and lack of process capability as shown in Fig. 5. Under the constraint to maintain the current framework, or, mechanism, we enhance the quality characteristic by adding new standard and/ or revision of the standard. Namely, among the variables which are not adopted in the standard such as:

$$x_{p+1},\ldots,$$

some variables which are considered to give relatively big impact to the quality characteristic "y" are selected and standardized as shown in the formula (2.2). In addition, the current standard $A_i = a_i \pm ?_i$ is changed into $B_i = b_i \pm ?*_i$.

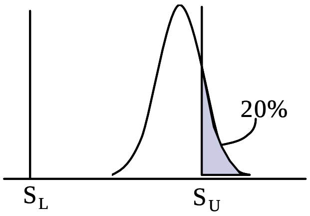

Fig. 4Pattern B: Bias

Since the expected value of "**y**" in the production process where the process standard is observed can be expressed as

$$E(y)=b_0(a_1,a_2,a_3,\ldots,a_p) \quad (2.5)$$

based on the formula (2.4) (additivty of expected value), it can be determined by standardized values of variables adopted in the standard:

$$a_1,a_2,a_3,\ldots,a_p$$

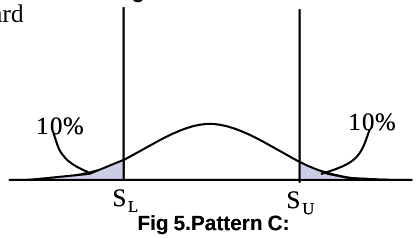

Fig 5.Pattern C:
Lack of Process Capability
Patterns of Non-Conformances

Since variation of quality characteristic "**y**" when "$x_1,x_2,x_3,\ldots,x_p$" can be deemed to be independent of each other can be expressed as

$$V(y)=b_1^2V(A_1-a_1)+b_2^2V(A_2-a_2)+\ldots+b_p^2V(A_p-a_p)+V\{e(x_{p+1},\ldots)\} \quad (2.6)$$

(additivity of variance), it can be understood that the variation is either one within the tolerance "$\pm ?_i$" of the standardized variables or by variables not adopted in the standard $x_{p+1},\ldots$ Therefore, where non-conformance is found to be happening even though the standard is observed, investigation is carried out from the three perspectives of:

(1) Whether it is the problem of setting standardized value "$a_1,a_2,a_3,\ldots,a_p$"
(2) Whether it is the problem of setting tolerance "$\pm ?_1,\pm ?_2,\ldots,\pm ?_p$", and
(3) Whether it is the problem of selecting standardized variables from the variables "$x_{p+1},\ldots$." not adopted in the standard.

Pattern A as shown in Fig.3 happens when the process standard is not observed, and therefore, if it is the case, the standard must not be changed. Patterns B as shown in Fig.4 and C as shown in Fig. 5 are non-conformance symptoms which occur where the standard is observed. As Pattern B is a problem of bias of the distribution center of "**y**", it requires an investigation along with the perspective of (1) above, while as pattern C is a problem due to lack of process capability, it should be done from the perspectives of (2) and (3).

The activity described in the above is called as *problem solving*.

2.4 Model behind Task Achieving

Task achieving intends to remarkably enhance the quality characteristic by replacing the current framework with new framework while problem solving intends to incrementally improve by selecting variables with a strong impact to the quality characteristic, and then revising their levels and tolerances. In addition, task achieving includes new system establishing.

If the causal relationship in an current framework is shown by

$$y=f(x_1,x_2,x_3,\ldots,x_p,\ldots)$$

then changing the framework by task achieving activity means that a different function is given for every alternative listed up as a new framework, and therefore, the following functions can be used to express different alternatives listed:

$$y=g(v_1,v_2,v_3,\ldots,v_q\ldots)$$
$$y=h(w_1,w_2,w_3,\ldots,w_r,\ldots) \quad (2.7)$$
$$\ldots$$

When one alternative out of these is selected, standardization for the alternative becomes necessary. For example, if

$$y=g(v_1,v_2,v_3,\ldots,v_q,\ldots) \quad (2.8)$$

is selected, pursuit of a success scenario would involve selecting

$$S_1,S_2,S_3,\ldots,S_q$$

for the standard values in the form of $S_i = s_i \pm ?_i$ for each of:

$$v_1,v_2,v_3,\ldots,v_q$$

It should be noted that if the framework is replaced, the form of function and its variables are changed. The activity described in the above is called as *task achieving*.

2.5 ProblemSolving vs Task Achieving

The following is interpreting the difference of problem solving and task achieving by an example of rice cooking with the taste of cooked rice as a quality characteristic.

In Tokyo, around 1950, we still cooked rice by burning wood. But, in the middle of 1950s, we started to use city gas and then around the middle of 1960s, the electric rice cooker appeared. Let's think about the improvement of the taste of cooked rice. Here, we have two ways of improvement: one is improving under the constraint of wood burning and another is improving without any constraints, namely, we can consider the use of city gas or electricity. In the former, we investigate such variables which consist of the function of wood burning as the item, thickness, length, and dryness of wood, the strength of flame with its timing chart, and wind blowing, etc. On the other hand, in the latter, first, we discuss which alternative we should select among wood, city gas or electricity and then investigate the process variables which consists of the function for a selected alternative. The former is an example of problem solving while the latter is an example of task achieving.

A big difference between problem-solving activity and task-achieving activity is that, while the former is an effort within the framework of current system and therefore, the scope of activity is limited, the latter is an effort to go beyond it, looking for a new framework.

3. Procedure for Quality Management

Work for achieving a given target is referred to as 'management' and work for achieving a given quality target is referred to as 'Quality Management'. The general procedure of this consists of four steps called the '*Management Cycle*', i.e.

Plan, Do, Check and Act.

It is also called the '*PDCA Cycle*' (Fig. 6).

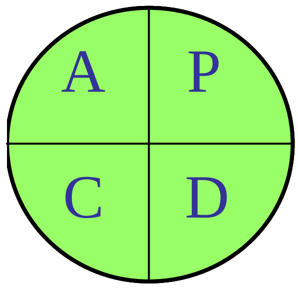

Fig. 6 PDCA Cycle

3.1 Procedure for Maintaining Current Status Quo (SDCA Cycle)

In every process of producing a product, people make efforts day and night to control the level of the various certain quality characteristics of the product by playing roles divided among its members based on its *current system* (system of how work is carried out). This is most basic activity called as *maintenance* described in Chapter 1 and 2.1. This activity is commonly conducted by operational organization and the procedure consists of

'Standardize (S)', 'Do (D)', 'Check (C)' and 'Act (A)'

by replacing 'Plan (P)' of PDCA cycle in Fig. 6 with 'Standardize (S)' and is repeated perpetually as

$S \Rightarrow D \Rightarrow C \Rightarrow A \Rightarrow S \Rightarrow D \Rightarrow C \Rightarrow A \Rightarrow$

Also referred to as *SDCA cycle* (Fig. 7), each of the four steps is as described below.

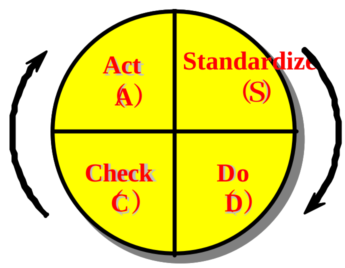

Fig. 7 SDCA Cycle for Maintenance

Step 1. Develop the standard for raw materials, equipment, operations and other elements required for producing products satisfying product specifications (S).

Step 2. Produce products by carrying out work according to the standard developed in Step (D).

Step 3. Inspect finished quality to check if they comply with the aims or product specifications, and divide them into those which conform to specifications and those which do not (C).

Step 4. Take necessary actions if non-conformances are found (A).

There are two types of actions taken in Step 4, i.e. immediate remedies (A1) and recurrence prevention measures (A2). Actions taken for non-conformances are immediate remedies, which can be broken down into the following types:

--- Rework , adjustment

--- Sell as sub-standard products (e.g. Second-grade products), and

--- Scrap

Actions taken after immediate remedies are recurrence prevention measures (A2), which involve analyzing non-conformance, followed by investigating and removing causes so that such non-conformance may be prevented from recurrence. Therefore, in Step 4, it is necessary to identify, before anything, if such non-conformance has

--- appeared because operation was not carried out according to the standard, or

--- appeared although operation was carried out according to the standard.

If it is the former case, we must clarify which part of the standard was not observed. If it is the latter one, the standard itself has some problem, and therefore, we must identify in which part of the standard the problem lies and correct it by revising the standard.

Repeating Steps 1 through 4 is referred to as rotating the SDCA cycle. Even if originally established standard is imperfect, rotating the SDCA cycle could refine the standard closer to its perfection, eventually changing the role of Step 3 (Inspection) from that of selection to one of conformances made conform to the product specification. This situation is expressed in a quality management axiom by Dr. Deming that goes:

"Build quality in the process; inspection alone cannot achieve high quality." Refer to Koyanagi (1950b)

Meanwhile, *preventing recurrence of problems is a typical example of those things that are 'easier said than done', for identifying causes is quite tough*. As taking an immediate remedy(A1) involves removing symptoms comprising non-conformance, it can be almost always executable. For preventing recurrence (A2) of the problem, however, needs to identify and eliminate the cause and finding the cause itself is often very hard to begin with. Time constraint adds to this difficulty. When many items of non-conformance are found in a day's production, engineers of the production workplace may end up in finding nothing after working over night trying to pursue the cause of the problem. In such a case, they cannot afford to give up production the next day just because they couldn't identify the cause, unless the non-conformance is of a critical nature. This means that, in reality, the following cycle is repeated instead of the SDCA cycle:

$$S \Rightarrow D \Rightarrow C \Rightarrow A1 \Rightarrow D \Rightarrow C \Rightarrow A1 \Rightarrow$$

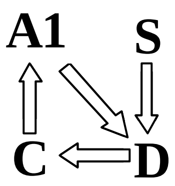

Fig. 8 S-(DCA1) Cycle

Let's call this cycle *S-(DCA1) cycle*. A problem which was found in the Check (C) step of the S-(DCA1) cycle but whose cause is yet to be identified is called a chronic problem. Repeating the S-(DCA1) cycle is nothing but assuring quality by inspection, and cannot realize the philosophy of 'building quality in the process'. Refer to Fig. 8.

Conversely, in case everything goes very well, nothing is found at Check and then no action is taken. Then the following cycle is repeated of the SDCA cycle:

$$S \Rightarrow (D \Rightarrow C) \Rightarrow (D \Rightarrow C) \Rightarrow$$

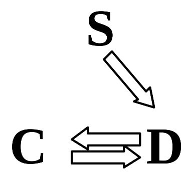

Fig. 9 S-(DC) Cycle

Let's call this cycle *S-(DC) cycle*. In this status, check is simplified and finally it will become something like just a repetition of Step Do(D) and then let's call this S-(D) cycle. Refer to Fig. 9.

3.2 Procedure for Problem-Solving

To break away from S-(DCA1) cycle and to rotate an SDCA cycle require taking comprehensive analysis of the data including all the cases of non-conformance. This activity is referred to as a problem-solving as described in Chapters 1 and 2.2. The following procedure is applied to eliminate non-conforming symptom(problems) :

First, grasp fully the symptom not conforming to the product specification. Next, examining the system, list up all the candidate factors of the cause of non-conforming symptom. Then, screen the factors through technical examination and boil down the remaining factors from statistical viewpoints to identify the very cause of the symptom. Subsequently, develop and implement a countermeasure to eliminate the cause. Make sure to confirm the effectiveness of the countermeasure taken, and if its effectiveness is proven, reflect it in the standard.

Thus, the cycle is

Non-conforming symptom ⇒ Factors ⇒ Cause
⇒Countermeasure ⇒ Effect ⇒ Standard

This entire cycle is organized into the procedure of Problem Solving QC Story (PS-QCS). The procedure consists of 7 steps indicated in below.

Step 1 Select a Theme
Step 2 Find Current Status Quo
Step 3 Analyze the current status quo
Step 4 Take a Countermeasures
Step 5 Confirm Effects
Step 6 Standardize into STANDARD
Step 7 Identify the Remaining Problems and Future Problem Solving Plan

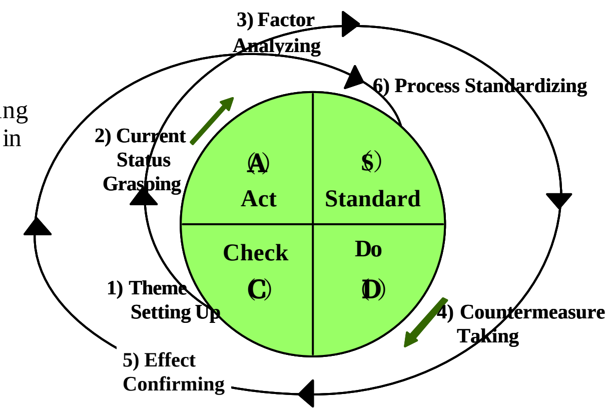

Fig. 10 SDCA Cycle and QC Story[Kano(1986)]

Refer to Fig. 10.

3.3 Procedure for Task-Achieving

When a company changes its management policy or introduces a new policy due to an evolving environment such as competitors' trend, it may be forced to widely change the current system even though SDCA cycle is smoothly turning. It is not possible to handle such cases by simply changing levels of variables composing the current system while maintaining the framework of the current system; we should change the framework partly by, for example, introducing a new mechanism into part of the system. Or else, we may even need to introduce an entirely new system. Such an activity is called a task-achieving activity described in Chapters 1 and 2.2. As this activity is commonly initiated and assigned by superior's policy, the term "task" is used.

Remark: Although an activity is initiated by Boss's direction or is set up by superior's policy, if the theme is to fill the gap of a current level from the aim for the current system, it should be handled by PS-QCS but not by TA-QCS.

Task-achieving activity may allow infinite number of alternatives, and if everybody concerned tries to go about it as he/she wishes, efforts made will be uncoordinated, failing to produce fruitful managerial results. Accordingly, it is customary that a task is either given by superiors or selected based on a superior's policy. What is necessary, then, in working out alternatives to achieve the selected task is to enumerate all the alternatives that are possible. Many worksites are found to jump on an alternative when they find a promising one, without comparing it with other conceivable alternatives. Such a 'love at first sight emotion' approach should be avoided and all possible alternatives should be taken into account. It is also necessary to evaluate enumerated alternatives and select the most valid one by establishing criteria from the viewpoint of appropriateness of alternatives against the task. The first basic rule of task-achieving activity is 'enumeration and evaluation of alternatives'. Refer to Fig. 11.

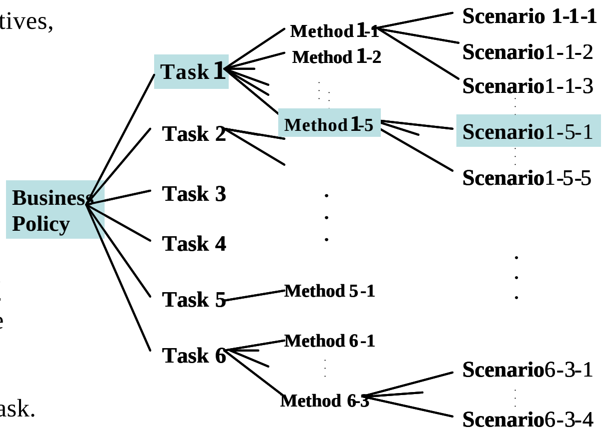

Fig. 11 Structure of Task Achieving QC Story

What should be remembered is that new frameworks and new systems are always accompanied by risks. It is, therefore, necessary to predict possible risks involved in selected measures and to devise measures to prevent such risks. 'Risk prediction and prevention' then is the second basic rule of task-achieving activity.

Since we are actually determining a broad framework when we select alternatives at this stage, we should clarify variables concerned with the framework and decide levels of each variable in order to materialize the framework. This is referred to as selection of a success scenario.

Remark: The same thing as explained above can also be explained by Fig. 11. It shows that the procedure aims at achieving an optimum scenario by listing and evaluating tasks, alternatives and scenario based on the management policy. The point here is to be aware that there are always multiple tasks, alternatives and scenarios to be considered.

After we implement this success scenario, we should make sure to confirm the effects, and when effects are confirmed, such measures should be incorporated into the SDCA cycle so that necessary actions are taken. This process is outlined in the following:

Policy ⇒ Task (Index, Goal) ⇒ Alternatives
⇒ Success scenario ⇒ Risks
⇒ Implementation ⇒ Effects

This process has been arranged into a procedure of TA-QCS (Task Achieving QC Story), which consists of the following 8 steps:

Step 1 Understanding management policy
Step 2 Setting a task
Step 3 Development and selection of alternatives
Step 4 Pursuit of a success scenario and Risks
Step 5 Implementation of the scenario
Step 6 Confirmation of effects

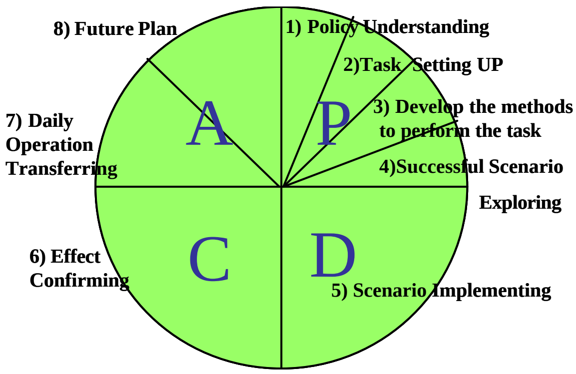

Fig. 12 Task Achieving QC Story and PDCA Cycle

Step 7 Transition to SDCA cycle
Step 8 Future direction
Procedure of TA-QC story can be considered as a more detailed procedure of PDCA cycle, and is shown in Fig. 12.

TA-QCS is commonly conducted by a project and this project dissolves at Step 7 in the above and transit the job to the routine work operation. If the activity of risk prediction and prevention at Step 3 or 4 has not been done well, the operation falls in S-(DCA1) cycle described in 3.1 and Problem Solving discussed in 3.2 will be immediately necessary.

3.4 Comprehensive Procedure for Quality Management

As discussed in 3.2 and 3.4, both of PS-QCS and TA-QCS are related with SDCA Cycle, respectively and it can be said that they are indirectly related with each other through of SDCA Cycle. Therefore, the three are consolidated into one Comprehensive Procedure for Quality Management or Comprehensive Quality Management Procedure (CQMP) as shown Fig. 13.

So far, problem solving, maintenance, and task achieving are considered as mutually independent activities. However, the application of this CQMP will help to unify these activities as one subset of the comprehensive procedure and will let quality managers and facilitator more easily and visibly plan and promote various quality management activities.

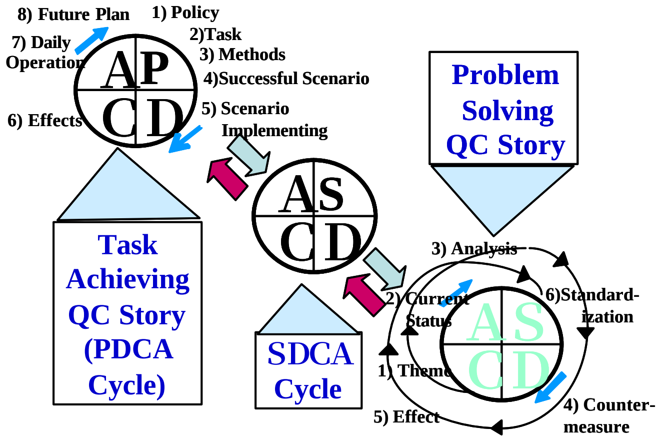

Fig. 13 Comprehensive Procedure for Quality Management

3.5 Points to be Noted in Application

1) While problem solving involves an analytical approach, task achieving approach is a design-type approach.
2) SDCA Cycle, PS-QCS, and TA-QCS in no way disapprove or replace 'inspirations of a genius'. If there is a genius from whom inspiration can be expected, there is no need for relying on these procedures.
3) 'TA-QCS' does not replace 'PS-QCS' which has been in wide use either. It is apparent that 'PS-QCS' will continue to play an important role.

4. Historical Development of PDCA cycle, PS QC Story, and TA QC Story

4.1 PDCA Cycle

a. The 8 Sectors of the Wheel of Quality Control shown in Fig. 14 is described edited by Koyanagi(1950) based on the shorthand note of the lecture of Quality Control Seminar conducted by Dr. W. A. Deming in Tokyo, July, 1950. The first 3 sectors discuss Quality Consciousness, Quality Responsibility and infrastructural requirements of development and production and study of various elements such as raw materials, machines workers and their attributes while the following five sectors discuss the phases such as development and design, manufacturing, testing, redesign, and sales.

Remark: The edition of Koyanagi (1950) was not looked over by Dr. Deming.

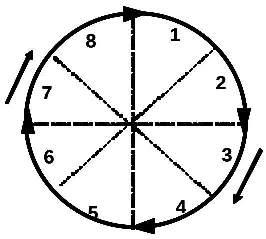

Fig. 14 W. A. Deming's 8 Sectors of the Wheel(1950)

b. The revised version of Deming(1952) rewritten by Dr. Deming proposes a cycle of four phases such as Design, Make and test, Sales, and Market Research in similar figure with Fig. 15.

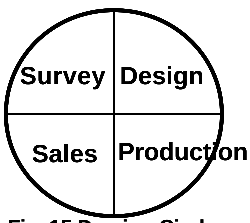

Fig. 15 Deming Circle As Cycle of Phases Ishikawa(1952)

c. Prof. Shigeru Mizuno, one of the Pioneers of quality control in Japan, referred to Deming(1952) described in the above b. and insisted at the JUSE Quality Control Basic Course which held 6 days every month for totally six months that we should apply Quality Control to 4 phases such as Design, Manufacture, Sales and Consumer Survey under the name of Deming Circle. Refer to Mizuno(1952a).

d. Prof. Kaoru Ishikawa introduced the similar ideas with Prof. Mizuno with Fig. 15. Refer to Ishikawa (1952).

e. Dr. J. M. Juran who visited Japan in July, 1954 left the lecture note based on shorthand note in Japanese. Refer to Juran(1955a) where we can find :

<u>*Definition of "control":*</u>

Control = Totality of all means by which we establish and achieve a standard

In addition, Juran (1955b) describes the procedure of control as follows:

As basic means to administer all , we have three stages such as planning, doing, and seeing. They are practically considered also as planning , operating, and controlling.

f. Shigeru Mizuno(1952b) continued to try to develop the steps to generalize the usage of Deming Circle in the above c for any types of management. This was written as his lecture note of JUSE QC Basic Course. Then, referring to the idea of Dr. Juran's lecture described in the above, he describes in Mizuno (1959):

Kanri("management" or "control" in Japanese) can be interpreted as a circle of Fig. 16.

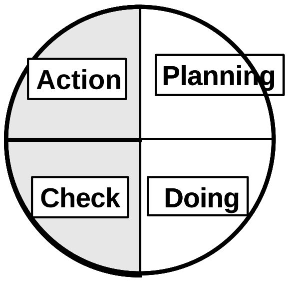

Fig 16 Circle of *Kanri* (Management) Mizuno(1959) The shaded part corresponds to "controlling."

Then, he described that;

Kanri means "Management" in English and the shaded part of the left half corresponds to "control" in English.

g. Kaoru Ishikawa (1954b) interprets that *Kanri* means 7 steps such as:

1. Objective, 2. Methods, 3. Education and Training, 4. Execution ,
5. Check , 6. Action, 7. Recheck of Action

from the practical viewpoint of quality control. Then, Ishikawa (1964) summed up 1and 2 as well as 3 and 4 and then the steps of 1 through 6 can be explained by plan, do, check, and action in English and this is influenced by plan-do-see of Scientific Management. This is the first time, PDCA was referred to in English.

h. In the reply to the inquiry by N. Kano about the origin of PDCA cycle in 1970s, Dr. Deming answered the 8 sectors were an expansion of a cycle of Specification, Production, and Inspection written in Shewhart (1939) and later Dr. Deming reduced to 4 steps for simplification.

i. To sum up, Dr. Deming's 8 sectors of the Wheel generated two streams: One is so-called Deming Circle which means the cycle of phases fromR&D through Marketing and Servicing and their resultsare fed back to R&D. We can learn from this themacroscopic principle of quality control including that

(1) we should control the quality at each phase but not only at the final stage.
(2) the lessons learned from the market about a product should be fed back to another coming new product.

This stream was developed by Ishikawa and intended to provide a procedure for Quality Management On the other hand, another is so-called PDCA cycle that provides both macro- and micro-scopic principles and general procedure helpful for any kind of management, not only for quality but also for cost, delivery, safety etc. This stream was developed by abstracting the basic ideas behind Fig. 16 by Prof. Mizuno. Refer to Fig 17..

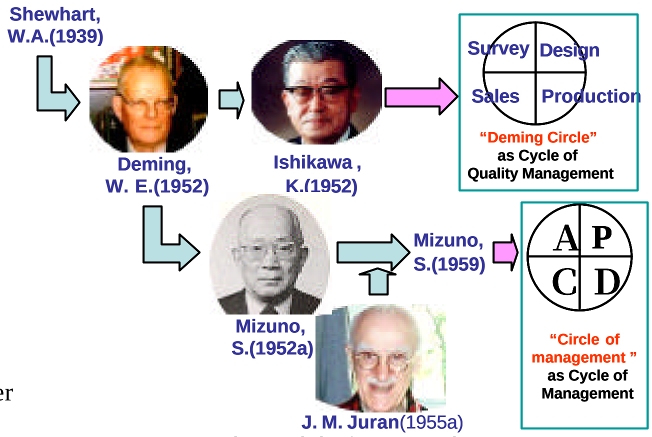

Fig. 17 Birth of PDCA Cycle

Remark: This section is reorganzized based on Kano(1993) supplemented other literatures referred to in the below.

4.2 Problem Solving QC Story

a. Dr. Juran(1955c) brought about various practical quality improvement cases which were solved with the combination of various simple techniques such as Pareto Diagram, histogram, various simple graphs, control chart, scatter diagram with principles how to improve quality. In addition, Dr. Juran (1955c)provided the procedure for quality control such as:

1. Economic Analysis, 2. diagnosis, 3. remedy, 4. maintenance, and 5. operate new quality planning.

which could be considered to become the base to develop today's problem solving procedure.

b. Komatsu Manufacturing Company Awazu Plant(1964) presented a standardized procedure for improvement under the name of "QC Story" with a copy of "How to improve with simple QC techniques" for QC circles. It is as follows:

1. Find a problem
2. Find factors for the problem
3. Investigate which factors most influence on the problem
4. Prepare countermeasure
5. Implement the countermeasure
6. Examine the effects
7. Conduct a Permanent Fix

c. Prof. Tatuo Ikezawa (1970) reorganizes and renames the steps provided by Komatsu so as to make it more appropriate as the procedure for managers and marketing shown in Fig. 18.

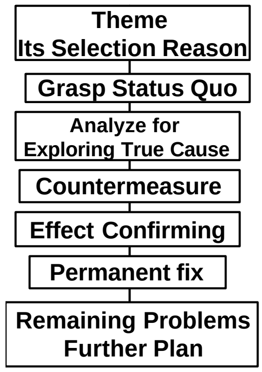

Fig. 18 QC Approach for Improvement Ikezawa(1970)

d. QC circle headquarters (1971) brushes up the procedure presented b. and c. in the above with name of Steps for Improvement

e. H. Kume(1985) introduces QC story in English. In addition, N. Kano(1986) transferred this technology to Florida Power & Light . FPL introduced various TQM techniques and methods in 1980s which developed in Japan and promoted quality improvement program very intensively and extensively. QC story was one of them and was applied with the name of QI Story. FPL was awarded Deming Application Prize in 1989 as first overseas recipient. After Deming challenge, many quality specialists of FPL moved to various corporations in U.S. and transferred what they learned in FPL. QI story was one of them.

h. To sum up the above, the stream of birth and development of PS-QCS can be illustrated in Fig. 19.

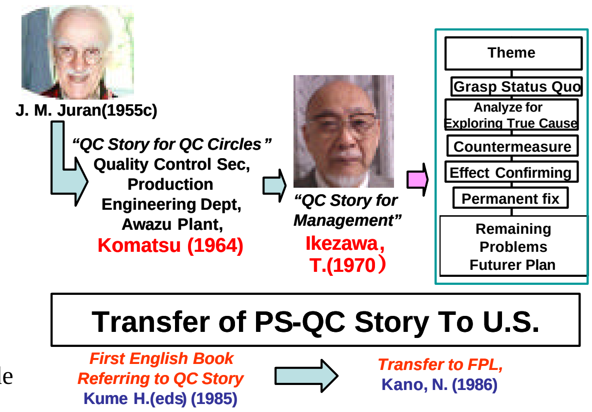

Fig. 19 Birth of PS-QC Story

4.3 Task Achieving QC Story

a. In the latter half of 1980s, very drastic Japanese Yen Appreciation attacked Japanese companies. This appreciation made QC activities focused on problem solving meaningless. Many companies shifted the activities from problem solving for the Current system to breakthrough of the current system and creation of the new system . This trend also attacked QC circles activities. They have never done such activities and then the voice to request to develop the new procedure fit for breakthrough and creation was became louder. Then, we organized a research grou to develop such a procedure. This output was named as Task achieving QC Story and then we published plural books relating with this method such as Kano et. al.(1993b), Kano et. al. (1994),, Kano et. al. (1995a) and Kano et. al.(1993b) for QC Circles.

b. Later, we were also requested to develop similar method for management and then we published Kano et. al.(1997).

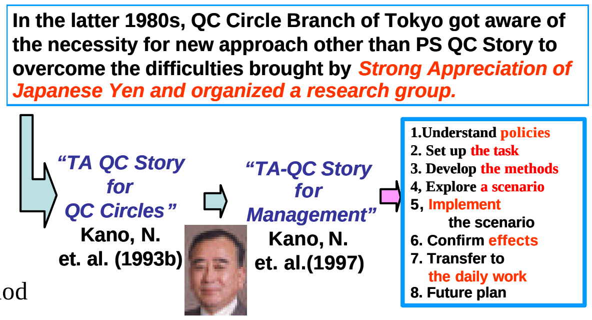

Fig. 19 Birth of TA-QC Story

5. What is the root of DMAIC of Six Sigma?

The standardized problem solving procedure of Six Sigma is DMAIC, which stands for

Define, Measure, Analyze, Improve, and Control.

This acronym has been globally well known. Comparing this procedure with the procedure of PS-QCS described in 2.2, 3.2 and 4.2, anyone would easily recognize them as essentially identical. However, among Six Sigma textbooks that I have studied, I have not come across any that describes how DMAIC was developed. In addition, I know many friends in the world who are convince that DMAIC the original procedure which was born in U.S. It is my hope that some Six Sigma Professionals would take up the responsibility for clarifying this point. If somebody says that DMAIC was born earlier than 1964, I must immediately scrap this article. If it were clear that DMAIC was developed after PS-QCS, then it would be proper to give the original developers credit. The letter from Ms. Kazuko Nishiwaki in the appendix will provide the readers some thought about this issue.

CONCLUSION

Before presenting this article, we handled each maintenance item, or problem or task by piece by piece with use of each of SDCA cycle, PS-QCS, or TA-QCS, separately. But we have Comprehensive Quality Management Procedure(CQMP). Now, we can consider quality improvement of a product by its life-cycle base, *Or, we can consider task achieving of an item under problem solving. Theoretically, so far PS-QCS and TA-QCS have no relation but we can relate one of them with the other by way of SDCA cycle.*

ACKNOWLEDGMENTS

I deeply thanks Dr. Masaya Fujisawa and Ms. Yoko Oyama for their excellent paper reading in advance and providing me various effective comments. In addition, let me express sincere gratitude to Ms. Noriko Hosoyamada for her helping me translating this into English.

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APPENDIX: The Letter from Ms. Kazuko Nishizaki

Subject: RE: QC story
Date: Mon, 9 May 2005 19:48:16 +0900
From: "Nishizaki, Kazuko" $$$$$$$$$$
To: "Noriaki Kano" <kano_n@ms.kagu.tus.ac.jp>

Dear Dr. Kano

Thank you for your interest in the original six sigma evolution process across the U.S. Motorola in 1988 and thereafter. Speaking about the high light of early phase of Motorola six sigma, I am pleased to mention the true contributors at Motorola who made six sigma known to the world.

In 1988, I was working at the TQC Promotion Office of Japan Motorola and was engaged in promoting company-wide TQC activities. The same year U.S. Motorola won the very first Malcolm Baldrige National Quality Award. The corporate vise president, Richard Beautow, vise president, Bill Smith visited us and explained to us about the MBNQ award and six sigma initiatives. By then the six steps of Six sigma were established with the concept of “Defects for opportunities”.

The director of the TQC promotion office, Mr. Kamei realized the TQC and six sigma can harmonize very easily and Nippon Motorola TQC team can work with U.S. Quality professionals hand in hand . Therefore we invited Mr. Buetow , Mr. Smith, Mr.Ponsedeleon from the government sector , Mr. Simpson from the Corporation quality office who were all VP of Motorola Corporation to the Company-wide QC Circle Conference held at Tokyo. They were very much pleased to see all levels of the employees who participate in the quality improvement activities through the small groups(QC circles). The following year of 1989, the quality office of the corporation asked me to send the English version of QC problem solving steps. I mainly used the QC circle book published by JUSE. Motorola promoted the TCS (Total Customer Satisfaction) team activities by adapting to some degree the QC problem solving steps and incorporating those steps with six sigma theory. I was appreciated by the quality office for my contribution to the introduction of QC story to the six sigma and world-wide TCS team activities .

As the result of the above mentioned process, the first Motorola six sigma was completely theorized by the Motorola executives mentioned above who truly bore the birth of six sigma at the company and gave the magnificent impact to the current six sigma drive being practiced all over the world today.

Sincerely yours,

Kazuko