

# PDCA Cycle for Facility Organization: First Step of the PDCA Framework Based on a Case Study of the Activity of Key Equipment Specialists

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## Abstract

It is generally known that after the 1990s many Japanese firms had negative growth and established production bases overseas. As economic activity slowed, domestic production volumes, employee numbers, and maintenance fees all decreased. For certain industries, such as the process industry, this situation reduced the ability to manage “quality control”, “safety”, and “environmental preservation”. To create a practical PDCA model to improve production potential, we analyzed the recent difficulties of Japanese firms and concluded that many of their troubles are caused by four common problems. The troubles of Japanese firms stem from reduced production potential and human abilities. Both of these reductions are related to information links: facility production activity involves equipment and human activities, the combination of which produce four types of information links. Each of these four types of information links is a common cause of difficulties. To maintain high quality production and low cost operations in an environment containing multiple types of information links requires training facility staff with various specialized skills. To improve facility production, we provide a practical model of how to improve production potential based on an information link, and how to observe and check facility production accordingly. This approach can detect the risk associated with an information link and let facility staff gain skills. Finally, we considered how to proceed and implement the new checking system for the PDCA cycle, and after several trials, we identified “Priority” for implementing the PDCA model, and created a new checking model for the PDCA cycle-integrated system of “Priority”, “Layer structure”, and “Information link”.

## 1. Background

The Japanese production style is based on a cost-down approach, technological progress, and high performance with strong workplace skills. In the 1980s, “Made in Japan” was a strong brand. However, after the 1990s, Japanese firms experienced negative growth and established production bases overseas.

The “Made in Japan” brand was not always as strong as it became in the 1980s. Historically, food scandals were a serious problem in Japan. In the 1950s and 1960s the food companies Morinaga, Yukijirushi, and Kanemi suffered serious poisoning scandals. Even as late as 1988, there was a food scandal involving toxic pesticide residue in imported oranges. Japanese firms have continued to face

problems related to lack of knowledge despite technological progress. We studied the reasons for these problems and concluded that it is important to develop extensive experience in planning, marketing, design, production, and sales, and cultivate specialized skills in various areas. Relevant experience that incorporates the above skills is required to integrate information and develop the ability to prevent problems.

This study aims to identify an effective method to maintain high production potential and skills. To improve facility production, we have previously provided a practical model on how to improve production potential with a PDCA checking system based on an information link. Baba (2012) discussed human failure and the four types of failure based on information links. The facility production activity must be observed and checked according to the information link. This approach can detect the risk associated with the information link and allow facility staff to obtain valuable skills.

## **2. Layer control and information links**

### **2.1 Layer structure and control**

The need to detect the weak points of a plant makes it important to understand the equipment and systems risk. The trouble-tree diagram is essential to find problems and helps detect information layer control through a visualized information layer. However, the other layers also require consideration. The quality layer contains the following items: “Quality guarantee”, “Standardization”, “Quality analysis”, “Quality information”, “Quality control education”, and “Quality control standard”. The equipment layer comprises: “Equipment inspection”, “Maintenance meeting”, “Equipment information”, “Maintenance education”, “Equipment design standard”.

If quality is prioritized, we must establish an adequate layer structure capable of detecting the weaknesses of facility operations. In this case it is desirable to place the equipment layer of the trouble-tree diagram under the quality layer to focus on the quality problem first. We must try to monitor the relationship between quality and equipment by observing the sources of trouble such as contamination, equipment deterioration, and failing to meet quality standards.

### **2.2 The links of individual layers**

Nakao (2007) identified ten “human” causes of failure: “ignorance”, “carelessness”, “ignorance of procedure”, “misjudgment”, “insufficient analysis or research”, “poor response to environmental change”, “poor concept”, “poor value perception”, “organizational problem” and “unknown cause”.

Hatamura (2005) identified four categories for cause of failure: “Failure caused by a poor transfer link”, “Failure caused by a poorly visualized link”, “Failure caused by an incompletely modified link”, and “Failure caused by delayed arrangement”. Hatamura analyzed and categorized numerous case studies of Japanese corporate problems and found that almost all problems belonged to one of these four categories.

“Failure caused by poor transfer link” includes the causes of human failure of “ignorance” and “insufficient analysis or research”. “Failure caused by poorly visualized link” includes “ignorance”, “misjudgment”, “insufficient analysis or research”, “poor response to environmental change”, “poor

concept”, “poor value perception”, and “unknown cause”. “Failure caused by an incompletely modified link” includes “ignorance ” and “poor response to environmental change”. “Failure caused by delayed arrangement” includes “misjudgment”, “poor value perception” and “organizational problem”.

Therefore, we decided that the “ten human causes of failure” are included in “four information links”, and decided to use the latter for PDCA checking parameters.

The first of the “four information links” is “Failure caused by a poor transfer link”, a pattern that causes many problems in organizations. Creating an information transfer system is not difficult. However, it is difficult to produce a culture that transfers this knowledge.

The second is “Failure caused by an incompletely modified link”. A sudden modification can cause serious troubles resulting in multiple organizations missing transfers. Each organization is independent, so knowledge transfer is difficult. Sometimes important modifications cannot be transferred, which can result in serious trouble. This is the most common problem encountered by factories.

The third is “Failure caused by delayed arrangement”. Important information must be transferred as soon as possible, but sometimes delays occur, and delayed arrangement decisions cause further serious trouble.

The fourth is “Failure caused by a poorly visualized link”. This link is dangerous because it is often useful to integrate related layers, and this failure will not show potential relationships that exist.

To prevent problems associated with information links, firms must create a “Layer control” system. This layer item is summarized in Figure 1.

Figure 1 combines three logic trees, which represent different layers of facility operations and visualize the relationship between the upper items and the downstream item.

The top logic tree depicts the typical organizational style for facility operations. This figure is same as a section diagram and makes the organizational structure easy to understand. Although this diagram meets our expectations, the focus is not clear from the perspective of the “four information links”. The contrast is unclear and it is difficult to detect important items referred to later.

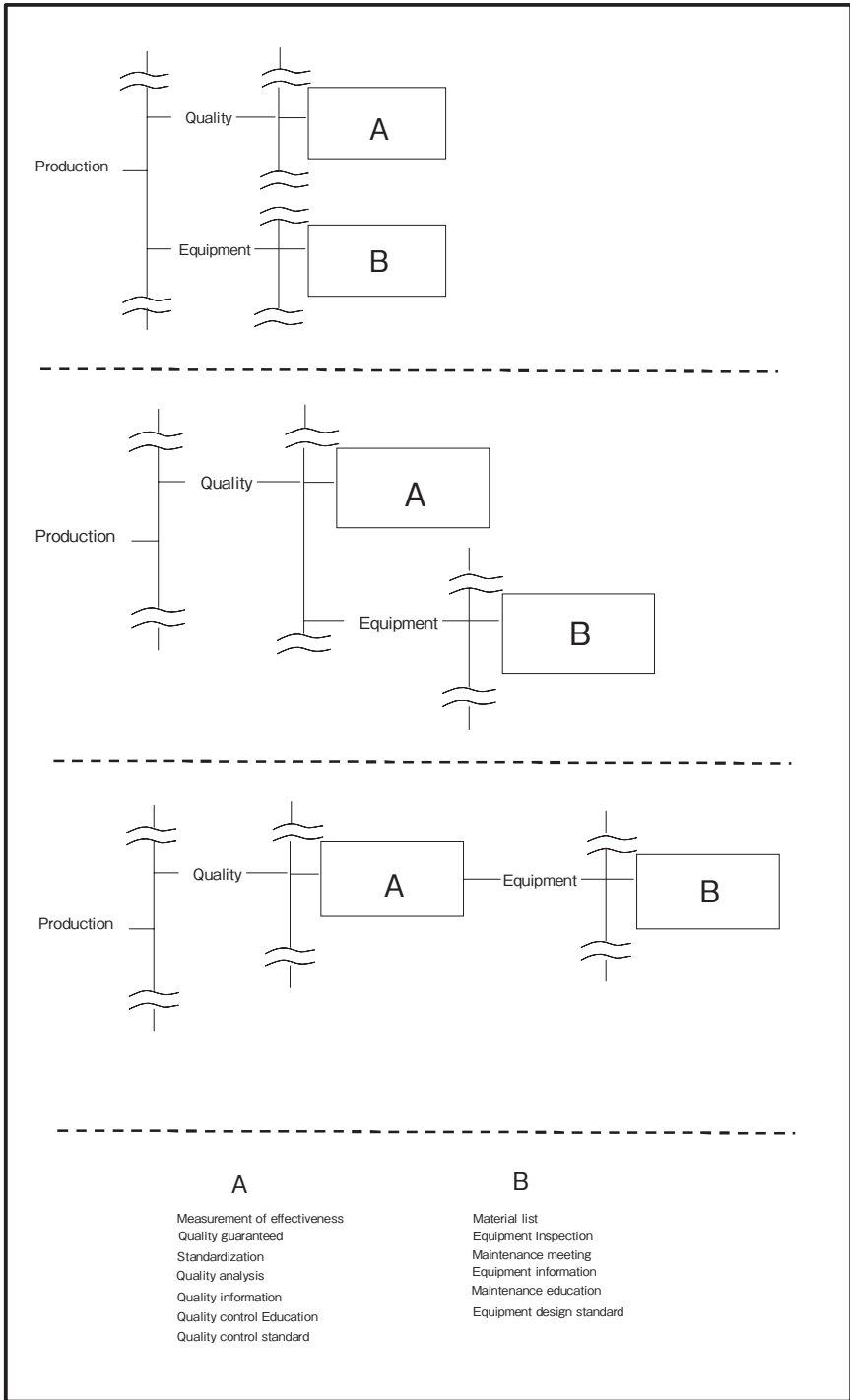
The middle logic tree indicates that the equipment item is located under the quality item, in the third dimension of the quality lineup. This placement of the equipment item relative to the quality item may not be entirely appropriate.

The bottom logic tree indicates that the equipment item is located under the “Quality guarantee”, a location that falsely suggests its function is to ensure quality. Senjyu (1987) noted that firms sometimes place the equipment item in this location as a result of TQC.

The optimal logic tree factory depends on personnel and human resource quality. The most important aspect should be to make sure that the “four information links” discussed above are checked.

### **3. Modification of the PDCA cycle based on layer control and information link**

Adequate maintenance in a factory denotes the sufficient fulfillment of three responsibilities, namely production quality, safety, and environmental protection. As mentioned in the previous section, these three items are sometimes difficult to maintain and a new system may be needed. This new system would require a mechanism for supporting skills, and for thorough layer control of the equipment information. Equipment control is not easy initially, and methods are required to control equipment information.



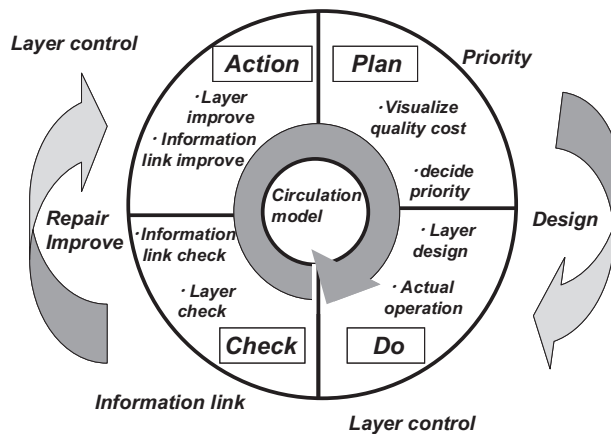
**Figure 1 Layer items**  
(Author's original figure)

Different types of information resemble “floating islands” that exist independently of one another. Information combination is not tightly integrated, creating potential for serious problems. All information is linked using integrated theory and has a layer structure.

Adequate maintenance involves deciding “Priority” based on “Quality” and “Cost”, and creating the “Layer control”, and “Information link”. The following four items all require constant improvement, a PDCA spiral that creates integrated knowledge.

- 1) “Integration theory” must be a key concept.
- 2) “Priority” must be determined based on “Quality” and “Cost”.
- 3) Visualization by “Layer control” must be provided.
- 4) Visualization by “Information link” must be provided.

The situation is summarized in Figure 2.



**Figure 2 Schematic representation of “adequate maintenance”**  
 (Partly modified by the author based on Hatamura (2005) and Naka (2006))

In the “Plan” phase of the PDCA cycle, we visualize the “Quality” and “Cost”. Visualized “Quality” and “Cost” help identify potential issues. This is a “Priority” decision.

In the “Do” phase of the PDCA cycle, we conduct layer design and perform the actual operations. We can also get important information regarding the layer. This is the “Layer control” area.

In the “Check” phase of PDCA cycle, we check the information link and information layer. This is the “Information link” area.

In the “Action” of the PDCA cycle, we improve layer control and information link. We can obtain improvement knowhow in this phase. This is the “improvement” area.

The “Plan” and “Do” phases correspond to “Design”, and the “Check” and “Action” phases correspond to “Improvement or repair”.

## 4. Model application

### 4.1 Case study of “Company L”

#### 4.1.1 Outline

Company L produces oil based products. Company L has about 1000 employees, five organizations, and seven factories. In 2009 the company established a new production line at its factory in the Tokyo metropolitan area, and checked the safety of raw materials, production processes, and distribution by HACCP (Hazard Analysis Critical Control Point). The control factors were listed as follows: individual production section personnel, production design, facility maintenance, quality control, packing, and supply of raw materials. Five persons selected from five facility sections together formed a small PDCA checking team and identified potential causes of problems in facility operations.

In December 2011, in order to understand Company L, our interview was conducted over about two hours with the factory manager and vice factory manager, who indicated rough cost data. They said that the cost data were based on the reference year 1995. The most serious quality management episode was the product recall in 2008, which resulted in large failure costs. In 2009 and 2010 the failure cost decreased slightly and the production situation becomes better. Future studies will analyze the data in detail.

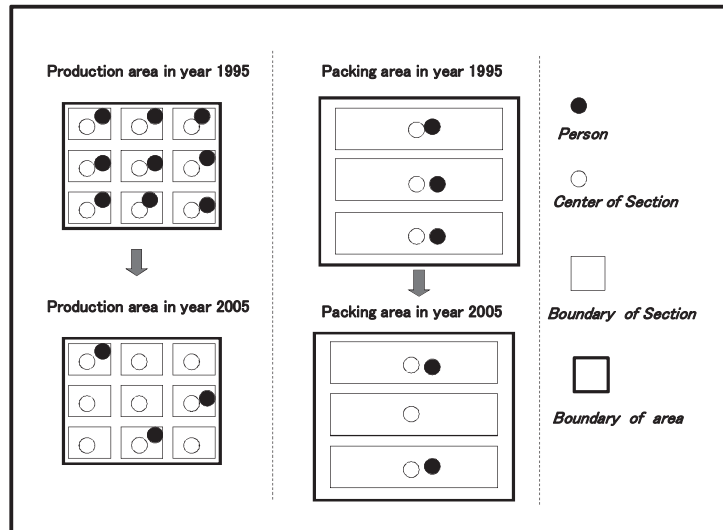
Figure 3 shows the relationship between the section and the equipment specialists (called key persons) based on interviews with Company L (Figures 4-6, below, are based on the same interviews). In 1995 a key person was assigned for each section, but after 10 years the number of key persons in the production area was halved, forcing each key person to look after multiple sections. The PDCA checking team comprised four key persons in several production area and one key person in the packing area.

The key persons discussed “equipment condition” and “contamination prevention”. They checked the following items: “raw materials”, “lack of cleaning”, “deterioration of valve packing”, “pipe corrosion”, “membrane breakage” and “magnet deterioration”.

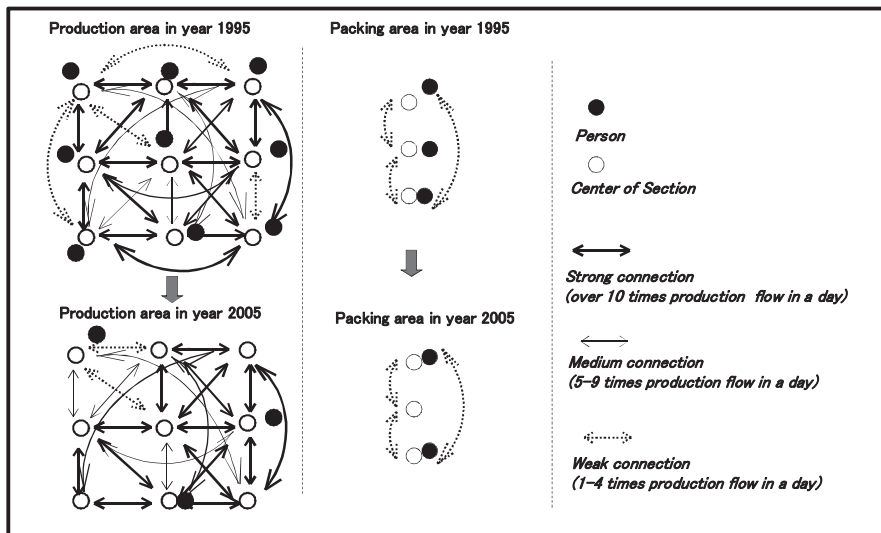
According to standard procedure, after establishing a new production line, Company L started the next step, in which a PDCA checking team analyzed the facility as it operated normally. The team checked the “Information link”, which comprised “Failure caused by a poor transfer link”, “Failure caused by a poorly visualized link”, “Failure caused by an incompletely modified link”, and “Failure caused by delayed arrangement”. In this case, with reference to the activity of the virtual layer structure for Figure 1 (bottom figure), the team located the equipment under the “Quality guarantee”.

The team started checking facility operations using “Information link” and detected danger areas associated with the sealing equipment.

Figure 4 indicates the strength of the relationship between sections and key persons. The thick solid line indicates a strong connection (Over 10 times production flow in a day), the thin solid line indicates a medium connection (5-9 times production flow in a day), and the broken line indicates a weak connection (1-4 times production flow in a day). In 1995, the production area had a complex web of strong connections among sections, but in 2005, some previously weak connections had disappeared and some strong connections had become medium connections. The web of connections became simpler, but lack of personnel meant each key person was busier than before.



**Figure 3 Relationships between sections and key persons**  
(Author's original figure based on interview)



**Figure 4 Strength of the relationships between sections and key persons**  
(Author's original figure based on interview)

In 1995, the workload of key persons in the production area was low enough to be manageable. However, in 2005 the workload of key persons increased to twice that in 1995. There was a possibility that key persons might miss something important or act carelessly. Moreover, when a key person transfers to a new section and the vacated section is filled by a replacement, the new key person will be exposed to

a heavy workload. An inexperienced replacement key person may be unable to handle the workload, and individuals typically have difficulty assessing their own abilities to handle workload. The relationship between personal ability and work load is generally difficult to explain. In this case, key persons must manage the equipment condition, maintenance planning, quality condition, distribution flow, and environmental condition, and this requires extensive information.

Connections between sections included numerous items, including raw materials flow diagrams, energy flow diagrams and other items. In the production area, the facility production activity was based on numerous pieces of equipment and human activities, the combination of which produced multiple types of information links. To maintain high quality production and low cost operations despite such complex information links required letting facility staff, mainly key persons, obtain specialized skills in various areas. Such facility staff had to have specialized skills in various areas. Originally the key person's role was equipment management, but the role expanded to include the integration of information intended to prevent problems, such as quality, equipment, environmental, and safety problems.

In 1995, each section included one key person who managed only equipment condition, but by 2005 the job of this person had expanded to include the management of numerous items, such as maintenance, quality, environment, and safety. Moreover, this person had to manage equipment in three or four sections instead of just one section. Since this increase in workload occurred gradually, the first generation had the opportunity to become accustomed to new jobs, but the next generation did not. In the 10 year interval from 1995 to 2005 many difficulties arose from inexperienced personnel.

In the packing area, the load of key persons was low and changed little between 1995 and 2005. The load number in 2005 was 1/20 or 1/10 of the production area. This is because the connections between sections within the packing area were weak and the influence on production problems of decreasing the number of key persons in individual sections was weak compared with that of decreasing the number in the production area.

#### **4.1.2 Priority**

Determining priority based on "Quality" and "Cost" is important to promote the PDCA cycle. If the changes in production loss are clear and we can visualize the failure cost, the trend of each year's internal and external failure costs becomes clear. Therefore, we can focus on how to decrease the internal or external failure costs. A clear target is necessary; to decrease the external failure cost, it is desirable to assign an effective checking machine and strengthen the quality check system. To decrease internal failure cost, it is desirable to review the production design, facility production system, and maintenance system.

The relationship between "Quality" and "Cost" helped identify hidden problems and clarify the direction of "Priority".

#### **4.1.3 Layer control**

The maintenance layer comprised the following items: "Material list", "Equipment inspection", "Maintenance meeting", "Equipment information", "Maintenance education", and "Equipment design standard".

The quality layer comprised the following items: "Measurement of effectiveness", "Quality guarantee",



“Standardization”, “Quality analysis”, “Quality information”, “Quality control education”, and “Quality control standard”.

The maintenance layer was set under the quality guaranteed layer, and controlled with a quality indicator. The PDCA checking team checked the quality guarantee and maintenance layers using the checklist based on the failure scenario, which showed the maintenance problem and the impact of the damage on the business. The information link was checked according to a layer structure as described in the next section.

#### **4.1.4 Information links**

The first information link was “Failure caused by a poor transfer link”. The PDCA checking team referred to past problems, detected the information “corrosion of pipe” and “breakdown of membrane”, and could list the “frequency and timing of damage”. Past failure provided useful information for damage prediction.

The second information link was “Failure caused by an incompletely modified link”. The design of the operation system was checked for incomplete modifications, as follows: a) Checking for changes in rule sequences; b) checking for changes in trouble treatment; c) checking for changes in distribution; d) checking for changes in quality standards; e) checking for changes in raw materials providers; f) checking for changes in volumes of goods; g) checking for changes in timing of provision; h) checking changes in design; i) checking changes in the transfer phase. The team detected several errors, as follows: “change in product sealing materials”, “change in valve type”, “change in construction company”, “change in shutdown interval”, “change in raw materials”, “change in raw materials supplier”, “change in pipe shape”, and “change in recycling method for defective goods”. Checking was followed by relevant maintenance actions.

The third information link was “Failure caused by delayed arrangement”. The team focused on the following items: “delayed construction”, “delayed equipment inspection”, and “lack of cooperation by the operation and maintenance sections”. They detected several errors and made relevant improvements.

The last information link was “Failure caused by a poorly visualized link”. The team detected the danger point of the valve, associated with its rubber lining. This valve was located on an important area and was vulnerable to deterioration under certain conditions. The PDCA checking team could predict contamination due to deterioration of the surface rubber. This activity identified a suitable cleaning method and changed the valve material. Discussion with material specialists selected from several technical fields was necessary to recognize the risk of valve deterioration. Following this intervention the production line began to operate without problems.

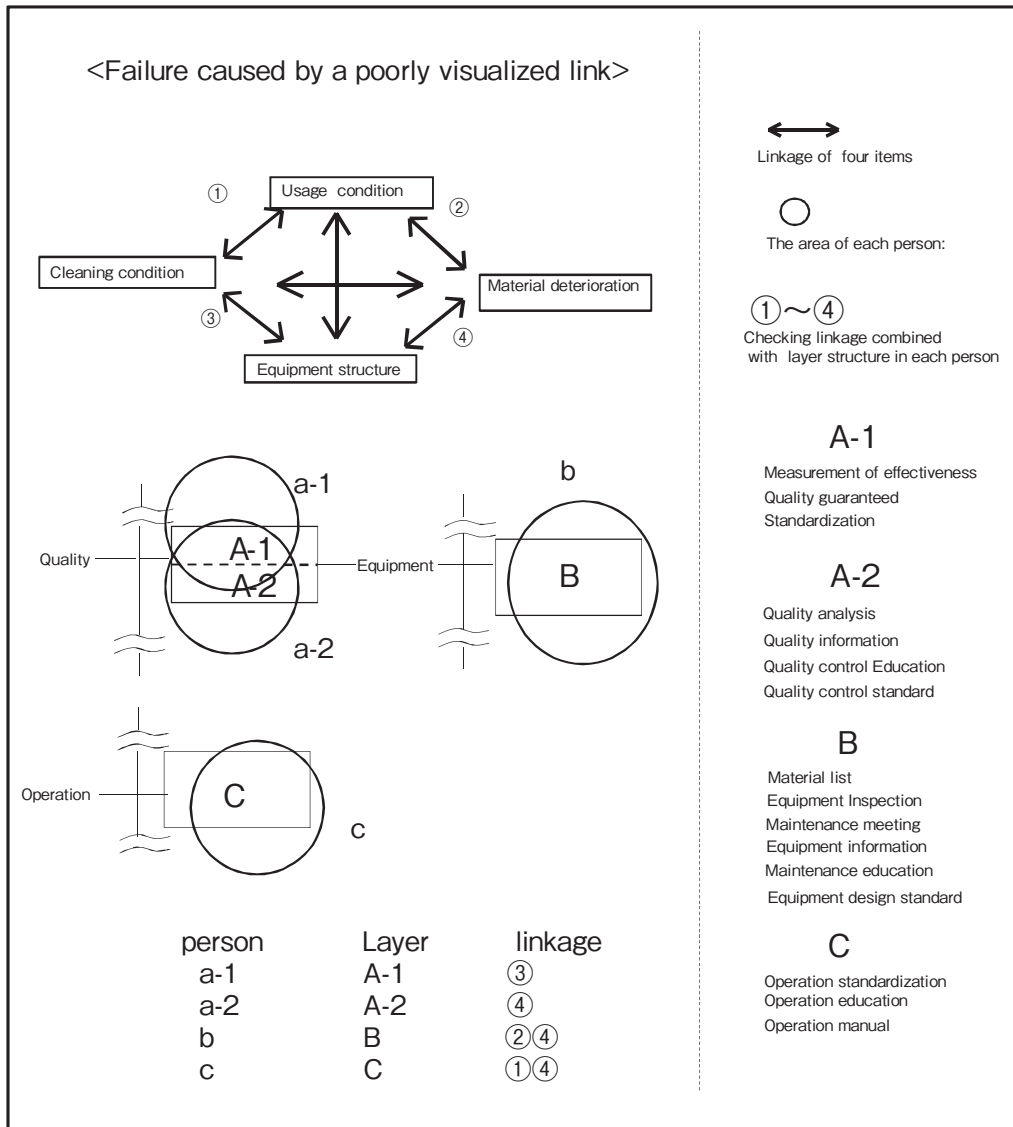
#### **4.1.5 An example of the PDCA checking team activities**

As already noted, there were four information links, and we selected “Failure caused by a poorly visualized link” as an example.

Figure 5 indicated the case study of Company L, which was focused on “Failure caused by a poorly visualized link”. In this figure the facility layer was listed as “Operation”, “Quality”, and “Equipment”. The upper of the figure showed the discussion themes: “usage condition”, “material deterioration”,

“equipment structure”, and “cleaning condition”.

The PDCA checking team discussed these four items to identify the “Failure caused by a poorly visualized link”. The visualized layer structure could assist this work and was related to these four items. These activities were linked with the relationships of each of the four items and listed the many risk scenarios. Baba (2012, p.28) described the knowhow of the risk scenario table and focused on its

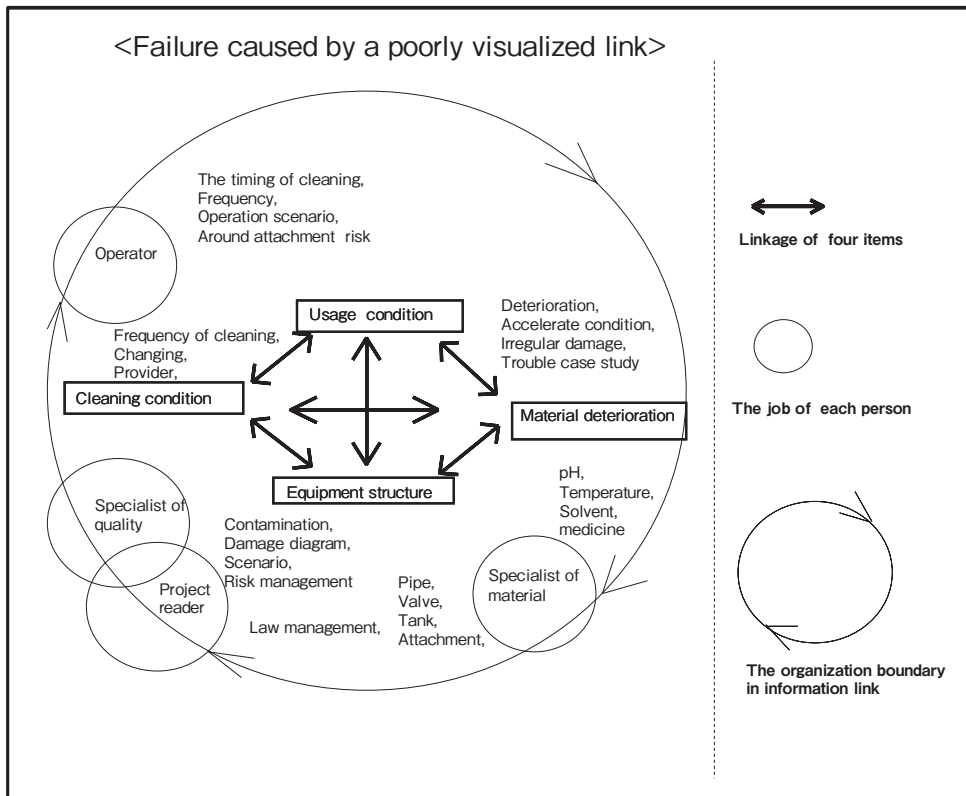


**Figure 5 The relationship between layer structure and information links in a case of failure caused by “a poorly visualized link”**  
(Author’s original figure based on interview)

effectiveness. In Figure 5, the linkages between facility operations and the four items were intuitively visualized, and the relationships between the layer structure and the four items were individually checked according to these linkages. Extensive discussion within the PDCA team supported problem detection. The four items made linked circles based on the role of the key person. All team members checked the layer activity.

Figure 6 indicates the relationship between the role of the key person and the checking items. Each item was ordered to identify “Failure caused by a poorly visualized link”. Examples of the checking items are summarized as follows:

1. Checking case studies of past issues.
2. Checking whole pipe and valve against the design diagram.
3. Checking the relationship between pipe and valve and their internal chemical condition.
4. Checking detailed cleaning procedures such as the use of oxidizer, reducing agent, and bleach.
5. Checking cleaning and fluid change frequency.
6. Checking contamination from other lines and the associated risk.



**Figure 6 Integration of the information diagram in a case of failure caused by a poorly visualized link (Author’s original figure based on interview)**

Each member of the PDCA checking team could discuss linkage information with other members. The individual team members each resembled independent “floating islands” and the combination of information was not tightly integrated, meaning that conscious integration of information was important.

## 5. The confirmation of the proposed PDCA system

This section confirms the PDCA cycle system based on “Priority”, “Layer control” and “Information link”. This system requires that a small number of persons, such as group leaders or chiefs, be trained in trouble-shooting.

The proposed PDCA system needs to make logic tree the layer structure comprising facility operations and check that activity from the “Information link” perspective. We already set the equipment item near the quality item, and check these items using four information links, including “Failure caused by a poor transfer link”, “Failure caused by a poorly visualized link”, “Failure caused by an incompletely modified link”, and “Failure caused by delayed arrangement”.

The equipment item is located near the quality item to integrate individual facility activities and search the linkage between the nearest item pair. Neighboring facility activities can easily connect with each other because they are organized using a visualized and simplified layer structure style, as shown in Figure 1. If an integrated item can include a maximum of five items, organizational linkage is theoretically limited to ten lines ( $n \times (n-1) / 2 = 10$ ), and so five persons can easily check the ten linkages (Baba (2012, p.32)). This PDCA checking system can be applied to preventative maintenance of newly built factories because it makes it easy to check equipment and systems. Moreover, this PDCA checking system not only applies preventive maintenance but also improves quality and efficiency.

If the subsection chief or group leader is trained in this PDCA checking system, they can obtain specialized skills in various areas. Training facilitates continuous skill exchange among members, and knowledge transfer from individuals to the organization.

The important point is constructing risk prediction, damage scenario, and activation organization with only four information links, namely “Failure caused by a poor transfer link”, “Failure caused by a poorly visualized link”, “Failure caused by an incompletely modified link”, and “Failure caused by delayed arrangement”.

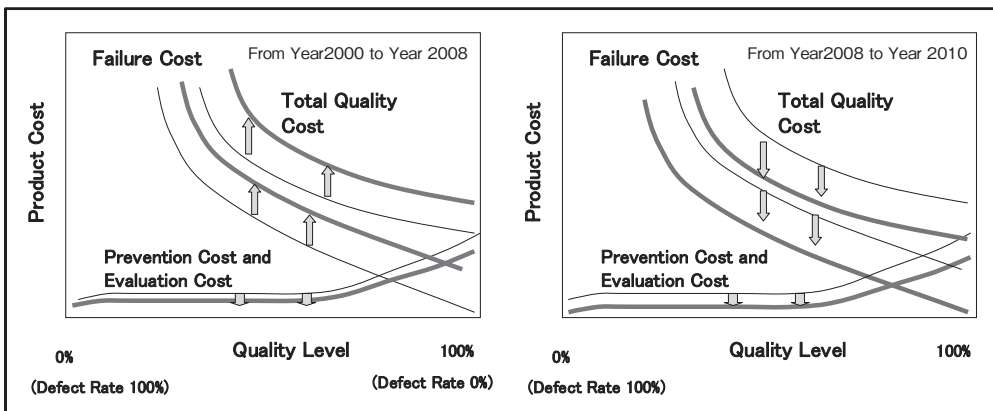
The PDCA checking system in Company L was based on four main steps. First, the priority was determined based on recent “Quality” and “Cost” data (Plan phase in figure 2). Second, the small PDCA checking team made a logic tree of the layer structure that comprised facility operations and checked those operations using the “Information link” perspective (Do and Check phase in figure 2). Third, the team integrated each facility activity and searched the linkages between near neighboring facility activities (Do and Check phase in figure 2). Fourth, the team conducted risk prediction, damage scenario, and activation organization using four information links, namely “Failure caused by a poor transfer link”, “Failure caused by a poorly visualized link”, “Failure caused by an incompletely modified link”, and “Failure caused by delayed arrangement” (Check and Action phase in figure 2).

Figure 7 shows the method of “Quality Cost Management” from Ito (2005). The left side of the figure shows a “Trade off” situation. In case of Company L, the number of key persons decreased with decreasing production volume, and the failure cost, which included recall costs, increased year-on-year.

This result suggested that the workload of key personnel considerably exceeded their abilities, and numerous mismatches existed between equipment and human activities.

Meanwhile, the right hand side of the figure shows the “TQM style”. According to Ito (2005, p.23), assuming a large initial value, a decrease in external failure cost directly reduces benefit loss and increases ROA.

However, because “Quality cost management” is still not popular in Japan, Company L did not usually record the “Failure cost” or “Prevention cost and Evaluation cost”. Therefore, it was difficult to gather data on failure costs except when serious recall problems occurred.



**Figure 7 Schematic diagram of Quality Cost Management  
(Partly modified by the author based on Ito (2005, p.21))**

The most serious quality management episode was the product recall in 2008, which resulted in large failure costs. In 2009 and 2010 “Failure cost” decreased. This was because the PDCA checking team detected failure resource in 2009. Improved prevention activity owing to the small PDCA checking team reduced total failure costs.

As already mentioned in section 4, the stress on the key personnel increased in 2005 compared with 1995. To maintain high quality production and low cost operations under such stress requires letting facility staff obtain specialized skills in various areas. The activity of the small PDCA checking team improves the ability of all personnel. Moreover, the layer control and checking of the facility operations using the “four information links” provides a useful tool for preventing failure because it can clarify facility problems and work styles that may produce human error.

## 6. Conclusion

Many Japanese firms have experienced negative growth and established production sites overseas. The economic slowdown has decreased domestic production volumes, employee volumes, and maintenance costs.

To create a practical model to help improve production potential, we analyzed the recent difficulties of

Japanese firms and concluded that most problems, whether human or organizational errors, occurred for four reasons, namely the “four information links”. Checking facility operations with a PDCA checking system focused on these “four information links” can limit problems. Facility production involves numerous equipment and human activities, the combinations of which produce “four information links”, namely “Failure caused by a poor transfer link”, “Failure caused by a poorly visualized link”, “Failure caused by an incompletely modified link”, and “Failure caused by delayed arrangement”.

Checking the “four information links” leads to checking of the “layer structure” in facility operations. This is because visualizing the “layer structure” can easily detect weak points from the perspective of the “four information links”. For example, sometimes it is desirable to locate the “equipment layer” under the “quality layer” to focus on quality, and sometimes it is desirable to locate the “equipment layer” under the “safety layer” to focus on safety. The layer structure corresponds to a logic tree, and so all items indicate specific facility activities and visualize the relationship between the upper items and the downstream item. The upper items correspond to the “subject” and the downstream item corresponds to the “solution”, so the layer structure is important to the design.

Generally, information resembles an independent “floating island”, and the combination of information is not integrated tightly, a situation that sometimes causes serious trouble. All information has to link with the integrated system, and information must have a layer structure.

To create the PDCA cycle, it is necessary to set the “Priority”, “Quality”, “Cost”, “Layer control”, and “Information link” mentioned in section 4. First we must decide the “Priority” in factory management. Second we must visualize “Cost” and “Quality” to help identify hidden problems.

In the “Plan” phase of the PDCA cycle, we visualize the “Quality” and “Cost” to help identify hidden problems. In the “Do” phase, we perform layer design and perform actual operations. In the “Check” phase, we check the information link and information layer. In the “Action” phase, we improve layer control and information link. The “Plan” and “Do” phases correspond to “Design”, while the “Check” and “Action” phases correspond to “Improve or repair”.

The second half of this paper described a case study focused on quality in Company L.

In this case study we confirmed the applicability of the PDCA cycle based on “Layer control” and “Information link”. In the proposed PDCA system, it is important that a small number of personnel, such as group leaders or chiefs, have training in troubleshooting. Actually, the case study of Company L demonstrates that the proposed PDCA system can detect and prevent serious error. The PDCA checking team predicted potential for contamination due to deterioration of the valve surface rubber, and in response identified a suitable cleaning method and changed the valve material.

In analyzing the relationship between “Failure Cost” and “Prevention and Evaluation Cost” in Company L, we realized that “Prevention and Evaluation Cost” remained little changed between 1995 and 2007–2010. After 2000 this cost decreased slightly owing to decreased facilities. On the other hand, “Failure cost” increased in 2008 because of serious design failures and recalls. In 2009 and 2010 “Failure cost” decreased. This was because the PDCA checking team detected failure resource in 2009.

The case study indicated that external failure cost could be decreased by strengthening quality check and thus decreasing total quality cost. The quality check in Company L was unchanged from the previous year, while prevention cost based on personal cost was decreased.

To maintain high production quality and low cost operations under stress, it is necessary to let facility staff obtain specialized skills in various areas. The activity of the PDCA checking team improves individual abilities. Moreover, the layer control and checking of facility operations using the “four information links” is a useful tool to prevent failure because it can clarify facility problems and potential human errors.

Adequate maintenance involves deciding “Priority” based on “Quality”, “Cost”, “Layer control”, and “Information link”. These five items all require constant improvement, a virtuous spiral that yields integrated knowledge. This philosophy can apply not only in maintenance activity but also in planning new plants overseas and improving the efficiency of existing plants.

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