Development of Root Cause Analysis Tool for Control Chart

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***Abstract*—Control chart is one of the statistical process control tool that its use is for monitoring and controlling variations in the production process. It enables one of variation sources - the special cause - to be identified, signaling at the quality manager that the process involved might be in a state of "statistically out of control". This particular state of production process jeopardises quality of the products produced. Clearly, the control chart is a prominent tool in the statistical process control. Despite this fact, the control chart suffers from inability to identify the true root causes of a problem behind the presence of the special cause. This paper reports on the result of research on developing a novel tool of root cause analysis designated for the control chart. It also reports of the successful result of validating the tool on a case study company in Indonesia.**

Keywords—control chart; root cause analysis; statistical process control; RCAN; SSQC

I. Research Gap

William Edward Deming [1] has asserted that the salient point of controlling the quality of product is how best we can deal with variations in the quality of the production process. The lower the variations, the higher the quality of products produced. The sources of variations fall into two causes [2] in which they are *special causes* and *common causes*. One of the *statistical process control* (SPC) tools available for controlling variations in the production process is *the control chart* [2]. The control chart was invented with the purpose of detecting the occurrence of the special causes of variation. A process that is operating in the presence of special causes is said to be an *out of control process* in that the process sustains high variations inflicting low quality on its products.

Unfortunately, the control chart does help merely detect the presence of special causes instead of identifying the true root causes that result in the presence of this particular source of variations [3]. The control chart is not equipped with the tool to conduct *the root cause analysis* (RCA). Notwithstanding this fact, the root cause analysis tool has been developing very rapidly though. An example of this can be taken from the recent research and development of *process root cause analysis*/ PRCA [4], *fishbone diagram* [5], *interrelationship diagram* [6], *current reality tree* [7], *apollo root cause analysis* / APRCA [8] and so forth. It is unfortunate that none of these tools is specifically designated for the control chart [9] leaving the "out of control" process with undisclosed root causes of problem. Hence, there still noticeably exists room for improvement in this field.

This paper reports on the result of research on developing a novel tool of root cause analysis designated for the control chart. The devised root cause analysis tool comprises of the RCAN logic (Root Cause Analytic Network) and the software, namely SSQC (Spreadsheet for Quality Control). It also reports of the successful result of validating the tool on a case study company in Indonesia. The following parts of this paper break the result of the research down in detail.

II. The Devised Root Cause Analysis Tool

In this research, a novel root cause analysis tool that is designated for a control chart has been developed to help identify *root causes* of a problem with the quality of a production process. Once a control chart signals that a production process is *statistically out of control*, with *special causes* heaving in sight engendering high variability in the production process, the devised root cause analysis tool is then taking up the role in identifying root causes of the special causes. This novel tool leads quality managers to the root causes with the use of a weighting method. Figure 1. shows the logic behind the devised root cause analysis tool, namely RCAN (Root Cause Analytic Network).

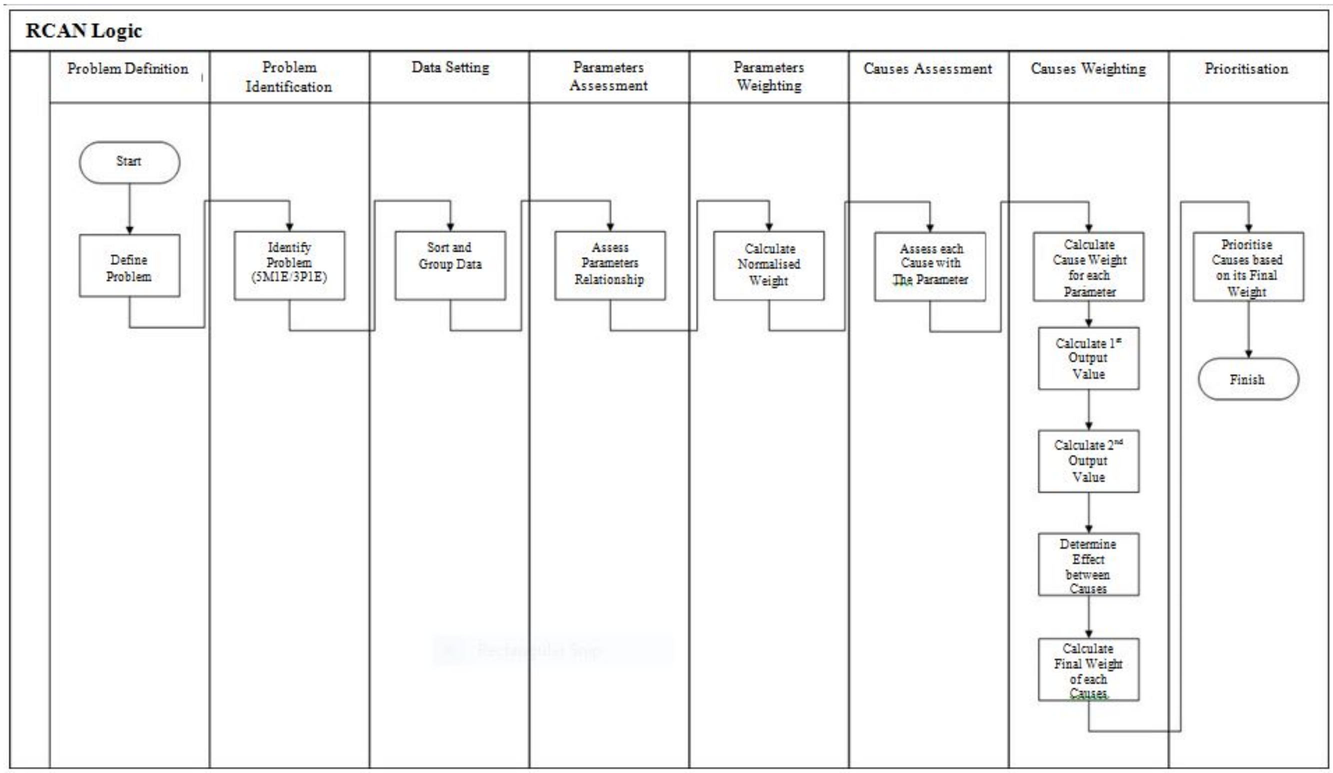

Fig. 1. The Logic of Root Cause Analytic Network (RCAN)

A. *Problem Definition*

At this stage, the problem in a production process that has caused the process *statistically out of control* as signaled by a control chart is carefully defined and identified. Thorough analysis is done to the special causes that a control chart has identified so that root causes of the problem can be listed.

B. *Problem Identification*

The aforementioned list is used for identifying the most potential root causes of the problem. This is done with *brainstorming* session using 5M1E classification for manufacturing industry - or, 3P1E if applied to service industry - of *the fishbone diagram*. The 5M1E classifies root causes of the problem under six categories in which they are Man, Machine, Material, Measurement, Method and Environment. Root causes of the problem in the 3P1E classification fall into four categories of Policy, People and Procedure.

C. *Data Setting*

Data parameter of the potential root causes which is responsible for the existence of the problem is then determined, alongside scale of the data parameter. The parameter includes the number of occurrence of the root cause, effect of the damage once the root cause occurs, and so forth. An example of scale of the parameter of occurrences is very often-often-sometime-rarely-never.

D. *Parameters Assessment*

Inter-related parameter assessment is conducted to quantify the relationship between the parameters. Result of such assessment will help us understand how one parameter affects others in a quantitative term.

E. *Parameters Weighting*

This stage deals with calculations to determine the geometrical mean as well as normalised weight of the parameters based on the results of parameters assessment.

F. Causes Assessment

Effect of each potential root cause is then assessed on every parameter so that inconsistencies between potential root causes can be avoided.

G. Causes Weighting

Having assessed the effect of each potential root cause on each parameter at previous stage, at first this stage assesses the effect of each potential root cause on the whole parameters in order that weight of each potential root cause on every parameter can be determined. Secondly, *sigmoid function* of the *Artificial Neural Network* is applied at this stage to calculate the first output value of the sigmoid. The first output value can be calculated using a formula [10], as in

$$f(nett) = \frac{1}{(1+e^{-\alpha(\sum XiWci)})} \quad (1)$$

where,

α = 1

Wci = weight of parameter

Xi = input value

The third stage calculates the second output value of the sigmoid, or the output weight of potential root cause on the whole parameters. A formula [10] as follows is used,

$$f(nett) = \frac{1}{(1+e^{-\alpha(\sum YciWvi)})} \quad (2)$$

where,

f(nett)= the second output value of the sigmoid

Yci = the first output value of the sigmoid

Wvi = weight of each potential root cause on every parameter

At fourth stage, results of calculation of the first and second output value are then inputed to the calculation in order to determine output value of each potential root cause. These output values are then used to determine the effect between the potential root causes. Final stage deals with calculation of the final weight of all potential root causes. It uses the formula [10], as in

$$\text{Final Weight} = f(net) + \sum(pi\ x\ fi) \quad (3)$$

where,

pi = proportion of a root cause to other root cause

fi = output value of a root cause

H. Prioritisation

Given the final weight of each potential root causes at final stage above, The potential root causes are then listed based on its weight in ascending order. The potential root cause with the highest weight would be the root cause with greatest potential for causing the problem. A Pareto Chart [11] with its 80:20 ratio could also be incorporated into the results of RCAN to justify how many root causes on the list will be addressed so that the problem is resolved.

In this research, a spreadsheet based software has also been developed in order to ease the way for the users of RCAN to implement it. The devised software is named as SSQC (Spreadsheet for Quality Control). Figure 2 shows the opening window of the SSQC.

Fig. 2. The Opening Window of SSQC Software

III. The Case Study

The SSQC software which carries logic of RCAN was validated in a case study company of sugar industry, located in Yogyakarta - Indonesia. It was tested for tackling problem with low sugar yield related to low level of factory productivity faced by the case study company. Having implemented SSQC in 2013, the case study company was recommended for taking its efforts to focus on a select group of potential root causes as listed and ranked in Table 1. A Pareto Chart was then applied to the prioritized list of potential root causes in Table 1 to narrow down the list so that the company’s resource level deployed to eliminating the root causes is always able to be in the effective and efficient way. The case study company would then address the potential root cause of (1) low labour skill, (2) bad communication between different departments and (3) low reliability level of factory equipment since the Pareto Chart prompted its managers to tackle those three potential root causes first rather than all at once. Figure 3 illustrates the aforementioned Pareto Chart.

Table 1. Select Potential Root Causes Recommended By SSQC

Rank	**Potential Root Cause**
1	Low labour skill
2	Bad communication between different departments
3	Low reliability level of factory equipment
4	Recurrent failures in the roller milling machine
5	Overstock of raw material
6	Improper imbibition system
7	Uncertain weather condition

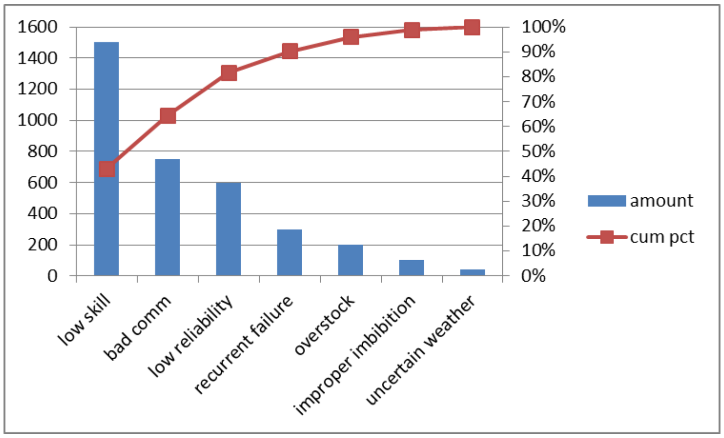

Fig. 3. The Pareto Chart of All Potential Root Causes

The result of tackling those three potential root causes is that the sugar yield produced by the case study company has finally increased since 2013. As can be seen in Figure 4, it covers the years 2007 to 2014 and shows that the sugar yield declined steadily from 2007 until end of 2012.It rose more and more steeply after that, throughout 2013 and 2014. The figure seems to indicate that the case study company has recovered from its problem in 2013 where the implementation of SSQC was initiated. This confirms the applicability of SSQC, with its RCAN logic, in a practical word as well as in industry.

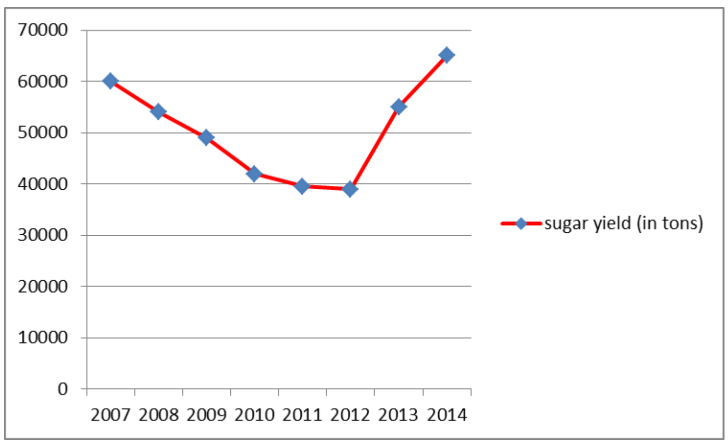

Fig. 4. The Implementation Results

In order to further examine the scope of applicability of the SSQC software alongside the RCAN logic, the Market Test developed by Kasanen and his colleagues for a Constructive Research Approach / CRA [12] was applied. It consists of three market–based validity tests: 'weak market test', 'semi-strong market test', and 'strong market test'. The 'weak market test' is passed if a manager of the case study company is keen to use the construct for his or her practical purposes. The 'semi-strong market' test is passed when a wide range of companies have adopted the construct. A requisite for passing the 'strong market test' is that the companies must gain significant financial benefits from applying the construct compared to those that are not using it. From the result of the case study it can be concluded that the 'weak market test' is passed since the case unit was evidently willing to adopt the SSQC software with its RCAN logic for tackling the recurring problem of low sugar yield. It was found that the RCAN logic of the SSQC software has helped the case unit to fully realize the problem in its entirety, and served them well in identifying the inherent root cause of the problem. The identified root causes could provide them with a clear idea of the problem-causation which is of use to generate viable solutions. In this case study the 'weak market test' has been validated at its strongest level, since not only the head department of the case unit, but also all heads of department in the case study company, were willing to adopt the SSQC software in practice. They expressed their great interest in adopting the devised software with its novel logic while a series of discussions in a number of workshops were held at the case study company in the initial stages of the case study. Referring to the 'weak market test' chart, as seen in Figure 5, the fact that the RCAN logic of SSQC software has now been formalized as the only Root Cause Analysis tool to be widely applied to problem solving in the case study company, indicates the extent and intensity of usage is definitely at its maximum for a 'weak market test'. This demonstrates a promising start on the generalizability of the RCAN logic as well as the SSQC software.

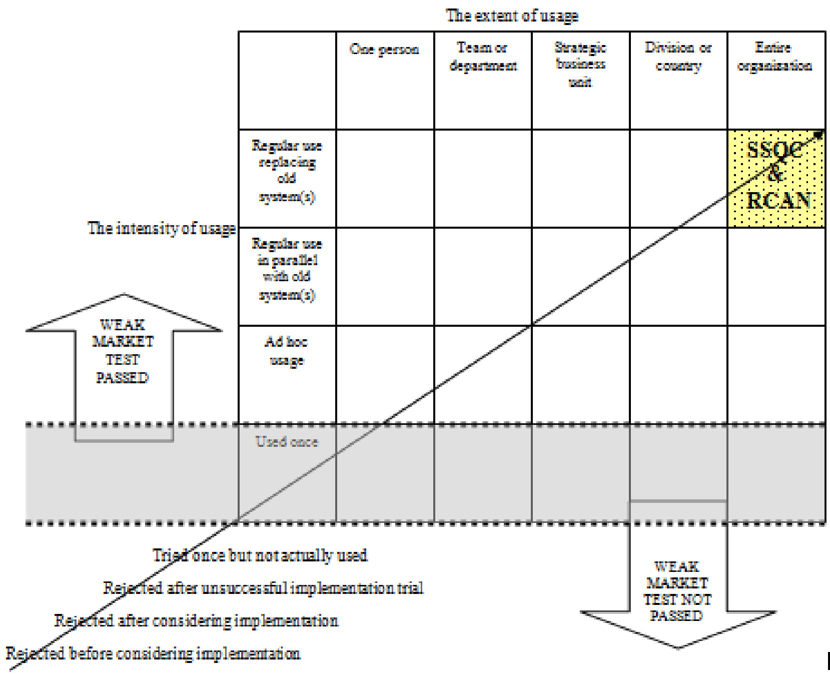

Fig. 5. The Constructive Research Approach Results

IV. Conclusions

In conclusion, it can be seen that a novel root cause analysis tool has been developed in this research as reported and explained in the paper. The devised root cause analysis tool comprises of the RCAN logic (Root Cause Analytic Network) and the software, namely SSQC (Spreadsheet for Quality Control). The tool was successfully validated in the case study company of sugar industry. A list of select potential root causes of problem has been identified and, once measures to eliminate those root causes were taken, the implementation results show that the sugar yield increases significantly and, from the results of the constructive research approach, it can also be concluded that the 'weak market test' is passed for the case unit was evidently willing to adopt the SSQC software with its RCAN logic for tackling the recurring problem of low sugar yield.

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