Implementation Statistical Quality Control (SQC) and Fuzzy Failure Mode and Effect Analysis (FMEA): A Systematic Review

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Abstract. In the era of technological development like now, industrial business one of the key factors in developing countries and manufacturing processes, both domestic and international. In the business world quality or product quality and productivity are the keys to success a company’s production system because quality is the main factor for consumers in choosing products. Increasing demand of product will make increased levels of business competition too between companies so that companies are always required to increase customer satisfaction, among others by continuing to improve the quality of products. To have quality product, production process must be considered. Statistical Quality Control is suitable used to identify product’s defects and to find factors that cause disabilities and defects that occur in order to support improvements in product quality in order to avoid more product defects. and Fuzzy FMEA is an efficient method in determining priority numbers of risk of failure of products to be identified prior to repair actions. The review of Statistical Quality Control (SQC) and Fuzzy FMEA case studies that are achieved Service Industry, the Product Manufacturing Companies, Renewable and Sustainable Energy, Construction Project and Healthy is showed in this paper.

1. Introduction
The Statistical Quality Control concepts was introduced on Control Chart book by Schewart, and next decade that developed by Romig in 1941 for basic acceptance sampling. Since this pioneering rises many new techniques that purpose to control product and process have been proposed and then literature about SQC developed, and it's be interest to determine extent control of charts and techniques of sampling, both old and new techniques that apply in industry [1]. Statistical Quality Control (SQC) is one of techniques as problem solving which used to monitor, analyze, manage, control and improve processes and products which use statistical methods as support tools. Statistical quality control is often equalized as statistical process control (SPC). Statistical quality control and process control statistics absolutely two interchangeable terms that is if used together then user will see the current overview and future process performance. Statistical Process Control or Statistical Quality Control is a technique as problem solving which used to monitor, controller, analyzer, manager, and improve the process using statistical methods. The known philosophy is output at the process or service can be put into statistical control through management tools and design actions. The goal is reduce the variation or error in the process, meanwhile the purpose is to detect the presence of special causes in variations or error process [2]. FMEA had been applied since 1949 by US Army that
used it to solve problem of reliability and safety in design and production phases in sector of aeronautic. Tools of FMEA had become the standard practice in some country like American, Japanese and company of Europe manufacturing, from the sector of aerospace, electronics to the automotive sector also use in the food industry, sector of energy and the arena of medical and pharmaceutical. Many research carried to increase the using FMEA performances in the previous decade. On the off chance that the consequences of QC tests can't satisfy the acknowledgment models, the aftereffects of examination of the entire arrangement of the estimations on that day must be eliminated or should be re-dissected, and an incomplete or full re-approval of the strategy considered [24].

2. Research Method
This paper discuss about the most general topics of using Statistical Quality Control and Fuzzy Failure Mode and Effect Analysis (FMEA) method in the Service and Product Manufacturing Companies, Sustainability Renewable Energy by review the literature that was issued in a systematic ways.

2.1 Inclusion Criteria
Journal of researches that use in articles taken through academic journals of in Statistical Quality Control and Fuzzy Failure Mode and Effect Analysis fields or relate it in lead databases of journal. The database of journal takes from Taylor and Francis, Springer, Science Direct and Emerald Insight.

2.2. Selection of Paper
Literature searching that used had derived from databases of academic such as Taylor and Francis, Springer, Science Direct, and some literature from Google Scholar from Indonesian so that the literature search in English and Indonesian language. The selection paper doing by two method including based on reading of paper abstract sides and then reading all of contents in the paper in order to get the final selection list of papers. List of paper collected by list the initial has 30 paper that relevant to the topic will include to the review. Process selection the initial of paper doing together by authors base on the name of author and read paper abstract. In the paper who the first author read all 20 papers chose in detail.

2.3. Output Data
Paper/journals which chose by the author count 20 journal that will be read again in order to consider the implementation of Statistical Quality Control and Fuzzy FMEA where the method application in Service Industry, the Product Manufacturing Companies, Renewable and Sustainable Energy, Construction Project and Healthy can be seen in Table 1.

| Journal Name                                      | Country               | Industries                              |
|--------------------------------------------------|-----------------------|-----------------------------------------|
| International Journal of Research in Engineering | India                 | Pipe Manufacturing Industry             |
| and Technology                                   |                       |                                         |
| Renewable and Sustainable Energy                 | Parana, Brazil        | CASA, Project Laboratory                |
| Manufacturing Technology                         | India                 | Automotive Assembly Manufacturing       |
| International Journal of Quality                 | Vicosa, Brazil        | Food Industry                           |
| and Reliability Management                       |                       |                                         |
| International Journal of Quality                 | Penang, Malaysia      | Food Industry                           |
| and Reliability Management                       |                       |                                         |
| The TQM Journal                                  | Tiruchirappalli, India| Rotary Switches Manufacturing           |
| International Journal of Quality                 | Ancona, Italy         | Manufacturing Industry                  |
| and Reliability Management                       |                       |                                         |
| International Journal of Production              | West Yorkshire,       | Chemical Manufacturing Industry         |
| Research                                         | Englund               |                                         |
3. Result

3.1. Statistical Quality Control and Fuzzy FMEA in Product Manufacturing Industry

The previously paper by Claudia Paciarotti Giovanni Mazzuto Davide D’Ettorre has proposed implementation Fuzzy Failure Mode and Effect Analysis to control the product quality in chemical manufacturing industry. A survey by questionnaire show that first part of the investigation, declare that industries sector was low in using technique of statistical quality control. Information from operation of Quality Control in an organization indicate that industry is well in procedure of analysis and data collect in big volumes. It show out that valid statistical interpretation and list of this material. This paper also discuss the quality control of lean factory suppliers and the correct choice of suppliers is a main key for component quality improvement [3].

The other research did by Tay and Lim shown their assign leading that enhancement of FMEA with fuzzy inference technique. Risk priority number was used to reckon actions which priority as a respond of failures in system. Paper also discuss the using of FMEA base fuzzy approaches as a technique to solve the problem that found by conventional approach. The using technique of fuzzy inference so, model of new fuzzy risk priority number model was generated and formulate on the basis of refining the weight of system existing [4].

S. Vinodh et al. using fuzzy grading technique on rotary switch. The relationship between failure mode and assessment is made on formulas basis. Furthermore, a ranking of various factors is carried out the effects at the same level and the next level. and the results show before and after taking action to solve the failure of the rotary switch. After detecting failure, act accordingly. After detecting a failure, the related actions that have been taken to correct this failure are also shown in this table. The new RPN is calculated after taking corrective action [5].

Pinnarat Nuchpho, et al. proposed SQC and Fuzzy FMEA to find the causes factors of defective products in plated bath of sanitary ware products type page settle (K-160). Result of research show there scratches on plated bath surface of products and by analyse the causes factors using total quality management (TQM) use statistic tools such as pareto chart, cause and effect diagram, and techniques of failure mode and effects analysis (FMEA) for continuous improvements and risk priority numbers determining, which will show the level of risk associated with a potential problem [6].

Other research also by Pinnarat Nuchpho, et al. discuss of using Fuzzy Failure Mode and Effect Analysis as method which can identify the factors that causes disabilities of product in the production
of poultry in the food industry. Some causes factors had analyzed by took brainstorming by the consensus that specialist in order to evaluate problems factor to achieve determination on the level of violence. FMEA method then give the number of risk priority number which indicates the risk must be correct immediately and can evaluate three parameters that are severity number, occurrence and detection. The results showed that the efficient and feasible fuzzy based FMEA method could reduce defects in poultry products [7].

Muhammad Ragil Suryoputro discusses Fuzzy FMEA method in a manufacturing company to had machines risk management that have performance in low level. The results of quarterly reports of four maintenance sections such as forklifts are the machines and facilities with the lowest NPM. The appropriate method to be used in this research is Fuzzy FMEA (Failure Mode and Effect Analysis), so that priority is obtained in forklift repair and maintenance. [8].

Vayska Eliana Runtuwene, et. al apply statistical quality control tools in the production process and in the final product to reduce defects by identifying where waste is highest and provide the improvement suggestions. The appropriate approach used in this study is direct observation, inspection of all production process lines, fishbone diagrams, and information gathered from the company through interviews, and a control chart (p-chart). It has been found that the company has good quality control but still finds defective products. The main objective of this study is to create awareness to the quality team on how to use statistical tools in problem analysis, especially to train the quality team on how to conduct effective sessions of brainstorming, and to utilize this data in the construction of causal and control charts construction [9].

Kapil Banker, et al applied statistical quality control in the pipe making industry. There found some defects in the manufacture of stainless steel welded pipes, because of these defects, the pipes are discarded wisely, and it is a very unproductive result for any industry. Statistical quality control (SQC) tools, such as x bar charts, R charts, C charts, P charts had used to measure the variability/disabilities in processes. It show good results about the process, whether controlled or not. This chart type will also provide quick results with which to take immediate action. Result showed it can used by any manufacture company to solve the defective products problem, increase productivity and quality of product [10].

Soham Kulkarni. Et al. applied technique of statistical process control to keep well the quality of the torque wrench that use in the workstation to produce the proper torque and other necessary precautions, taking into account the completeness of the economy. Process in each workstation, the ability of the process to reduce dependence on inspection. Application of the torque required to achieve the correct amount of clamping force preventing the fastener from loosening or the joint from failing due to its relative motion. The project improves process safety in the ABC industry using statistical process control (SPC), control charts and process capability indexes and further reduces errors at 10 scooter stations and 11 motorcycle stations [11].

Sachin Kumar Mangla, et al. use FMEA method with Fuzzy membership approach method to facilitate manager of Green Supply Chain (GSC) and plan to model and access risks of Green Supply Chain and potential failures. They use the method to assess the risks that associate with the GSC to benchmark performance in terms of the effectiveness of implementing GSC management and sustainable production. The results show that the failure modes was gave of Improper green operating procedure like process, operations, etc. (R6) and Green issues while close loop of the GSC (R14) had the highest RPN and FRPN scores in FMEA conventional analysis and Fuzzy FMEA too [12].

Last literature that explain about SQC and FMEA method was show by Kai Meng Tay and Chee Peng Lim which use the simplify fuzzy logic based FMEA method to reducing the number of rules that needs to provide by FMEA users for modelling process of the fuzzy risk priority number (RPN) process. By apply rules of guides reduction system proposed to regulate the number of rules required during the fuzzy RPN modelling process. The effectiveness application that model investigated using three of the case in the real world studies in semiconductor manufacturing process [13].
3.2. Statistical Quality Control and Fuzzy Failure Mode and Effect Analysis in Service Industry
Md. Fazle Rabbi, et al. discusses developed FMEA based on the fuzzy theory approach and a prototype risk assessment using expert system, in this case implement fuzzy logic and inference systems to the Reach Stacker Crane (RST) that work consistent at the port. Reach Stacker Crane (RST) analysis is used to verify the using fuzzy base FMEA method that proposed. The results of the analysis of the study produced by the traditional FMEA and the FMEA fuzzy method indicate that a more accurate and reasonable ranking can be achieved by apply fuzzy based FMEA [14].

Ruey Huei Yeh and Mei-Huan Hsie propose an FMEA based on fuzzy theory approach and develop a prototype of an expert system of risk assessment. A sewage treatment system (STS) analysis is presented to demonstrate the proposed fuzzy FMEA method. According to the function of that method, so sewage treatment system can be classified into five subsystems such as waste collection, deposition, treated water disposal, chemicals, and sludge treatment [15].

Nalinee Chanamool and Thanakorn Naenna proposed of apply the Fuzzy Failure Mode and Effect Analysis in aim to develop a form of prioritization and failure assessment that suitable for work processes in the ER with analysis and identification of failures according to the Failure Mode and Effects Analysis (FMEA) method. Result of the application Fuzzy FMEA in the emergency department can be adopted properly. All members can judge without refraction from member of team. In addition, it can reduce the disadvantages of conventional FMEA. From prioritization to problem risk, it can also assist emergency departments in making decisions to correctly select problems for remedial and corrective action. Finally, it can build trust in the emergency process as well [16].

3.3. Statistical Quality Control and Fuzzy Failure Mode and Effect Analysis in Construction Project
Mohsen Ahmadi, et al present a comprehensive framework for manage major event of risk of a road construction project which classify in three stages that are (i) identification of potential risks, (ii) identify risk assessment and priority based on fuzzy FMEA and (iii) identify of appropriate responses. The main criteria analyzed to prioritize potential risk events are cost, time and quality which are combined and quantified using fuzzy AHP. One expert system is advised to identify appropriate risk response strategies for risk events based on risk factors, control numbers and risk allocation [17].

Debasis Sarkar and Manvinder Singh discuss the method for developing an integration Fuzzy Expected Value Method (FEVM) and the Fuzzy Failure Mode and Effect Analysis (FFMEA) method for the complex of infrastructure projects like elevated corridors constructions of metro trains in Ahmedabad, India. Identified risk analysis based on likelihood, impact, severity, detection, occurrence, and risk priority number. Further calculations of fuzzy risk severity (FRS), fuzzy risk priority score (FRPS), and risk ranking are carried out through the new application of fuzzy EVM and fuzzy FMEA methods. It was found that land acquisition, feasibility, tendering, segment installation, segment casting, mandatory widening, construction planning, launch girders, road widening, piles and piers were very risky and had a very high severity of fuzzy risk and a very high value of FRPS (0.605 - 0.775) [18].

3.4. Statistical Quality Control and Fuzzy Failure Mode and Effect Analysis in Renewable and Sustainable Energy
Arash Grunts, et al proposed SQC and Fuzzy FMEA to modifying and enhancing features of the quantitative / mathematical by aspect of failures by take computational and analytical then effects analysis (FMEA) process. It was to have a hybrid approach including FMEA based on Fuzzy Logic (FFMEA) and collective process capability analysis (CPCA) has been developed in three stages. First, the failure mode had determined according of the lack quality which characteristic of quality under investigation, next prioritized using the Fuzzy FMEA. Second, most critical failures were selected the analysis of statistical by using collective process capability analysis, in order to lead corrective action of the third phase. Then can investigate the proposed approach at manufacturing company an electrical equipment. The results showed a diameter deviation of insulators [19].
Maurício Guy de Andrade, et al. used Statistical Quality Control (SQC) with the aim of evaluating irrigation system of a micro-sprinkler using water pumping with a photovoltaic system, through the coefficient of uniformity and total energy generated by statistical quality control, by comparing the Shewhart control chart, Moving Average Weighted Exponential (EWMA) and Cumulative Sum (CUSUM) and classifies processes using a process capability index. Control charts are adequate for diagnosing treatments under limit control, and the EWMA is relevant for detecting small variability result of the test. The process capability index is relevant to classify the using of the processes. Statistical quality control is sufficient to determine process variability, recommending the use of the proposed system in the treatment, because of the lower of variability that relate to control charts [20].

3.5. Statistical Quality Control and Fuzzy Failure Mode and Effect Analysis in Healthy

G. Nilay Yüceur, et al. using the method where to risk analysis application into operational processes of a pharmaceutical company. In application study, operational processes of sample’s company were examined and analyzed from October to May. In the first phase, fishbone analysis was carried out to determine the risks in the operational processes and the potential risks in two separate production lines were determined. In the second stage, the risk prioritization method was used and risk priority numbers (RPN) were calculated for all risks. In all these analysis, more realistic and valid results were obtained with the usage of fuzzy logic and the calculations of RPNs were made more objective and independent from analysts. As a result, all examined failures’ risk prioritization numbers were reduced in the ratio between 72% and 90%, the operational processes were improved [21].

4. Conclusion

Statistical Quality Control (SQC) is a method using statistical tools that are used to collect and analyze data in determining and supervising the quality of production results efficiently and to identify or look for the root causes of problems with production failures / defective products. This method is generally used in the manufacturing industry to control the performance of the production process. The principle of SQC is product improvement by making improvements to the process so that the process can produce quality products. The FMEA method consist qualitative management that used for improvement process.

Method of FMEA will produce number of risk priority, it will show of risk problems and next evaluate the parameters of assessment, called severity (S), occurrence (O), and detection (D). Sometimes, this risk assessment give wrong priorities number/ranking. FMEA has become a standard practice tool in manufacturing companies in Japan, America and Europe in both the aerospace to automotive and electronics sectors, from the food industry to the energy sector and the medical and pharmaceutical arenas. FMEA is a tool and method for analyzing the causes of failure and predicting the impact of factors. The main purpose of FMEA is to assess the causes and consequences of failure modes in each component, determine possible failure modes, reduce possible failure modes and determine what can be eliminated. RPN is applied in the FMEA method to identify the causes of failure, and contains three parameters called severity (S), occurrence (O), and detection (D) [22]. The results of the analysis can help correct errors; pinpoint the causes of the adverse events in the process and resolve the performance in each phase of the operation. Fuzzy methodology is a popular method applied by FMEA technique [23]. In the assessment section, Fuzzy FMEA calculates a risk priority value rating (Risk Priority Number: RPN) to eliminate these defects. Fuzzy and FMEA methods have been widely applied in the construction industries, food and agriculture, industry of gas and oil, industry aerospace, industry of nuclear, steel section and others.

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