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# Quality Control with Six Sigma DMAIC and Grey Failure Mode Effect Anaysis (FMEA) : A Review

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**Abstract.** Currently, manufacturing industry competes in improving the quality of products produced, High demand leads to competition in similar manufacturing industries. Therefore, it becomes a challenge for companies to reduce product abnormality. Six sigma is a very early and potential ideology in this field. In production sector across the world, six sigma is well known and its asset is being taken for improving capacity and character achievement and also to make the course sturdy to quality alteration. The effectiveness of Six Sigma is well supported by anecdotal evidence. However, academic research on Six Sigma is still in its early stage. The review of Six Sigma and Grey FMEA case studies that is achieved in modest scale corporation, service company and product construction is showed in this paper.

## 1. Introduction

Six Sigma is quality tool aim for near perfection that is used in many organizations,. Six Sigma is based on evidence, analytical access and procedure. It is based on disqualify the deformity in any action. It can be used in management, product or service companies. [1] In the last two decades, Six Sigma is an important advance in quality management and process advancement. Six Sigma has gained wide reputation in various types of organizations since the 1990s.[2]. The Greek letter  $\sigma$  or 'sigma', analogous to our's', is a documentation of abnormality in the impression of standard deviation. According to the Six Sigma technique, a stable course the gap from the course mean to the nearest resilience cap should be at least six times the standard variation  $\sigma$  of the course amount. At most 3.4 Abnormalityives Per Million Opportunities (DPMO) will appear if the amount is normally distributed if the process mean varies at most 1.5  $\sigma$  from the target value, then on average at most. [3]

The fundamental goal of Six sigma technique is the application of strategy that is based on measurement and focused on course improvement and minimize the abnormality. The Six Sigma DMAIC courses (Define, Measure, Analyze, Improve, Control) is an advancement process for current courses that falls below stipulation and searching for additional advancement. [4].

The review of Six Sigma and Grey FMEA case studies that is achieved in modest scale corporation, service company and product construction is showed in this paper.



## 2. Research Methods

This paper discusses the most common topics Six Sigma in the modest Scale Companies, Service Companies and the Product Construction Companies by reviewing the literature that has been issued in a systematic way.

### 2.1. Inclusion criteria

Journal for research articles are conducted through academic journals in Six Sigma fields issued in leading journal databases. The database includes Elsevier, Taylor and Francis, Emerald Insight, Springer, and Inderscience. The main criterion used is to include paper which describes the research in quality control field by six sigma method in Modest Scale Companies, Service Companies and also the Product Manufacturing Industries.

### 2.2. Paper selection

The search literature is derived from academic databases including Elsevier, Taylor and Francis, Emerald Insight, Springer, and Inderscience. The literature search is only in English. The selection process has two parts where the initial selection of the search results, based on abstract reading of the paper, and then the final selection of the list of papers originally selected by reading the entire contents.

The initial list consists of 50 papers where there are relevant topics to include in our review. The initial selection of paper is done jointly by the author on the base of the name and abstract of the paper reading. The first author of the paper then read all 24 papers in detail.

### 2.3. Data output

Journal that has been selected as many as 24 journals will be read back to consider the application of Six Sigma. Information about 24 Six Sigma in the modest Scale Industries, Service Industries, Product Manufacturing Industries and also the Gry FMEA as seen in Table 1.

**Table 1. Information of Six Sigma Papers in Academic**

Journal Name	Country of Origin	Industries
Management Science Letter	Rohtak, India	Modest-Intermediate Enterprises
International Journal For Research In Mechanical & Civil Engineering	India	Modest Scale Thermoforming
Advances in Mechanical Engineering	United States	Modest-Intermediate Company
International Journal of Production Research	UK	Modest-Intermediate Company
International Conference on Industrial Engineering and Operations Management	Malaysia	Modest-Intermediate Company
The TQM Journal	India	Modest-Intermediate Company
International Journal of Mechanical Engineering and Technology	India	Modest-Intermediate Company
Total Quality Management & Business Excellence	London	Banking
International Journal for Quality Research	UK	Hospital
Journal of Healthcare Engineering	Jordan	Hospital
International Journal of Productivity and Performance Management	USA	Financial

International Journal of Retail & Distribution Management	US	Service
Managerial Auditing Journal	UK	OrganisationsService
International Journal for Quality research Scientific Research and Essays	UK	Aluminum Company
International Journal of Engineering Trends and Technology	Taiwan	Food
Engineering	India	Manufacturing
Fuel Processing Technology	KSA	Manufacturing
International Journal of Lean Six Sigma	Spain	Manufacturing
International Journal of Industrial Engineering	UK	Rubber Gloves
Integrated Manufacturing Systems	Mexico	Manufacturing
Engineering Failure Analysis	China	Manufacturing
Advances in Production Engineering & Management	Taiwan	TFT LCD Manufacturing
Safety Science	Turkey	Automotive manufacturing
	Singapore	Tanker Equipment

### 3. Results

#### 3.1. Six Sigma DMAIC in Modest Scale Industries

Prabhakar Kaushika, SandeepKumarb (2017) [5] discuss about Six Sigma is the technique of enhancing the aspect by minimizing courses abnormality, The knowledge that exists at this time continues to develop continuously to the subject. The case study used in this journal is a medium car company. In the locking part of the seat wheel nut with minimal components by reducing the K @ seat incompatibility with the DMAIC method. After applying the six sigma method, it is hoped that it will benefit from reducing waste and increasing product quality. Obtain six sigma results of  $5.53\sigma$  from  $1.59\sigma$ , have a significant increase.

AkhilKhajuria, AnkushRaina (2018) [6] has proposed implementation of six sigma technique is found successful in reducing the number of abnormalityive pieces and thus improving the level of sigma in modest scale thermoforming companies. Accomplishment was achieved in minimizing the abnormality rate and thereby enhancing the sigma value in. The final sigma value of 4.566704 is completed. However if companies want to retain or ehnanse this sigma amount, necessary control measures have to be done and proper checks have to be imposed. Quality culture must be developed amongst employees and proper training must be given to them. A good determination for project generation not only generates profits but also enhances customer amusement.

MuriloRiyuzoVendrame Takao, Jason Woldt Iris Bento da Silva (2017) [7] discuss about intense competitive production habitat output in modest- and intermediate- amount companies looking for technique to drive cost cutback and enhance quality. Integration The tools used in the six sigma method have problems, namely quality problems. In this journal the research uses the six sigma method and techniques related to minimizing cycle time and increasing sales. In this case, what you want to improve is measurement, analysis, market research and control using the DMAIC method. By way of market research researchers can define problems, and improve customer satisfaction. The results offered provide the effectiveness of companies from the middle to upper levels and many of the same companies use the same method.

Six Sigma method guarantees customer satisfaction and product quality discussed by Taieb Ben Romdhanea, Ahmed Badreddineb, ManelSansaa (2016) [8]. This method is difficult to apply to middle and lower companies, because there will be several problems such as lack of data and corporate financial

problems. The tools that are used are also complex, which are difficult to implement if the company is in the middle or lower so that the DMAIC method is difficult to implement. In this study discussed methods that can make six sigma can be used in the middle to lower companies, by avoiding blk belts, optimizing the structure, and optimizing operating costs. The results in this journal are companies that generate profits and customer satisfaction..

Another method that can be applied to SMEs is Lean Six Sigma (LSS) which will be discussed in this journal by Joshua Chan RenJie, ShahrulKamaruddin and IshakAbdAzid (2014) [9]. The LSS framework proposed in this study has a slight difference. The LSS method in this study was applied to SMEs only so the results were maximum. This research has a significant impact on the structure of LSS regarding the problems faced by SMEs before. One example of progress is on the A1 engine, where the engine produces productivity of 3,303 impressions / hour from 2,709 impressions / hour with a percentage of progress of 21.93%..

Application of Six Sigma Techniques for SMEs, the case study taken in this study is the bicycle chain UKM by PrabhakarKaushik (2008) [10]. This research can help other SMEs to create low-cost products with high quality. After the six sigma method is applied to SMEs, results are found that these chain companies can increase profits by controlling the rejection rate of orders and minimizing cycle times. The approach of this method recommends the project to produce the same result of 5.46 from 1.40 by reducing the defect in the diameter and in the process of making bicycle chain bushes. This increase in value is in line with the increase in SME profits by 0.288 million per year. These results indicate that the six sigma method can be applied to SMEs and middle and lower businesses..

Using the six sigma method on business or medium-sized companies or SMEs has been proposed by U. D. Gulhane, C.A. Nalawade, K.P.Sohani, V.S.Shirodkar (2012) [11] for a long time, but can only be applied now. He already has a file company to implement this method. At first he used the DMAIC method for this company to reduce the rejection rate by 35000 per million opportunities. This method lowers the rejection rate of 25.00 which was originally 35000 now to be 10000. This number is a minimum rejection rate with maximum profit..

### 3.2. Six Sigma DMAIC in Service Industries

The Six Sigma method is a method that has developed widely in the field of industrial services by integrating TRIZ techniques to support trasidonal techniques such as Lean Six Sigma discussed by Fu-Kwun Wang, Kao-Shan Chen (2013) [12]. Theoria Resheneyva Isobretate Iskehuh Zadach (TRIZ) is an effective method for analyzing customer needs and developing innovative solutions to meet those needs. One of the problems solved by the TRIZ method is that banking in the real world and lean six sigma are applied to the process so that the process becomes effective and relevant. The methods of implementing DMAIC and TRIZ applied to company T eliminate waste of waiting time to open accounts, modify business opportunities and create infrastructure to start and maintain greater performance and profitability. The concrete performance of the use of LSS at T-companies shows a cost savings of US \$ 828,000 and a clear increase in short-term and long-term process capabilities from 0.86 and 0.57 to 2.04 and 1.51.

S. Arun Vijay (2014) [13] aims to reduce the processing time and handling cycle of patients using the DMAIC and six sigma methods with a multi-disciplinary hospital model in India. He uses the five-phase DMAIC model with different tools and methods. Reducing cycle times and the patient's return process became the main goals in this study with a 61% reduction in the process time and patient cycle tim. Also, a control plan check sheet has been developed to sustain the Advancements obtained. This Study would be an eye opener for the Health Care Managers to minimize and optimize the cycle time of Patients discharge process in Hospitals using Six Sigma DMAIC Model.

MazenArafah (2018) [14] discuss about the Six Sigma process advancement technique was applied to reduce patients' discharge time in a cancer treatment hospital. Data on the duration of all activities, from

the physician signing the discharge form to the patient leaving the treatment room, were collected through patient shadowing. These data were analyzed using detailed process maps and cause-and-effect diagrams. Discrete event simulation was utilized as a decision support tool to test the effect to the advancement under different scenarios. Simplified and standardized processes, improved communications, and system-wide management are among the proposed advancements, which reduced patient discharge time by 54% from 216 minutes. Cultivating the necessary ownership through stakeholder analysis is an essential ingredient of sustainable advancement efforts.

Sameer Kumar, Anthony D. Wolfe and Katherine A. Wolfe (2008) [15] discuss the method of initiating customer credit cards at the middle and lower level of cooperatives that are dependent on various divisions and provide service companies with effectiveness in US finance. As a result, time and money can be effective and efficient. The method used in this study is to determine inefficiency, especially to reduce the number of days a company needs in response to requests, from the beginning to the time agreed before and have a good impact of 25%.

Sameer Kumar, Erika Strandlund, and Douglas Thomas (2008) [16] in the early stages they analyzed customer structure and store service to customers who came to be compared to the next competitor's shop. This study will examine the receipts of each buy buy service customer, the geek squad, and recommend growth rates that are more promising to buy buy customers, where buy buy has shared services such as poka-yoke in customer satisfaction..

Jiju Antony (2004) [17] discusses the application of six sigma which is increasingly developing in various manufacturing processes ranging from service to production processes that have various. Reduction of defective proceedings, and uncertain defective products can all be corrected which move significantly to the bottom of the organization. Simple comparisons between manufacturing and service processes. The survey results in this paper are presented in the material graph and the successful application of six sigma in the service sector.

### *3.3. Six Sigma DMAIC In Manufacturing Industries*

Kunal Ganguly (2012) [18] has discussed the issue regarding the export of Flat Rolled products with the number of requests that fluctuate every day with high variations with current resources. The method or principle of Six Sigma is used in identifying the factory situation when a milling operation is carried out at the factory. Know the source of the lack of resources, build variables and implement a quality control design. The result of this method is to find the most effective and efficient way to use resources. The most important benefit of this research is how to make the resources well-educated to support the company's future company. so that management techniques and methods can continue to grow.

Hsiang-Chin Hung and Ming-Hsien Sung (2011) [19] once used the DMAIC (define measure-analyze-improve-control) method at a restaurant company in Taiwan. The DMAIC method is used in solving the most basic problems and reducing the variability in the process. This study identifies how a food company has a systematic and orderly structure to achieve good quality management. The DMAIC phase is used to reduce the level of abnormality of simple custard bread by 70% from the baseline to the right. At the start of this project, the abnormality rate was 0.45% (Baseline), and after progress measures were carried out over a six-month period, this dropped to below 0.141%

Mohit Taneja, Arpan Manchanda (2013) [20] used the six sigma method to increase the productivity of a manufacturing industry company. In his research he began by identifying six sigma, then studying the literature as a whole about six sigma and DMAIC, applying six sigma in manufacturing industries from small-scale industries to large-scale industries. He also conducted a literature survey on six sigma quality techniques in the manufacturing industry and its tools. Process capability analysis, fishbone diagram and two sample tests he also discussed in his journal.

Lateef Ur Rehman, Ateekh-ur-Rehman (2012) [21] used the six sigma method in manufacturing management in the safety department of the company. The repair dam prevention system has its own department to know the health and safety of work that regulates the problem. Using the DMAIC or six sigma technique will reduce the company's costs and danger to the company in order to develop the application framework and control room..

D. Velázquez Alonso, L.M. Luis Pérez Lombard (2011) [22] proposed the six sigma method in an effort to increase energy efficiency in a naphtha plant installation. The results show that there was a savings of 150,000 € / year. This study uses 5 DMAIC phases to optimize the installation process and information that is useful in achieving maximizes the DMAIC process, and for progress in the future..

PloytipJirasukprasert et. al (2012) [23] used the six sigma method in a study he did in the abnormal process of making gloves. The technique of Six Sigma or DMAIC is one method that is often used in manufacturing for an organization. This study aims to reduce product variability and improve the management of company organizations. The results show that 50% occur in the sigma 2.4 defect product to 2.9. Company quality problems in Thailand.

AdanValleset. al (2009) [24] have used Six Sigma DMAIC technique in a semiconductor company dedicated to the manufacture of circuit cartridges for inkjet printers. Six Sigma project conducted at a semiconductor company dedicated to the manufacture of circuit cartridges for inkjet printers. They are tested electrically in the final stage of the process measuring electrical characteristics to accept or reject them. Electrical failures accounted for about 50% of all abnormalities. The major factors that were found through a design of experiments 3 factors and 2 levels were: abrasive pressure (90-95 psi), height of the tool (0.06-0.05) and cycle time (7000-8000 msec). The advancement was a reduction in the electrical failures of around 50%. The results showed that with proper application of this technique, and support for the team and staff of the organization, a positive impact on the quality and other features critical to customer amusement can be achieved

### 3.4. Grey Failure Mode Effect Anaysis (FMEA)

Ching-Liang Ping-Hung Chang Liu Chiu-Chi Wei (2001) [25] once discussed FMEA to determine priority numbers when multiplying the score to three. However, scores were obtained from subjective linguistic assessments, and the relative importance of factors was not considered. In the end the results of traditional FMEA theory are far better because they have a small bias value and it can increase product reliability and a stable process in determining what problems can be fixed from product design to process planning improvement..

Kuei-Hu Chang, Yung-Chia Chang, Tien Tsai (2013) [26] investigated the traditional RPN method that would be used extensively and thoroughly to calculate and understand the characteristics of a problem. But this method has serious drawbacks because the elements on the RPN have many numbers or the same results so that it is easy to imitate. But, it does not consider the direct and indirect relationship between FM and CF. So from that the RPN and GRA methods can be developed as needed. We have tried to reduce duplication problems and set priorities for criteria assessed according to GRA. Besides that, it uses the DEMATEL method to draw alternative results..

Baynal K. Sari, T.Akpınar B (2018) [27] discuss about contribute to risk management activities by proposing solutions to assembly line problems in an automotive manufacturing company by using combined GRA and FMEA method. Failure modes and effects analysis (FMEA) method is a risk management tool to stabilize production and enhance market competitiveness by using risk priority numbers (RPN). Although the traditional FMEA technique is an effectively and commonly used method, it has some shortcomings such as assumption of equal importance of the factors, severity, occurrence and detectability, and not following the ordered weighted rule. Thus, in order to improve RPN, an integrated method combining grey relational analysis (GRA) with FMEA is used in this study. In the proposed

method, the priorities of production failures were determined by GRA technique and these failures were minimized by using FMEA technique. The study results indicated the actions that lead to enhancement in the product. The application of corrective/preventive activities resulted in 96 % advancement in door seal cuts problem caused by the door step assembly. Door seal cuts problem caused by instrument panel assembly and the noisy door window problem are solved completely.

Qingji Zhou and Vinh V. Thai (2015) [28] discussing Mode Failure and Effect Analysis (FMEA) have been widely used in industries that have variability and other problems. In contrast to traditional FMEA, the risk factors for events (O), severity (S) and detection (D) of each of the criteria criteria will be evaluated by linguistic and fuzzy methods, and calculating the relative weights of criteria whose results will be good in choosing alternatives. The two theories above are used to calculate the ranking of priorities and risks that will be caused. Ranking of FRPN techniques and gray theory. The rating of the failure mode is determined by FRPN and gray theory. Examples of oil tanker equipment failures are provided, and the results show that evaluation of failure modes by fuzzy theory and gray theory is quite similar. The practical application of the fuzzy and gray theories proposed in this paper helps to improve predictive reliability, and equipment failure rating predictions can be used for better decision making regarding inspection and maintenance, which in turn will make tankers safer and more reliable.

#### 4. Conclusion

DMAIC Six Sigma techniques are often used in small and large scale companies, manufacturing services and manufacturing such as metal manufacturing, automotive parts processing, laser mouse manufacturing, semiconductor manufacturing, glove manufacturing, milling operations, rolling mills, file manufacturing. To maintain where the company also uses the IX Sigma method, the service industry such as hospitals has also used this method. This method is commonly used in projects that have high discipline to reduce work accidents. So many existing literature journals have found that there is no work that six sigma can do except in the steel casting process where the company is continuous. Use of this method to reduce the amount of disability and energy used or spent when producing defective products. as unexpected expenses. The results of the GRA and FMEA methods are flexibility in calculating the weight of each factor in FMEA, identifying the inner parts that will be discussed. Processing linguistic information based on expert knowledge and experience allows a pragmatic, thoughtful, and flexible way to suggest judgment.

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