Application of lean six sigma in energy saving lamp assembly process

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Abstract. Lean Six Sigma is an improvement strategy. Stimulated by global high-profile enterprises including CE, Motorola, Pfizer and Boeing, increasingly number of enterprises select it and promote its implementation. It can be observed, as an important measure, to study Lean Six Sigma and how to effectively apply the management approache of it gives preference to further the development of enterprises. Attributing to the high demand in energy-saving lamp, herein energy-saving lamps manufacturing industry is selected. Taking its one-off assembly yield as an instance, we integrate the data pre-treatment into the Lean Six Sigma Management Process, employ specific DMAIC implementation pattern and apply measuring system analysis, SIPOC analysis, fishbone diagram, FMEA analysis etc. For analysis to reduce in-process defectives, improve first time success ro, thereby to have the operation cost lowered, company quality level lifted and company competitiveness enhanced.

1. Introduction

Since the emergence of Six Sigma in Motorola, it has been defined as a technology to improve enterprises’ quality process management. It can provide impetus to lower quality cost to a large extent in the pursuit of “zero defective”, finally yield a higher financial effectiveness and breakthrough in enterprise competitiveness. Six Sigma Management has gradually developed into Lean Sigma Management which is combined with production and pure statistical technique. LEAN is such a most preferred mode that through the transformation of system structure, personnel organization, operation mode and market supply etc. It is implemented through PDCA (The meaning of PDCA is to divide quality management into four phases, which are planning, doing, checking and action). With the development of theories and practices, the theory of Six Sigma and LEAN are synthesized to have compensated for the imperfectness when either of them is individually applied. With DMAIC (Defining, Measuring, Analysing, Improving, and Controing), a specific pattern to push enterprises to continuously modify the Six Sigma, it represents the five phases of LEAN and Six Sigma Management. [1]

Research in the paper Management and Implementation of Six Sigma (2007) by Hezhen, Yuegang and Wang Lilin [2] indicate that the emergency of Six Sigma se per is an innovation in management and statistics. Generally, DMAIC process is adopted for follow-up existing process modification. And strictly speaking, Deming PDCA and DMAIC share no difference in nature. While at each stage of DMAIC, specific technologies and instrumental support are given, and voluminous methods and tools for modern management and statistics are generated. Therefore, Six Sigma is applied to have provided
the system with the ability to detect, analyse and resolve problems as well as technology route and methods to proceed in parallel therewith.

Analysis on Key Factors of Six Sigma’s Success (2009) by Bo Xiangping and Fang Fei [3] reveals its research outcomes: key factors of Six Sigma’s success mainly focus on the scientficity of Six Sigma process implementation and goal orientation of projects featured by source-saving and customer-centre, except for the attention and participation of senior leaders.

Wang Gang [4] analysed the reasons for the decreasing performance of SV companies in the appliance factories and then started from the current operation of the company, using the Lean Six Sigma theory, Lean manufacturing tools, DMAIC Six Sigma and so on. The result is improving production efficiency, product qualification rate, cost savings. He summarized methods and experiences, which are of reference value and practical significance to other enterprises.

In Research on quality improvement of the carriage in limited quantities based on six sigma management, Wang Jing [5]used six sigma ideas and methods which are aimed at improving the business process and customers satisfaction, combing with the passion analysis and regression analysis.

Combining with the actual case of bumping rate of water jacket core in ABC Company, Wang Xingxing [6] focused on the structure of Six Sigma DMAIC process and analyzed and studied the five stages of Lean Six Sigma in A Case Study of Lean Six Sigma Application in ABC Company.

In a research of Yu Hongbin [7], the application of advanced management methods was of vital importance to reduce the quality cost and improve the management level. Based on the current application of Six Sigma, this research put forward some problems that should be paid attention to in the future promotion of Six Sigma in China.

All these scholars’ researches indicate the increasingly vital role of Six Sigma has played in enterprises development. As Jack Welch, the youngest CEO of GE, said: “Six Sigma Management-Training plan is the birth place for the GE’s leadership for next century.

As for the industry of energy-saving lamp manufacture, the paper Application of Six Sigma Management in Energy-saving Lamp Assembly Based on Minitab by Wan Yuqian and his peers [8] was published in 2011. In their research, they chose the same DMAIC mode to improve assembly rate of energy-saving lamp mainly by Two-factor analysis of variance. This paper, based on the incomplete original data of their research, puts more efforts into pre-processing of missing data.

2. Method

2.1. Brief on energy-saving lamp production industry

Energy-saving lamp, also known as electricity-saving bulb, electrical bulb, compact fluorescent lamp or integrated fluorescent lamp, is a lighting equipment combined by fluorescent lamp and ballast (stabilizer). Due to the huge demand for energy-saving lamp from modern society and subtle differences in energy-saving lamp techniques, the integrity of process flow turns out to be the core competency for manufacturers, that is to enhance the qualified rate in one-off assembly of energy-saving lamp.

2.2. Data pre-processing

Our analysis is based on the example of lamp output and unqualified cases of group 2 in April, 2011. However, our data for processing is abstracted from Application of Six Sigma Management in Energy-saving Lamp Assembly Based on Minitab, so lacking of data from 18 April to 21 April results the origin data incomplete. Therefore, we introduce data pre-processing to deal with the incompleten. The step is to type known data to Mathematica and use method of interpolation function and interpolation to fit the absent data, and the data, calculated by interpolation, which is tested to be within the range of allowable error in acceptance.
Figure 1. Energy-saving lamp production of group 2 in April from interpolation.

- NS refers to no lighting on back lid.
- GL refers to gas leakage on back lid.
- ONS refers to no lighting on upper line.
- HLF refers to hot lamp failure.

2.3. D (Definition stage)

2.3.1. Current situation of qualified rate of one-off assembly. From figure 1, we can learn that there were total 89,804 energy-saving lamps of group 2 in April, among which unqualified products were 1,268 reaching 97% qualified rate. Figure 2 pareto chart reveals the main reasons for failures. It means that no lighting in back lid is the main reason, nearly as half as the lamp faults.

Figure 2. Pareto chart of reason.

2.3.2. Analysis on project process. We have made a SIPOC mode as figure 3, for clear reviewing of whole process, key points project and critical problems in each stage. As for the one-off assembly rate of energy-saving lamp, both S’s (Supplier) components quality, I’s (Input) assembly methods and environment, P’s (Process) quality control and other stages in process will affect the assembly rate.

2.3.3. CTQ and benchmark of energy-saving lamp. Specification of energy-saving lamps in this case is EB1, 52 25W 127V 50—60HZ. With precondition of 127V voltage, the qualified range for power is 22.5—27.5W. The paper aims to make analysis and modification on power data of energy-saving
lamps to reduce unqualified rate and hope to realize the goal of improving qualified rate from 97% to 99%.

2.4. M (Measurement)
Due to large quantity data of production of energy-saving lamps in April, we choose sampling measurement for better analysis on unqualified rate and its reason. Two operators A and B have measurement 3 times on 10 sampled energy-saving lamps and record as following table 1.

Table 1. Data analysis of measurement system in U=100V.

| operators | A   | B   |
|-----------|-----|-----|
| components| 1   | 2   | 3   | 1   | 2   | 3   |
| 1         | 23  | 23.1| 22.8| 23  | 22.9| 23  |
| 2         | 22.7| 22.9| 23.1| 22.8| 22.7| 22.9|
| 3         | 22.9| 23.1| 23.1| 23.2| 22.9| 23  |
| 4         | 22.7| 22.7| 22.7| 22.8| 22.6| 22.8|
| 5         | 23.3| 23.1| 23.1| 23.3| 22.9| 23  |
| 6         | 23  | 23  | 23  | 23.1| 23  | 23  |
| 7         | 22.8| 22.6| 22.7| 22.9| 22.7| 22.8|
| 8         | 23.4| 23.2| 23.3| 23.3| 23.1| 23.1|
| 9         | 23.4| 23.3| 23.4| 23.3| 23.3| 23.4|
| 10        | 23  | 22.9| 22.8| 22.9| 23  | 22.9|

Note: data from Application of Six Sigma Management in Energy-saving Lamp Assembly Based on Minitab

Power data measurement as consecutive data, the reason for choosing is that analysis of systematic measurement could reflect its comprehensive condition. The analysis on the above data by Minitab software reaches outcomes shown in figure 4 and figure 5.

![Figure 4. GR&R analysis outcomes.](image)

![Figure 5. R&R analysis outcomes.](image)

From above outcomes we can conclude that:
(1) The ratio of preciseness of measurement system to process specification is 8.82%<10%, which indicates that gage is acceptable for specified measurement capability.
(2) Category 5 based on ISO 9000 indicates that measurement system could make responsible classification on process variation in acceptable range.

(3) The 1st variation graph shows that most variations arise between components. The last graph tells us that no differences in operators and zero variation among evaluation persons.

2.5. A (Analysis)
Given the analysis target and reason of lamps failure, 100 more unqualified lamps in one-off assembly are sampled to do FMEA analysis for failure detection. The analysis mainly uses the simplified hazard-analysis method with risk priority number RPN as its core in FMEA analysis. [4]

According to the analysis of the influence factors in the above measurement stage, 9 influencing factors are divided into three parts of input, process and output, and the analysis results are shown in table 2.

**Table 2. FMEA analysis.**

| Potential Failure Mode       | Severity | Occurrence | Dection | RPN  |
|------------------------------|----------|------------|---------|------|
| Inputs                       |          |            |         |      |
| pseudo soldering             | 8        | 8          | 6       | 384  |
| poor diode quality           | 5        | 6          | 5       | 150  |
| crossing filament            | 6        | 7          | 6       | 252  |
| Process                      |          |            |         |      |
| unstandard operation         | 8        | 7          | 4       | 224  |
| uncertain fatigue status     | 6        | 4          | 2       | 48   |
| lack of relevant professional knowledge | 7 | 5 | 4 | 140 |
| poor contact or misdetect    | 5        | 3          | 5       | 75   |
| Outputs                      |          |            |         |      |
| unappropriate temperature    | 6        | 2          | 4       | 48   |
| untidy and dusty             | 7        | 3          | 3       | 63   |

9 main reasons and RPN value rank form table 3 below. Based on principle of RPN rank, A-level, over 200 scores, defines as factors for urgent improvement; B-level, between 100-200 scores, as factors for improvement; C-level, 100 scores below, as factors for general improvement.

**Table 3. RPN rank.**

| RPN rank | Potential Failure Mode       | RPN  | Priority |
|----------|------------------------------|------|----------|
| 1        | pseudo soldering             | 384  | A        |
| 2        | crossing filament            | 252  | A        |
| 3        | unstandard operation         | 224  | A        |
| 4        | poor diode quality           | 150  | B        |
| 5        | lack of relevant professional knowledge | 140 | B | |
| 6        | poor contact or misdetect    | 75   | C        |
| 7        | untidy and dusty             | 63   | C        |
| 8        | uncertain fatigue status     | 48   | C        |
| 9        | unappropriate temperature    | 48   | C        |

2.6. I (Improvement)

2.6.1. Modification for uncritical factors. Table 4 below provides modification advice for uncritical factors above, status of environment and staff or components quality.

2.6.2. Modification for critical factors. With Six Sigma’s principal “zero-fault”, we have acquired 3 critical factors for effects on one-off assembly rate of energy-saving lamp through a series of
experiments and evaluation in above analysis. This has laid a foundation to rate modification for further factors analysis.

1) Workers’ inappropriate operation, human variation, defines as A-level factor, which means the current workers in inadequate quality can easily make mistakes. Therefore, enterprises should strengthen vocational training on workers to improve their skills, quality and job responsibility.

2) Deficient welding: enterprises should provide workers with professional welding-technology training and check whether flux spraying vents narrowed routinely to avoid dust jam. Also attention should be paid to components depth. [8]

3) Threads winding as a critical stage of energy-saving lamp production, the research of Wang Yuqian indicates to choose filament winder with light vibration and thin sound, and adjust the machine to 2# position meanwhile using vertical winding as the best.

**Table 4. Modification for uncritical factors.**

| Failure                        | Modification                                                                 |
|-------------------------------|------------------------------------------------------------------------------|
| Untidy and dusty              | Employ cleaners and set up cleaning group to secure workshop tidy            |
|                               | Set some trash cans and rags for cleaning in workshop                        |
| Uncertain fatigue status      | Set shuttle work hours to avoid workers in long and consecutive job          |
| Inadequate temperature        | Turn on ventilating fans in workshop to maintain a suitable temperature      |
| Poor contact or misdetect     | Collate elements before covering plastic components to avoid elements contact especially electrolysis, capacitor, inductance, etc. |
| Poor diode quality            | Operators should be cautious and careful about components poor connect or misdirect. |
| Lack of relevant professional | Purchase diode from legitimate manufacturers and check its fine function before knowledge | installation. |
|                               | Set recruitment standard for production staff and provide pre-post training   |
|                               | Put job manual forehand to secure reasonable operation                       |

2.7. C (Control)

According to modification program, factory is supposed to do lamp production in May. And use computers to simulate the production results of May.

In order to test whether the production situation is getting better, drawn from daily qualified-rate of production data in April and May, I-MR (individual-moving range) has depicted figure 6 and figure 7 below.

![Figure 6. I-MR of April.](image-url)
Figure 7. I-MR of May.

It is clear that qualified rates of 3 days are failed to pass average test in April, whose moving range is large and even exceeds the required upper limit. After stimulation data modified, all points pass the average test without large moving range. The production becomes more stable and the process gets more fluent after modification.

3. Conclusions
The method of pre-processing of missing data performs an important role in this paper. It can be used more widely in later research. The research has improved the one-off assembly rate of energy-saving lamp of the enterprise nearly to standard of Six Sigma, both reducing rework rate and resource waste, and improving productivity and providing new method to follow-up quality management.

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References
[1] He X Q and Fu S J 2016 Six Sigma Quality Management and Statistical Process Control (Tsinghua University Press)
[2] He Z, Yue G and Wang L L 2007 Six Sigma Management and Its Implementation Application of Statistics and Management 26(6) 1049-1055
[3] Bo X P, Fang F and Krabbendam K 2009 Analysis of Six-sigma’s Critical Success Factors Journal of Hunan University (Social Science) 23(1) 1049-1055
[4] Wang G 2015 Application of Lean-6Sigma in Assembly Production of Company SV (University of Electronic Science and Technology of China)
[5] Wang J 2016 Research on quality improvement of the carriage in limited quantities based on six sigma management (University of Chinese Academy of Science)
[6] Wang X X 2016 A Case Study of Lean Six Sigma Application in ABC Company (Chongqing Normal University)
[7] Yu H B 2007 Application research of Six Sigma management in manufacturing enterprises in China (Hohai University)
[8] Wang Y Q, Fan S H, Pan M M, Wu B and Xia C Y 2011 The Application of Six Sigma Management Based on Minitab in the Manufacture of Energy-Saving Lamp Industrial Engineering and Management 16(03) 131-137