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# A systematic methodology for the creation of Six Sigma projects: A case study of semiconductor foundry

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**Abstract**

Nowadays, Six Sigma has been widely adopted in a variety of industries in the world and it has become one of the most important subjects of debate in quality management. Six Sigma is a well-structured methodology that can help a company achieve expected goal through continuous project improvement. Some challenges, however, have emerged with the execution of the Six Sigma. For examples, how are feasible projects generated? How are critical Six Sigma projects selected given the finite resources of the organization? This study aims to develop a novel approach to create critical Six Sigma projects and identify the priority of these projects. Firstly, the projects are created from two aspects, namely, organization's business strategic policies and voice of customer. Secondly, an analytic hierarchy process (AHP) model is implemented to evaluate the benefits of each project and; a hierarchical failure mode effects analysis (FMEA) is also developed to evaluate the risk of each project; and from which the priority of Six Sigma projects can be determined. Finally, based on the project benefits and risk, projects can be defined as Green Belt, Black Belt, or others types of projects. An empirical case study of semiconductor foundry will be utilized to explore the effectiveness of our proposed approach.


*Keywords:* Six Sigma; Project selection; Six sigma projects; FMEA; AHP

## 1. Introduction

Over the past few decades, Six Sigma has been espoused by many world-class companies and has also a lot of successful cases. The main benefit of a Six Sigma program is the elimination of subjectivity in decision-making, by creating a system where everyone in the organization collects, analyzes, and displays data in a consistent way (Maleyeff & Kaminsky, 2002). Six Sigma is regarded as a well-structured methodology for improving the quality of processes and products. It helps achieve the company's strategic goal through the effective use of project-driven approach. Six Sigma projects must be linked with business strategy and should meet the requirements of the customer. As Six Sigma is a project-driven methodology, it is essential to prioritize projects which provide maximum financial benefits to the organization (Coronado & Antony, 2002). Generating and prioritizing the critical Six Sigma projects, however, are real challenges in practice. To our knowledge, Six Sigma initiatives are not driven based on business strategy and thereby the Six Sigma projects neither achieve the expected benefits nor satisfy the requirements of customer due to the incorrect direction.

Pande, Neuman, and Cavanagh (2000) have indicated that there should not be too many factors in project selection; instead, choosing the five to eight that are the most relevant criteria for the organization would be sufficient. In Six Sigma initiative, although there are many criteria on which to judge the performance of Six Sigma projects, for instance, net cost savings, cost of poor quality, capacity, and customer satisfaction (Harry & Schroeder, 2000), it still lacks to have an standard and unanimous rule for selecting or prioritizing of those projects. Traditionally, Six Sigma initiative uses impact and effort on both dimensions to find out desirable Six Sigma project (Pande et al.,

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2000; Pyzdek, 2003). The effort of each project, however, is difficult to evaluate. Impact and effort dimensions are also hard to quantify. To resolve these problems, the facile quantification dimensions should be further developed.

Projects may differ in size, duration, objectives, uncertainty, complexity, pace, and some other dimensions. It does not matter how different or unique a project is; there is no doubt that every project contains some degree of uncertainty and there is no risk-free project (Tüysüz & Kahraman, 2006). The project manager should pay more effort to accomplish the project goal if the project involves with the high risks (Elkington & Smallman, 2002). In addition, the widespread applications of Six Sigma are possible because to the organization are able to articulate the benefits as reflected in financial returns (Goh, 2002; Kwak & Anbari, 2006). Therefore, the risk and benefits can be considered the dimensions to be used for selecting and prioritizing Six Sigma projects.

Semiconductor industries all over the world have had significant growth over the last decade in the world and also make up for the bulk of economic benefits (Arita & McCann, 2002). Semiconductor foundries are major suppliers of global semiconductor products. Owing to the market's competitiveness, a foundry usually employs a systematic and disciplined approach to move towards the world-class quality level. Nowadays, many foundries are interested in implementing Six Sigma to improve the quality of their products. Indeed, the implementation of Six Sigma methodology into a semiconductor foundry has become globally popular.

Semiconductor foundry requires a large volume of human resources, capital, and complex technology; therefore its organization structure has a complicated hierarchy and is usually divided into many different departments. Due to the organization structure is huge, when a semiconductor foundry wants to execute Six Sigma methodology some problems may arise. Some of these problems include the ways on how to link the projects with the business strategy, while the responsibility over the projects is scattered in different departments. Another concern is how to select the critical Six Sigma projects under the finite organization's resources? In a semiconductor foundry, projects are usually separated into several subsystems where a different department manages each subsystem. In this way, it is difficult to evaluate the priority of those projects. As a result, a systematic methodology is desired to solve these problems. This study aims to help a semiconductor foundry determine the Six Sigma projects and decide the project benefits and risk of those projects. Based on the benefits and risk priority, the projects can be defined as Green Belt, Black Belt or other projects.

This paper is organized as follows. Section 2 reviews the relevant literature used in this study. Section 3 presents a systematic methodology to generate Six Sigma projects and decide the project benefits and risks of those projects. In Section 4, a real case is studied to demonstrate the feasibility of the proposed methodology. Finally, the conclusion will be drawn in Section 5.

## 2. Relevant research

### 2.1. Six Sigma

Six Sigma was first espoused by Motorola in 1987 and was taken up by Allied Signal in 1991. In 1995, Jack Welch, the CEO of General Electric successfully established and published Six Sigma. He implemented Six Sigma in many processes and documented significant gains in process and financial results (Coronado & Antony, 2002; Pfeifer, Reissiger, & Canales, 2004). The simplest definition for Six Sigma is to eliminate waste and to mistake proof the processes that create value for customer. The elimination of waste led to yield improvement and production quality; higher yield increased customer satisfaction. Naumann and Hoisington (2001) have indicated that the concept of Six Sigma is the development of a uniform way to measure and monitor performance and set extremely high expectations and improvement goals. Treichler, Carmichael, Kusmanoff, Lewis, and Berthiez (2002) have concluded that Six Sigma is a highly disciplined process that helps an organization to focus on developing and delivering near-perfect products and services. The Six Sigma methodology of measuring and monitoring performance issue deals with a variety of statistical applications. The objective of Six Sigma is to enhance the sigma level of performance measures that reflects the needs of the customer. In addition, the Six Sigma level of performance means a product defect rate of 3.4 per million opportunities for error.

In order to achieve company goals, the critical-to-quality (CTQ) representatives of the product or service are identified. As the average CTQ capability increases, the capability of the corresponding process increases, make it further achieve strategic business goals. In an organization, Six Sigma is a top-down initiative led by the company CEO, and the hierarchy of trained personnel designated as Champion, Master Black Belt (MBB), Black Belt (BB), and Green Belt (GB) usually constitutes the infrastructure of a Six Sigma project. Current applications of the Six Sigma methodology emphasize the phases that are integrated in conducting a project, which include define-measure-analyze-improve-control (also known as the DMAIC cycle). The DMAIC cycle comes into play to meet the customer needs consistently and perfectly (Kuei & Madu, 2003). Su, Chiang, and Chiao (2005) have summarized the unique features of the Six Sigma approach include (1) sequences and links improvement tools into an overall approach (known as DMAIC); (2) integration of the human and process elements for improvement using a belt based organization (Champion, Master Black Belt, Black Belt and Green Belt), and (3) attention to bottom-line results and the sustaining of gains over time.

With Six Sigma methodology, the benefits of an organization include not only higher levels of quality but also lower levels of costs, higher customer loyalty, better financial performance and profitability of business. More related applications about Six Sigma methodology could be found in (Goh & Xie, 2004; Harry & Schroeder, 2000; Raisinghani, 2005).

### 2.2. Project selection

Project selection is the process of evaluating individual projects or groups of projects, and then choosing to implement some set of them so that the objectives of the organization will be achieved. Project selection is the one of the most critical success factors for the effective deployment of a Six Sigma program. The prioritization of projects in many organizations is still based on pure subjective judgment. Very few powerful tools are available for prioritizing projects. Snee (2002) has indicated good Six Sigma projects must possess some characteristics that are connected to business priorities, major importance to the organization, reasonable scope, etc. Gijo and Rao (2005) have proposed the Six Sigma projects must be selected in line with the organization's goal and objectives; furthermore, selection of suitable belt projects plays a vital role in successful Six Sigma implementation.

Snee and Rodebaugh (2002) have exhibited four key phases to maturation of the project selection process. Those phases include: identify Black Belt projects; create a project hopper; examine the project portfolio; and create an improvement system. Bañuelas, Antony, and Brace (2005) employed the cause-and-effect matrix to list all potential projects that are likely to affect the outputs of the process. The criteria used in this evaluating process are quality, waste and runtime. Through the evaluating process, the rating of each project provides the guidance that leads the team to select the right project. Antony (2004) has indicated some project selection criteria when a service organization wants to implement Six Sigma programs. Those criteria include financing, customer satisfaction, cost, risks and alignment of strategic business goals and objectives. If project selection is systematically sloppy, the entire Six Sigma effort could fail.

### 2.3. Failure mode and effects analysis

The failure mode and effects analysis (FMEA) is a reliability form of analysis. FMEA was originally used by the US military to evaluate the impact of system and equipment failures on mission success, and the safety of personnel or equipment. FMEA is a widespread technique that engineers can use to improve the reliability, quality, safety, and reduce the potential risk of their products (Roland & Moriarity, 1990; Teoh & Case, 2005). The method provides a well-defined process to inspect failure modes when manufacturing a device in serial product processes. In particular, FMEA can help an organization to identify, define and eliminate known or potential failures, problems and errors from products, designs, systems and services before they reach the customer.

The most important characteristic of FMEA is to evaluate the risk of potential failures identified for each subsystem or component. The risk priority number (RPN) is determined by three risk parameters which include:

- Severity rating (S): Severity is ranking according to the seriousness of the potential effect of the failure rated.
- Occurrence rating (O): Occurrence is ranked according to relative probability that the potential failure will occur.
- Detection rating (D): Detection is an assessment of the ability of a design to detect a potential failure before the part or assembly is released for production.

The multiplication of Severity, Occurrence and Detection values leads to what is known as the RPN.

$$\mathrm{RPN} = \mathrm{S} \times \mathrm{O} \times \mathrm{D} \tag{1}$$

Fig. 1 illustrates the process to enforce FMEA. FMEA can be divided into two phases; the first phase is to identify the potential failure modes and decide the value of Severity, Occurrence and Detection. In the second phase, the manager should make recommendations for correct actions, and the RPN needs to be re-calculated after correct actions. Today, FMEA is mainly applied in the industrial production of machinery, motorcars, mechanical and electronic components. The implementation of FMEA in a service area can be considered as a step toward a new direction (Adachi & Lodolce, 2005; Kozakiewicz, Benis, Fisher, & Marseglia, 2005; Scipioni, Saccarola, Centazzo, & Arena, 2002).

### 2.4. Analytic hierarchy process

Analytic hierarchy process (AHP) is a powerful and flexible tool for multiple criteria decision-making. It enables decomposition of a problem into a hierarchy and makes the best decision that involves the comparison of decision elements. Wu, Blackhurst, and Chidambaram (2006) used AHP method to decompose the inbound supply problem into several risk factors and evaluate the intensity of each risk factor. Hwang (2004) used AHP method to evaluate engineering project. The AHP is an eigenvalue approach to the pairwise comparison. The pairwise comparison judgments of AHP involve filling up absolute numbers into a reciprocal matrix. The numerical values are based on the relative impact between elements and the corresponding intensities are: 1 = equal, 3 = moderately dominant, 5 = strongly dominant, 7 = very strongly dominant and 9 = extremely dominant, along with intermediate values for compromise and reciprocals for inverse judgments and even using decimals to compare homogeneous elements whose comparison falls within one unit (Satty, 2006). More related applications about AHP could be found in Vaidya and Kumar (2006). The steps of AHP can be summarized as follows:

1. Set up a decision problem into a hierarchy with an objective, alternatives and criteria.

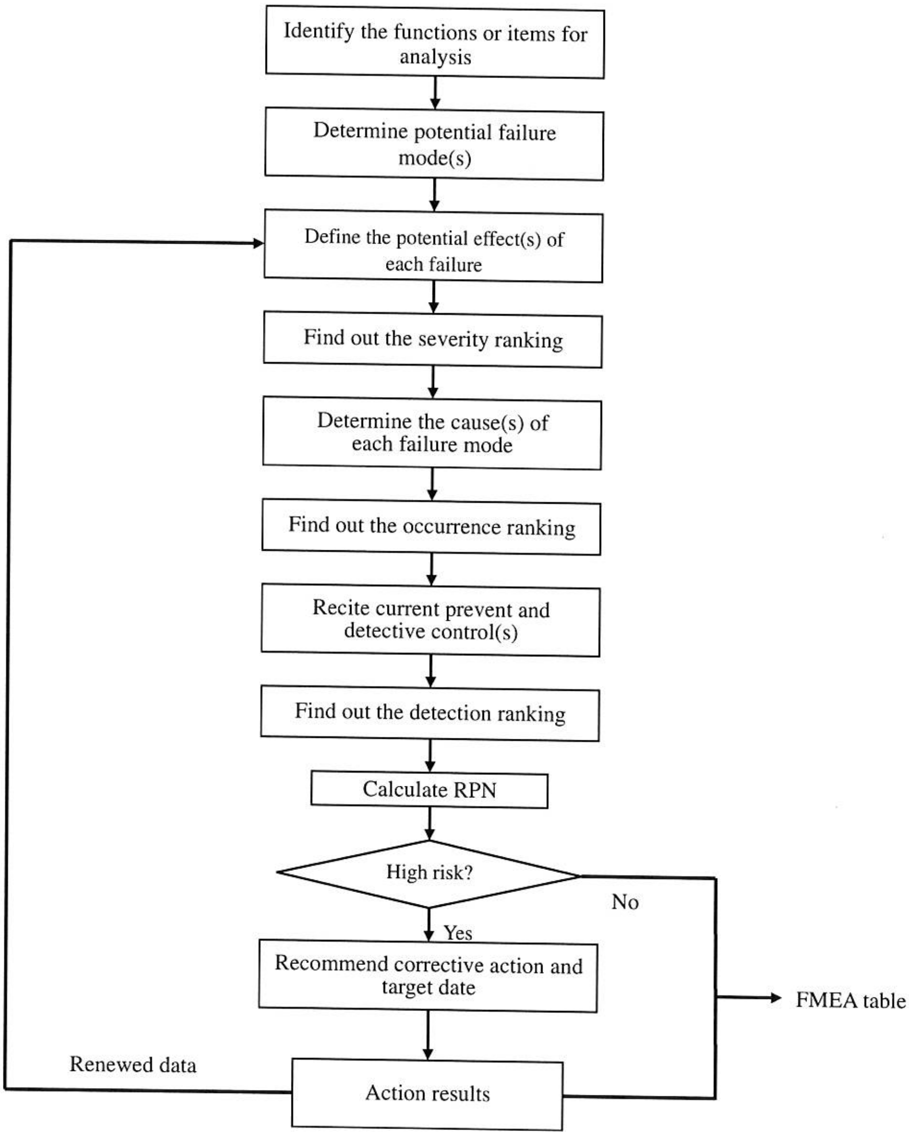


Fig. 1. The process of FMEA.

2. Construction of a series of pairwise comparison matrices on the basis of the relative importance of the criteria.
3. Perform all the pairwise comparisons and encode using the AHP relational scale.
4. Make calculations to find the maximum eigenvalue, consistency index (C.I.), and consistency ratio (C.R.) for each criteria or alternative.
5. Complete the synthesis by multiplying the criteria vector by the alternative matrix and obtain the best decision.

## 3. Proposed methodology

Six Sigma is a project-driven approach and by which the organization can achieve the strategic goal through effectively accomplishing projects. Deploying the organization's strategic goal into possible projects plays an important role in achieving success of Six Sigma implementation. Besides, a criterion to map the projects to GB or BB level seems crucial. Pursuing these problems, a systematic methodology was proposed in this study which aimed to identify the procedures of Six Sigma project generation, evaluation and mapping.

The proposed approach falls into four phases. The first phase is about project generation; the aim of this phase is to create possible Six Sigma projects directly linking to the voice of customer and the organization strategic goal. The second phase is the project benefits evaluation. Usually, Six Sigma benefits can be divided into two categories: hard savings and soft savings. Hard savings can be found by doing a financial analysis while soft savings involve intangibles, which may result in additional savings to the organization. We will use the hard savings and soft savings to evaluate the benefits of each project. The third phase is about project risk evaluation; this phase attempts to decompose a practical project into several subsystems and employ FMEA to evaluate the relative risk of each subsystem and determine the corresponding RPN of potential failure mode. Furthermore, using the pairwise comparison to decide the intensity of each subsystem's relative importance and integrate the subsystem RPN to be the project RPN. The final phase is the project mapping; in this phase each project will be grouped into GB, BB or other projects based on the project benefits and project RPN. Our proposed methodologies are detailed as follows:

1. Project generation
   - (Step 1.1) Understand and analyze the voice of customers (VOCs).
   - (Step 1.2) Drawing up the organization's business strategic policies.
   - (Step 1.3) Deploy the possible Six Sigma projects based on the organization business policies and the voice of customers.
2. Project benefits evaluation
   - (Step 2.1) Define the content of hard savings and soft savings.
   - (Step 2.2) Prioritize the benefits of each project through AHP method. The steps are as follows:
     - (1) Construct a set of pairwise comparison matrices for each subsystem.
     - (2) Calculate the weight between subsystems based on its relative importance.
     - (3) Inspect the consistency of the calculation.

The eigenvalues of each matrix represent the intensity among projects and will be used as importance weight to evaluate each project.

3. Project risk evaluation
   - (Step 3.1) Decompose a project into several subsystems based on the corresponding responsibility. The hierarchy structure is shown in Fig. 2.
   - (Step 3.2) Perform the FMEA for each subsystem.
   - (Step 3.3) Calculate the RPN value for each subsystem using geometric mean. The formula of geometric mean is:

$$(a_1 \times a_2 \times \cdots \times a_n)^{1/n} \tag{2}$$

     where $a_1, a_2, \ldots, a_n$ are the RPN value potential failure modes in each subsystem.
   - (Step 3.4) Generate the weight of each subsystem on the basis of its intensity of relative importance among all subsystems using the AHP method.
   - (Step 3.5) After obtaining the RPN and weight of each subsystem, the project's overall RPN can be calculated by summing up the multiplication of each subsystem's RPN and corresponding weight. The formula of the project's overall RPN is:

$$\mathrm{RPN}_{\mathrm{overall}} = \sum_{i=1}^{n} W_i \times \mathrm{RPN}_i \tag{3}$$

     where $W_i$ and $\mathrm{RPN}_i$ are the weight and the geometric mean of the RPN value for each subsystem, respectively.
4. Project mapping
   - (Step 4.1) The project benefits fall into three categories. The first category with inferior benefits has less impact to both company and customer. The second category with medium benefits is worthwhile and deserves to be executed. The third category with superior benefits is directly linked with the company's profit. The overall weights generated through AHP method can be the criterion for dividing projects into above three categories.
   - (Step 4.2) The project risk can be divided into three types based on the rule of thumb. The first type is low risk; this type is without urgent damage. The second type is medium risk; this type involves higher risk grade and needs a powerful tool or method to achieve the expected outcome. The final type is the high risk; this kind of project has the highest risk and might be with complex system.
   - (Step 4.3) From the two dimensions, namely, project benefits and project risk, the projects can be figured as a map. The project map shows as Fig. 3. As the diagram indicates, the project map consists of five different projects. They are low hanging fruit, GB, BB, non-value and laborious projects. The low hanging fruit project is easy to implement and require little in terms of capital, people, time or effort. A non-value project is a waste of effort to execute no marginal utility assignment. Despite laborious project provides superior benefits, it merits more attention because of the higher risk involved.

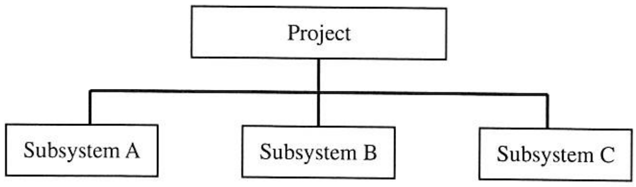

Fig. 2. Project hierarchy structure.

## 4. Case study

### 4.1. The case company

The case company is a world-leading semiconductor foundry located in Hsinchu Science Park, Taiwan. Its

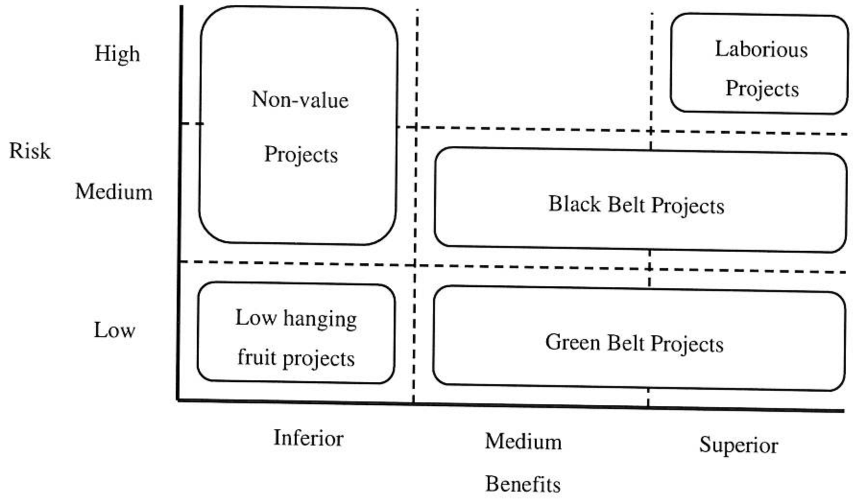


Fig. 3. Project map.

position as the foundry industry technology leader has been a major contributing factor to its rapid growth. The case company delivers the cutting-edge foundry technologies that enable sophisticated system-on-chip (SoC) designs, including 0.13 μm copper, 90 nm copper, and mixed signal/RFCMOS. The case company employs over 12,000 people worldwide and has offices in Taiwan, Japan, Singapore, Europe, and the United States. The case company wants to implement the Six Sigma and institute a Six Sigma department to overall plan the execution of Six Sigma initiatives.

When executing Six Sigma, the case company lacks an efficient way to deploy the business strategic policies to possible projects. Also there is no exact criterion to evaluate the benefits, the risks of each project and mapping the project. To overcome these problems, our proposed approach was carried out.

### *4.2. Implementation*

#### *4.2.1. Phase 1. Project generation*

To understand the voice of the customer, the case company performed a formal investigation by utilizing a customer satisfaction table (see Table 1). Each customer evaluated the products or services using a five-point scale, where A is excellent, B is good, C is acceptable, D is fair, and E is unacceptable. The case company chose its top ten important customers and asked for their opinion. The customers' feedbacks are shown in Table 1.

From the information gathered through the customer satisfaction investigation, the shipping on time rate and yield of wafer are the areas of most dissatisfaction. Through case company internal transfer, the wafer yield rate and product hit rate are the critical issues for customers. Therefore, the case company will combine the two

Table 1
Customers satisfaction table

| Customer | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| *Delivery* | | | | | | | | | | |
| (1) Speed of order reply service | C | B | C | C | A | B | B | C | C | C |
| (2) Daily WIP report | C | B | C | C | A | A | C | C | C | C |
| (3) Online network information | C | C | C | B | B | A | C | C | C | C |
| (4) Shipping on time rate | B | D | D | D | B | C | C | D | B | D |
| *Engineer service* | | | | | | | | | | |
| (1) Capability of manufacture | B | B | B | C | B | B | B | B | A | A |
| (2) Capability of engineering treatment | B | B | B | A | A | C | B | B | C | A |
| (3) Replay of customer complaint | B | B | C | C | A | A | B | B | B | B |
| *Quality* | | | | | | | | | | |
| (1) Yield of wafer | D | C | D | C | A | B | B | D | C | D |
| (2) Reliability of wafer | C | C | C | C | A | B | B | C | B | D |
| (3) SPC report | B | C | C | C | A | A | B | C | B | D |
| Service quality | | | | | | | | | | |
| (1) Service attitude of Sales department | B | C | B | C | A | A | B | B | A | A |
| (2) Service attitude of CE department | B | C | B | B | A | A | B | B | B | A |
| (3) Service attitude of Logistic department | B | B | B | C | A | A | B | B | B | A |

Table 2
Business strategic policies deployment

| Business strategic policies | Objectives | Important degree | KPI | Current status | Target | Possible projects |
|---|---|---|---|---|---|---|
| Increase the customer satisfaction | (a) Hit rate of product reach are more than 95% | A | Product hit rate | 91.15% | 95% | Increase of machine utilization in photo module |
| | | | Cycle time per layer | 3.85 days | 3 days | NMOS average cycle time exceeds four days, thus curtailing the NMOS product cycle time is necessary |
| | (b) Visit customers and understand their requirements | B | Number of CAR | 10 | 6 | Establish CAR systems and reduce the amount of customer complain |
| | | | The totality proportion of A, B and C grade in customer satisfaction table | 91.54% | 98% | Establish customer feedback systems and increase customer satisfactions |
| | (c) Increase the yield of wafer | A | Yield rate | 93.58% | 98% | Polishing of wafer project<br>Reduce Mvia Rs error rate<br>Improve IMD performance project |
| Focus on the critical production process and ensure the optimal quality and quantity | (a) Foster the critical manpower (Etch, Thin) | B | Quantity of persons for key stage | 15 | 25 | Recruit advanced manpower in critical stage |
| | (b) CVD, Poly etching are included in critical process | A | Scrap quantity per month | 800 | 100 | Establish SPC auto alarm systems and avoid questionable lot passing to next stage |
| Increase the order quantity of CMOS product | (a) Develop CMOS product order | A | Monthly order quantity | 9000 | 13,000 | C2010 product technology transfer |
| | (b) Product capability evaluation | A | Monthly product capability | 10,000 | 15,000 | |
| | (c) Engineering capability of critical CMOS product | A | Yield of C2010 engineering product | 60% | 85% | |

issues with the business strategic policies to deploy the possible projects.

The business strategic policies of the case company defined by the top management convention are as follows:

1. Increase customer satisfaction.
2. Focus on the critical production process and ensure the optimal quality and quantity.
3. Increase the order quantity of CMOS product.

Next, the business strategic policies served as guiding principles to deploy the objectives which consist of important degree and key performance index (KPI). In addition, the possible projects were generated based on the VOCs and each objective. The deployed results are shown in Table 2.

#### 4.2.2. Phase 2. Project benefits evaluation

The case company evaluated the anticipated project benefits. In terms of hard savings, the cost reduction and

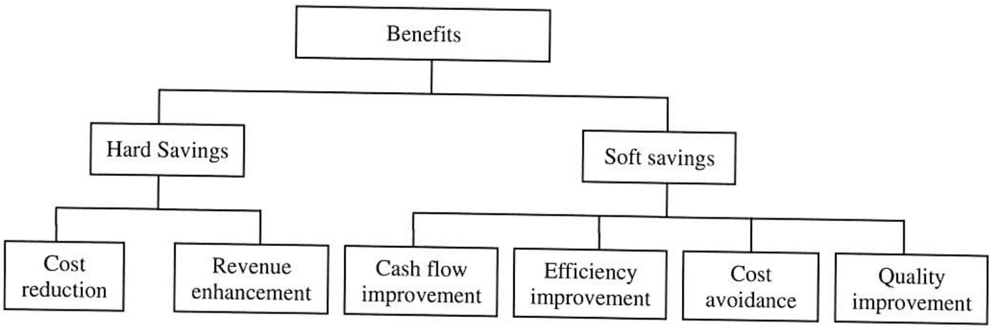


Fig. 4. Project benefits contain.

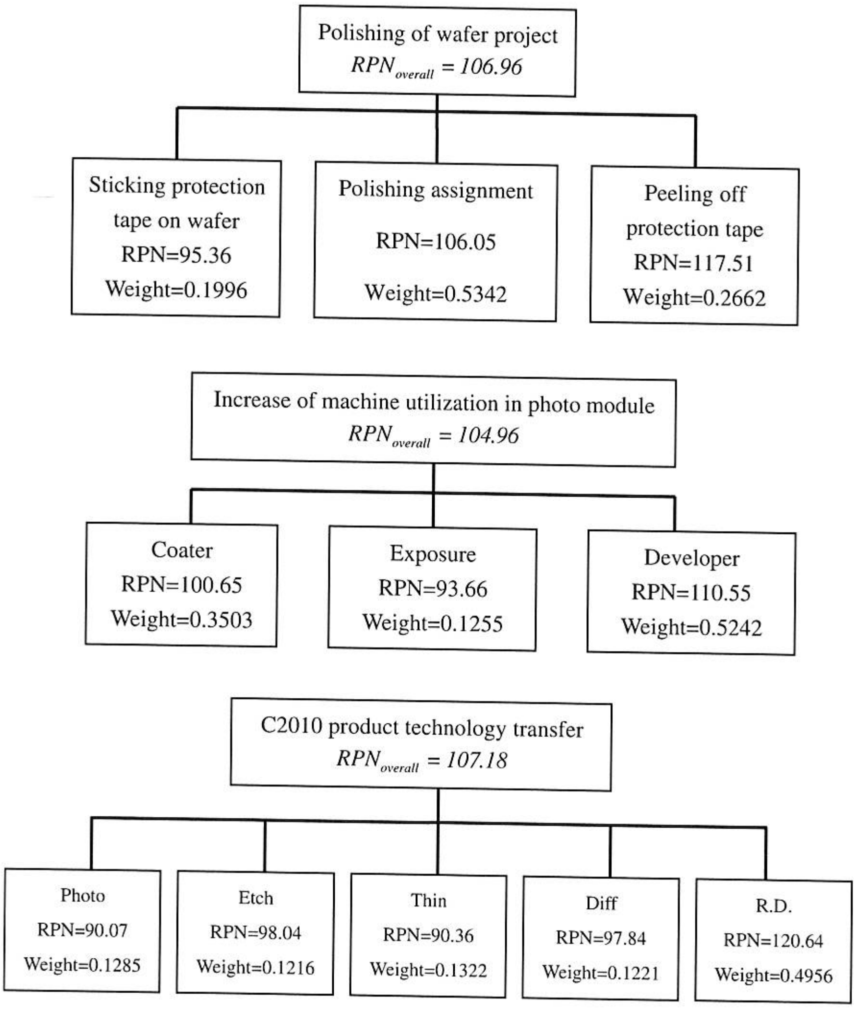


Fig. 5. Results of three projects' $RPN_{overall}$.

revenue enhancement were chosen to be the evaluated factors. The cash flow improvement, efficiency improvement, cost avoidance and quality improvement were used to criticize the soft savings. The project benefits structures are shown in Fig. 4. Each possible project was evaluated during project evaluation meeting. The meeting was led by a Master Black Belt. He convened the relevant members to discuss the benefits of possible projects. In this study, we selected three projects, increase of machine utilization in photo module, polishing of wafer project and C2010 product technology transfer, for a further demonstration.

### 4.2.3. Phase 3. Project risk evaluation

Due to the huge organizational structure and complex operational characteristic of the semiconductor foundry, each selected project was decomposed into several subsystems based on their corresponding responsibility by the leader of Six Sigma department. The polishing of wafer project was decomposed into three parts: sticking protection tape on wafer, polishing assignment and peeling off protection tape. The increase of machine utilization project was decomposed into three subsystems: coater, exposure and developer. The C2010 product technology transfer project was decomposed into five subsystems: photo, etch, thin, diff and R.D. For each subsystem, process improvement teams are organized by engineers to perform FMEA.

Each subsystem's RPN value can be obtained through calculating the geometric mean of the potential failure modes' RPN. For example, the RPN value in sticking protection tape operation was $(32 \times 32 \times 108 \times 112 \times 56 \times 64 \times 80 \times 96 \times 96 \times 112 \times 168 \times 168 \times 168 \times 168 \times 168)^{\frac{1}{15}} = 95.36$. Similarly, the RPN values in polishing assignment and peeling off protection tape operations were 106.05 and 117.51, respectively. Fig. 5 shows the decomposition results of selected projects and the corresponding RPN value of each subsystem.

The next step is analyzing the importance of each subsystem and generating its weight. The key person who conducts the pairwise comparison is the Master Black Belt. The reciprocal matrix for the polishing of wafer project through pairwise comparison is shown in Table 3. The maximum eigenvalue, consistency index, consistency ratio can be calculated through the information in Table 4. We used the Expert Choice software package to perform the weight of each subsystem. In the polishing of wafer project, the maximum eigenvalue was 3.0042, C.I. was 0.0021, C.R. was 0.0041. The C.I. and C.R. were both lower than 0.1; therefore this reciprocal matrix possess the consistency. The corresponding weights of each subsystem via pairwise comparison were 0.1996, 0.5342 and 0.2662.

Next, the project's overall RPN of polish of wafer project is: $\text{RPN}_{\text{verall}} = 0.1996 \times 95.36 + 0.5342 \times 106.05 + 0.2662 \times 117.51 = 106.96$. Similarly, the $\text{RPN}_{\text{overall}}$ of two other projects can be computed as shown in Fig. 3. The project with the highest risk was C2010 product technology transfer, followed by polishing of wafer project and finally the increase of machine utilization in photo module showed the least risk.

Table 3
The comparison matrix of polishing of wafer project

| | Sticking protection tape on wafer | Polishing assignment | Peeling off protection tape |
|---|---|---|---|
| Sticking protection tape on wafer | 1 | 0.35 | 0.80 |
| Polishing assignment | | 1 | 1.88 |
| Peeling off protection tape | | | 1 |

Table 4
Project evaluation results

| Code | Possible projects | Project risk | Project benefits |
|---|---|---|---|
| A | Increase of machine utilization in photo module | 104.96 | 0.130 |
| B | Curtail the NMOS product cycle time | 99.03 | 0.123 |
| C | Establish CAR systems | 93.62 | 0.066 |
| D | Establish customer feedback systems | 95.73 | 0.076 |
| E | Polishing of wafer project | 106.96 | 0.134 |
| F | Reduce Mvia Rs error rate | 98.73 | 0.124 |
| G | Improve IMD performance project | 106.73 | 0.152 |
| H | Recruit advanced manpower | 85.21 | 0.042 |
| I | Establish SPC auto alarm systems | 94.56 | 0.072 |
| J | C2010 product technology transfer | 107.18 | 0.081 |

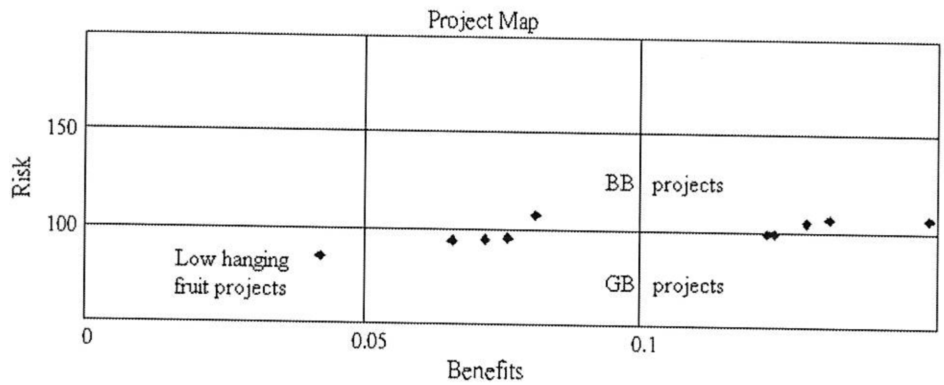


Fig. 6. Project mapping results.

#### 4.2.4. Phase 4. Project mapping

In this case, the value of $RPN_{overall}$ is used as the criteria for evaluating the project risk. As the value of $RPN_{overall}$ is lower than 100, the project qualifies as low risk. The medium risk is the value of $RPN_{overall}$ approximately between 100 and 150. While the value of $RPN_{overall}$ is higher than 150, it will be classified as a high risk project. The overall weight generate through AHP method can be the standard for ranking the project benefits. The first type is inferior benefits whose overall weight is lower than 0.05. The second type is medium benefits; the overall weight of this kind project is around 0.05–0.1. The final type is superior benefits; as the overall weight is higher than 0.1, it is classified under superior benefits.

The project evaluation result can be summarized as Table 4 and the project map shows as Fig. 6. From the analyzed results, those projects are divided into 4 BB, 6 GB and 1 low hanging fruit project. The next step is deciding on the suitable project leader and executing the improving action.

## 5. Conclusions

Six Sigma is the most fervent managerial methodology not only in manufacturing area but also in the services industry. Many investigations (Bañuelas et al., 2005; Goh, 2002; Linderman, Schroeder, Zaheer, & Choo, 2003) have indicated that Six Sigma can increase organization's competitive capability and enhance the quality of products or services by conducting the projects. Notably, project generation and priority performs the most critical parts while carrying out Six Sigma initiations. A good decision for project generation not only provides profits but also increases customer satisfaction. However, there still lacks a well-structured approach to assist a company in creating the feasible projects. This study aims to develop a systematic methodology to generate the project on the basis of the company's strategic policies and VOCs and determine the benefits and risk priorities of each project. Finally, the projects can be grouped into low hanging fruit, non-value, GB, BB or laborious projects.

This study has two advantages. First, a complete procedure from project generation to project mapping is provided which can assist top management in deciding on the critical projects. Second, the proposed approach is without complicated mathematical inference and can be easily implemented. The proposed approach, however, was applied to just one case, the semiconductor foundry service. The generalization of the proposed approach should be further investigated. Moreover, our proposed approach can be employed as a framework to develop computer software for general industrial application in the future.

## References


Adachi, W., & Lodolce, A. E. (2005). Use of failure mode and effects analysis in improving the safety of i.v. drug administration. *American Journal of Health-System Pharmacy, 62*(9), 917–920.

Antony, F. (2004). Six Sigma in the UK service organizations: Results from a pilot survey. *Managerial Auditing Journal, 19*(8), 1003–1013.

Arita, T., & McCann, P. (2002). The spatial and hierarchical organization of Japanese and US multinational semiconductor firms. *Journal of International Management, 8*, 121–139.

Bañuelas, R., Antony, J., & Brace, M. (2005). An application of Six Sigma to reduce waste. *Quality and Reliability Engineering International, 21*(6), 553–570.

Coronado, R. B., & Antony, F. (2002). Critical success factors for the successful implementation of six sigma projects in organizations. *The TQM Magazine, 14*(2), 92–99.

Elkington, P., & Smallman, C. (2002). Managing project risks: A case study from the utilities sector. *International Journal of Project Management*(20), 49–57.

Gijo, E. V., & Rao, T. S. (2005). Six Sigma implementation-Hurdles and more Hurdles. *Total Quality Management, 16*(6), 721–725.

Goh, T. N. (2002). A strategic assessment of Six Sigma. *Quality and Reliability Engineering International, 18*, 403–410.

Goh, T. N., & Xie, M. (2004). Improving on the Six Sigma paradigm. *The TQM Magazine, 16*(4), 235–240.

Harry, M., & Schroeder, R. (2000). *Six sigma: The breakthrough management strategy revolutionizing the world's top corporations*, Currency.

Hwang, H.-S. (2004). Web-based multi-attribute analysis model for engineering project evaluation. *Computers and Industrial Engineering, 46*(4), 669–678.

Kozakiewicz, J. M., Benis, L. J., Fisher, S. M., & Marseglia, J. B. (2005). Safe chemotherapy administration: Using failure mode and effects analysis in computerized prescriber order entry. *American Journal of Health-System Pharmacy, 62*(17), 1813–1816.

Kuei, C.-H., & Madu, C. N. (2003). Customer-centric six sigma quality and reliability management. *The International Journal of Quality & Reliability Management, 20*, 954–964.

Kwak, Y. H., & Anbari, F. T. (2006). Benefits obstacles and future of six sigma approach. *Technovation, 26*(5–6), 708–715.

Linderman, K., Schroeder, R. G., Zaheer, S., & Choo, A. S. (2003). Six Sigma: A goal-theoretic perspective. *Journal of Operations Management, 21*(2), 193–203.

Maleyeff, J., & Kaminsky, F. C. (2002). Six Sigma and introductory statistics education. *Education & Training, 44*, 82–89.

Naumann, E., & Hoisington, S. H. (2001). *Customer Centered Six Sigma linking customers process improvement and financial results*. ASQ Quality Press.

Pande, P. S., Neuman, R. P., & Cavanagh, R. R. (2000). *The Six Sigma way: How GE, Motorola, and other top companies are honing their performance*. New York: Mcgraw-Hill.

Pfeifer, T., Reissiger, W., & Canales, C. (2004). Integrating Six Sigma with quality management systems. *The TQM Magazine, 16*(4), 241–249.

Pyzdek, T. (2003). *The Six Sigma handbook: A complete guide for green belts black belts and managers at all levels*. New York: McGraw-Hill.

Raisinghani, M. S. (2005). Six Sigma: Concept tools and applications. *Industrial Management & Data Systems, 105*(4), 491–505.

Roland, H. E., & Moriarity, B. (1990). *System safety engineering and management*. John Wiley & Sons Inc.

Satty, T. L. (2006). Rank from comparisons and from ratings in the analytic hierarchy/ network processes. *European Journal of Operational Research, 168*, 557–570.

Scipioni, A., Saccarola, G., Centazzo, A., & Arena, F. (2002). FMEA methodology design implementation and integration with HACCP system in a food company. *Food Control, 13*, 495–501.

Snee, R. D. (2002). Dealing with the Achilles' heel of Six Sigma initiatives – project selection is key to success. *Quality Progress, 34*(3), 66–69.

Snee, R. D., & Rodebaugh, W. F. (2002). The project selection process. *Quality Progress, 35*(9), 78–80.

Su, C.-T., Chiang, T.-L., & Chiao, K. (2005). Optimizing the IC delamination quality via Six-Sigma approach. *IEEE Transactions on Electronics Packing Manufacturing, 28*, 241–248.

Teoh, P. C., & Case, K. (2005). An evaluation of failure modes and effects analysis generation method for conceptual design. *International Journal of Computer Integrated Manufacturing, 18*(4), 279–293.

Treichler, D., Carmichael, R., Kusmanoff, A., Lewis, J., & Berthiez, G. (2002). Design for Six Sigma: 15 lessons learned. *Quality Progress, 35*(1), 33–42.

Tüysüz, F., & Kahraman, C. (2006). Project risk evaluation using a fuzzy analytic hierarchy process: An application to information technology projects. *International Journal of Intelligent Systems, 21*, 59–584.

Vaidya, O. S., & Kumar, S. (2006). Analytic hierarchy process: An overview of applications. *European Journal of Operational Research, 169*, 1–29.

Wu, T., Blackhurst, J., & Chidambaram, V. (2006). A model for inbound supply risk analysis. *Computers in Industry, 57*(4), 350–365.