PROCESS IMPROVEMENT FOR NEW PRODUCT DEVELOPMENT

CASE STUDY: INTEGRATED CIRCUITS CHIP

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จุดมุ่งหมายของวิทยานิพนธ์ฉบับนี้คือริเริ่มวิธีการที่จะใช้ในการปรับปรุงประสิทธิภาพของกระบวนการพัฒนาผลิตภัณฑ์ใหม่ของชิพแผงวงจรรวม โดยวิธีการที่นำเสนอได้แนะนำแนวทางแก่ผู้นำโครงการถึงวิธีการจัดการโครงการที่เกี่ยวกับการพัฒนาผลิตภัณฑ์ใหม่อย่างมีประสิทธิภาพโดยลดการเกิดความล่าช้าในการดำเนินโครงการให้น้อยที่สุดได้อย่างไร โดยแนวทางการปฏิบัติเพื่อลดความล่าช้าที่เกิดขึ้นระหว่างดำเนินการพัฒนาผลิตภัณฑ์ใหม่ประกอบด้วย การจัดการข้อกำหนดและขอบข่ายของโครงการ (Scope and Requirement management), การเขียนแผนผังโครงสร้างงาน (Work Breakdown Structure), การวิเคราะห์รูปแบบความเสียหายและผลกระทบ (Failure Mode and Effect Analysis) และการบริหารจัดการมูลค่าที่ได้รับ (Earned Value Management)

แนวทางในการปฏิบัติที่ได้นำเสนอมีความมุ่งหมายที่จะแก้ปัญหาความล่าช้าในการพัฒนาผลิตภัณฑ์ใหม่ซึ่งเป็นอุปสรรคในการเจริญเติบโตขององค์กร โดยแนวทางเหล่านี้จะช่วยเหลือผู้นำโครงการให้จัดการพัฒนาผลิตภัณฑ์ใหม่เป็นไปอย่างมีประสิทธิภาพ เนื่องจากแนวทางเหล่านี้จะช่วยยกระดับการจัดการของผู้นำโครงการโดยให้ดำเนินการถูกต้องตั้งแต่ครั้งแรกที่ดำเนินงาน และให้ความเชื่อมั่นว่าจะไม่มีงานที่ไม่ได้อยู่ในแผนงานแทรกเข้ามาเพิ่มเติมระหว่างการดำเนินโครงการ อีกทั้งยังช่วยควบคุมและวัดผลการดำเนินโครงการเป็นระยะ

กรณีศึกษาที่ได้นำเสนอเพื่อที่จะทำการประเมินประสิทธิภาพของแนวทางการปฏิบัติที่ได้กล่าวไว้ในข้างต้น ได้ถูกเลือกมาจากหนึ่งในโครงการของบริษัทA โดยการนำแนวทางเหล่านี้จะถูกนำไปปฏิบัติในระยะต่างๆของโครงการซึ่งประกอบด้วยช่วงการริเริ่มโครงการ, ช่วงการวางแผนโครงการและช่วงการดำเนินโครงการ ซึ่งผลจากการนำแนวทางที่ได้นำเสนอไปปฏิบัติได้สาธิตให้เห็นถึงการกำหนดขอบเขตุและข้อกำหนดของโครงการอย่างเหมาะสม รวมไปถึงการจัดตั้งแผนงานอย่างละเอียดและการประเมินความเสี่ยงที่เกี่ยวข้องกับการพัฒนาผลิตภัณฑ์ใหม่ในเชิงวิเคราะห์ อีกทั้งยังแสดงให้เห็นถึงการดำเนินแนวทางการแก้ไขปัญหาที่ทันเวลาเพื่อลดผลกระทบเมื่อเกิดความล่าช้าขึ้นระหว่างดำเนินโครงการ

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The objective of this thesis is to develop the approaches to improve performance of new product development in semiconductor device. The proposed approaches are focusing on aspect of time which provides the guidance on how the project leader will effectively develop the new product with minimum of delay in schedule. The approaches that will be implemented to reduce or prevent the delay in schedule of new product development are consist of scope & requirement management, work breakdown structure (WBS), failure mode and effect analysis (FMEA) and earned value management (EVM).

These approaches are primarily intended to solve the delay in schedule problem that painfully hampers the business growth of Company A by assisting the project leader to effectively manage their new product development. The approaches will promote the project leader to manage it right at the first time, and assure there shall be no additional work in later phase of project while also periodically monitors and controls the progress of the project.

The case study is proposed to validate these approaches by selecting one project in Company A and implement these approaches into various phase of the project including initiation, planning and execution. The results of implementation have demonstrated the appropriate defined scope and requirements of the project, detailed constructive planning, analytical risk assessment of new product development and timely expected corrective action under project time line during execution.

Department:	Regional Centre for Manufacturing Systems Engineering	Student's Signature	....
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CHAPTER 1: INTRODUCTION AND STATEMENT OF PROBLEM

1.1 Introduction

Nowadays, technology plays an important role in driving this world to move forward and technology is dynamic. It keeps changing at an astonishing speed. Thus, we now realize that it is simple fact of life that when new advanced technological product is released, it always replaces any out-of-date previous products which have inferior function. It can be argued that if any technological company has possessed robust new product development process with capability to timely launch new product, it shall seize the competitive position and prevail among their rivals.

Although the achievement of new product development process with timely launching of new product is not simple as a thought, it requires a lot of efforts and disciplines of people in the organization to construct a good quality of new product development process. New product development process is complex and most of the organizations are facing with chaos and immature in this process. Unfortunately, there is no one-for-all solution to improve and maintain this development process; it depends on the organization to choose the approaches and improve it appropriately.

Furthermore, this thesis is directly intended to describe improvement for new product development which Innovation department (new product development team) of “A” company will be using as a case study. With regard to the fact that products of Company A are classified as technological product, so new product development and suitable launching period are considered as one of the key competitive advantages and has played a major role in enabling the Company A to thrive aggressively in this strong competitive market. Nevertheless, new product development process of Company A is ad hoc, immature and low success rate. Accordingly, Company A will encounter with dilemma to survive in the market that is necessary to introduce an appropriate solution to improve the situation.

1.2 Company Background

Company A is a global semiconductor company with deep core competencies and broad range of product portfolio which enable the company to become rigid supplier in this business for over 50 years of operating history. Moreover, Company A manufactures Integrated Circuit (IC) chips (or sometimes called semiconductor chips) that are used in a many types of business includes automotive, identification, wireless infrastructure, lighting, industrial, mobile and computing applications. In addition, Company A has designed and manufactured electrical solutions to serve the challenging needs of the electronic system. They embrace a broad spectrum of analog and digital technologies with the innovative ideas to deliver the unique electrical solutions that meet the critical requirement of their customers.

In operational perspective, Company A has divided its operations into two major sites. The first site is generally called front-end operation or fabrication site which primarily fabricates the semiconductor chip. The fabricated semiconductor chip contains the miniaturized electrical circuit that has a specific function regarding to customers' application. Another operation site is named as back-end or assembly operation. Generally, assembly site will receive the fabricated semiconductor chip from fabrication site, and then encapsulate it to protect the circuit from external environments or any hazards that can damage the circuit and cause it to malfunction. Additionally, Company A has 11 of operation sites worldwide which include Europe and Asia. All of the assembly plant are located around Asia while fabrication plant is mainly located in Europe and some in China.

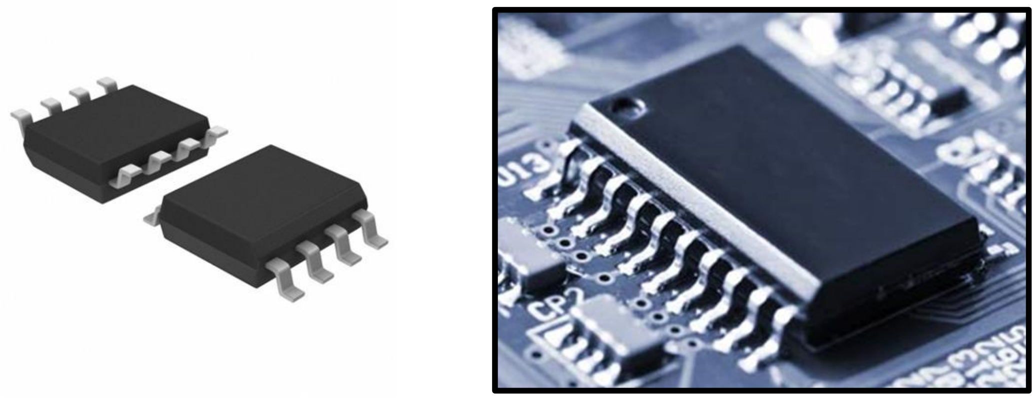


Figure 1 Outline figure of semiconductor chip

1.3 General Knowledge of Integrated Circuit Chip (Semiconductor Device)

Integrated Circuit (IC) is the miniaturized electrical circuit which constructed on to the surface of the semiconductor material by using micro-fabrication techniques. Micro-fabrication is an advance technology that has been used as the methods to create the super-small scale of the circuit pattern. IC semiconductor circuit (frequently called semiconductor die) plays variety roles in electronic systems which revolutionize the world of technology by increasing the functional performance while size of the device tends to be smaller. One of the major roles of this device is micro-controller or micro-processor which can be found in all kinds of electronic device in nowadays. Micro-controller provides the real time response to the electronic system and also establishes the programmable system. In addition, it is the advance of integration technology of analog and digital system. However, plain IC semiconductor die is too vulnerable, it is unable to withstand the operating environment and will be degraded with an expeditious rate.

Therefore, in order to shield the IC semiconductor die, it must be assembled into the electronic package. Then, this electronic package will be mounted on to the Printed Circuit Board (PCB) and enables semiconductor die to perform its function by connecting with the input/output peripheral device. The electronic package allows the

IC semiconductor die to tolerate the degradation while operating and also grants the mechanical support to IC semiconductor die. Another main advantage of this package is the enhancement of reliability performance and prolongs the operating life time. Furthermore, there are three fundamental categories of the packages including Plastic lead frame-based packages, Plastic ball grid array and Hermetic packages

1.4 New Product Development Process in Company A

The product of Company A is the electrical solution for the advance electronics system that sells in form of integrated circuit device and due to rapid technological advancement, it has directed the demands in the market to keep move forwards for new product that possesses in superior function, quality and cost. In such case, the new product development process is very critical because it is one of the core competitive advantages of business in this aggressive market.

New product development process is the development route which cover in design, qualification and implementation of new product with intention to assure that the new product is released with quality and met customers' requirements. Every new product will be separated to each individual project, and these projects will be assigned to available project leaders. Furthermore, these projects shall be executed in accordance with new product development process. Company A has created it own development process which is called *Business Creation and Management* (BCaM) process. It is the standard method for new product development inside the company. Moreover, BCaM process is based on stage-gate project management system. This system will divide the development activities into each particular phase and is separated by the decision gate. For each decision gate, project leader must submit a presentation of the progress made for that particular phase to the Project Review Board (PRB). Essentially, the authorization to pass the decision gate must be granted from

PRB team in order to move the project to next development phase. The new product development of Company A or BCaM can be divided into five distinct phase, each phase has different activities and deliverables. These five phases consist of Project Initiation Approval (PIA), Specification (S), Available (A), Verification & Validation (Weaver) and Release for Supply (R). The following diagram demonstrates BCaM process of Company A. The detail of each phase will be explained in later chapter.

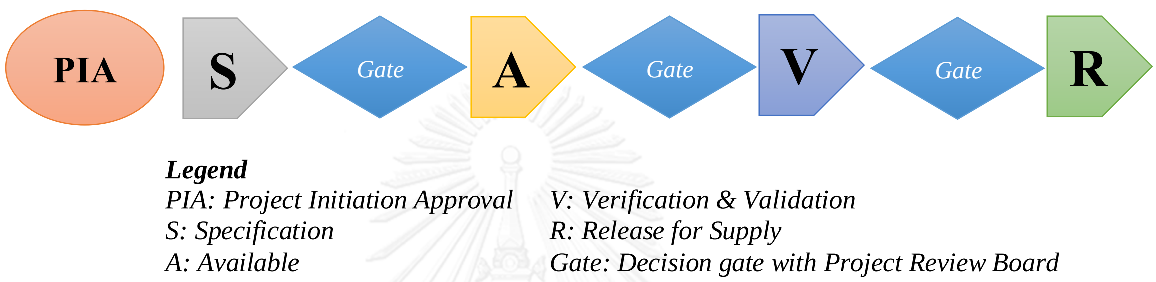


Figure 2 New product development process of Company A (Company A, 2011)

1.5 Statement of Problem

In new product development process of Company A, every new product will be separated into each individual project then assigned to each project leader in Innovation department. These development projects will be executed with regard to BCaM process. Furthermore, in this process, project management is intensively used to manage and introduce new product to manufacturing in mass production. A successful project management targets to allocate the limited resource to complete the project in the right time at minimum cost while preserving the quality of work.

Furthermore, the genuine product of Company A is the electrical solution that will be applied to the electronic system but the appearance of that electrical solution is demonstrated in form of semiconductor chip. Nowadays, technology is rapidly growth and most of the technologies are developed on the basis of electronic system. This has force the electronic provider to continuously develop their system in order to be competitive in the market. Subsequently, the very quick advancing of the electronic system has directed the needs of new challenging electrical solution (product of Company A) to serve it new electronic system requirement. Therefore, in order to fulfill the need of rapid technological advancement in electronic system, time to market of new product of Company A has become a key success factor to gain competitive advantage in the market. Launching new product in time with the demand in the market will greatly drive to the business of Company A.

Nevertheless, the complexity of semiconductor device tend to be continuously increasing whereas the customers also demand to deliver the product in shorter time. With regard to these constraints, new product development process has become very essential element to win the business because new product development process is the pathway which covers all activities that relate to new product introduction. Strong new product development process will significantly help the company to deliver new product to the customers with better quality and time-to-market of new product. Therefore, Company A requires to have robust new product development process in order to secure the business and increase their market share accordingly.

In these recent years, the level of complexity of each project is notably increased by technological advancement and the demand to use more resources to develop while the amount of new product development project is significantly plunged, it has driven the situation of new product development process of Company A into dilemma. Eventually, Company A has encountered with the delay in development of new product which leads to fail in time-to-market for launching new product into the market. This circumstance has caused Company A to start losing their market share and also failed to secure their position in the business.

As in 2011, one of the big automotive customers have requested Company A to improve the quality of one legendary product. Otherwise they will start to share the demand of this legendary product to Company A's competitor who have planned to launch their new product which has similar function but better in quality compare to product from Company A. Accordingly, Company A began to develop this new product to secure the business from their competitor, failure to do so will award the competitor for 4.6 million US dollars (3 years forecast) as demonstrated in Figure 3. Regrettably, the development of this legendary product have taken significantly longer time compared to their competitor, thus Company A have to lose the market share and it is extremely hard to bring this demand back because once automotive customers decide to change anything, they will not switch back easily, unless the product has really encountered with severe quality problem.

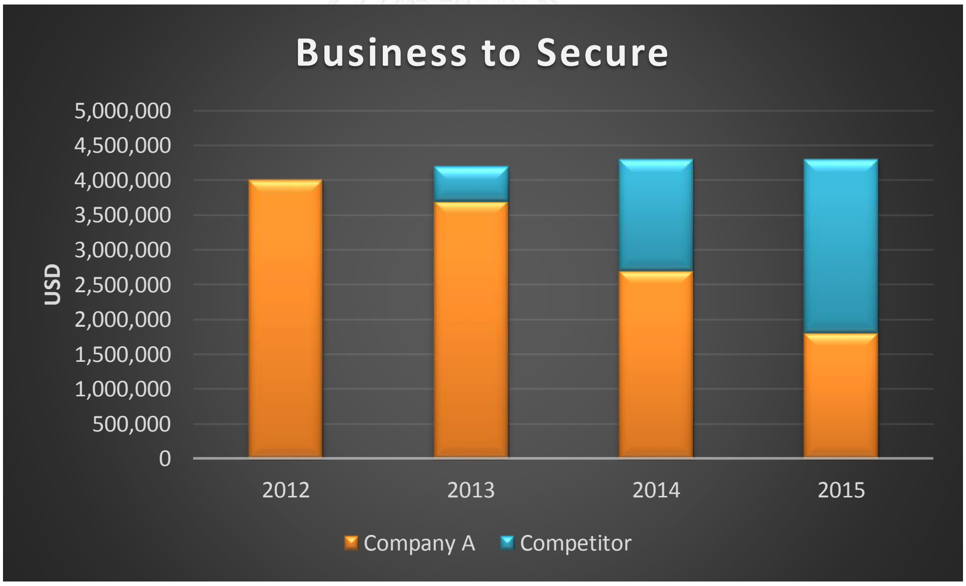


Figure 3 Historical data of business to secure of Company A

Furthermore, in 2013, the factory of one raw material supplier was severely damaged by the avalanche in Japan and it required almost a year for recovery the mass production of this raw material. This had effect to the whole supply chain of the affected products in Company A because this is one of the core materials in IC device. The alternative raw material was proposed but time is of the essence. The alternative raw material needs to be qualified with limited time otherwise, the material will be shorted, therefore the customers' production line has to be stopped due to shortage in supply of the IC device. In this situation, delay in qualification is extremely critical. Although, the qualification is delayed and the alternative raw material don't release in time and causes the production line down at customers' site while our competitors and subcontractors can fully release this alternative raw material in prior. The customers are absolutely dissatisfied. Company A has lost a lot of credits from this failure, and the damages are cost more than ten millions US dollars.

In addition, many large electronics manufacturers especially mobile phone maker usually hire more than one IC manufacturers to develop the same IC device, if that given IC device is considered to be very critical of the feature in electronic system. In such case, time is of the essence and success to timely deliver the product will lead to win the business of that developer. However, there are many cases that Company A has failed to earn the business because they are using very long time to develop the new product. These failures have caused the Company A to miss the opportunities to increase their revenue more than 10% growth in three years.

These tragedies have caused Company A to lose opportunities to thrive in the market and if it is continuously happening, the company might risk to lose the position in the market and lead to business failure and then cease operation at the end. In order to assess severity of the problem, the historical review was performed to identify the problem that has been occurred and it has been shown that the success rate of new product development is significantly declined from 73% to 30% within the past four years as illustrated in Figure 4. After declination of success rate has been noticed, further data collection is performed. The measurement for project time is agreed to count from Specification gate (S-gate) to Release gate (R-gate) which namely as S-R time. Timing for entering each gate and milestones of the project are recommended for defining at S-gate and shall be updated at every gate review. It has been observed that many of development activities in each project has encountered with the delay and leads to delay of the project. In 2013, there are 120 projects (out of 172 projects) that are considered to be failed (which is 70% from total projects) and 85% of failure is related to delay during development which leads to failure in introduce new product with time-to-market.

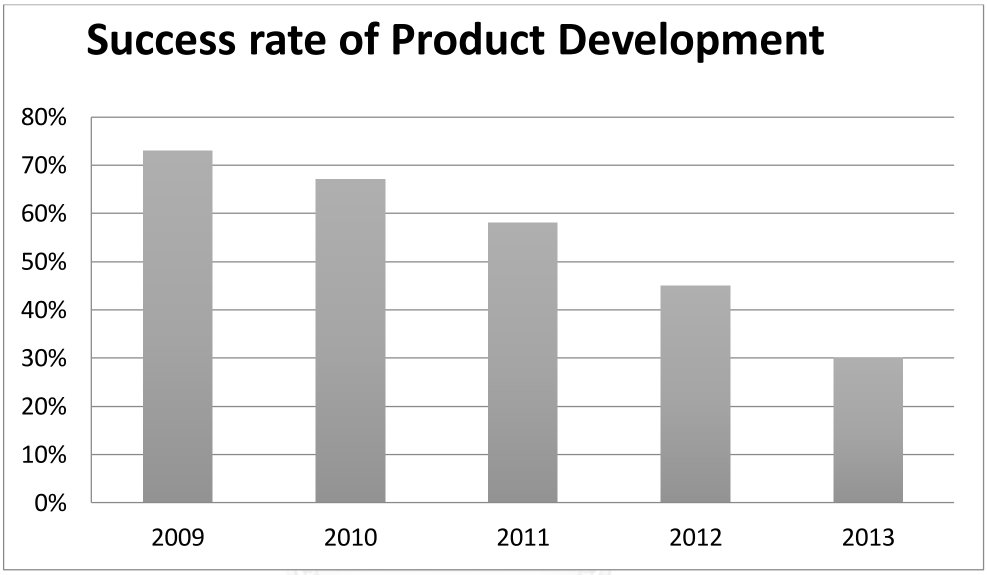


Figure 4 Success rate of new product development from 2009 to present

Accordingly, it can be argued that most of the failures in new product development process are contributed from project delay. Generally, project life cycle can be divided into four different elements which consist of project initiation, planning, progressing (execution and control) and closure. In order to have deeper insight to the problem of why project is delayed, the historical data are reviewed to observe the delay time on each process area of project. As demonstrated in Figure 5, it is found that most of the delay that was happening in new product development occurred in project progressing process area.

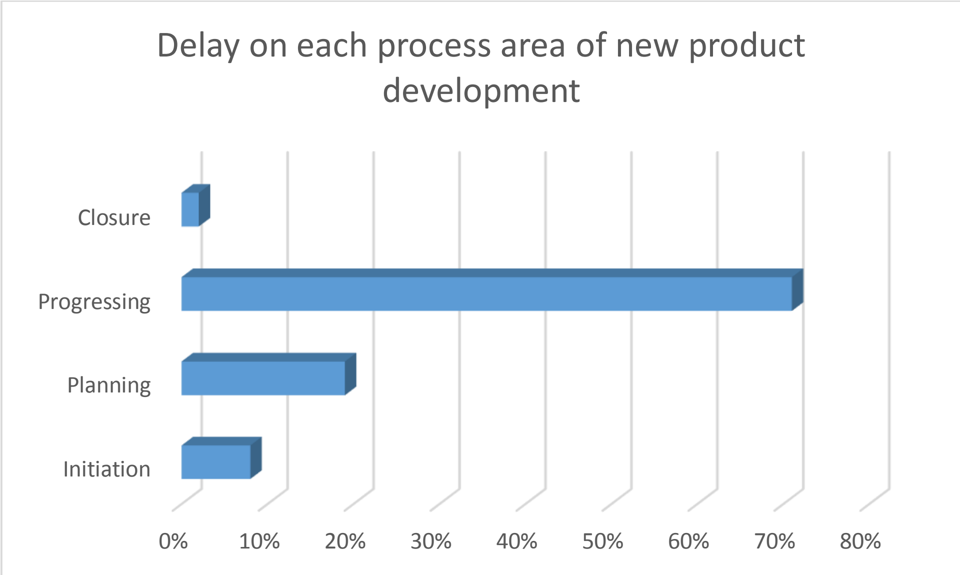


Figure 5 Proportion of total delay time on each process in new product development

Subsequently, Cause and Effect (C&E) diagram is introduced to identify the reason of why the progress of the project is slow and causes a lot of delay to complete the project. Improving performance of this process area can potentially reduce the delay in new product development process of Company A. The C&E diagram is demonstrated in Figure 6.

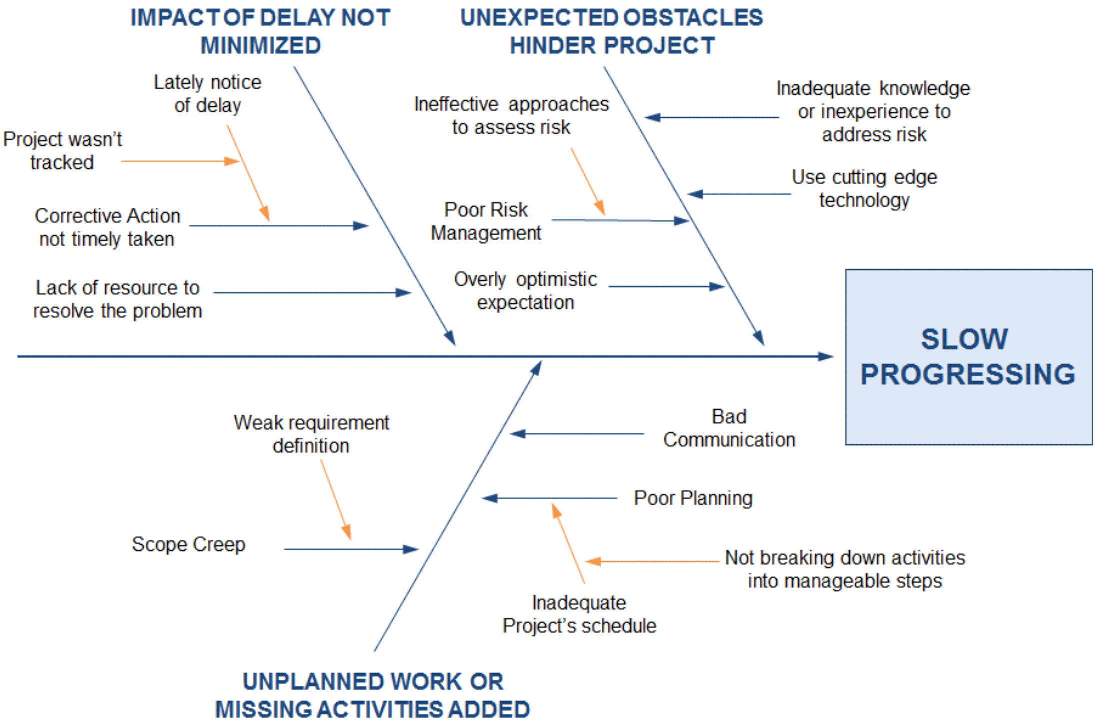


Figure 6 Cause and Effect Diagram of slow project progressing

With regards to the analysis from C&E diagram, it is shown that three factors covering unexpected obstacles of project hindrance, non-minimized of delaed impact and additional of unplanned work might potentially become major cause in hindering during the project progression.

Unexpected obstacles are the incidents that unanticipately happen and hinder the project to accomplish from their original agreement either in term of quality, time or cost. These majority of obstacles came from unidentified risk which will not have any contingency plan to mitigate the risk and this is happening because of poor risk assessment since planning phase. The poorer of risk assessment, the higher chance of unexpected obstacle to occur. Furthermore, it is typical for every project that shall encounter with the delay, if the project schedule doesn't develop by including all required deliverables or activities, so the project might encounter with the delay because it needs more time to complete the required deliverables which are not firstly identified since planning phase.

Therefore, it can be argued that the project planning is poorly developed. Another reason which can potentially cause the addition of unplanned work come from change in scope of the project during execution or commonly called scope creep. As the scope of the project is served as boundary, changing in scope regularly lead to the unexpected additional work which definitely requires more resources and time to complete, and it will result in fail to deliver the project in committed delivery time. Moreover, another reason that might cause the significant delay in project progressing is because of the impact of delay is not minimized in time. In case that the deliverables are not completed as planned but this deliverable is required for further activities, this will impede the progress of the project and create the delay that effect the whole planning unless the corrective action is timely taken to mitigate the impact.

Consequently, with regards to these existing problems, it can be implied that new product development of Company A requires a significant improvement. Otherwise, if these problems are not solved and keep persisting, it will hinder new product development process of Company A and cause many impacts to business of the company as described below.

- Decrease in revenue and losing market share because product is not competitive
- Lose an opportunity to sale
- Mistrust on commitment of delivery new product from customers
- Fail to launch new product with time-to-market to serve market demand

1.6 Research Objective

To improve performance of new product development process for IC semiconductor chip product.

1.7 Research Scopes

The process design in this research will mainly focus on improvement of new product development process and it is limited to use for assembly process of integrated circuit package in Company A.

- ❖ In this research, only three process areas will be taken into account consist of project initiation, project planning, project monitoring & control
- ❖ One of the priority projects in Company A that has suitable timeline with for verification will be selected as a prototype for verification and assessment.
- ❖ The timeline of implementation in this study is possible to cover only some part of the project, because the project has too long lifecycle (progressive elaboration)
- ❖ Some tools in this thesis will not be newly generated because those tools are available in the organization but not properly utilized
- ❖ Only Standard Outline (SO) IC semiconductor package will be discussed in this research

1.8 Research Methodology

1.8.1 Historical information review

The intention of this step is to review and collect historical data and demonstrates the success rate of new product development

1.8.2 Identify existing problem

1.8.3 Analyze and address the root cause of the problem

1.8.4 Literature Review

Study relevant literature, article and journals to this research for appropriate approach or concept that can be applied to this research

1.8.5 Define approaches and concept

Identify the approach, advantages and how to use that particular approach to solve the problem.

1.8.6 Implementation

Apply identified approaches to the case study (selected project in Company A) in order to validate the effectiveness of approaches.

1.8.7 Summary and compose the thesis

1.9 Expected Benefits

- Development activity in new product development process shall be planned and executed in accordance with the development policy
- Reduction of the frequency of delay in schedule of new product development project
- Increase the success rate of new product development in Company A
- Deliverables are properly controlled and satisfied their specified requirements, standards and objective

CHAPTER 2: LITERATURE REVIEW

2.1 Gantt Chart

One of the most accepted and widely used appearances for project schedule is Gantt chart because it is a simple tool but provides very good outlook of overall timeline throughout the project life cycle (Brassard & Ritter, 1994). Gantt chart is horizontal bar chart that presents the planning of activities or tasks to be completed with timeline axis to indicate the timing of each activity or task with more retrospective and diagnostic than the traditional bar chart. The first Gantt chart was developed with purpose to use in production control system (Weaver, 2012; Wilson, 2003). However, the Gantt chart is extensively practiced in nowadays as mostly applied to use in project's planning, coordinates and tracks the particular activity in the project (Rosso-Llopart, 2005). There are several advantages those make Gantt chart become useful in project scheduling. Firstly, the method provides realistic timeline and project's activities are organized according to the timeline. Secondly, it also clearly demonstrates the start and end date of all activities in the project. Additionally, Gantt chart is commonly constructed in horizontal bar chart which gives graphical demonstration for better of visualization to understand the relationship of each activity (ZigZagEducation, 2012).

2.2 Work Breakdown Structure

One of the essential elements that leads to effectively manage the project is planning, as CMMI (2010) has given the definition of the project schedule as the plan for controlling the project. As Yang, Chen, and Wang (2014) has mentioned in his research that many of product development companies have the best practices in project planning in order to reduce the risk in delay and cost overruns of the project while also note that the planning process is the key to success of any type of the project. Failure or lack of good practices in this process frequently lead to hindrance to the achievement of new product development process (Page, 1993). The project plan is the planning about the estimation of works or tasks that require to complete the deliverables, and transforms into the schedule for addressing the commitment to the project's customer (CMMI, 2010). Furthermore, the majority of the studies have suggested that the development of Work Breakdown Structure since project initiation phase will greatly help the projects leader to construct the detailed project's plan during the planning phase (Brotherton, Fried, & Norman, 2008; Project Management Institute, 2013; Taylor, 2009).

WBS is one of the most globally well-known project management techniques. It is the organized grouping of work elements or required activities of the project which demonstrate in hierarchy structure by subdividing the large activities to small pieces (Department of Energy, 2003) with the intention to identify the required deliverables. Project Management Institute (2013) provides the definition of WBS is the hierarchical structure of the scope of work with the process to subdivide the project's works and deliverables into smaller part which make it easier to manage. Hans (2013) has stated in his research that WBS provides the basis of better cost and time estimation during the planning phase because it serves as a foundation of the project, also emphasizes that it is an effective tool to increase the performance of project management. In addition, CMMI (2010) also mentions that with the sufficient detail of WBS, then the estimation of project tasks, responsibilities and time will be more specifically which assist in creating more realistic of project's schedule.

Furthermore, WBS has been widely used with several reasons that it has been contributed to the project. Firstly, it deconstructs the work and makes it easier for assigning the responsibilities. It also demonstrates the overall project in macroscopic level which help in communication with stakeholders and to assure that all deliverables are listed out. Moreover, with the hierarchy structure of the project tasks, it assist project leaders to have more accurate project organization and better estimation of cost, risk and time (Devi & Reddy, 2012). Moreover, it emphasizes the project team members to understand what is needed to be accomplished to complete the deliverables. In addition, as Devi and Reddy (2012) has been discussed in his research that the WBS can be used to quickly identify the deliverables that might impact from the delay of any activity that has been occurred during project execution. Furthermore, during the execution, WBS allows project leaders to have better performance on project tracking by measuring the performance on that WP or better focus on the area that issue or problem might effect.

The graphical form of WBS has facilitated the user to communicate work activities to stakeholders about the set of deliverables that is necessary to be delivered in order to complete the project's objective (Hans, 2013). Although, WBS is the best practices and has many advantages to project management, but poorly developed of WBS can leads to the unfavorable results in project management including, ambiguity of work assignment, unmanageable of work, time extension, missing activities and wrong estimation of time and cost as Brotherton, Fried & Norman, (2008) has mentioned in his article.

Additionally, Taylor (2009) describes the common mistakes and misconceptions as WBS is not the intensive list of work but rather as the decomposition of project scope with comprehensive of required deliverables and tasks. It was also mentioned that WBS is not a project schedule, but instead, it is used to develop the project schedule. Consequently, it is encouraged as the finest practices to complete the appropriate WBS in prior to start constructing the project schedule. Moreover, he also stated that some users have developed the WBS in the shade of the organization structure. WBS is not the organization chart while it is used for assigning the responsibility according to structure of the organization. In such case, the WBS will not demonstrate the comprehensive view of the project scope.

2.3 Risk Management

There are many definitions to describe the meaning of risk but the most common one is referred to the uncertain situation or even that might have positive or negative outcomes, if it occurs. Nevertheless, risk is everywhere and it is unavoidable, it inherent in every decision that we have made or any activity that we are going to do. Even in the business point of view, risk underlie in every form of business activities either in strategies, operations or developments. Although, risk might has possibilities to bring the undesirable incidents but it also offer the potential benefits in exchange of taking that risk (Project Management Institute, 2013). Many companies have successfully operated their business and becomes market leaders because they have decided to take a risk but success or failure on taking the risk is utterly determined by how the risks are managed and responded. As Suzanne Labarge has stated that (Merkhofer, 2011);

"Risk in itself is not bad. What is bad is risk that is mismanaged, misunderstood, mispriced, or unintended"

Definitely, in project management aspect, risk is one of the key factors that alters the deliverables of the project defer from original agreement either in cost, time or quality. This means project’s objectives are not achieved which leads to project failure. As the primary purpose of the risk management is to identify the potential problem in advance before it occur, thus the response can be developed in time to handle when the risk actually occur. Moreover, the effective risk management process needs to include early and dynamic risk identification with the relevant stakeholders since the project planning phase (CMMI, 2010). Rodrigues-da-Silva and Crispim (2014) has stated in his study that the risk management process is the rational series of practices with the purpose to keep the progress of the project remaining under normal condition or moving forward as planned.

Furthermore, risk management is very essential in project management because it is the practice where risks are identified, analyzed and mitigated (CDC, 2006). Well risk management will greatly reduce the chance of negative incident that leads to project failure while propelling project to the success. Mulcahy (2013) states that proper performance of risk management will help to avoid and mitigate many problems that might potentially happen on the project or reduce the impact of that risk. On the other hand, risk is double edge that also has the positive side which commonly called as opportunities. Increasing the likelihood and impact of the outcome of the opportunities can contribute great benefits. For instance, the new project is proposed, and might be accepted if it offers opportunities to gain the rewards and the threats (negative risk) is evaluated and expected to be limited. These are the reasons why risk management is required as crucial elements for proper project management. Project Management Institute (2013) also emphasizes that the organization should engage to constantly and proactively perform the risk management process throughout project life cycle as best practice for successfully managing the project. In contrast, executing the project by omitting or ignoring the risk management process is similar to move the project to failure because it is likely to lead the project to encounter with the problems that will be arising from unmanaged risks.

In addition, the fundamental process of risk management consist of risk management planning, risk identification, risk analysis, risk response planning and risk monitoring (Project Management Institute, 2013). These fundamental processes are similar to a few simple questions (Caltrans, 2012):

- What risk that has potential to negatively or positively affect the project from accomplishing the project's goal? (risk identification)
- Which of these identified risks are the most critical or important? (risk analysis)
- What action can be taken to handle these identified risk and who needs to be involved? (risk response planning)
- How does the taken action effect to the risk? Does it work? (risk monitoring)

Moreover, Angel (2010) has described in his work, that to have better risk management, risk factors should be introduced and considered including risk event, probability of occurrence, range and impact of the consequence. To initiate the risk management process more systematically, Heldman (2009) has suggested to categorize the risk into four types which compose of technical risks, project management risk, organizational risks and external risks. However, these categories can be revised depending on the industry or application area of the project. Additionally, it is also important to differentiate the risks from their risk-relevant features such as cause and effect. Causes are the source of the risk which will occur in the future and risk will be arisen from this while effects are the consequence if that risk is happening. The risk, cause and effect can be applied to the structured risk analysis to ensure that those risks are properly understood (Project Management Institute, 2009).

Importantly, for every risk management practice, it should be kept in mind that the risk management is iterative process and should be reviewed periodically to monitor the risk and action taken to mitigate the risk as the detail and information of the risk is changed throughout the project life cycle (Project Management Institute, 2009). Arguably, risk management is one of the hardest processes in project management and it would be chaos and ad hoc if the organization allows the project leader to create their own way to manage the risk. Therefore, many organizations have developed the practice or format for risk management in order to ensure that every project leader will have appropriate method to manage the risks. One of the most well-known methods has been widely accepted in many industries as the excellent practices for risk management, named Failure Mode and Effect Analysis or FMEA.

FMEA was firstly introduced in 1949 for using in military by the US Armed Forces, then later it was applied to the development of aerospace to prevent and mitigate the failure mode in rocket technology due to the limited sample size in the development. Afterward, it was widely spread to use as a risk management methodology in many types of industries such as food service, healthcare, semiconductor, software and especially in automotive industry and it was noted as fundamental tool for transforming the design from concept to the development in reality (Prajapati, 2012). The application of FMEA was introduced in semiconductor by Texas Instrument and Intel Corporation as the suppliers of Ford Motor Company. It was also extended to use in Japanese semiconductor as a tool and technique for preventing the risk in introducing new machine or new design equipment at Nippon Electronics Corporation (Villacourt, 1992).

FMEA is the risk management process that identifies risk based on failure mode that could happen in that particular application area, also combines the risk analysis and monitoring in structured format, so the user can perform risk management more systematically. The procedure in FMEA will control the user to identify the effect and cause of failure mode of that particular application area and assess those failure mode with analytical approach to prioritize the problems according to their significance.

Furthermore, if identified failure modes are analyzed that they are exceeding the threshold of tolerance, the FMEA will require the user to determine the corrective actions related to the application area (Belu, Khassawneh, & Ali, 2013).

Carlson (2014) also stated in his study that the FMEA is the guidance with complete set of actions that will mitigate the risk that relevant to the system or application area while also emphasize the extension use of FMEA throughout the product life cycle rather than use it in the product development phase. The result of the research has improved in quality, reliability, safety, delivery and cost. As Belu, Khassawneh and Ali (2013) also mentioned that the FMEA is considered to be in the quality improvement program for manufacturing process which can significantly contribute the cost reduction in process area. In addition, FMEA can be used as the knowledge bank to document the know-how and information relevant to the design, development or process area in order to prevent the recurrence of failure mode in case of similar feature of new product in the future (Villacourt, 1992).

2.4 Project Monitoring and Control (PMC)

The main objective of PMC process is to know and understand the progress of the project, the fundamental concept of this process is to use the original plan as a baseline to compare with actual progress made in the project at the particular time, then identify the deviation and determine the appropriate corrective actions if required (Acebes, Pajares, Galan, & Lopez-Paredes, 2014). Likewise, Al-Jibouri (2003) mentioned in his research that in project management, it has to be ensured that the work is accomplished according to the plan with limited time and budget. The incident that causes any deviation from the plan is commonly happened during project execution. Therefore, the progress made is necessary to be closely monitored and compared with the plan in order to measure the discrepancies.(Magnaye, Sauser, Patanakul, Nowicki, & Randall, 2014) stated in his study that proper project planning, monitoring and control have been discovered as critical factors that associated with the success in managing new product development and research projects.

Furthermore, the fundamental activity in PMC process consist of measuring performance of the project against baseline (plan), determining corrective action if needed, reporting and documenting any changes (Heldman, 2009). Alternatively, the process of PMC is similar to PDCA cycle which is firstly introduced by Shewhart and modified by Deming (Project Management Institute, 2013). PDCA cycle was introduced as the quality tools for continuous improvement with the core concept on quality control and assurance. However, the concept of PDCA cycle can be applied to PMC process because the intrinsic purpose of the PMC is intended to control and assure the quality of the project throughout the project life cycle. The basic concept of PDCA cycle that is applied to PMC as demonstrated in Figure 7 (Athayde, Elswick, & Lombard, 2013). The first process is planning (P), then the plan is implement (D). Subsequently, the progress is measured and identified whether the deviation from original plan is occurred or not (C). After that, if the deviation is significant, corrective action is required (A) to recover the project performance. Afterwards, the process is iterated to the same loop by re-planning, implementation the revision plan and measure.

In addition, one of the most widely used techniques to monitor and control project progress is Earned Value Management (EVM). EVM was firstly developed in 1960s by U.S. Department of Defense for developers to track and check the progress of the project while also detects deviations from original plan, so the corrective action can be timely implemented (Acebes, Pajares, Galan, & Lopez-Paredes, 2013).

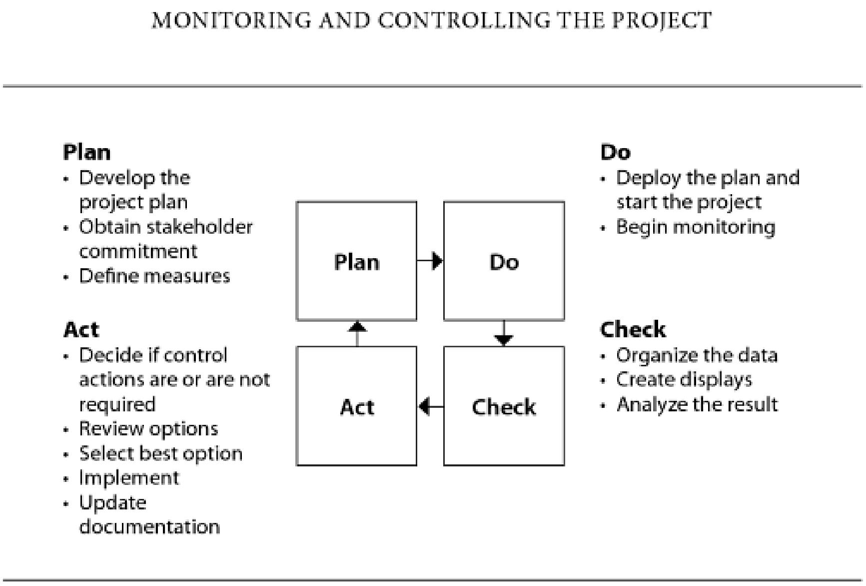


Figure 7 PDCA diagram for project monitoring and control (Athayde, et al., 2013)

In addition, one of the most widely used techniques to monitor and control project progress is Earned Value Management (EVM). EVM was firstly developed in 1960s by U.S. Department of Defense for developers to track and check the progress of the project while also detects deviations from original plan, so the corrective action can be timely implemented (Acebes et al., 2013).

EVM combines the aspect of cost and time under the same framework with monetary basis to compare and identify the deviation in the project either from delay or cost overruns (Acebes et al., 2014; Aliverdi, Naeni, & Salehipour, 2013; Hazir, 2014). Several researches have attempted to improve the performance of EVM by integrating the concept to other statistical tool. Nevertheless, the fundamental concept of EVM is still extensively accepted as an effective tool for tracking the progress of the project (Aliverdi, Naeni, & Salehipour. 2013). Additionally, CMMI (2010) also suggested the EVM as a recommended measurement and analysis tool for project monitoring and control. Besides, EVM has been named as “management with lights on” because it impartially serve as the beacon of light to indicate where the project is going and what the current progress is with comparison to where it should be and what progress supposed to be done. It exploits historical data and pattern on what have been occurred to determine the current situation and predict the future. Besides, EVM also provides important information that is commonly questioned during project execution either from stakeholders or management team, the example of questions might be asked are listed as follows (Project Management Institute, 2005):

- Indicates the executed progress is ahead or behind schedule
- Indicates the executed progress is under or over budget
- Efficiency of time and budget that has been spent is possible to be measured
- The status of remaining work relative to cost and time that has been spent

2.5 Scope and Requirement Management

Presently, the market's demand of technological product currently is increasingly growth with the urge of new products that deliver in better performance, quality, lower prices and shorter time of development. The organizations that possess the strong new product development process and innovation will be able to sustain their future growth of revenue. Correspondingly, the new product development projects are beginning to have a lot more complexity, and the number of the requirements is also advancing which causes it harder to manage effectively but it is essential to do for remaining competitive in the market. Failure or poorly to identify, understand and transform the customer's requirements during the development phase will negatively affect to the design and development of new product in terms of quality, time and cost (Violante & Vezzetti, 2014).

As Montagna (2014) has researched that the quality of identifying and managing the requirement will affect the performance of market penetration of new product. The organization that succeeds to establish proper requirement management in new product development will be able to develop and launch the product that is rapidly accepted and widely distributed in the market. Furthermore, Hackenberg, Richter, and Zah (2014) pointed out that with the increasing layer of product complexity and complication of the engineering process, it is also surging the requirements of the new product. Therefore, appropriate handling of these requirements is one of the key success factors for any projects.

In addition, Yang, Chen and Wang (2014) mentioned that scope and requirement management will affect the plan and required works of later phase of the project, and the compliance among requirement, deliverables and required work is critical to the accomplishment of the project while they also stated that one of the primary challenges of new product development process is properly managing the project's requirement. Importantly, the ambiguity of the requirement must be eradicated and it should be clearly determined before defining the scope of the project because the scope is served as project boundary which will indicate on what work will be included or excluded from the project.

Moreover, Mogk (2014) suggested in his research that the requirement or constraint should be specified into two major classifications for better understanding while he mentioned that objective is different from requirements because the objective is description of what or how the customers need new system or product to function. The two classifications of requirement or constraint are "binding" and "non-binding". In this case, the binding requirement or constraint refers to the set of features that the product or system need to specifically meet whereas non-binding is the set of features that expand beyond the demands of the binding requirement or constraints. Generally, it is the classification that separates "need to have" or "nice to have" feature of new product or system.

The processes of requirement and scope management are majority including the process of determining and documenting all the required works that need to be performed in order to successfully complete the project. The requirement will specify on what the new product needs to be exactly achieved while the scope is defined the boundaries of the project and describe what the project is all about (Angel, 2010). Once the requirement and scope are defined, it should be documented as the agreement between the project and stakeholders on what work of the project will be included and what deliverables will be produced. Project Management Institute has named this document as "project scope statement". Besides, this document also serves as a basis for decision making in the project (Heldman, 2009).

2.6 Root Cause Analysis Tool

2.6.1 Cause & Effect (C&E) Diagram

C&E diagram is a tool for identifying the root cause of the problem which provides the structural presentation of relationship between effect and cause of the problem. It was firstly introduced as a tool for quality control. The method allows user to determine the cause in secondary level relative to the particular effect (Ilie & Ciocoiu, 2010). Furthermore, with graphically display of the C&E diagram, it is easy to use, while also provides good demonstration of the problem analysis for communication to stakeholders (WBI Evaluation Group, 2007). The C&E diagram will help users to explore all possible causes that potentially to happen rather than focus on single cause of the problem (Mindtools, 2014). Likewise, it provides the snapshot of relationship between cause and the problem, while also distinguish and classifies potential causes of the problem and enables team or stakeholders to focus on the overall content of the problem (Phillips, 2013). These reasons has influenced the C&E diagram to be accepted as a root cause analysis tool, and widely used in many industry areas such as, manufacturing, service, healthcare and development.

2.6.2 Why-Why Analysis

Why-why analysis is a root cause analysis technique that is widely used to understand and deep down on the particular problem. This technique is sometimes called 5-Why analysis. The fundamental concept of the Why-Why analysis is to logically peel out the layer of problem from layer by layer until it reaches the root cause. It provides the user to understand more on "what happened" to the incident and what genuinely causes it (Mahto & Kumar, 2008). This technique is one of the most useful brainstorming as it is one of the simplest tools for analyzing the root cause without statistic. The process will start from the statement of the incident or problem, then repeatedly ask why this is occurred until the root cause is revealed (Praveen & Rudramurthy, 2013). Although Kohara (2011) stated that the using of Why-Why analysis should be carefully performed because it is not easy to use it effectively, it requires to have an expert or experienced person on the area who is relevant to the problem.

CHAPTER III: GENERAL INFORMATION

This chapter describes general information and key process area of Company A that will be used in the later chapter. The information that will be provided in this chapter demonstrates in the following topics.

- Core material for integrated circuit (IC) package
- Integrated circuit package assembly process
- New product development process of Company A

3.1 Core material for integrated circuit package

The core materials of semiconductor device or IC package are composed of lead frame, adhesive, wire and molding compound.

3.1.1 Leadframe

Leadframe is a thin patterned metal sheet that serves as a skeleton structure of the semiconductor package. It provides mechanical support to semiconductor die throughout the entire assembly processes. In addition, there are two main components of leadframe that are die pad and lead finger. Die pad is a place where the semiconductor die is attached. For lead finger (Figure 8; red rectangle), its appearance is similar to package legs (imagine that the semiconductor package is the live bug); however, they were frequently named as lead. The primary function of these leads is to create electrical connection between semiconductor die and external circuit such as peripheral components on PCB.

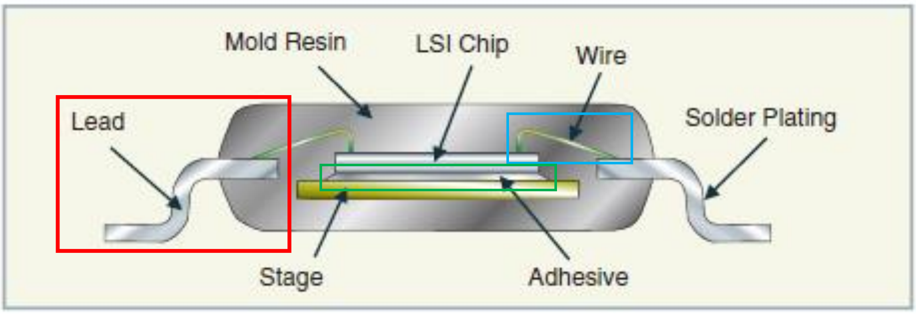


Figure 8 Cross-section figure of semiconductor chip
(Fujitsu Microelectronics Limited, 2009)

3.1.2 Adhesive

Adhesive is polymer based material. In general, it is used in semiconductor package in purpose to attach semiconductor die to die pad of the leadframe (Figure 8; green rectangle) in order to immobilize the semiconductor die on the die pad throughout the assembly process. Accordingly, the proper adhesive should be able to provide strong adhesion between semiconductor die and metal layer of the leadframe. In addition, there are two major types of adhesive that are conductive and non-conductive adhesive. The use of these two adhesive is depended on applications of semiconductor die, in case that the semiconductor die require to have electrical conductivity and thermal dissipation, the conductive adhesive will be selected. The difference of these two types are the filler particle in the adhesive, metal particle as a filler for conductive adhesive and polymer or silica particle for non-conductive adhesive.

3.1.3 Wire

The primary purpose of wire is to create electrical connection between the semiconductor die and leads (Figure 8; blue rectangle). Definitely, all wire type are metal based because it requires to have excellent electrical conductivity with marvelous mechanical properties. The challenge of wire material in this application relies on the size of wire because it has to be ultimately thin, roughly lower than 25µm in diameter. There are several types of metal wire that include copper, silver, aluminum and gold. Although, most of the IC devices are assembled with gold wire because gold is noble material with naturally corrosion resistance and good thermal stability (Heraeus, 2006). These properties will improve the reliability and operating lifetime of the IC device. Typically, the gold wire will be composed of gold with 99.999% purity and 100ppm dopant level. The common dopant material is Palladium (Pd) because Pd will enhance the strength of the wire, and also promote the bonding ability.

3.1.4 Encapsulation Material or Mold Resin

In order to protect semiconductor die from external environment such as moisture, contamination, and corrosion, it must be encapsulated. Encapsulation material (Figure 8; black area) is the most complex material in IC packages, and also has many property requirements such as low moisture absorption, low stress, low ionic content, absence of hazardous substance and high adhesion to leadframe material. There are several type of encapsulation material but only plastic material will be considered in this discussion. The main function of this compound is to shield the semiconductor die and also establish the final package structure with electrical insulation property for this electronic package.

3.2 Integrated Circuited Package Assembly Process

The general assembly process of SO package is composed of Die Attach, Wire Bonding, Encapsulate (molding), Laser Mark (include singulation), and Functional Test. Figure 9 and 10 illustrate the schematic diagram of the assembly process flow for the SO package. In addition, prior to begin the assembly process flow with Die Attach process, the semiconductor wafer will be sent from wafer fabrication site and it requires to have Pre-Assembly process to prepare the semiconductor die for Die Attach process.

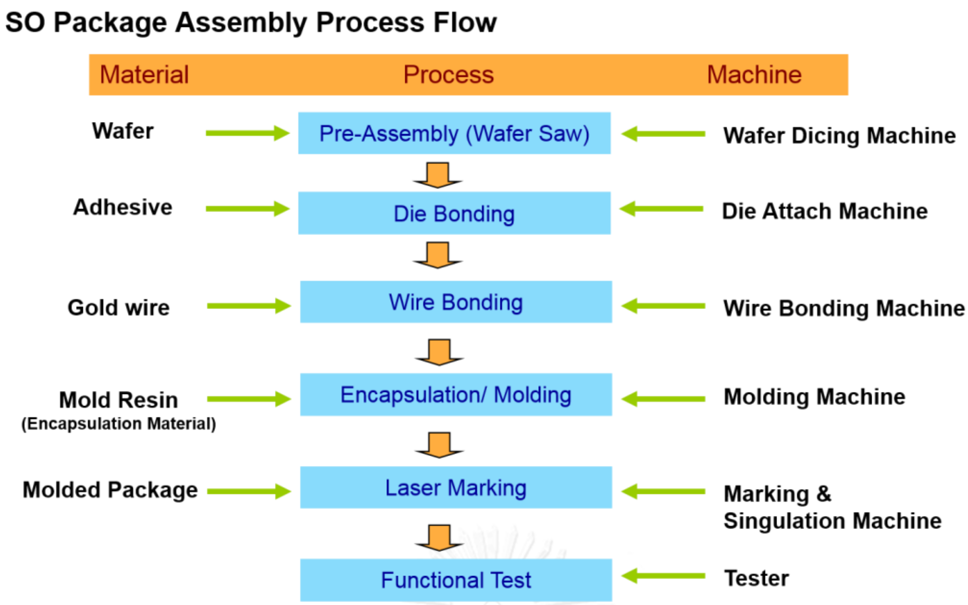


Figure 9 Schematic diagram of assembly process flow

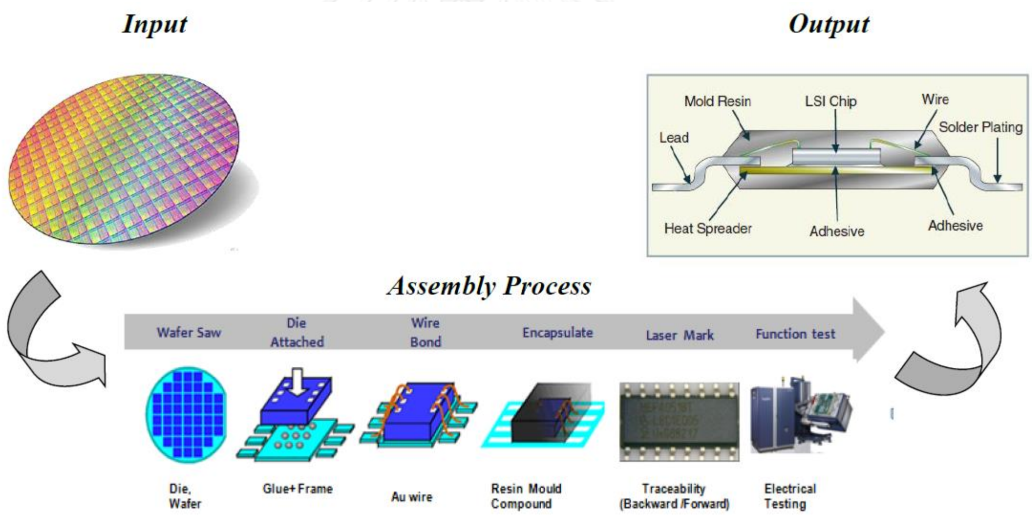


Figure 10 Assembly process flow (Fujitsu Microelectronics Limited, 2009; Tanaka Denshi Kogyo K.K., 2009)

3.2.1 Pre-Assembly Process

The micro circuits of semiconductor dies are mostly fabricated on the surface of silicon wafer. The silicon wafer might contain many thousands of semiconductor dies depend on the size of silicon wafer and semiconductor die. Every semiconductor die on the silicon wafer will not yet separate from each other. With regards to this condition, it is not possible to attach the die on the die pad of the leadframe individually. Therefore, Wafer Saw or Dicing is introduced in order to obtain the single die for processing in assembly process. In prior to saw the wafer into single semiconductor die, wafer shall be mounted to the dicing tape which will hold and immobilize the semiconductor die after wafer is sawn. Moreover, the dicing tape will also provide the mechanical support during the sawing process and also for handling the sawn wafer during process to the Die Attach. In conventional wafer sawing process, diamond blade tip will be used as a dicing tool to saw the wafer and during wafer is sawn, deionized (Aliverdi et al.) water is injected to the wafer surface to wash out the silicon particle from dicing process and reduce the heat that has been generated from the dicing blade.

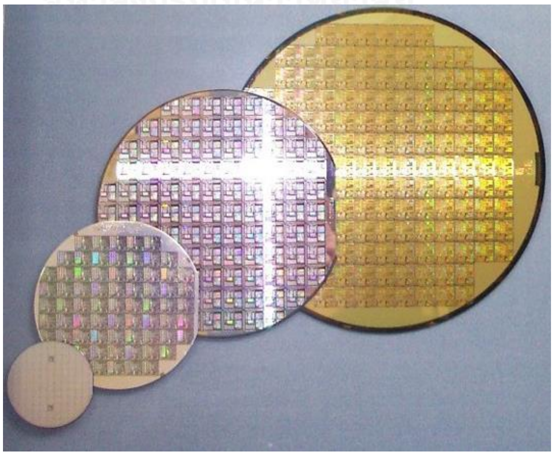


Figure 11 Semiconductor wafer (Grozdani, 2013)

3.2.2 Die Attach Process

Die Attach is the beginning of the assembly process. The essence of this process is to create the strong adhesion between semiconductor die and die pad on leadframe. Strong adhesion provides the good mechanical support and also immobilizes the semiconductor die throughout the whole assembly process. Die Attach process can be divided into 3 main parts which are Dispensing, Pick & Place, and Adhesive Curing.

Dispensing is the process that controlled amount of adhesive is dispensed to the die pad in the desired shape. Shape and amount of the dispensed adhesive are vital parameters in this step because with improper shape or amount of dispensed adhesive, it can lead to an incomplete filling of adhesive under the semiconductor die after it has been attached.

Furthermore, Pick & Place is the subsequent step after the adhesive is dispensed. The word "Pick" is referred to pick up the semiconductor die from the sawn wafer that attached with the dicing tape. In order to detach the semiconductor die from the dicing tape, it requires to be lifted up first. Hence, the injector pin is applied to lift the semiconductor die from the dicing tape; the injector pin will pierce to the backside of the semiconductor die with an appropriate force in purpose to lift the semiconductor die up. Subsequently, the lifted die is picked with the vacuum rubber tip. Finally, "Place" is relevant to align the picked die into the proper orientation and position on the die pad with dispensed adhesive. Adhesive Curing is the final process of Die Attach. There are many types of curing method; however, the most common method is temperature curing and the adhesive refer is included in this type of curing method. Furthermore, the main purpose of this process is to strengthen the adhesion of the adhesive by vaporizing the resin component. Moreover, there are two types of curing method that are oven and snap cures. Typically, oven cure can create greater adhesion to the adhesive; however, this method has low output. On the other hand, snap cure can provide higher output to this process but the adhesion is relatively lower than another cure.

In addition, the coverage of the adhesive around the semiconductor die is vital; it has a tremendous effect on reliability and performance of the package. Presence of voids will reduce adhesion strength and it also impacts the capability of die attach material for instance, electrical conductivity and thermal dissipation. In addition, insufficient glue thickness is able to lead in reliability failure, and also has an impact in subsequent process performance such as wire bonding.

3.2.3 Wire Bond Process

The primary purpose of this process is to create electrical connection between the semiconductor die and lead finger on leadframe. With the ultimately thin diameter of wire, it is very sensitive to mechanical stress that made wire bonding becomes the most critical area in semiconductor assembly process. The diameter of wire is estimated around 25 μm or less in some packages. Thermosonic method is introduced to fuse the wire with bonding pad (mostly pure aluminum) on semiconductor die and lead finger. This method will apply ultrasonic pulse to the wire to vibrate the gold in molecular level and heat up to soften the wire in order to fuse it on desired area. With thermosonic bonding, it has enabled the wire to form sufficient amount of intermetallic compound as an interfacial layer between gold and bonding pad. The bonding strength is directly proportional to the amount of intermetallic compound.

Wire bonding process can be classified into two major parts that are the first bond and the second bond, the first bond refers to the first time bonding that usually occurs on the semiconductor die. After the first bond is formed, the wire bond machine will drag the wire to create the loop until it reaches the final position, called the second bond. The wire will be ripped simultaneously after the second bond is formed, then it regenerates the first bond and process in the same loop. The appearance of the first bond and the second bond is demonstrated in figure 12.

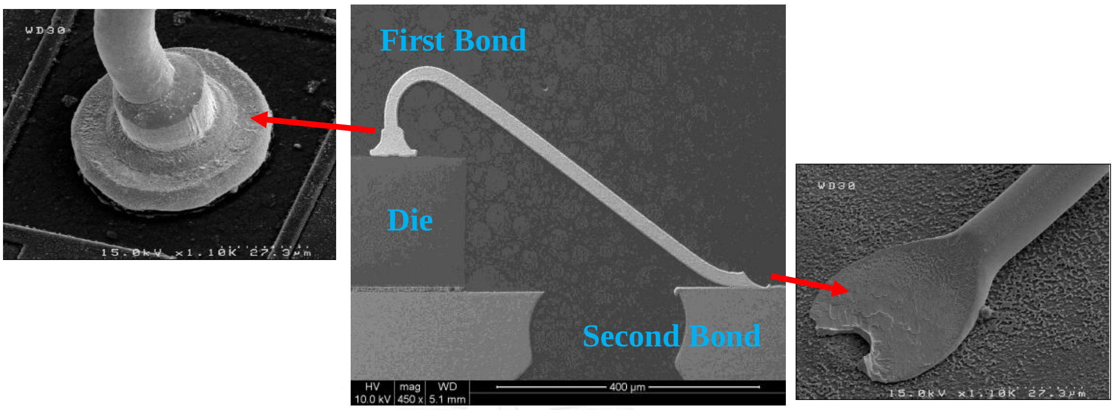


Figure 12 SEM image of first bond and second bond (Nanolab technologies, 2014)

In addition, there are parameters that have crucial effect on bonding strength i.e. bonding force, ultrasonic energy, bonding time. Optimization these parameters will greatly enhance the bonding strength. Moreover, the condition of bonding pad also has influenced to intermetallic formation such as cleanliness of the bonding pad surface, surface roughness and grain size.

3.2.4 Encapsulation Process

The intention of this process is to seal bonded semiconductor die in order to protect it from mechanical stress and external environment. Encapsulation process can be divided into two main processes which are Molding and Post Mold Cure. Encapsulation is the process to enclose semiconductor package with molding compound. Molding compound will be turned into liquid phase then injected into the mold cavity to perfectly encapsulate the semiconductor die and embody the package. Subsequently, the molding compound is cured to initiate chemical reaction after that the molding compound will be turned into solid phase. However, the molding compound in state is only in semi-cured that the chemical reaction has not yet completed. Accordingly, Post Mold Cure is required to have further cure cycle in order to allow molding compound to complete the chemical reaction which will ensure that the molding compound is completely cured. Same as other processes, molding also requires parameter optimization such as flow rate, curing time and temperature profile. Optimizing these parameters to ensure that the molding compound is completely filled in the mold cavity and also prevents void formation. In addition, with proper design of molding tool and molding cavity, it also helps in quality and productivity of this process.

3.2.5 Laser Mark & Singulation Process

After the mold process, the semiconductor device is embodied. However, it still connects each other in leadframe strip. To isolate the semiconductor device into individual, cutting process is required. Nevertheless, most of the assembly processes usually perform marking before singulating the device into individual because it gives higher productivity. The marking process is the process to label the product. The general information that commonly marked on the package is product name, manufacturing date, site and company logo.

This cutting process is commonly called “Trim”. Firstly, molded semiconductor device will be loaded into the Trim machine then it is isolated by applied mechanical stress to each lead to separate the semiconductor device from leadframe strip. Regarding SMD package attribution, forming the leads into the proper shape is necessary because it was unable to mount the semiconductor device to circuit board with an improper lead’s shape. Mechanical stress is applied to form the lead into desire shape, illustrated in Figure 13. In lead forming process, lead coplanarity after forming is critical and should be aware of this process.

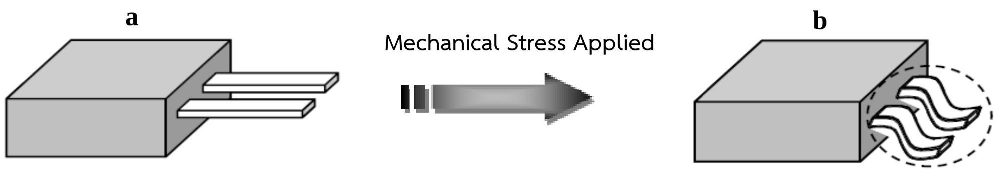


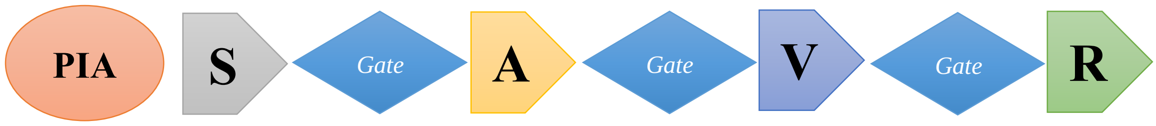
Figure 13 a. the shape of the lead after undergone Trim process. On the right hand side, b the proper shape of the lead after applied mechanical stress in Form process.

3.2.6 Functional Test

The purpose of this process is to sort out defect product before distributing them to customers. In this process, electrical test is perform in order to ensure that the semiconductor die is able to perform its function after it has been assembled into the package. Moreover, some of the products require special test conditions such as high temperature test and low temperature test. In case that the semiconductor device has failed in Final Test, it will be separated out and categorized according to the failure criteria.

3.3 New Product Development Process of Company A

As mentioned some background in previous chapter, this section is intended to describe the process of new product development process with Company A in more details. Figure 14 demonstrates the stage-gate process to divide the phase of development.



Legend

PIA: Project Initiation Approval

S: Specification

A: Available

V: Verification & Validation

R: Release for Supply

Gate: Decision gate with Project Review Board

Figure 14 New product development process of Company A (Company A, 2011)

3.3.1 Project Initiation Approval (PIA)

This phase is occurred in prior to distribute the project to each project leaders. The main activity in this phase is to review the possibility of success on the project before giving a green light to assign the project. Project charter will be created and assessed the difficulties of the project, technology capabilities and expertise whether the project will be accepted or rejected in prior to assign the project to available project leaders.

3.3.2 Specification (S)

The activities on this phase are mainly focused on planning and preparation before executing the project. The main deliverables in this phase are listed as in below.

- ➢ Completion in detail of package requirement and specification as much as possible
  - ✓ Approval of new package design (all drawing must be approved and not violated design rule)
  - ✓ Definition of processes and Bill of Material (BoM), multiple BoMs are allowed but selection criteria must be demonstrated.

- Project Planning
  - ✓ Scope, Objective and termination criteria, if new product can't be achieved
  - ✓ Agreement on time when new product will be released, and schedule planning for each decision gate (S,A,V,R) and activities
  - ✓ Detailed work plan such as design of experiment (DOE), workability & reliability testing, criteria, etc.
  - ✓ Agreement on selected test vehicle as a representative for qualification
  - ✓ Proposal on the request of capital investment if require
- Risk Assessment
  - ✓ Determination on what is new and what would be the risks of the change or new elements
  - ✓ Assembly related risks must be identified

3.3.3 Available (A)

After S-gate has been granted, the prototype is permitted to be built for initial assessment in order to determine the capability of manufacturing system and verify the risk that would happen in manufacturing process due to new product introduction. The initial assessment shall include workability, start process optimizations, execute DOE (if needed) and finalize tooling and machine. Qualification samples are encouraged to be built after these activities are completed and multiple batches of qualification sample are recommended but have to be independent to each other. Moreover, in prior to build the qualification sample, initial screening on material, tooling and package structure are recommended. In addition, the required deliverables in this phase are elaborated as below.

- Qualification samples
    - ✓ Samples must be available to submit to further reliability test
    - ✓ Must pass functional test
- Engineering Report
    - ✓ DOE results (if DOE is required for qualification)
    - ✓ Including all parameters and equipment for new product, also the final of process flow
    - ✓ Collection of yield from assembly and functional test includes every defect that has been found during initial assessment and qualification batches
    - ✓ Verification and analysis on assembly related risks
    - ✓ Conclusion with statement that demonstrate whether the new product can be manufactured or not

3.3.3 Verification & Validation

When the qualification sample has been built, it will be submitted to reliability test in order to verify that the product will be able to function in operating environment with promising life time. Another intention of reliability test is to study the failure mode that might happen (technical risks) in operating life time of the new product by using concept of acceleration test. There are many types of reliability test such as temperature cycling (TMCL), humidity-biased acceleration test (HAST), high temperature storage lifetime (HTSL), construction analysis (ConAna), etc. The type of the reliability test on each project will be different depending upon the risk of that change.

Additionally, the duration of the reliability test is relied on the operating life time that product is expected to function and the reliability test will be performed until it has reached the read-point where it has guaranteed the product life time. In company A, read-point has been divided into three types i.e. require, target and extend read-point as the shortest to the longest respectively. Each read-point has different purpose, required read-point that guarantee operating life time that customers have expected it to be. For target read-point, it is continued to ensure the customers that the product is very robust and will not fail after it has reached the expected life time. Lastly, extended read point, is for study and observation on what will happen if the product has been tested with ultimate condition. Most of the extended read-point will be equal to 15 years of operating time.

The required deliverable for this phase is the result of reliability tests at required read-point. Accordingly, the V-gate will be approved only when these results are available because it has already guaranteed in an acceptable level that the product is feasible to operate until the expected life time. In addition, if any failure mode is occurred during the reliability test, (acceleration model) it needs to be analyzed and verified whether the failure is relevant to the change or not.

3.3.4 Release for supply

In general, the timing for R-gate is the results of reliability test available at targeted or extended read-point. Then, project leader has to present the result and prepare all relevant documents to assure the stakeholders that new product is ready to manufacture and sell to the customers. In addition, all related specifications must be updated and approved in the system. Furthermore, pre-production or initial production monitoring (IPM) is optional depending on the change and agreement with production team. In case of new material or package, it is recommended to have IPM in prior to full release of mass production. The obliged deliverables for R-gate approval are detailed as follow:

- Development Report
    - The report should clearly explain on “What” has been developed and “How” it is developed
    - Including every failure mode and analysis that happen and relevant to the change or new product
    - All relevant risks and mitigation plans must be included
- Release certificate
    - Approval from management team to release new product, evidence for approval will be archived in the system

CHAPTER IV: METHODOLOGY

In this chapter, the root cause analysis will be performed to identify and understand the underlying reason that cause the new product development to be delayed. Afterwards, the approaches will be defined for resolving the situation and overcoming the delay problem in new product development process.

4.1 Root Cause Analysis

With regard to the Cause and Effect Diagram (Figure 6), it indicates the potential cause of major failures that might influence to delay the project as follows:

- Poor project planning
- Poor risk assessment
- Scope creep during execution
- Corrective action weren't timely taken

Why-Why analysis is a quality tool to explore the root cause of the problems that hide behind the surface cause. It demonstrates the relationship of the cause and the problem in hierarchy aspect which guides users to understand the problem and has a right focus on the factors that genuinely cause the problem or failure (Kohara, 2011). Accordingly, Why-Why analysis will be applied on each factor to identify the root cause.

4.1.1 Poor Project Planning

The example of the planning that was poorly developed is shown in Figure 15 that closed to Company A planning of the previous project. The purpose of this project is to qualify the new leadframe design for SO8 package which is the leadframe material development project (similar to the case study).

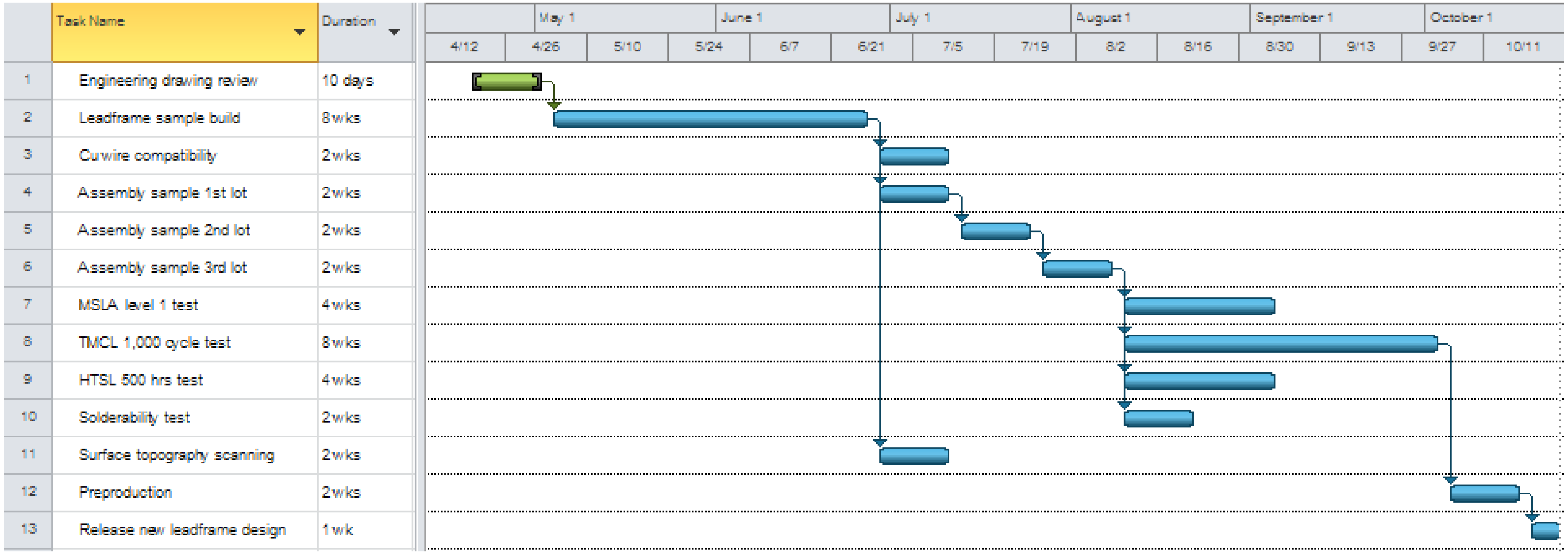


Figure 15 Example of poor project planning

However, the planning in Figure 15 is considered to be poor because it has several missing elements or activities that should be included in the plan such as milestones (gate-review), documentation (report that related to the development), incoming inspection of new leadframe, qualification strategy (test plan), and knowledge transfer from development to production.

With regard to Figure 16, Why-Why analysis of poor project planning has demonstrated the reason of poor project planning problem from inadequate schedule development. In terms of inadequate developing of project schedule, this refers to inadequate list of project activity against timeline. List of required activity shall be completely identified before planning. Missing activity will risk in delaying the project because those missing activities will not recognize by project leader and when it suddenly raises up, it will affect the overall project timeline and might cause a significant delay. Furthermore, incomplete list of project activity is happening because there is no guideline or standard outline such as Work Breakdown Structure (WBS) to guide in planning phase but project leaders have their own individual way of working to perform it.

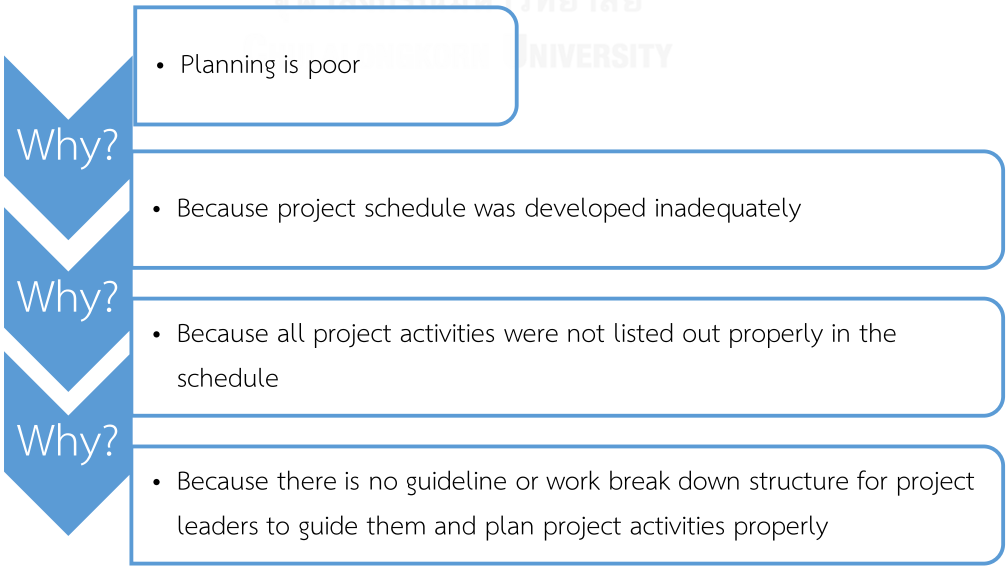


Figure 16 Why-Why Analysis of poor project planning

Table 1 Historical data of action list of Company A gate review

Project No.	Action List after gate review	Severity	Effect on Project
2351	Develop risk assessment and discuss with all stakeholders to get their approvals	High	Project delay
2691	Add lead vehicle for material selection	High	Project delay
3374	Review leadframe drawing order the leadframe to supplier	High	Project delay
2498	Revise qualification plan and get approvals before submit to S-gate	High	Project delay
2498	Revise project plan in more detail with milestone and required activities	High	Project delay
2655	Compare the cost reduction between new product and current one	Low	Project have chance to be delayed
2655	Revise project plan based product development and include all activities until product is release for mass production	High	Project delay
3379	Incoming inspection result for new material	High	Project delay
3491	Require approval from product architecture that new product design does not violate design rule	High	Project delay
2944	Arrange kick-off meeting before start the development	Low	Project have chance to be delayed
3031	Need to clearly specify the minimum specification of new test method	Medium	Project slightly delay
3009	Review qualification plan and get approvals from quality team	High	Project delay
2972	Must also consider packing material and process	Medium	Project slightly delay

4.1.2 Poor Risk Management

As there are many cases that unexpected obstacle have been occurred and impeded the progress of the new product development in Company A and requires a lot of time extension to complete the project. This unexpected obstacle comes from poorly perform of risk assessment. When risk refers to the situation or incident that can create the uncertainty event that has potential to lead undesirable consequence and if risks are overlooked and unidentified risk is happening (unexpected obstacle) while contingency plan for mitigating that risk has not yet defined, it will has high potential for project to delay. Additionally, risk is the contributing factor that disturbs project accomplishment from original agreement either in terms of quality, time or cost. Risks can be arisen from either external or internal factors that sometimes they are inevitable. Accordingly, success or failure in project management is also depending on how project team manages and mitigates the risks. The example of poor risk assessment is shown in Table 2.

Table 2 Example of poor risk assessment

Technical Risks	*Risk lv*	*Mitigation & Verification*
Poor second bond quality	Low	Second Bond Pull test and observe remaining of second bond on lead area, then result compare with original material
	Low	Second Bond Pull test and observe remaining of second bond on lead area, then result compare with original material
LF Warpage after molded	Low	Observe warpage after Post mold cure and compare between CuNi3 and CuCr
Burr/ Smear (after package sawn)	Low	Quality inspection after package is sawn into individual unit
Effect on RF performance	Low	Product characterization check on RF product

The above risk assessment is considerably poor because the quality of risk identification and analysis is relatively low as it doesn't include any source and consequence of that particular risk. Besides, the determination of risk level is ambiguous as it does not include any clear justification or explanation of how the criticality of risk is defined.

According to Why-Why analysis in Figure 17, the reason that the risk assessment is poorly performed because the current approach is not effective to identify and analyze the risk in new product development as it doesn't provide the structural platform to identify the risk as well as the clear justification for determining the criticality of the identified risk.

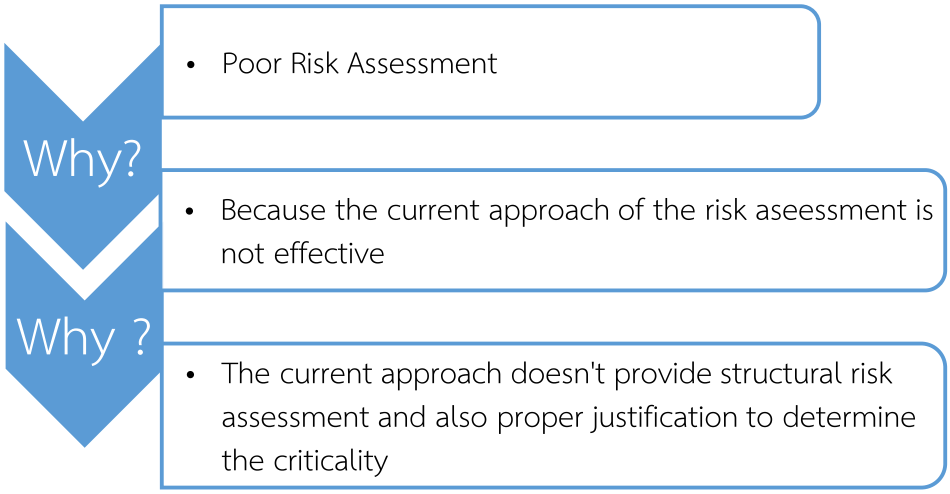


Figure 17 Why-Why Analysis of poor risk assessment

In addition, if the approach of risk assessment is not effective, it can lead to overlook of the risk during assessment that will cause unexpected obstacle during project executed as shown in Table 3. It demonstrates the example of problem and obstacle that occur during manage the project which intends to develop new encapsulation material for IC package in Company A. The data were obtained from the obstacle that has been found in the project in each development phase. For instance, this project has to be delayed for four weeks because we have found the defect of new raw material during prototype building phase, so it has to be put on hold until new shipment of raw material will be sent. Moreover, the project has to face with another delay because project leader didn’t reserve the capacity of the reliability test (to assess package robustness) in advance that causes about three weeks delay. As most of the problems that have occurred in this project is because risk assessment is poorly performed. Accordingly, project have encountered with delay because risks weren’t appropriately addressed and mitigated in advance.

Table 3 Example of obstacles during new product development

Problem	Problem Description	Why risk is not mitigated	Effect on Project
Change in maximum mold shot	Did not validate the maximum number of molding shot of new encapsulation material that will start to clog in machine	Did not in risk assessment that the maximum mold shot will be changed if encapsulation material is changed	Project delay due to activity doesn't include since planning phase
Stress test to determine package robustness	When encapsulation material is changed, package robustness will also change but stress test does not inlcude in the evaluation	Risk assessment does not review and approved by quality team, so risk is overlooked	Project delay because stress test capacity does not reserved in advance
No reference lot	When failure happens with new package and there is no reference lot to compare the result. It is hard to judge that the failure happened because of new material or from the process	Qualification plan and risk assessment is not reviewed and approved before prototype sample is executed	Might have to rebuild the sample to confirm the failure which cause project to delay
Defect on sample of new raw material	Defect on raw material was found after or in the process of building prototype sample	Risk was not recognize so the criteria for incoming quality inspection of new raw material is not defined in the plan	Project delay because need to wait new shipment of raw material

4.1.3 Corrective actions weren't timely taken

When the project is encountered with the delay, it needs to be recovered with any action that can possibly mitigate the impact of this delay. And most of the cases in Company A, the corrective action is not timely developed, so the cost overruns and time extension is more severe than it should be. The Why-Why analysis has demonstrated in Figure 18. The cause of why the corrective action is not timely taken because the project leaders lately notice the delay in the project as the progress wasn't tracked regularly. The root cause of this problem is because there is no approach to periodically monitor and control the progress of the project, so it should not be surprised that the project leaders in Company A lately notice when the progress made is slower than what has been planned. Furthermore, without project monitoring and control process, the new product development of Company A will rather depend on the heroic manner of each project leader, even the sufficient resources are assigned to execute, that particular activity are still possible to encounter with the delay if the progress of that activity was not properly monitored and controlled.

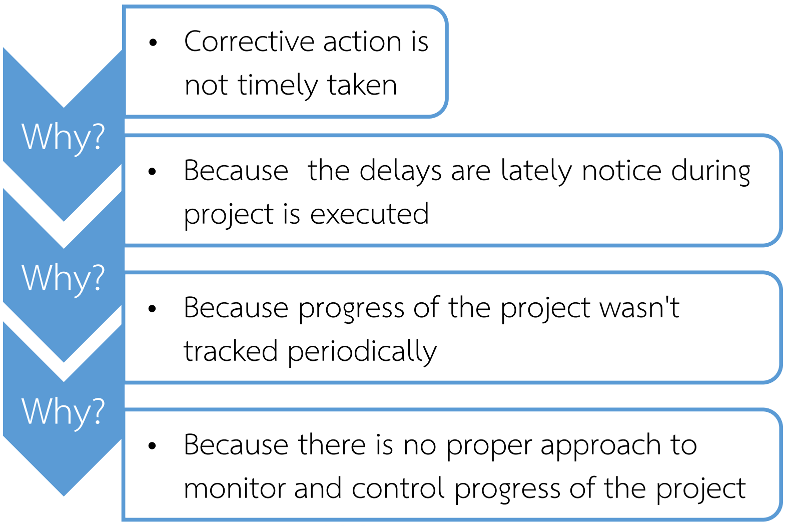


Figure 18 Why-Why Analysis of why Corrective action weren't timely taken

As in Company A, the progress of the project will be reviewed only if it has already reached the milestone or gate-review. Since planning phase, the project leader will be asked for commitment from the PRB when the project will be submitted to gate review of each phase (S-A-V-R gate) after project was assigned to project leader. S-A-V-R gates are the principle milestones that have been used for reviewing the project on each phase.

Although the project will be only monitored during project gate review that is not enough to track the progress of the project to move forward in accordance with the plan. As it is demonstrate in Figure 19 that there are more than 50% of delayed projects from gate submission because deliverables in that phase are not yet completed to be submitted for gate review that definitely cause a delay in the project. Accordingly, the progress of the project should be regularly monitored and controlled against schedule in order to encourage the project leader to manage the project and complete the deliverables on time.

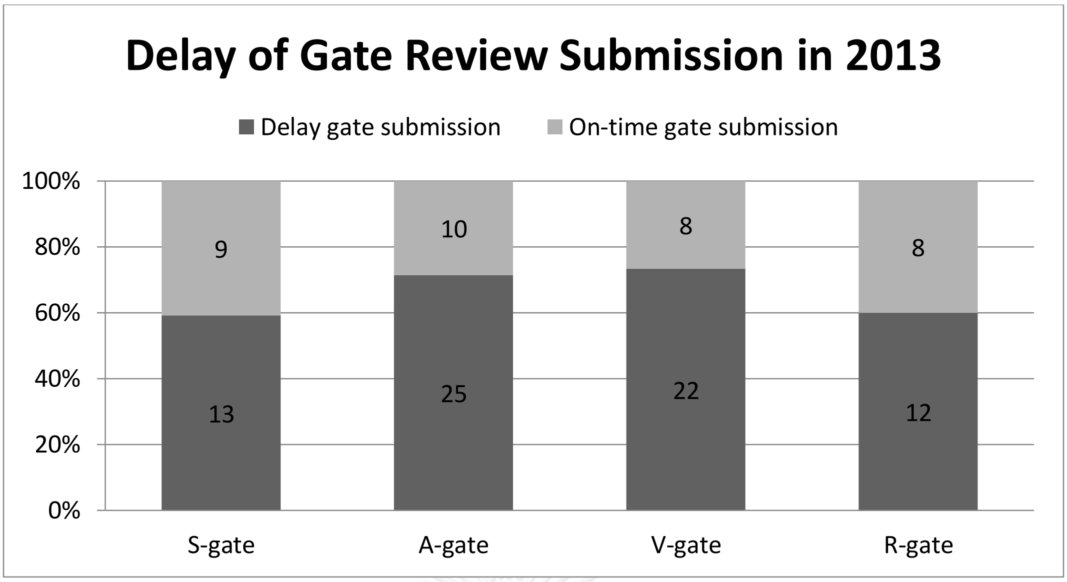


Figure 19 Historical data of delay on gate review submission in 2013

4.1.4 Scope creep during execution

Scope is similar to the boundary of the project that uses as a baseline to determine which activity shall include and which one shall exclude. The creep in scope is referred to the change in scope during project is executed are regularly leads to addition of unplanned deliverables which didn't include in the original plan. This will cause time extension and project will delay from committed delivery time. The Why-Why analysis in Figure 20 provides the explanation of the cause of scope creep as the requirement, and scope are not properly defined and controlled before constructing the project plan. As activities of project are mainly determined with regards to scope and requirement of the project, so if the scope and requirement are not appropriately defined, the project plan might include some activities that are not necessary or miss required activities for objectively completing the project.

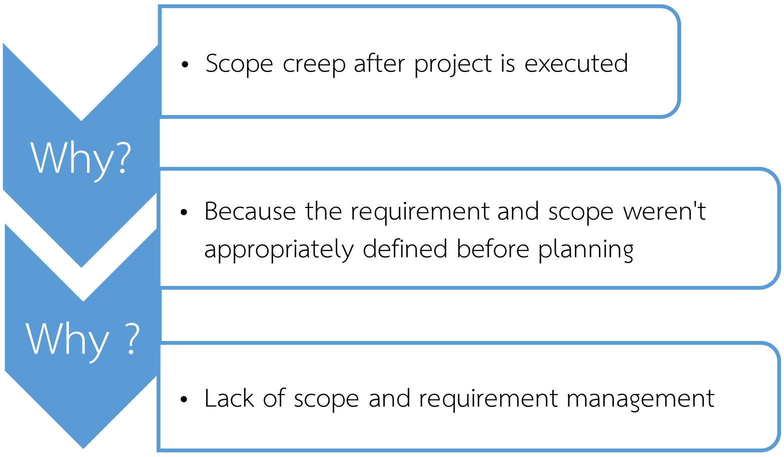


Figure 20 Why-Why analysis of scope creep during execution

In product development process of Company A, there are many cases that scope and requirement are missing or excessive after projects are executed because the requirement and scope of the project are not defined and agreed properly since the project is initiated. Generally, Company A will use the document called "Qualification Strategy" (QS) as the agreement to what test is needed to perform to verify and validate the quality of new product and serve as the guidance for each particular development. In prior to create the proper qualification strategy the scope and requirement should be appropriately defined and controlled. However, more than half of the qualification strategies were composed without good settlement of scope and requirement strategy as shown in Figure 21. Additionally, the majority of deliverables in new product development process are estimated based on the technical requirement, thus these projects have a very high chance to found missing deliverables or perform redundant activity because scope and requirement are not properly defined and controlled that might cause a delay during project execution.

According to Why-Why analysis on each cause of why there are several delays during project progression, and it has been found that there are various potential root causes that might be reasons for these problems. They can be summarized as below.

- Poor planning: No guideline or work breakdown structure
- Poor risk assessment: The risk assessment approach is not effective
- Corrective action weren't timely taken: No project monitoring and control
- Scope creep: No scope and requirement management

Consequently, these potential root causes shall be solved in order to reduce amount of project delay in Company A while also are considered as improved performance of product development process of Company A.

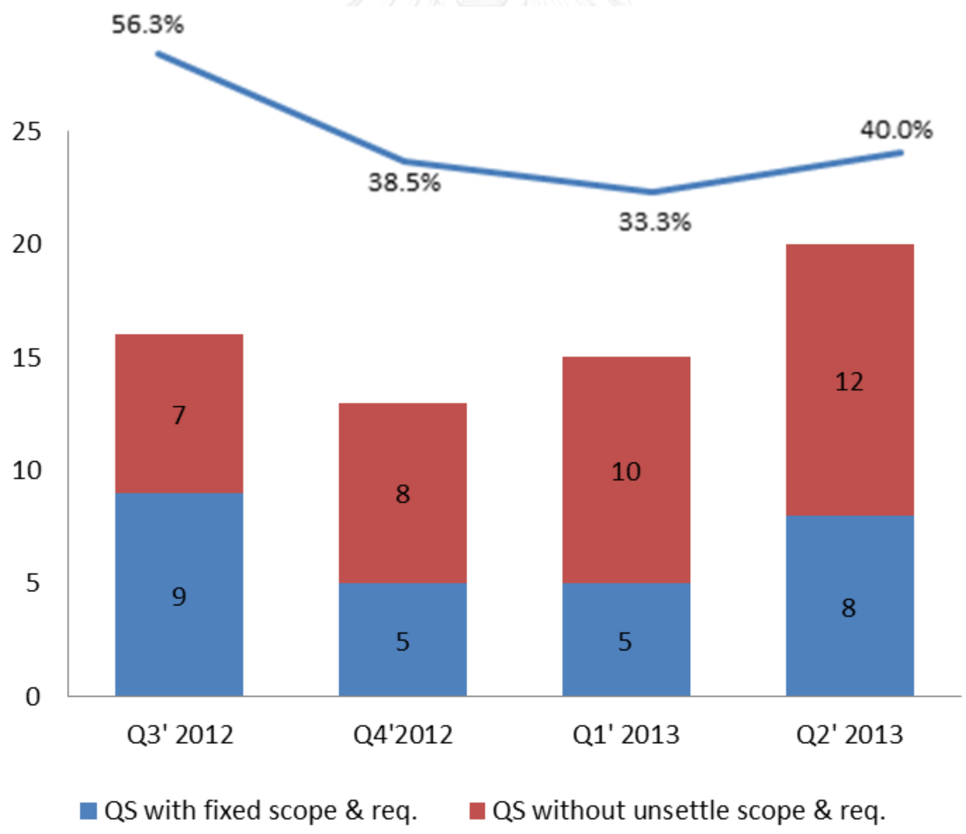


Figure 21 Historical data of project with unsettled of scope and requirement

4.2 Define Approaches for New Product Development Process

As the causes of why the project is delayed have been analyzed in previous chapter, the author would like to introduce the approaches that will be developed to tackle the causes and solve the problem in project delay. The approaches that will be introduced will separate into three different areas: project initiation, planning, and progressing. Improvement in these three areas would help to reduce the amount of project delay.

4.2.1 Approaches for improving project planning (Work Breakdown Structure)

With regard to why-why analysis in previous chapter in order to find the reason on why the project schedule is developed inadequately. It has been demonstrated that because there is no guideline or Work Breakdown Structure to guide the project leader to effectively develop the complete project plan that cover all activity since the first time.

WBS will assist project leader to make the complex project to be more manageable. In general, WBS is constructed by capturing all deliverables and required tasks that need to be completed in order to achieve project objectives. Although the WBS should be created with adequate detail of activity breakdown, too little detail will cause the breakdown tasks to be too large and not manageable as it should be. On the other hand, breaking down the activities in too much detail will lead to excessive work and might hinder the progress of the project rather than facilitating (Tenrox, 2014). As it has been mentioned previously that the appearance of WBS is in hierarchy structure, it commonly demonstrates in multi-level of block diagram as illustrated in the following figure. The tasks in the project will be deconstructed from large size into smaller size. The tasks that locate at bottom level of the WBS is called as work package (WP). WP is a task which combines the set of simple and effective activities that can be managed and controlled by the project leaders or team members. However, the question is how “small” or “simple” that is enough to call it as WP (Devi and Reddy 2012).

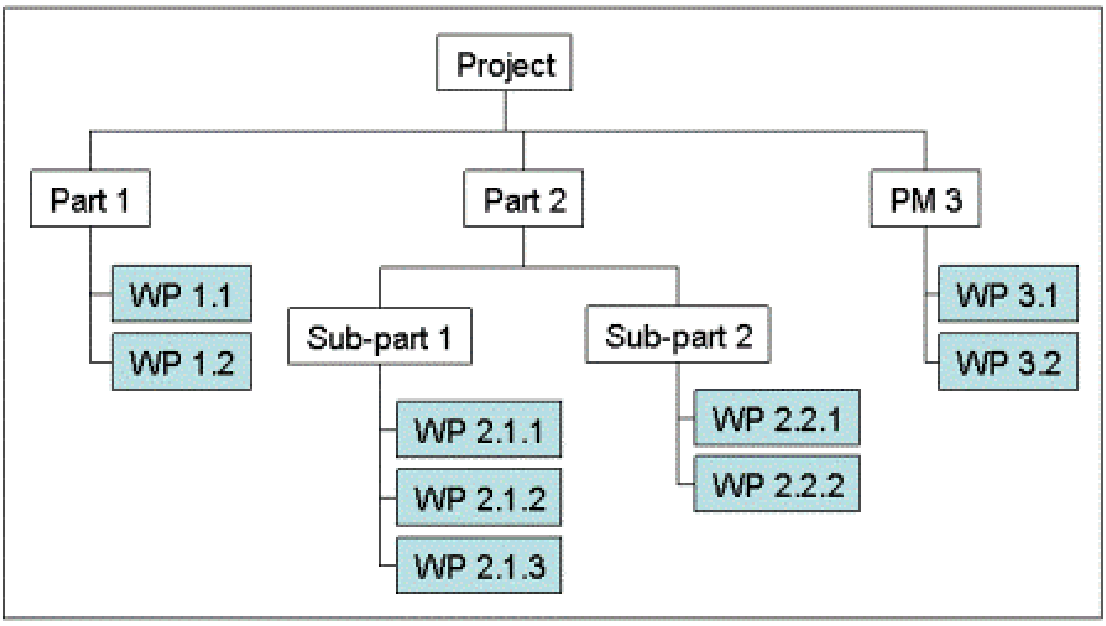


Figure 22 WBS structure

There are the set of attributes which can refer to the identity of the WP, if the tasks are deconstructed until they possess these attributes, then the user can stop deconstructing the tasks and consider those tasks as WP. The identity attributes for WP is in the following list (Department of Energy, 2003; Devi & Reddy, 2012).

- Definable ➔ Have clear description of work and deliverables, easily to be understood by team members
- Assignable ➔ The task has clear particular responsibilities, can be assigned to individual project personnel for execution and the sub task under WP should contain work that use similar skills to complete.
- Independent ➔ Apparently separate from other tasks or minimum association with the other tasks or on-going elements.

- ❖ Estimable ➔ Time (duration) and resources that require to complete the tasks can be precisely estimated.
- ❖ Measurable ➔ The task can be used to measure the project progress, or interim milestones.

Furthermore, WBS is different from project schedule should not be constructed in chronological basis but rather be in deliverable oriented framework. Alternatively, the WBS can be also used to create the effective project schedule because the output of WBS is the set of deliverables that can be applied to the project milestone. Moreover, properly creating WBS will capture all required deliverables in the project, thus the project schedule that developed based on WBS completion is more effective because it can ensure that the project schedule will develop with no missing activity.

4.2.2 Approaches for improving project risk management (FMEA)

4.2.2.1 Risk Management Process

Risk Management is the structural practice that enables the users to systematically think on how the risk should be properly managed and treated. Effective risk management should provide the contingency plan for responsive action of identified risks in order to eliminate or mitigate those risks. Additionally, effective risk management also ensures that in the consequence of worst case scenarios, it shall not happen beyond expected boundaries (Heinz-Peter, 2010). Typically, the process of risk management is composed of identifying, analyzing, responding planning and monitoring respectively as demonstrated in the following flow chart.

Figure 23 Risk Management Process

❖ Risk Management Planning

This is the process where the project leaders need to define how risk management will be conducted for the project. The key benefits of this process are to create the plan for the subsequent process of risk management while also obtain the agreement from relevant stakeholders in order to ensure that risk management will be effectively performed during project life cycle.

❖ Risk Identification

The primary intention of this step is to identify the risks that might affect to achieve project objective and note the characteristics of them (Department of Transportation, 2013). These risks refer to the incidents that happen either the source is from inside or outside the company but have potential to deviate the project from original agreement. In addition, there might be a lot of risks that have been identified but it is recommended to ensure that those risks are truly related to the project objective. Alternatively, hundreds of risk will be taken into account that is a huge burden and not pragmatic to effectively manage such a full array of risks. In such case, the true risk might be omitted and never have any contingency plan upon (Samad-Khan, 2008). The suggested techniques for risk identification process is the cross-functional workshop and brainstorming approach with stakeholders in order to gather the relevant information from the affected parties (Price Waterhouse Cooper, 2008).

❖ Risk Analysis

Risk analysis is fundamentally related to prioritizing and organizing the risks in order to define on which risk is critical and require to develop the contingency plan to mitigate the probability or impact of risk (CDC, 2006). The high-priority risks will be focused that will improve project's performance. Furthermore, risk analysis will determine the priority of the identified risks by evaluating the impact of that risk to the project and probability of the occurrence of that risk. Furthermore, constituting the description of the rank of impact and probability of occurrence will assist the accuracy of the risk analysis process because it reduces effect of bias (Project Management Institute, 2013). However, risk analysis is a repetitive process, it requires progressive activities throughout the project duration (CDC, 2006) and it might need to take a lot of effort of brainstorming and discussion to obtain the most accurate risk priorities. The assistance from experts on respective fields of the identified risk is encouraged to be involved during the analysis (Department of Transportation, 2013).

❖ Risk Response Planning

As Project Management Institute (2008) has stated that *"Risk response planning is the process of developing options and actions to enhance opportunities and to reduce threats to project objectives"*. Accordingly, this process is to primarily develop the action or strategy to deal with the identified risk which has already determined its impact that would deviate the project's objectives. The process must also identify and assign the responsible person for each action taken with agreed timeline (Department of Transportation, 2013). Importantly, it is necessary to assess the cost of implementation of the strategy or action for reducing the threats or probability of occurrence of that identified risk in order to decide whether it is worth to implement that action (AIRMIC, 2010). Moreover, the action to respond the risk that might jeopardize the project's objective can be classified in the following types (CDC, 2006).

- Mitigation ➔ Action that would be implemented or triggered in early stage in order to reduce the impact or probability of occurrence of that risk.
- Transfer ➔ Action is relevant to transfer the negative impact or responsibility of the risk to the third party
- Avoidance ➔ Revise the project scope, change the project objective or strategy to entirely eliminate the impact of the risk
- Acceptance ➔ This type of action is fundamentally to encounter with the risk when it is happening because sometime it is not possible to avoid or mitigate the risk. However, the regular practice is to develop the contingency plan to handle with the risks in case they happen. Although in some situation, doing nothing might be the best option for the project. This depends on the effort, time and cost whether it is worth to deal with the risk or not.

❖ Monitoring and Review

The main activities of this phase is to monitor and review the existing risks and new risks. The process also refers to monitor the effectiveness of actions or strategies that have been implemented to respond with identified risks. In addition, risk monitoring and review are the continuous process that makes the risk management become an iterative process because it requires to have regularly update and track the condition of the identified risk (Caltrans, 2012). Moreover, regular monitor and review the risk will help to ensure that the identified risk is still under control. However, if there is any changed relevant to the risk, it must be re-analyzed then triggered the execution of new risk response, if require. Therefore, periodically conduct the meeting to monitor and review the risk will greatly enhance the performance of the risk management.

4.2.2.2 Failure Mode and Effect Analysis (FMEA)

FMEA is an analytical model that has been used in risk management process in order to assure that the potential risks will be addressed and responded in the development process (Automotive Industry Action Group, 2008). Additionally, FMEA is the model that construct in table or matrix platform which enables the sequential thinking to users on how they are going to execute the risk management. The model combines all aspects of risk management in one matrix that includes risk identification, risk analysis, risk response planning and risk monitoring & review.

In this research, the FMEA is chosen to be applied as the analytical model for risk management and it will be developed based on FMEA approach that has been designed from Automotive Industry Actin Group (AIAG). The primary intention of AIAG is to design as a guidance for suppliers to assist them in development process. Accordingly, it has been used in risk management by firstly applying to the automotive industry and now the model is widely spread out to many industries such as nuclear, medicine, semiconductor and mechanical sectors (Belu, Khassawneh and Ali, 2013 refer Stamatis, 2003). Presently, FMEA has been included as a key element of many industry standardization and becomes the important examining item in ISO-9000 series, ISO/TS 16949 and QS-9000 (Belu et al., 2013).

As mentioned previously, the FMEA model from AIAG is designed in matrix or table platform. The model also includes the analytical part to prioritize the risk; thus, the user can respond with potential risk more precisely. In addition, it also provides the framework for users to have a sequential thinking to identify the risk and source of the risk in rational way. The framework is composed of four sequential inquiries as described in Figure 24.

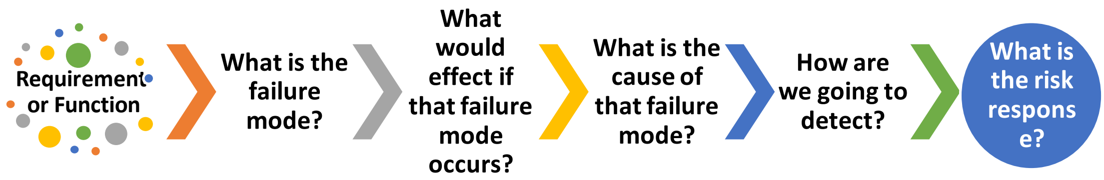


Figure 24 FMEA sequential inquiries

Furthermore, on the analytical part for risk prioritization, the model has divided into four elements covering Severity (S), Occurrence (O), Detection (D), and Risk Priority Number (RPN). The ranking of priority will be indicated by RPN value that is the product from S, O, and D. The details of each element are described in below.

Figure 25 Risk Priority Number (RPN) formula

- Severity

This element is particularly indicated the level of impact that might cause from the potential failure mode. The value of severity will correlate with the level of impact of given failure mode that effect to the function of the product as perceived by users or customers (Belu, et al., 2013). In general, the rating scale of severity is rated from small to large value respectively with severity of the impact from the given failure mode. For instance, if the rating scale is divided into ten levels, 1 is referred to the minimum impact while 10 is ranked as the ultimate impact scenario.

❖ Occurrence

Occurrence is considered as the likelihood of particular cause of the given failure mode will occur. However, if the cause of failure mode is hard to notice or observe, it is allowed to refer the likelihood that the given failure mode will occur. The rating scale of occurrence must be divided in the same level of severity. If the severity scale is divided into ten levels the level of occurrence must breakdown into ten levels, as 1 is assigned to the very low likelihood of occurrence while 10 is indicated the extremely high level of occurrence.

❖ Detection

Detection is element where it is used to specify the capability of detection or verification method that has been used to detect the failure mode or the cause of given failure mode. Similar to the occurrence, the number of detection level must also associate with the level of severity. If the scale of severity is broken down into ten level, detection must comply to split into ten level, as 1 indicates the very effective of detection capability while 10 refers with very poor of detection capability. In case that there is more than one detection method on the same given failure mode or cause of failure mode, the best control method will be selected to rank the detection.

❖ Risk Priority Number

Prioritization in criticality of the failure mode is indicated by RPN or risk priority number. RPN is the product of score from severity, occurrence and detection. Arguably, RPN is the most crucial part in the FMEA because it is the aspect where specifically indicate on which failure mode shall be firstly responded. The higher of RPN value, the higher criticality of that failure mode. In addition, not all failure mode that requires to have a risk response, the threshold value of RPN is the indicator that if the RPN for the specific failure mode has exceeded this value, that failure mode requires to have response action (Automotive Industry Action Group, 2008). Regularly, the threshold value is determined from the square of the level of rating scale. For instance, if the rating scale is divided into 10 levels, the critical value of RPN is 100. However, it should be reminded that the approach of threshold value is not an index for indicating the need of response or action. It encourages to have the response for each specific failure mode, especially the one with high level of severity.

4.2.2.3 How to use FMEA for risk management?

The FMEA for risk management in new product development of Company A is designed based on the model from AIAG. In this section, I would like to describe on how the table of FMEA will be used for risk management. The template of FMEA is shown in Table 4. First of all, column A is for determining the interesting section or area which users want to focus for risk management. It can be either the requirements or process area. Afterwards, the next column is B or "Potential Failure Mode" which has primary intention to identify the failure mode that relate to the field as specified in column A. This is equivalent to risk identification. After the potential failure mode is identified, the template will guide the user to determine the impact of failure mode by considering the expected effect. The column is located next to potential failure mode which is named as "Potential Effect(s) of Failure" (column C).

Moreover, one failure mode can have many potential effect of failure. Importantly, the effect of failure mode shall be detailed in terms of what customers are going to perceive or experience. Then, the level of severity should be defined with regards to the effect of potential failure of that given failure mode. Subsequently, the source or mechanism of failure mode shall be discovered and noted in the column of "Potential Cause of Failure Mode" (column D) for further analysis. It is recommended that the description of cause or mechanism should be completely detailed but concisely as much as possible (Automotive Industry Action Group, 2008). Additionally, the FMEA table will lead the user to have input on rating scale of the occurrence score. As mentioned above, the template of FMEA is designed for users to perform sequential inquiries in order to proceed the risk management, if the source of failure mode is happening. Then, the question is how we are going to detect it. Accordingly, the required information in column E and F is the prevention and detection method respectively. The input method should sufficiently prevent or detect the potential failure mode or potential cause of failure. The approach for prevention is not a must, but preferable if it is available because not all failure mode can be prevented or eliminated. Then, the score of detection shall be filled in adjacent column which is column F1.

Afterwards, all rating elements are scored, so the RPN value shall be calculated and filled into the column “RPN” (column G) then this is the final part of risk analysis in FMEA. The consecutive process after risk has been analyzed is the risk response planning which comparable to column “H” to “O”. In the beginning of risk response planning, the FMEA will direct the user to define the recommended action to respond with the failure mode. The response is suggested to be handled in priority based on RPN value. Then, the user needs to identify a responsible person for the action that will be applied to respond the risk while also indicates the expected finishing date of the action. After the action has been taken, it must be documented on what final action has been implemented to deal with the failure mode and what the action has solved by reducing the severity, occurrence, or improving the capability of the detection method. Lastly, RPN score will be re-calculated on the basis of revised score of the three elements.

Table 4 Format of general FMEA from AIAG's guideline

Function / Requirements	Potential Failure Mode	Potential Effect(s) of Failure	SEVERITY	CLASS	Potential Cause(s) of Failure	OCCURANCE	Current Design Controls		DETECTION	RPN	Recommended Action (s)	Responsibility	Target Completion Date	Action Results				
							Prevention	Detection						Actions Taken	SEVERITY	OCCURANCE	DETECTION	RPN
A	B	C	C1	C2	D	D1	E	F	F1	G	H	I	J	K	L	M	N	O

The name of each column is labeled for describing in "How to use FMEA for risk Management" section.

4.2.3 Approaches for project monitoring and control (PMC)

The concept of project monitoring and control (PMC) is utterly different from the risk management process because the PMC are determining the situation that has already occurred in the past while risk management are primary considering the future (Rodrigues-da-Silva and Crispim, 2014) . However, the robust PMC process is one of the key success factors of new product development process (Magnaye, et al., 2014).

Furthermore, the primary objective of PMC is to track, check and manage the project progression during the execution. It also provides the good visibility to regularly observe and measure the status of project then help to identify the problems that has been occurred and significantly deviate the project's performance from the original plan. Hence, the corrective action can be timely developed when the project does not follow according to what was planned (CMMI Product Team, 2010; Project Management Institute, 2013). The significant deviation is referred to the problem or incident that, when ignore, it obstructs the project from achieving the objectives. The common practices that has been taken when the project's status is significantly deviated from the plan is to revise the original plan, add the mitigation activities and set new terms of agreement if necessary (CMMI Product Team, 2010). The corrective actions for solving the significant deviation of the project has to be carefully considered and taken if it is worth and appropriate for taking the effort. The common process for PMC is illustrated in Figure 26 (BIS, 2010).

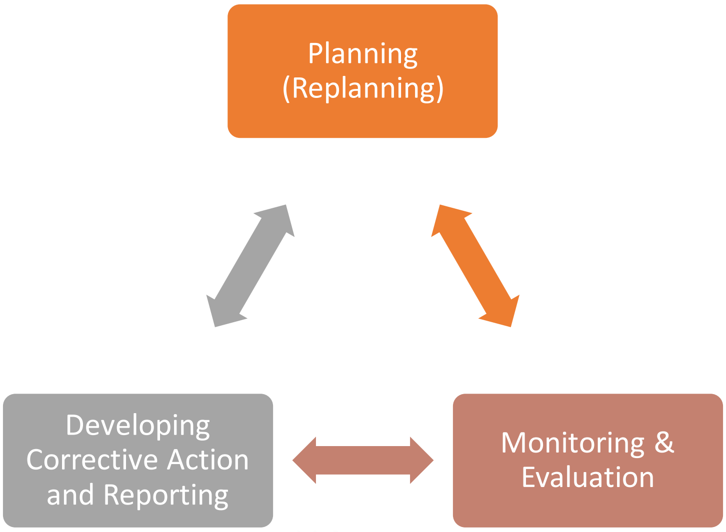


Figure 26 General project monitoring and control process

This iterative process is similar to the concept of PDCA (Plan-Do-Check-Act) cycle which is one of the best problem solving methods that is widely used in many businesses. PDCA cycle can be used in PMC because the key concept of PMC is about how to handle the problem that has been occurred during executing the project, and that problem has negatively deviated the progress or performance of the project from project's goals. The PDCA cycle will assist project leaders to manage and tackle the problem more effectively. The concept of PDCA cycle can be applied to PMC process as described below (Rava, 2012).

Figure 27 PDCA cycle with project monitoring and control

- ❖ Plan ➔ Develop the project planning or revise the original plan in order to achieve project's objective
- ❖ Do ➔ Execute the project according to the plan or revised plan
- ❖ Check ➔ Monitor the performance or progress of the project and determine whether the progress has achieved the target or not
- ❖ Act ➔ Implement corrective action to improve the project performance and reduce the impact of the deviation. Also reporting the progress and action taken.

4.2.3.1 Progress Measurement

The critical part of the PMC is on "how do the performance or progress of the project will be monitored?" The typical practices of progress monitoring is to periodically monitor the completion of activities, milestones and deliverables. Moreover, the completion must be compared against the original plan. In case that any deviation is identified, it must be verified whether it significant or not (CMMI Product Team, 2010). One of the most well-known methods for tracking the progress of the project that possesses these three elements is Earn Value Management (EVM).

EVM is a technique that integrates the performance measurement of cost and schedule in the same framework which enhance the decision making process. It assists users to detect the delay or cost overrun in the project with the parameters of performance variances and indices. Additionally, EVM has enabled the user to determine the status of the project by comparing what has been completed with what was planned. There are three key variables that will be used to determine the status of the project, terminology of these elements are described below (Patil, Patil, & Chavan, 2012).

- **Planned Value (PV):** this value is defined as the budget that plan to be expended for completing the work at any given time. This formerly named as BCWS which abbreviated from Budgeted Cost of Work Scheduled (Khamooshi & Golafshani, 2014).
- **Earned Value (EV):** this value was previously called Budgeted Cost of Work Performed (BCWP) which indicates the progress of the project that has been completed or the actual works those have been accomplished at any given time in monetary term (Khamooshi H. & Golafshai H., 2014). Moreover, the monetary value of each work or activity in EV must be based on the cost of PV
- **Actual Cost (AC):** this value is referred to the actual of total cost that has been spent in order to complete the work or achieve the progress at any given time. This value once called Actual Cost of Work Performed or ACWP (Patil, Patil & Chavan, 2012).

Furthermore, these three variables will be used to derive the variances and indices of EVM analysis in order to track the progress of the project. The variances are defined as Cost Variances (CV) and Schedule Variances (SV). For indices, they are defined as Cost Performance Index (CPI) and Schedule Performance Index (Rodrigues-da-Silva & Crispim). The definition and interpretation of each variances and indices are briefly summarized in Table 5.

- Cost Variances (CV) → Comparison of the amount of work performed to what was planned to be done
- Schedule Variances (SV) → Comparison of the value or budgeted of work performed with the actual cost that has been spent
- Cost Performance Index (CPI) → The index that use for demonstrating how efficiency of the expense that has been occurred in the project

❖ Schedule Performance Index (Rodrigues-da-Silva & Crispim) ➔ The index relatively shows how much the project progress made is ahead of schedule or delay

Table 5 Variances and indices of EVM (Acebes et al., 2014; Pajares & Lopez-Paredes, 2011)

Variances & Indices	Formula	Interpretation
Cost Variances (CV)	CV = EV - AC	CV ≥ 0 ; Project is still in the budget CV < 0 ; Project has cost overrun
Schedule Variances (SV)	SV = EV - PV	SV ≥ 0 ; Project is ahead or in schedule SV < 0 ; Project is behind schedule
Cost Performance Index (CPI)	CPI = EV/AC	CPI ≥ 0 ; Fund is efficiently expense in the project CPI < 0 ; Fund is inefficiently expense in the project
Schedule Performance Index	SPI = EV/PV	SPI > 0 ; Project is ahead of schedule SPI = 0 ; Project is on schedule SPI < 0 ; Project is behind the schedule

Figure 28 demonstrates the concept of EVM in graphical manner, the examples of cumulative value of PV, EV and AC are plotted with respect to the time (Acebes, et al., 2013).

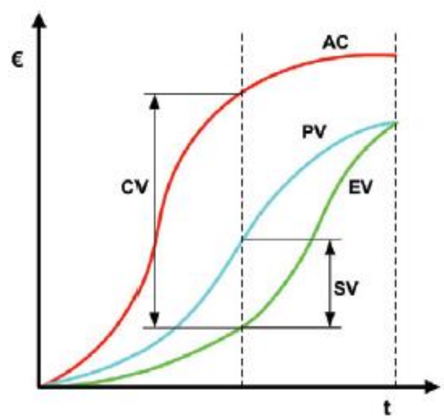


Figure 28 EVM main variables and variances

4.2.3.2 Progress Checkpoint Design

Although, the EVM is one of the best methods to track the progress of the project but without the proper approach to conduct the checkpoint for providing regular comparison of the plan against the progress made. The checkpoint is the project's status at any given time after the project is executed. When the work activities are performed, then the progress made and impacts will be reviewed at the checkpoint and informed to the relevant stakeholders whether there are any critical issues or deviations (CMMI, 2010). Therefore, this section is intended to describe how to design the checkpoint for tracking the project's progress. As BIS (2010) summarized the key elements that should be considered to design the checkpoint for tracking the progress made including:

- Frequency and duration of the checkpoint
- Method for the checkpoint (meeting, conference call, email or informal chat)
- Participants
- Format of the report that will be used to communicate the project's information

The frequency of the checkpoint should be appointed based on the intensity of activities or deliverables, the range of the checkpoint can be varied from fortnight to daily meeting even in the same project. For instance, the frequency of the checkpoint can be set in fortnightly during the reliability test which requires long process time whereas it should be arranged in every two days during implementation or first prototype built. Moreover, the meeting approach and participants is possible to vary but shall be informed in advance.

Furthermore, after the information of the progress made is gathered, it should be documented in the same format either for project leader updated to development manager or team members updated to the project leader. The information in the progress report shall include highlights and lowlights of the current status, period of time, status dashboard of cost, schedule, resource and deliverables. Importantly, if any deviation is occurred, and the corrective action is needed to be developed (as the A stage of PDCA cycle), it must also be documented in the report.

In addition, the deliverables checklist is introduced to facilitate the project leader to track the progress of the project. Deliverables checklist will provide the macroscopic picture of all deliverables in each phase of the project, thus it assures that the project leader will not overlook on the deliverables in each phase of the development (University of Notre Dame, 2013). Moreover, the checklist also emphasize that on which phase of the project that the deliverable should be initiated and when to be delivered. The checklist also serves as a key note for project leaders to ensure that they have completed all deliverables before entering the milestone review (Company A's gate review).

4.2.4 Approaches Scope & Requirement Management (SRM)

The primary objective of the SRM process is to assure that all activities or works that require to successfully complete the project and meet project's objectives, and only the required work is included. The output SRM process will indicate on what shall and shall not be included in the project (Project Management Institute, 2013). In addition, it also ensures that the requirements, project's plan and deliverables are aligned, and to prevent any divergence of these three elements can cause redundancy during project execution (CMMI, 2010).

In prior to define the scope of the project, the requirements should be gathered and finalized on how to validate this requirement. The processes to manage the requirement consist of requirement elicitation, requirement analysis and requirement verification & validation (Violante and Vezzetti, 2014) as illustrated in the following diagram (Figure 29).

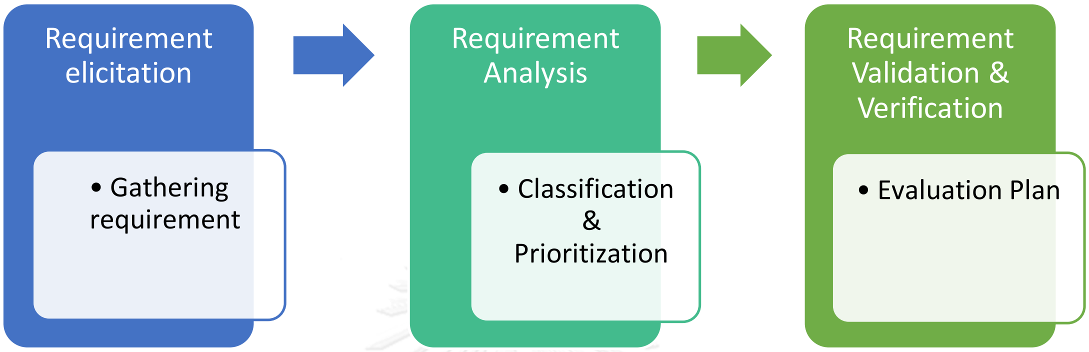


Figure 29 Requirement Management Process

The requirement elicitation is the process where requirements are gathered from the stakeholders. There are several techniques that commonly used to collect the requirement but the project leader shall select the option that most appropriate to the project. The techniques cover historical review, interview, brainstorming, facilitated workshop, questionnaire, observation, prototypes and benchmarking (Mulcahy, 2013). After the requirement are all gathered, it needs to be analyzed in order to categorize and prioritize those requirements on which one is need and preference. Furthermore, the validation and verification of the requirement are intended to develop the evaluation plan to decide whether new product or deliverables meets the requirement or not. Technically, it is the process where the evaluation plan is developed to test the product or the criteria are constructed to assess the quality of deliverables.

As Violante and Vezzetti (2014) has suggested that in order to create the efficient scope and requirement management process, the organization shall have the particular tool that will be used for defining, controlling and documenting any change of the scope and requirement. Moreover, it should also allow the relevant stakeholders to access in order to ensure that the scope and requirements are accurately defined. Accordingly, the project scope statement is introduced as a tool to construct the robust scope and requirement management process of Company A.

The project scope statement is detailed description of the project's scope, requirement, required deliverables, assumptions and constraints (Project Management Institute, 2013). The good preparation of the project scope statement is one of the keys to propel project to the success. It demonstrates major deliverables, work that requires to complete those deliverables and the technical solution to assure the quality and reliability of new product. Besides, it also describes the criteria and condition that the new product should be complied before it is released to mass production (output from requirement validation and verification). Furthermore, this project scope statement will be used as baseline to decide whether the additional request are contained within scope of the project or not (Project Management Institute, 2013). Mulcahy (2013) has provided the intrinsic definition of this document as "Here is what we will do on this project".

CHAPTER V: IMPLEMENTATION

The approaches for improving new product development process of Company A has been introduced in previous chapter. The primary purpose of these approaches is to ensure that the new product will be timely developed and minimized the amount of delay that might happen during the project life cycle. One of the new product development projects in Company A is selected as a case study for implementing these approaches. Although in this case study, the implementation of some approaches might not be applied to involve and cover the whole of project timeline because new product requires long period of time to develop. The approaches that will be implemented are demonstrated in the following action plan.

Table 6 Action Plan

What needs to be done?	When?	By whom?	Expected outputs
Scope and Requirement management	After project is initiated and before planning	Project leader	Project scope statement
Work Breakdown Structure	Planning phase	Project leader	Detailed planning based on WBS
Effective Risk Management	Planning phase	Project leader	FMEA
Earn Value Management	Execution phase	Project leader	Project monitoring and control

5.1 Case Study

The project that has been selected for this case study is related to develop leadframe material in semiconductor package. The approaches to improve project performance will be applied to this project as a case study. However, some information need to be limited to disclose in details with regard to company confidential.

Since leadframe has been one of the key elements that effect to the robustness of semiconductor package because all materials of semiconductor package need to be adhered on the leadframe material, it serves as the backbone of the package. One of the most critical area is the adhesion strength of leadframe and encapsulation material. If the adhesion strength is not high enough, the interface layer between encapsulation material and leadframe surface will originate the gap after the package has been operated and undergone to stress from operating condition. The gap is very critical as it mostly leads to fail function of the semiconductor device. The most acceptable method for improving adhesion strength is leadframe surface modification by applying roughening treatment (RT). The normal surface of leadframe will be smooth but after applying this RT technique, the surface will be roughened as demonstrate in Figure 30. The roughening surface in Figure 30 is the RT technology that currently used in Company A. However, the customers always demand to have better package robustness, and it is expected that the current RT technology might not be able to serve this need in the near future. Accordingly, the objective of this project is to qualify new RT technology in order to improve performance of the semiconductor package. The snapshot of project charter after project has been initiated is shown in Table 7.

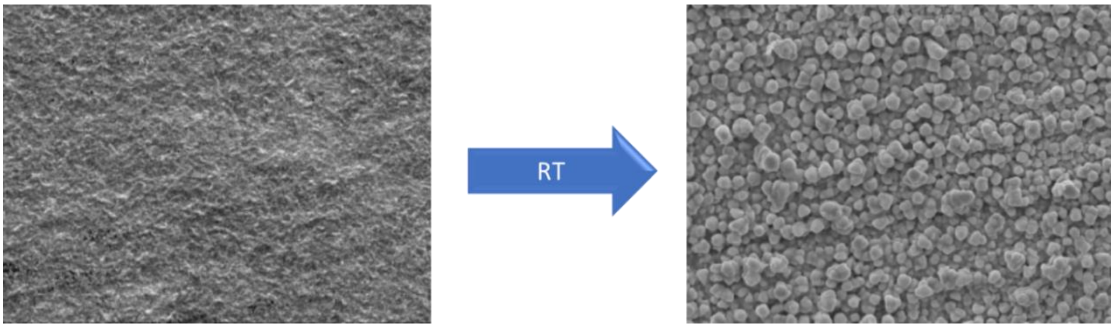


Figure 30 SEM image of leadframe surface, non RT (left) and RT (right)

Table 7 Snapshot of case study project's charter

(Project Charter) APPLICATION SHEET No.	AUT4351			
1. BU / BL / MAG code / at location or indicate other Sponsoring Org & location (BE Operations, CTO, others)	Business Unit / Sponsor Org.	Business Line	Cost Center	Sponsor Location
	BU automotive	In Vehicle Networking	BL70	Nijmegen
2. Product Type / Application	Every product that currently used RT leadframe technology in SO/TSSOP package			
3. Project objective / expected outcome	To qualify the alternative RT leadframe technology which has better perfromance			
4. Lead Customers	Electronics part manufacturer in automotive industry			
5. Expected to be released by	2nd Quater of 2015			
6. Charter approval date	20 June 2014			

5.2 Implementation of the approaches in each phase of project

5.2.1 Scope and requirement management

The intention of this approach is to properly define the scope and requirement in prior to develop the project planning. The approaches are including requirement elicitation, requirement analysis, requirement validation and verification. Subsequently, the scope, assumption, deliverables and constraints will be determined in project scope statement.

5.2.1.1 Define requirement of the project

❖ Requirement Elicitation

The requirements are gathered from relevant stakeholders of the project. There are several ways to gather the requirement. However, in this case study, the author decided to interview key stakeholders in order to obtain the meaningful requirements.

The interview will be arranged via email, international call and face-to-face meeting depending on the convenience of each interviewee. The interviewee includes key project sponsor, business line (customers), product manager, supply chain and quality team.

❖ Requirement Analysis

After the requirement has been gathered, it will be classified and prioritized to have better understanding about project's requirement. Author has conducted the conference call to brainstorm on requirement analysis, while also created an alignment and ensured that all stakeholders are on the same page. The results of requirement analysis are shown in Table 7. In this case study, the priority ranking has been divided into three levels which are:

- 1 ➔ Requirement is needed to have or demand by customer. Lack in fulfillment of this type of requirement leads to customers' dissatisfaction.
- 2 ➔ Requirement is nice to have. Fulfillment of this type of requirement will lead to customers' satisfaction while absence of it not leading to customers' dissatisfaction.
- 3 ➔ This type of requirement will not have any effect on customer satisfaction or dissatisfaction either presence or absence of it.

Table 8 Requirement analysis and verification

Item	Requirement	Priority	Given by	Verification
	Material Requirement (leadframe)			
1	Good roughen surface topography	1	Business Line	Technology and capability survey and SEM image
2	Availiability of process control to measure quality of roughness at supplier site	1	Quality team	Technology and capability survey
3	Topmost layer must not contain metal that reactive to oxidation	1	Business Line	Technology and capability survey
4	Be able to solder	1	Business Line	Solderability Test
5	Must be able to bond with Au and Cu wire	1	Product Manager	Wire pull and shear test
6	Not patented technology	3	Business Line	Technology and capability survey
7	Leadframe thickness is 250µm	1	Product Manager	Technology and capability survey
8	Pre-plated leadframe	1	Product Manager	Technology and capability survey
	Supply chain requirement			
9	Price	2	Purchasing	Not more than 10% price increased from current technology
10	More than one manufacturing location	2	Purchasing	Technology and capability survey
11	Technology already commercialize	3	Purchasing	Technology and capability survey
12	Suppliers comply with Company A payment terms	2	Purchasing	Supplier Agreement
	Supplier certification			
13	Certified TS16949 or passed VDA6.3 audit	1	Quality team	Technology and capability survey
	Package Requirement (Reliability)			
14	Achieved Moisture sensitivity Level 1 (MSL1)	1	Business Line	MSL Assessment
15	No crack on second bond after MSL test	1	Product Manager	Decapsulation and SEM on second bond
16	Passed Temperature Cycling (TMCL) test for 500 cycle without any gap occur inside the package and device still functional	1	Product Manager	Gap analysis after TMCL
17	Device still functional after passed TMCL 1,000 cycles	2	Product Manager	Electrical test after TMCL 1,000 cyc
18	Device still functional after passed TMCL 1,500 cycles	3	Product Manager	Electrical test after TMCL 1,500 cyc
19	Device still functional after passed Humidity Accelerated Stress Test (HAST) for 96 hrs	1	Product Manager	Electrical test after HAST 96 hrs
20	Device still functional after passed HAST for 192 hours	1	Product Manager	Electrical test after HAST 192 hrs
21	Device still functional after passed HAST for 384 hours	2	Product Manager	Electrical test after HAST 384 hrs
22	Device still functional after passed High Temperature Storgate Lifetime (HTSL) test at 500 hrs	1	Product Manager	Electrical test after HTSL 500 hrs
23	Device still function after passed HTSL test for 1,000 hrs	2	Product Manager	Electrical test after HTSL 1,000 hrs
	Package Requirement (Workability)			
24	Material is compatible with existing production machine	2	Process Engineer	Workability test with production machine
25	No resin bleeding after adhesive is dispensed	2	Process Engineer	Resin bleed test
26	Good strength of first and second bond	1	Product Manager	Wire pull and shear test
27	No copper exposed after lead is formed into desired shape	1	Process Engineer	Lead inspection after trim and form process
28	Must passed final test at 150, 25 and -40°C	1	Product Manager	3 temperatures electrical test
29	Good coverage of intermetallic compound (IMC) on first bond	1	Product Manager	Decapsulation and IMC check
30	No package crack or incomplete filled of encapsulation material	1	Product Manager	Visual inspection after package is encapsulated
	System			
31	New package code	1	Supply chain team	Request new package code
32	New leadframe drawing	1	Quality team	Finalize leadframe drawing with supplier

❖ Requirement Verification & Validation

This step is to provide the method or process to verify and validate the requirements. The method will be specified by consulting and brainstorming with the expert or responsible person on that relevant field. Then, the project leader will consolidate these verification plans for those requirements and inform to stakeholders. The methods for evaluating the requirements in this case study are provided in Table 8.

5.2.1.2 Develop Project Scope Statement

The content in project scope statement may include scopes, assumptions, milestones, success criteria, constraints and deliverables of the project.

- Scope Definition
  - ✓ This qualification will consist of qualifying new leadframe material based on available RT technology from various suppliers.
  - ✓ New RT leadframe technology will only be applied on SO/TSSOP package family.
  - ✓ The supplier of selected RT technology must be certified by TS16949 or compatible and must be registered into the supplier list of Company A.
  - ✓ Be completed within 2nd quarter of 2015.
  - ✓ Selecting RT technology must be also verified to demonstrate the compatibility with copper wire.
  - ✓ Price of the new RT technology will not be a primary concern and price negotiation will be responsible by purchasing team.

  - ✓ Any new RT technology that will be introduced after S-gate will not be included in this qualification.

- Assumptions
  - ✓ The process of new RT technology must be appropriately qualified and released at supplier site.
  - ✓ This project must be counted as priority project in 2015 and management must willing to support in a timely manner.
  - ✓ To be completed by 2nd quarter of 2015, resources shall be made available to support when required within a timely manner.
- Constraints
  - ✓ Project must be completed by the end of 2nd quarter 2015.
  - ✓ Availability of RT technology is purely depended on supplier capabilities
  - ✓ The methodology for inspecting quality of RT topography might be cost prohibitive and remarkably difficult to perform. This capability might need to be relied only on supplier site.
  - ✓ Payment term policy of Company A is very strict, some suppliers might not able to comply.
- Project's milestones
  - ✓ Technology selection → Preliminary study and selection of potential RT technology for further qualification process
  - ✓ S-gate → Finalize specification and planning
  - ✓ A-gate → Sample available

- ✓ V-gate ➔ Sample has been undergone reliability test until it reaches the required read-point
- ✓ R-gate ➔ Release new RT leadframe technology

▪ Success criteria

- ✓ Be able to find new RT technology enhances package robustness within 2nd quarter of 2015
- ✓ New RT technology can pass MSL1 and TMCL 500 cycles with no gap occurrence at interfacial layer
- ✓ Device is still functional after passed TMCL 500 cycles, HAST 96hrs and HTSL 500 hrs
- ✓ Positive workability, sample must unconditionally pass the quality criteria of assembly process line in Company A

▪ Deliverables (high-level)

- ✓ Prototype sample with new RT leadframe
- ✓ Reliability report
- ✓ Development report
- ✓ Specification for new RT leadframe
- ✓ Failure analysis report (if there is any failure occur)

5.2.2 Work Breakdown Structure (WBS)

Requirement exposes the needs and expectations of the project while scope determines the boundary of the project. In addition, project scope statement will be used as the agreement to regulate the direction and activity of the project. Therefore, after scope and requirement are properly defined, WBS approach is introduced to decompose the scope of the project into more manageable pieces and provides the comprehensive outlook of the project in order to facilitate and improve project planning process. The WBS is applied to the case study and shown in Figure 31.

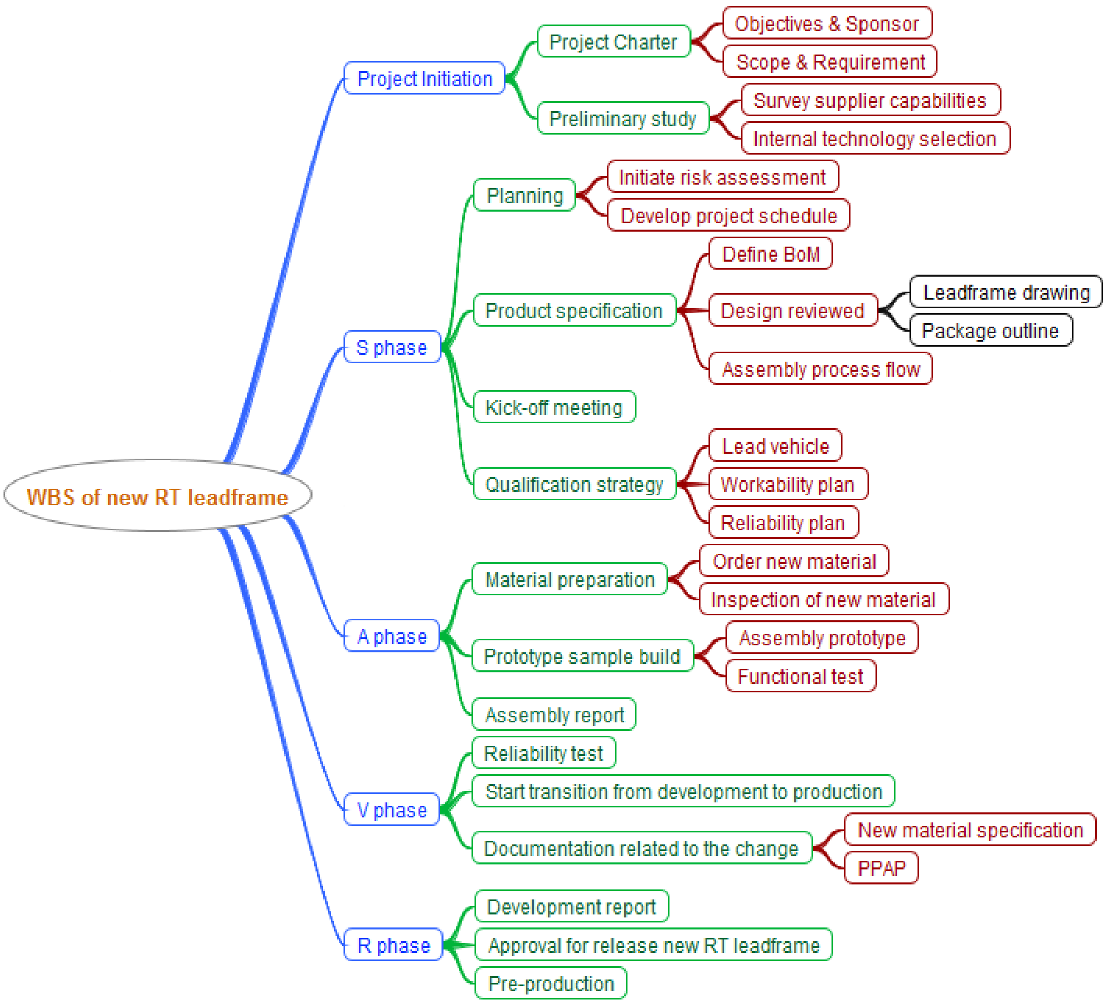


Figure 31 Work Breakdown Structure of case study

To have better understanding of this WBS structure, list of deliverables and required activities based on this each work package of this WBS are demonstrated in Table 9.

Table 9 Deliverables and activities checklist

Item	Work Package	Deliverables and activities	Time (wk)
Charter	Objectives & Sponsor	Define project's objective and project's sponsor	1
	Scope & Requirement	Project scope statement	0.5
		Requirement analysis	1
Preliminary study	Supplier capabilities	Material capabilities provided by supplier	2
	Internal technology selection	Internal characterization	3
		Decision matrix	0.5
Planning	Risk Assessment	FMEA	2
	Project scheduling	WBS	0.5
		Time plan	0.5
Product specification	Define BoM	List of material that need for new product	0.5
	Leadframe drawing	leadframe drawing review and approved	2
	Package outline	Requested code for new package	1
		Gather information of new package	0.5
	Assembly process flow	define new process flow (if process changed)	0.2
Kick-off meeting		Introduce new project and inform support needed from stake holders	0.1
Qualification strategy	Lead vehicle	selection of lead vehicle for prototype sample	1
	Workability plan	Quality criteria that related to new RT leadframe	1
	Reliability plan	define reliability test that related to new RT leadframe	1
Material Preparation	Order new material	Create purchasing order to leadframe supplier	1
		Leadframe sample build	8
	Inspection of new material	Dimension check	1
		Plating thickness	1
		Surface topography	3
Prototype sample build	Assembly prototype sample	Workability test and prototype sample built	2
		Assembly yield check	0.2
	Functional test	Functional test yield and report	0.2
	Assembly report	Document result of workability and functional test	0.5
Reliability test		Submit sample to reliability lab	0.1
		MSLA	4
		TMCL 1,500 cycles	11
		HAST 396 hrs	5
		HTSL 1,000 hrs	9
Transition from development to production		Meeting and share result and process parameter to process engineer	0.1
Documentation related to the change	New material specification	Upload approved specification into internal system	2
	Production Part Approval Process (PPAP)	Signed PPAP	2
Development report		Signed development report	1
Approval for release new RT leadframe		Release certificate with signature of authorized person	2
Pre-production		Working instruction	0.5
		Closely inspection on first 10 production lot	4

The WBS in Figure 31 will be used as a guideline to develop the detailed project planning, the project planning of this case study is shown in Figure 31 and 32. The red bar indicates the critical path in this project's schedule.

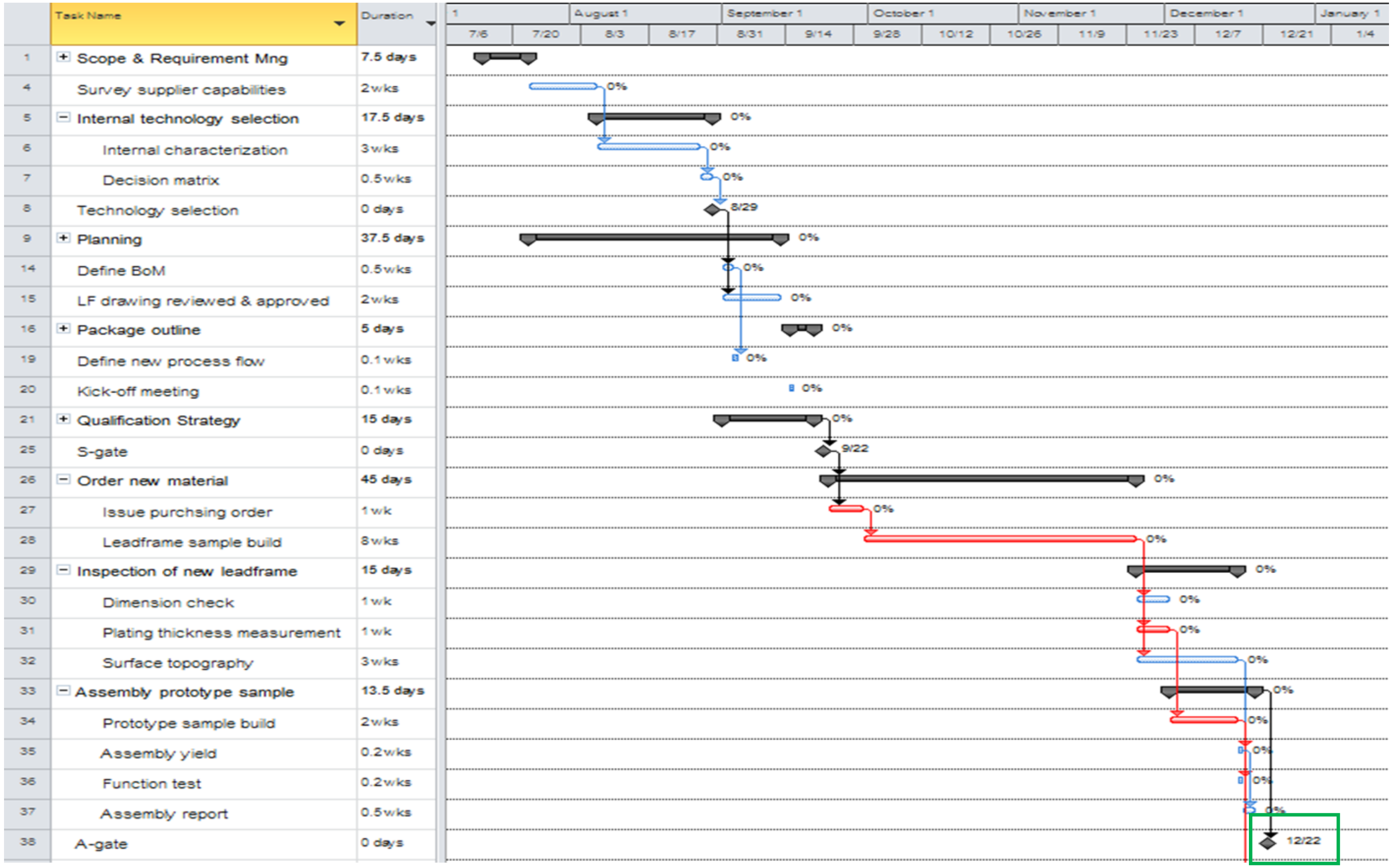


Figure 32 Time plan of case study from initiate until A-gate (green rectangle)

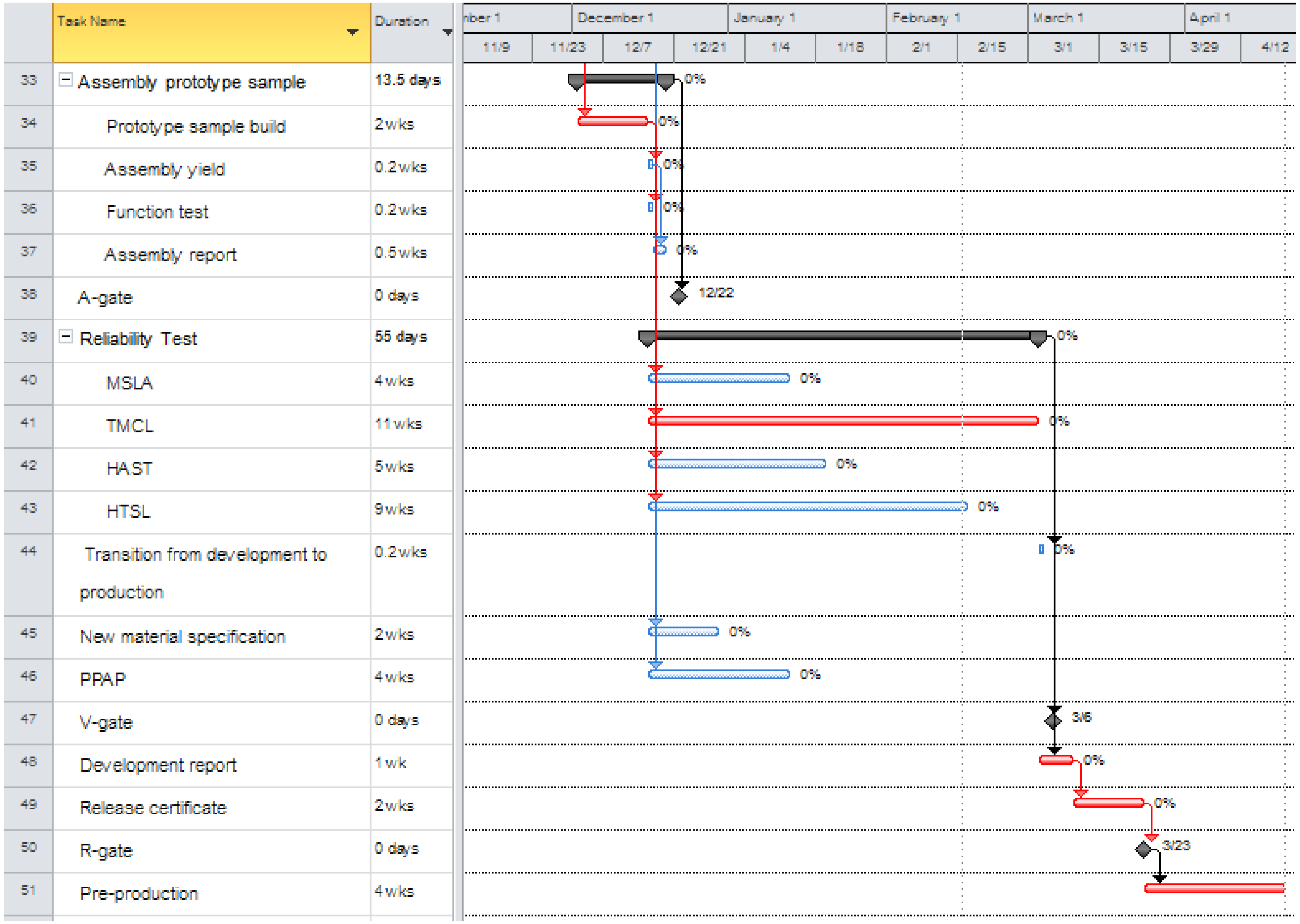


Figure 33 Time plan of case study from A-gate (green rectangle) until R-gate (continue from Figure 32)

5.2.3 Risk Management

FMEA concept will be used as a tool to bring the effective risk management either for non-technical or technical risk management. As risk management process is necessary to be conducted throughout the project life cycle, but with the limited time frame of this research, author will only be possible to demonstrate the result of this approach only from project initiation until project has reached the A-gate.

5.2.3.1 Technical risk management

This section will describe FMEA concept that will be implemented to the case study for new product development process in Company A.

5.2.3.1.1 FMEA ranking scale and criteria

As mentioned in previous chapter, the key element of the FMEA is ranking score consist of Severity (S), Occurrence (O), Detection (D) and Risk Priority Number (RPN). Importantly, the "customers" that will be used in description of these ranking score are referred to internal and external customers. Internal customers are the next process while external customers are the end customers. The scale and criteria in this section are the description of the score in FMEA that will be used in a technical risk management of the case study as demonstrated in the following tables.

Table 10 Ranking scale and criteria for Severity (S)

Impact level	Description of severity of effect	Rank
Negligible	Failure or defect has no effect on the function of the device and shall has no effect to the customers	1
Minor	Effect of failure is has minimal effect and device still fully functional	2
Low	Device operable, failure can be noticed by customers but as the cosmetic defect	3
	Device operable, failure can be noticed by most of customers and create dissatisfaction	4
Moderate	Slight performance degradation, correction is possible	5
	Slight performance degradation, correction is not possible	6
High	Performance degradation but device still operable	7
	Device inoperable or severly fails to meet specification	8
Extreme	Potential to create hazardous effect or non-compliance to government regulation	9
	Failure of device can create safety-related problem	10

Table 11 Ranking scale and criteria for Occurrence (O)

Likelihood	Description of likelihood of occurrence	Rank
Negligible	Preventive control has eliminated the failure (or less than 1ppm)	1
Low	No failure with almost identical design or > 1 in 100,000 (10 ppm)	2
	Unlikely failure with almost identical design or > 1 in 10,000 (100 ppm)	3
Moderate	Irregular failure with almost identical design or > 1 in 5,000 (0.02%)	4
	Irregular failure with similar design or > 1 in 1,000 (0.01%)	5
	Frequent failure with similar design or > 1 in 500 (0.2%)	6
High	Irregular failure with new design or > 1 in 100 (1%)	7
	Frequent failure with new design or > 1 in 10 (10%)	8
Negligible	Failure inevitable with new design or > 1 in 4 (25%)	9
	New technology, no history or > 1 in 2 (50%)	10

Table 12 Ranking scale and criteria for Detection (D)

Detection level	Opportunity of detection by control method	Rank
Prevention	Failure are prevented or very unlikely to happen	1
Very Effective	Design analysis or control can detect in prior to freeze the design	2
High	Non-destructive automatic detection with strong capability	3
	Product validation by degradation testing	4
Moderate	Product validation by failure or destructive testing	5
	Failure is detected in-process by judgement of operator	6
Low	Failure is detected post-porcess by judgement of operator	7
	Product validation after design freeze, and require large volume to detect failure	8
Unlikely	Control have weak detection capability, has possiblity of misdetection	9
Impossible	No contronl method to detect the failure mode at any stage	10

5.2.3.1.2 Risk Priority Number (RPN)

RPN is the elements that determine the criticality of identified risk and require the response when that particular risk has RPN value exceed the threshold. Generally, the threshold value must be specified with the alignment from quality team and customers. However, as the FMEA is applied based on guideline from Automotive Industry Action Group where the common practices of the threshold for RPN is suggested to be 100.

5.2.3.1.3 FMEA case study (new RT leadframe technology)

The technical risk management of the case study is demonstrated in following FMEA (Table 13 and 14)

Table 13 Technical FMEA

Function / Items	Potential Failure Mode	Potential Effect(s) of Failure	SEVERITY	Potential Cause(s) of Failure	OCCURANCE	Current Design Controls: Prevention	Current Design Controls: Detection	DETECTION	RPN	Recommended Action (s)	Responsible person	Target Complete	Action Results: Status	Action Results: SEVERITY	Action Results: OCCURANCE	Action Results: DETECTION	Action Results: RPN
Assembly process																	
Die Attach	Adhesive resin bleeding cover functional area	Unable to wire bond on resin bleed area	8	High surface energy on RT surface	10		Observe resin bleed after adhesive is dispensed	6	480	Request supplier to coat anti-resin bleed agent on RT surface	Project leader	Before order leadframe sample	Done	8	1	6	48
		Gap on resin bleeding area after encapsulation	6	Encapsulation material have poor adhesion with resin of adhesive	10		Observe resin bleed after adhesive is dispensed	6	360	Request supplier to coat anti-resin bleed agent on RT surface	Project leader	Before order leadframe sample	Done	6	1	6	36
	Fail die shear test	Die lifted after MSL test	6	Adhesive has low adhesion to RT layer	7		Die shear test	5	210	Perform DST on new RT leadframe sample	QA team	24 Nov' 14	Done	6	2	6	72
Wire Bonding	Second bond pull fail	Crack on second bond on subsequent process	7	Poor intermetallic strength of wire and leadframe surface	10		Stitch pull test	6	420	Perform second bond pull test on new RT leadframe sample	QA team	27 Nov '14	Done	7	2	6	84
Encapsulation	Leadframe warpage after encapsulated	Leadframe jam at output Mold and Trim/Form	7	Adhesion between compound and leadframe was changed	7		Virtual similation	2	98								
Trim & Form	Pre-plating layer crack	Poor solderability	7	Unsuitable of lead forming tool	2		Discuss and analyse new design with trim & form expert	2	28								

Table 14 Technical FMEA

Function / Items	Potential Failure Mode	Potential Effect(s) of Failure	SEVERITY	Potential Cause(s) of Failure	OCCURANCE	Current Design Controls: Prevention	Current Design Controls: Detection	DETECTION	RPN	Recommended Action (s)	Responsible person	Target Complete	Action Results: Status	Action Results: SEVERITY	Action Results: OCCURANCE	Action Results: DETECTION	Action Results: RPN
Material																	
Environmental factor	Lead Discoloration	Poor solderability	7	Metals react with external environment lead to loss in their natural properties	7		Discuss the mechanism of failure with chemical expert	5	245	Discoloration test	Failure Analysis lab	10 Dec '14	Done	7	3	5	105
										Use shielding bag to pack the product	Packing team		Done	7	1	5	35
Poor roughening surface	Gap occur between leadframe and encapsulation material	Package cannot achieve primary requirement	7	Low roughness topography	7		Surface characterization on different batch of RT leadframe	4	196	Assess roughness control method at supplier site	QA and leadframe expert	end of Jan'15	On going				
Reliability																	
MSLA	Delamination more than control lot	Package Crack	7	Low adhesion between compound and lead frame	8		Ultrasonic scan to observe gap inside package	3	168	Cross section package and verify gap	Reliability team	After MSL test	Not start, sample not yet available				
TMCL	Stitch neck broken	Open circuit	8	Incompatible thermal expansion of two materials	8		Electrical test after TMCL	3	192	Decapsulation and observe initial crack on second bond	Reliability team	After 500 cycles and 1,000 cycles of TMCL	Not start, sample not yet available				
HAST	Metal dendrite	short circuite between lead	8	Metal extently growth due to temperature and biased	2		Decapsulation after HAST	5	80								
HTSL	Degradation of second bond	Open circuit	8	Intermetallic layer degraded after passed high temperature	2		Decapsulation after HTSL	5	80								

Risk is one of the primary factors that cause failure to the project management. Development of effective risk management since planning phase is critical to the success of the project. The process of developing FMEA is initiated as the project leader will conduct the meeting to gather the input of the potential failure mode in each field. For instance, the input of failure mode that relevant to assembly process flow will be gathered from expert in each process area either from process engineer or process development team as Table 15 demonstrated the example of participants for assessing risk in wire bonding process area. Furthermore, this FMEA has divided into three major areas that are related to the technical aspects which are assembly process, leadframe material and reliability test.

Table 15 Participant in FMEA to assess risk in wire bonding area

Partcipants	Knowledge area	Expectation
Front-End Process Engineer	Wire bonding process Die attach process	Provide input about potential failure mode that relevant to the change in wire bonding and die attach process
Wire Bonding process Development Engineer	Wire bonding process	Provide input about potential failure mode that relevant to the change in wire bonding process
Development manager (DM)	New product development	Experienced in development and provide strong comment on possiblity of detection and corrective action
QA Engineer	Quality control	Provide input related to current control method on that particular failure mode and quality of new product
Project leaders (PL)	Manage technical staff who relevant to that particular failure mode	Gather experienced staff to be involved and obtain input to create proper FMEA
Material Development Engineer (leadframe)	Leadframe material	Could provide input on each process area that interact with leadframe, recommended action to verify the failure mode

In addition, to score severity, occurrence and detection of each particular failure mode, the score will be received from each participant, then averaged those input scores and filled into the table (round the number if the average is not an integer) as demonstrated in Table 16. On the first version of FMEA, most of the occurrences in each particular failure mode are relatively high because of new technology of RT leadframe and since only some of technical attribute can be referred to the historical design. However, the failure mode is verified by the recommended action to determine the appropriate level of occurrence and detection of that particular failure mode.

Table 16 Scoring on "Second bond pull fail" failure mode

Failure mode	Participants	Effect	S	Cause	O	Detection	D
Second bond pull fail	Front-End Process Engineer	Crack on Second bond on subsequent process	7	Poor Intermetallic strength of wire and leadframe surface	9	Perform second bond pull on new LF sample and observe remaining wire shape	6
	WB development Engineer		7		10		5
	QA Engineer		6		10		6
	Development Manager		7		10		5
	Project leader		6		9		5
	Material Development Engineer		8		10		6
		Average	6.8	Average	9.7	Average	6

5.2.3.2 Non-technical risk management

FMEA is the structural risk management on the basis of the failure mode of the application area. To apply this FMEA to non-technical risk management might need some modification from the technical risk management but the main concept will remain the same. For non-technical risk management, the detection attribute will be removed as it might not applicable in some situation. Likewise, the ranking description of the impact of the risk will be based on severity of the delay on schedule, as the new product development in Company A is time oriented where time-to-market is the critical attribute in new product development.

5.2.3.2.1 Ranking scale and criteria

Table 17 Ranking scale and criteria of severity (non-technical)

Impact level	Description of severity of effect	Rank
Minor	Insignificant of delay	1
Low	1 weeks of schedule delay	2
Moderate	2-3 weeks of schedule delay	3
High	4-5 weeks of schedule delay	4
Extreme	more than 6 weeks of schedule delay	5

Table 18 Ranking scale and criteria of probability of occurrence (non-technical)

Likelihood	Probability of occurrence	Rank
Minor	1-10%	1
Low	11-20%	2
Moderate	21-35%	3
High	36%-50%	4
Extreme	50%-100%	5

The participants in scoring of non-technical risk will mostly include only project leader and development manager as most of the risk are related management aspect and they are considered to be an expert in this field. The score on severity and occurrence will be aligned between project leader and development manager similar to technical risk assessment.

5.2.3.2.2 Probability and Impact rating

For non-technical risk management, the rating of criticality is a bit more delicate. The score of severity and occurrence will be matched and assessed the criticality with risk matrix in Figure 34. If the particular risk is matched in red zone, that risk must have contingency plan. Even the product of severity and occurrence are the same but the criticality is different as the impact of severity effect is dominated the level of occurrence. However, it encourages to have contingency plan for risk mitigation in every identified risk as a precaution because risk is always unanticipated.

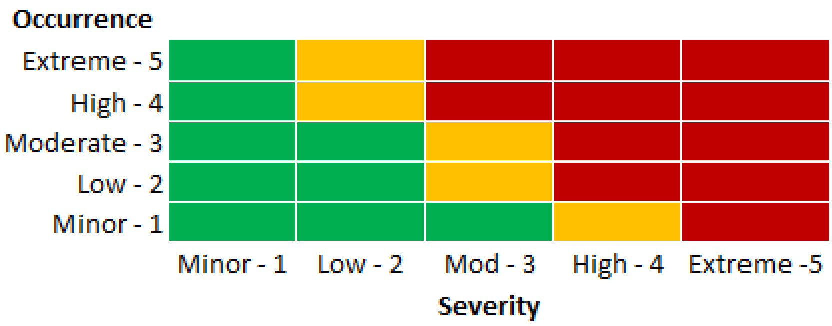


Figure 34 Non-technical risk matrix

5.2.3.2.3 Non-technical risk management of case study

The non-technical risk management of the case study is demonstrated in Table 19

Table 19 Non-technical risk assessment of the case study

Function	Potential Risk	Consequence	S	Cause	O	Color zone	Mitigation	Who?	When?
Material	Delay of leadframe sample delivery	Project delay because sample can't be built	3	Supplier delay to deliver sample and not notice in advance	2		Frequently follow up with supplier about the progress of sample and encourage them to raise any issue found	Project Leader	During leadframe sample built
	Poor quality of leadframe sample	Project delay because sample can't be built	5	Supplier didn't aware of low quality of sample	1		Request the report of outgoing quality control of the sample from supplier	Project Leader	Before order leadframe
	No response from leadframe supplier during RT technology survey	Project delay, due to no input for decision making	3	Contacted person overlook on request or forget	2		Follow up via email or phone call, in case of no response more than one week	Project Leader	During technology survey
Assembly process flow	No resource from support team to build Prototype sample	Project delay because sample can't be built	2	Resources are allocated to support urgent isse	1		Request technician in production line to support, but need to inform in advance	Project Leader	After develop project schedule
	Production can't allocate machine to support prototype sample built	Project delay because sample can't be built	3	Demand ramp up, production full capacity	3		Reserve machine in advance (min. 4 weeks), so production can manage their capacity	Project Leader	After develop project schedule
	No eletrical test board to support new product	Project delay because sample can't be tested	5	Package outline change, current test board can't support	1		Align new package outline with final test engineer	Project Leader	After develop project schedule
Reliability	Long queing time of reliability test after submit sample to lab	Project delay because sample can't be tested	3	Full capacity in reliability lab	4		Reserve capacity in reliability test in advance	Project Leader	After develop project schedule

5.2.4 Earned Value Management (EVM)

EVM is a technique that combine aspect of cost and time in the same framework with purpose to measure the performance of the progress made against what was planned. The technique includes indices and variances of cost and schedule to enable users to track the cost overrun or delay on schedule. However, the new product development in Company A is time oriented because time-to-market of new product is the primary concern. The aspect of time is significantly dominated the aspect of cost. Accordingly, in this case study, only the aspect of time will be used to measure the performance of the progress made for project monitoring and control. The formula of index and variance regarding the aspect of time is demonstrated in Table 20. As mentioned in previous chapter, EV stands for Earned Value and PV is Planned Value.

Table 20 Variance of EVM for case study

Variances	*Formula*	*Interpretation*
Schedule Variances (SV)	SV = EV - PV	SV ≥ 0 ; Project is ahead or in schedule SV < 0 ; Project is behind schedule

Furthermore, as the case study requires very long duration that is almost 40 weeks for development, under the limited time of this research. Therefore, the author will only be possible to demonstrate the result on some portion of the development since project is initiated until it has reached A-gate (milestone). In prior to demonstrate the implementation of the EVM to the case study, author would like to explain on some parameter that will be shown in the EVM approach. Table 21 demonstrates the work packages from WBS in Figure 31 with the details of cost and effort on each work package that has been converted into monetary basis (Planned Value or PV) while also indicate the plan of start and expected finish date in couple with actual start and finish date of each individual work package.

The week code that has been used in Table 21 is labelled in four digits, the first two digit of the week code are the last two digit of A.D. year, and the last two digits of the week code are calendar week of each particular year. For instance, if it is week 37 of 2014, the week code is 1437. Furthermore, on “resource” column of Table 21, it states the resource that requires for each work package, the percentage in parentheses indicates the level of effort of each particular resources.

With regard to Table 21, the cost in column “PV” is converted to the effort and expense that require for each work package into monetary value. Table 5.17 shows the price list of each resources and operations. The information of these costs is received by financial department of Company A. However, the cost structure of each resource is only estimated value from the actual value as it is confidential and not allowable to disclose, some items are estimated in lump sum for ease of use in calculation.

Table 21 Details of cost and resource for each work package

Item	Work Package (WP)	Time (wk)	Resources	PV (USD)	Planned Start	Planned Finish	Actual Start	Actual Finish
1	Objectives & Sponsor	1	PL(20%)	120	1428	1428	1428	1428
2	Scope & Requirement	1.5	PL(50%)	450	1429	1430	1429	1430
3	Supplier capabilities	2	PL(50%)	600	1430	1432	1430	1433
4	Internal technology selection	3.5	PL(10%) + Ext. Lab	5,210	1432	1435	1432	1437
5	Risk Assessment	2	PL (50%)	600	1436	1437	1437	1439
6	Project scheduling	1	PL (50%)	300	1430	1431	1430	1431
7	Define BoM	0.5	PL (50%)	150	1436	1436	1437	1438
8	Leadframe drawing	2	Design (50%)	500	1436	1437	1439	1440
9	Package outline	1.5	PL (20%) + Design (50%)	555	1438	1438	1438	1438
10	Assembly process flow	0.1	PL (80%)	48	1436	1436	1437	1437
11	Kick-off meeting	0.1	PL (50%)	30	1438	1438	1441	1441
	Qualification Strategy							
12	- Lead vehicle selection	1	PL (20%) + DM (20%)	290	1436	1436	1437	1438
13	- Workability plan	1	PL (50%)	300	1437	1438	1439	1440
14	- Reliability plan	1	PL (50%)	300	1437	1438	1440	1441
15	Order new leadfame (300kpcs + tooling)	9	Mat. Cost	4,000	1439	1448	1440	1449
	Inspection of new material							
16	- Dimension Check	1	QA (100%)	300	1448	1449	1449	1450
17	- Plating thickness	1	QA (100%)	300	1448	1449	1449	1450
18	- Surface topography	3	Ext. Lab	5,000	1448	1451	1449	
19	Assembly prototype sample	2.2	Support (80%) + sample	3,792	1449	1451	1449	1451
20	Functional test	0.2	FT Eng (100%)	140	1451	1451	1451	1451
21	Assembly report	0.5	PL (100%)	300	1451	1452	1451	
	Reliability test							
22	- MSLA	4.1	MSLA	1,000	1451	1503		
23	- TMCL 1,500 cycles	11	TMCL	3,000	1451	1510		
24	- HAST 396 hrs	5	HAST	3,000	1451	1504		
25	- HTSL 1,000hrs	9	HTSL	2,000	1451	1508		
26	Transition from development to production	0.1	PL (50%)	30	1510	1510		
27	New material specification	2	PL (50%)	600	1451	1452		
28	PPAP	2	Purchasing & QA (50%)	800	1451	1503		
29	Development report	1	PL (100%)	600	1510	1511		
30	Approval for release new RT leadframe	2	DM (50%)	850	1511	1513		
31	Pre-production	4.5	PL (20%) + PE (20%)	1,080	1513	1518		

Table 22 Price list of resource, operation and material

	Category	Description	Cost (USD)
1	supplier	External lab (lump sum)	5,000 per request
2	supplier	Leadframe cost	10 per kpcs
3	supplier	Leadframe tooling cost	1,000 per design
4	Internal	Prototype sample (lump sum)	3,000 per lot
5	Reliability	MSLA (lump sum)	1,000 per lot
6	Reliability	TMCL (lump sum)	1,000 per 500 cycles
7	Reliability	HAST (lump sum)	1,000 per 96hrs
8	Reliability	HTSL (lump sum)	200 per 100 hrs
9	Human	QA operator	300 per week
10	Human	Project Leader (PL)	600 per week
11	Human	Process Engineer (PE)	600 per week
12	Human	Development Manager (Heldman)	850 per week
13	Human	Support team	450 per week
14	Human	Purchasing	500 per week
15	Human	Design Engineer	500 per week
16	Human	Final Test (FT) engineer	700 per week

As previously mentioned, the approaches are only planned to apply to the case study until the status reach A-gate or week 1451. Accordingly, the column of “actual finish” is filled in only the work package that finished by week 1451. The blank space is referred to the particular work packages which are actually completed later than week 1451.

Furthermore, Table 5.18 is EVM analysis of the case study in tabular form with timeline since project is initiated. This table demonstrates the cumulative value of PV and EV according to the progress of the project and specifies on which work package is completed and which one is still in progress. Moreover, it also includes the SV or schedule variance as the indicator to identify the delay in schedule of progress made.

Table 23 EVM analysis in tabular format

Timeline	Cumulative PV	Cumulative EV	PV	EV	WP Completed	WP on Progress	SV	Status
1429	120	120	120	120	1	2	0	On
1431	870	870	750	750	1-2, 6	3	0	On
1433	3,970	3,970	3,100	3,100	1-3, 6	4	0	On
1435	6,680	3,970	2,710	0	1-3, 6	4	-2710	Behind
1437	8,268	6,728	1,588	2,758	1-4, 6, 10	5, 7, 12	-1540	Behind
1439	11,453	8,323	3,185	1,595	1-7, 9-10, 12	8, 13	-3130	Behind
1441	11,453	11,453	0	3,130	1-14	15	0	On
1443	11,453	11,453	0	0	1-14	15	0	On
1445	11,453	11,453	0	0	1-14	15	0	On
1447	11,453	11,453	0	0	1-14	15	0	On
1449	16,553	15,953	5,100	4,500	1-15	16-19	-600	Behind
1451	22,985	20,485	6,432	4,532	1-17, 19-20	18,21	-2500	Behind
1501	23,885		900					
1503	25,685		1800					
1505	28,685		3000					
1507	28,685		0					
1509	30,685		2000					
1511	33,685		3000					
1513	34,535		850					
1515	34,535		0					
1517	34,535		0					
1519	35,615		1080					

The column "Timeline" in Table 23 is referred to the checkpoint where the progress made is monitored. The frequency of the checkpoint in this case study is appointed in fortnightly because majority of the lead time of each work package is one to two weeks, so fortnightly monitoring the progress is the duration that significant progress to be done. The method for monitoring the progress is agreed to set as the face-to-face meeting while the main participants are project leader, development manager and personnel who relate to the work package.

In addition, the method for determining the progress or EV of each particular work package in this case study is “Fixed Formula Method” as this method is recommended to be applied if the accounting period is less than 3 months (Patil, Patil and Chavan, 2012). Generally, the method applies the percent of completion to each work package only on the starting and finishing date of that particular work package. The percentage that will be used in this case study is 0/100 and 50/50.

- 0/100 ➔ Referring to nothing is earned when the work is initiated but earned 100% of the value when that work is completed. This percentage criteria will be applied to the work package that require the use of internal resource.
- 50/50 ➔ Referring to 50% of the value is earned when the work is initiated and earned another 50% when that work is completed. This percentage criteria will be applied to the work package that require to outsource or any activity that performs outside the company such as purchasing raw material from supplier.

Likewise, Figure 35 demonstrates the result of EVM approach in graphical format that was plotted from the data in Table 23. The “red” rectangle in Figure 34 is intended to emphasize the progress is already behind the schedule which also indicated by negative SV value during week 1435 to 1439. Since the delay is notably started on week 1435 and effects to subsequent activity which can cause significant delay in the project if any corrective action weren’t timely taken.

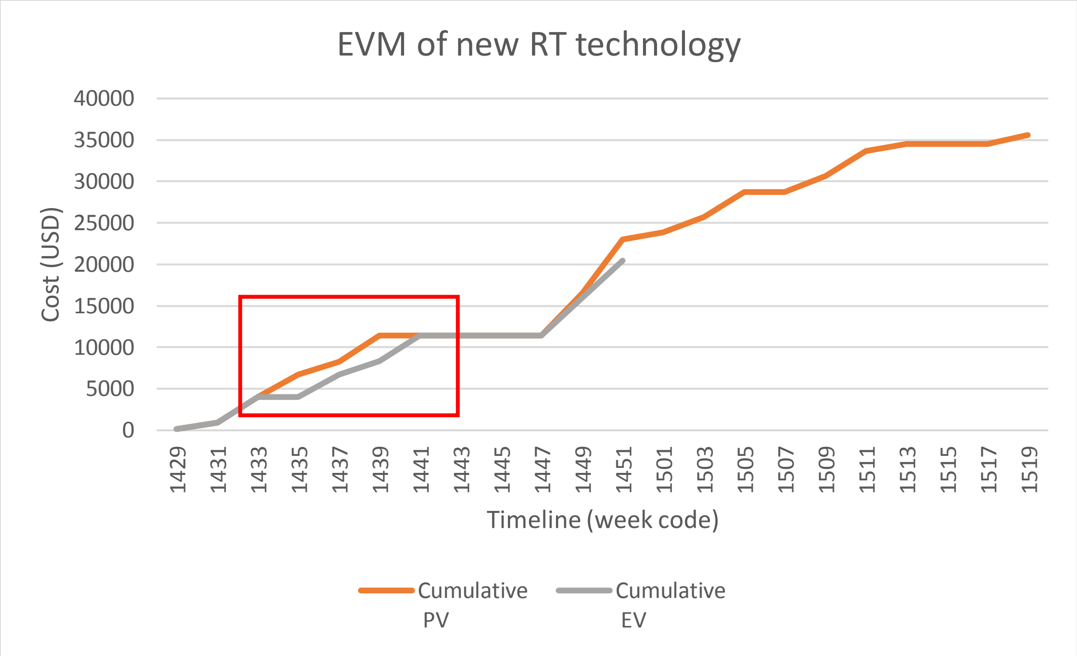


Figure 35 EVM in graphical form

CHAPTER VI: RESULTS AND ANALYSIS

After the case study that provides in this research to demonstrate on how these approaches will be implemented in each phase of project, in order to have better understanding on these approaches, this chapter is determined to discuss the results of the implementation of proposed approaches.

6.1 Scope and requirement management

Firstly, the scope and requirement management is implemented to gather and prioritize the requirement from relevant stakeholders since project has been initiated. The requirement management will ensure that the requirement is aligned among stakeholders. Then, the project scope statement is derived from the requirements that have been gathered and prioritized. Project scope statement includes scope, success criteria, deliverables, assumptions and constraints of the project in order to create boundary of the project and determines on what activity shall be included and what shall not. In addition, during the executed project there are no additional work or deliverables, it can be argued that because of effective scope and requirement management as "what are we going to do in this project" it is already defined since day one. The result has shown that there is no unexpected work or scope creep to cause the delay during execution phase.

6.2 Work Breakdown Structure (WBS)

WBS is constructed to decompose the scope of the project into manageable task then used it as a guideline to develop the project schedule that include all activities to complete the deliverables which required to accomplish the project objective. Moreover, the project planning that has been developed from WBS will be more detailed and effective in using for new product development. The comparison of planning without (from the former project) and with (from the case study) using WBS is demonstrated in Figure 36 and 37 respectively. The project's schedule from WBS covers all activities and milestone that required for developing new product in Company A. The detailed project schedule will ensure that all activities are included since planning phase. A result, no additional work has been added to cause the delay in project after project execution. The red bar in project schedule indicates the critical path of this project schedule.

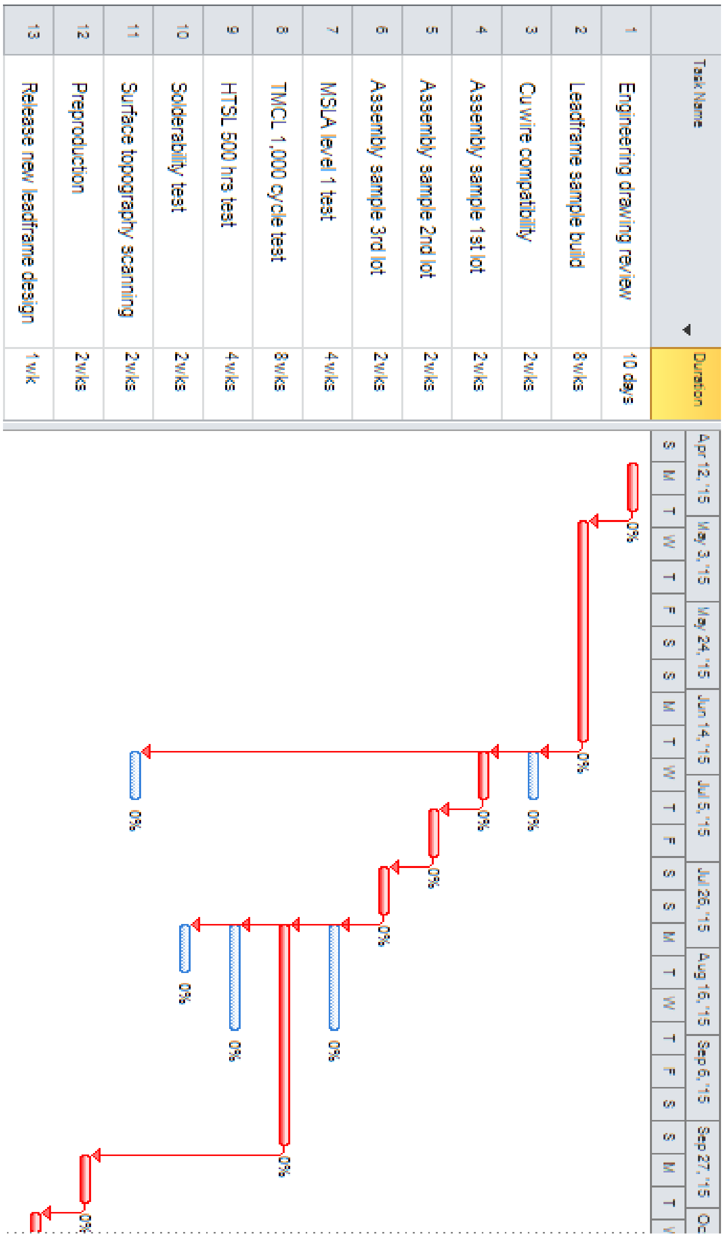
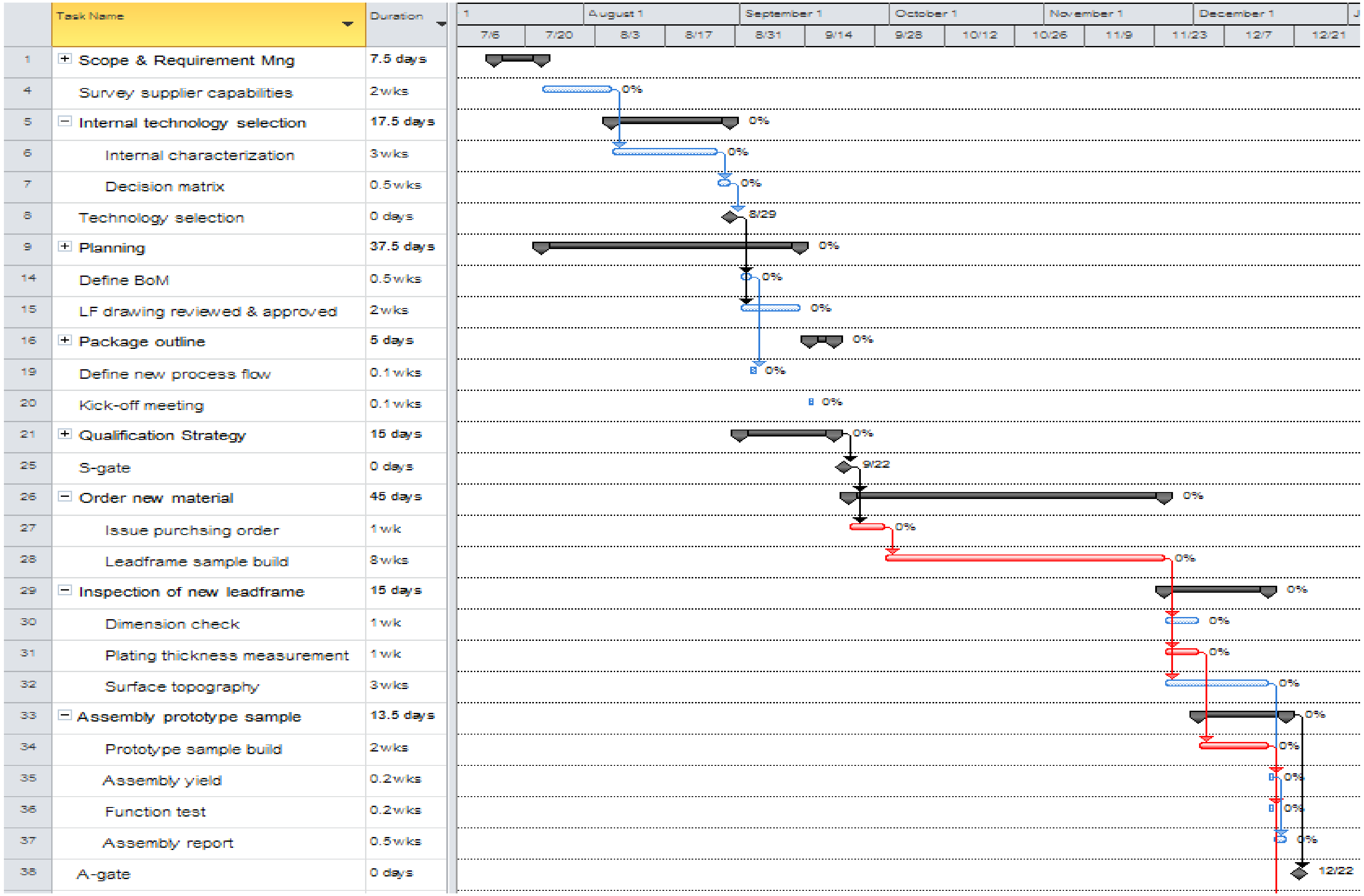


Figure 36 Poor project schedule

Figure 37 Detailed project's schedule from WBS (since initiation to A-gate)



6.3 Failure Mode and Effect Analysis

Furthermore, FMEA is applied to identify and analyze technical risks which also determine the recommend action to mitigate the particular risk that considers to be critical by using RPN threshold as major criteria. FMEA has brought an analytical risk management that helps project leaders to perform risk management more effectively. The risk will identify, analyze, respond and monitor in more appropriate manners as the comparison with Table 24 and 25 to demonstrate the difference between former risk management and FMEA respectively. Risk management with FMEA provides a better way to systematically assess the risk that discloses the cause and effect of the problem, and how the problem will be detected while also prioritized and monitored the risk which considers as significant improve from the current risk management. In case of non-technical risk, the method in risk analysis is modified from conventional FMEA with primary focus on the impact of schedule while the process concept of risk identification remains the same. The criteria to determine the criticality of non-technical risk are indicated by using risk matrix.

Table 24 Project risk management without implementing FMEA

Technical Risks	*Risk Lv*	*Mitigation & Verification*
Poor second bond quality	Low	Second Bond Pull test and observation of its remaining on lead area, comparison of its result with original material
LF Warpage after molded	Low	Observe warpage after Post mold cure and compare between CuNi3 and CuCr
Burr/Smear (after package sawn)	Low	Quality inspection after package is sawn into individual unit
Effect on RF performance	Low	Product characterization check on RF product

Table 25 Project risk management with FMEA

Function / Items	Potential Failure Mode	Potential Effect(s) of Failure	SEVERITY	Potential Cause(s) of Failure	OCCURANCE	Current Design Controls: Prevention	Current Design Controls: Detection	DETECTION	RPN	Recommended Action (s)	Responsible person	Target Complete	Action Results: Status	Action Results: SEVERITY	Action Results: OCCURANCE	Action Results: DETECTION	Action Results: RPN
Assembly process																	
Die Attach	Adhesive resin bleeding cover functional area	Unable to wire bond on resin bleed area	8	High surface energy on RT surface	10		Observe resin bleed after adhesive is dispensed	6	480	Request supplier to coat anti-resin bleed agent on RT surface	Project leader	Before order leadframe sample	Done	8	1	6	48
		Gap on resin bleeding area after encapsulation	6	Encapsulation material have poor adhesion with resin of adhesive	10		Observe resin bleed after adhesive is dispensed	6	360	Request supplier to coat anti-resin bleed agent on RT surface	Project leader	Before order leadframe sample	Done	6	1	6	36
	Fail die shear test	Die lifted after MSL test	6	Adhesive has low adhesion to RT layer	7		Die shear test	5	210	Perform DST on new RT leadframe sample	QA team	24 Nov' 14	Done	6	2	6	72
Wire Bonding	Second bond pull fail	Crack on second bond on subsequent process	7	Poor intermetallic strength of wire and leadframe surface	10		Stitch pull test	6	420	Perform second bond pull test on new RT leadframe sample	QA team	27 Nov '14	Done	7	2	6	84
Encapsulation	Leadframe warpage after encapsulated	Leadframe jam at output Mold and Trim/Form	7	Adhesion between compound and leadframe was changed	7		Virtual similation	2	98								

6.4 Earned Value Management (EVM)

EVM is applied to monitor and control the progress in the project by comparing the monetary value of the progress made and what is planned. Fixed formula is introduced for determining the value that earns on each deliverable or activity. With early warning of the indicator from EVM analysis, it has noticed project leaders that some deviation is happening and corrective action is need to be taken to recover the status of the project as demonstrated in Figure 38 (red rectangle). The delay is happening during week 1435 and back on track in week 1441. The progress report is shown in Table 26 and 27 to demonstrate the corrective action that has been timely taken to resolve the delay that happens in the case study.

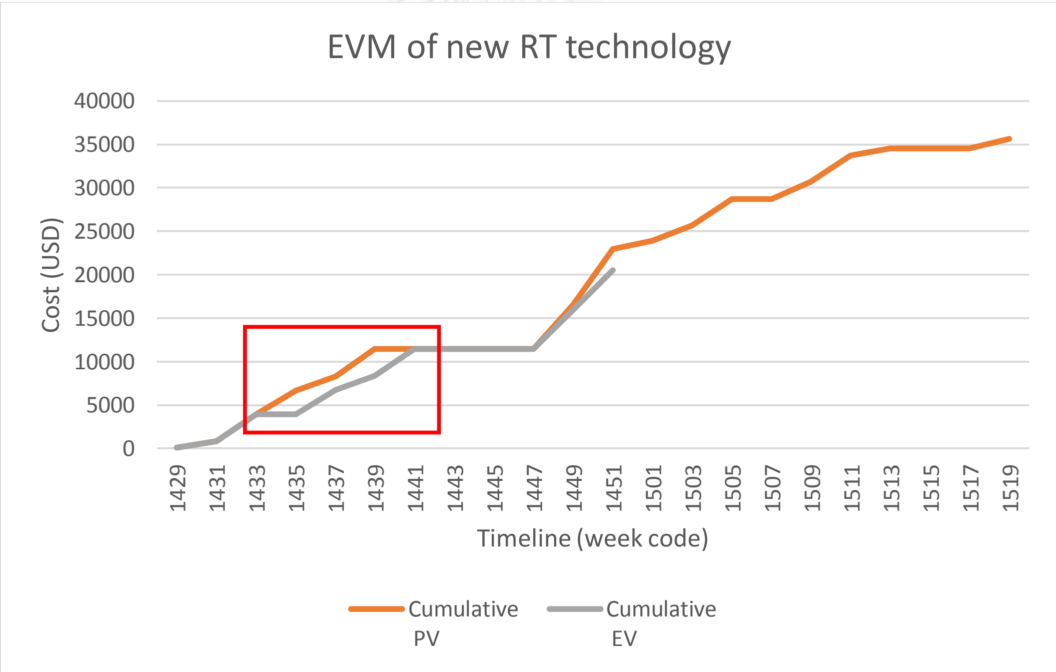


Figure 38 EVM in graphical form with emphasize of delay from the case study

The progress during week 1435 to 1439 is start to behind the schedule because of the delay of internal of technology selection (WP no. 4) which effects on risk assessment (WP no.5), lead vehicle selection (WP no.12) and finalize leadframe drawing (WP no.8). This will leads to delay of S-gate (milestone) and if the corrective action isn't taken, it will cause the delay to order new material (WP no.15) for assembly prototype sample. This will cause the delay of A-gate (milestone). In general, new material will be approved to place an order only if the S-gate is granted but the S-gate can't be granted unless the qualification strategy (required WP no.12-14) is finalized and approved. Accordingly, the S-gate has to be shifted to week 1442 (as all work package for s-gate were completed in 1441) but the corrective action will be taken to recover the plan in order to maintain the target of A-gate, not to be shifted from original plan. The corrective action is to pull in the order of new material before S-gate is granted by finalizing the lead vehicle, leadframe drawing and inform Project Review Board to have an approval for ordering new material in prior.

Table 26 Progress report of week 1437

Week	1437	MileStones	S-gate	A-gate	V-gate	R-gate
Project	New RT Technolgy	Plan	1439	1452	1510	1513
Objective	To qualify the alternative RT leadframe technology which has better perfromance	Actual				
		SV (EVM)	Negative --> Behind schedule			
No.	Status	No.	Lowlights/ Risks			
H1	Finish all supplier capabilities survey	L1	Delay of lead vehicle selection and leadframe drawing review due to Delay of technology selection			
No.	Effect of Lowlight on project	Action Taken			Owner	When?
L1	S gate delay and cause the delay to place order of new leadframe material	Finalize lead vehicle, have an agreement and approval to order new leadframe before S-gate is granted			Project leader	1439

Table 27 Progress report on week 1443

Week	1443	MileStones	S-gate	A-gate	V-gate	R-gate
Project	New RT Technolgy	Plan	1439	1452	1510	1513
Objective	To qualify the alternative RT leadframe technology which has better perfromance	Actual	1442			
		SV (EVM)	Zero --> On schedule			
No.	Status	No.	Lowlights/ Risks			
H1	S-gate is granted	L1	Order of new leadframe is expected to be delivered on week 1449			
H2	All S-gate deliverables is completed					
Effect of Lowlight on project		Action Taken			Owner	When?
L1	Might not be able to submit prototype sample to reliability lab by week1451 and A-gate is risk to delay	- Build prototype sample without waiting incoming inspection result			Support & PL	1449
		- Closely follow up with supplier about progress of sample			Project leader	weekly

Although, the order of new material is the critical path of this project as shown on the red bar in Figure 37 (or Figure 32) and delay in critical path will effect on subsequent activities in the planning. The purchasing order of new leadframe material had been placed later than plan for one week as demonstrated in the progress report of week 1443 (Table 26), so the new material was received in week 1449 which shifted from original plan for one week (1448). Furthermore, in this case, the one week delay is more significant because it is very close to the end of the year (week 1452) which most of the capacity will be fully utilized. Moreover, the reliability lab will only allow the project leader to submit the sample latest by week 1451 in order to operate the test across the year; otherwise, the reliability lab will allow to submit the sample again on week 1502 which is three weeks delay. Accordingly, the assembly of prototype sample has to be pulled in advance in order to have prototype sample in week 1451. Generally, when the new material is received, it needs to be passed incoming inspection in prior to use it for building prototype sample. However, in this case the new material will be used to build prototype sample simultaneously with incoming inspection process as the quality of new material will be firstly referred to outgoing inspection report provided from suppliers.

Arguably, the EVM has noticed the project leader on the deviation that happens to the project as similar to the “C” in PDCA cycle, where project is tracked the progress by EVM to observe any deviation. If the deviation is occurred, the corrective action will timely taken, and re-planned if needed, then the process is iterative. As in the case study, the delay is occurred and effects to delay the A-gate but the corrective is timely taken which solves the problem on delay of the A-gate. The situation is amended and recovered the status of the project to become right on track again. Even though, the result of implementation is reported only until the project has reached the A-gate, but the approaches have shown the promising performance that further uses of them will avoid the project from the delay.

CHAPTER VII: CONCLUSION

7.1 Conclusion

The work that is studied in this research provides the approaches to improve performance of new product development process by focusing in aspect of time with intention to reduce the amount of delay that severely happens during managing the project in Company A. And it has been found that the most of the delay are occurred while project is executed. Although the root cause analysis has reported that the cause of the problem is not only to exist during project execution but also to conceal in other phase of project. Therefore, the approaches are applied to various phase of project including initiation, planning and execution with objective to improve the way of how project leaders could timely execute their project in order to launch new product with proper time-to-market.

The proposed approaches of mitigating the delay in new product development are widely accepted as the effective practices in project management area. These approaches are implemented as the practices that project leader should follow to properly qualify the new product since it has initiated, planned and executed while also mitigated the delay that might happen in new product development process. These approaches consist of scope & requirement management, work breakdown structure (WBS), risk management and EVM for project monitoring and control. Each approach is separately adopted into different phase of project in order to literally assist the project leader to qualify new product with the first time right.

Furthermore, scope and requirement management is adopted after project is initiated but must be in prior to construct the project's schedule as the requirement will specify on what needs to be done and delivered to successfully complete the project, while scope will indicate the project boundary which determine what shall be included or excluded in the project.

Thus, properly defining and controlling project scope and requirement since the beginning will greatly ensure that all required activities and deliverables are taken into account and there shall not be any additional task in later phase of the project. Likewise, the WBS is applied with primary intention to assist the project leader to create the project schedule more accurate on estimation of time and effectively manage the sub-task (work package) of the project. In addition, as risk is one of the critical elements that causes the project to delay, proper managing the risk in advance can remarkably reduce the chance that project will encounter with unexpected incident or threats that will deviate the project from original timeline. Failure Mode and Effect Analysis (FMEA) is introduced as the structural risk management that analytically assesses risks based on the failure mode that relates to that application area. Additionally, FMEA is extensively used in many industries and has been widely accepted on its effectiveness to management the risk in new product development. The last approaches is earned value management (EVM) that is the method to monitor and control the progress of the project. Appropriately monitor and control the progress made will ensure that the project is moving right on track if it diverges from the plan. The corrective action will be timely taken to minimize the impact while attempt to recover it to the original plan if possible. In addition, EVM analysis also provides the outlook of progress made in the project with timely notification of performance of the project. Moreover, periodically monitor the progress of the project will also create the sense of urgency to the project leader.

Consequently, the practices of the proposed approaches will ensure that time is very essential elements in new product development in Company A. These approaches have navigated the project leaders to prevent any possible factors that can significantly delay the project by providing the firm guidance on managing the scope and requirement, construct detailed project schedule with WBS, effective risk management from FMEA, monitor and control the progress of the project by using EVM and PDCA concept. Lastly, with regards to implementation in the case study, these approach has demonstrated that they have assisted the project leader to manage the project more effectively in aspect of time which has prevented the delay that has occurred during the case study. Therefore, extensively use these approaches can potentially reduce amount of the delay in new product development process of Company A.

7.2 Constraints

The implementation of proposed approaches requires a lot of trainings and must be truly understand the concept by the project leaders or user in order to perform it successfully. Additionally, the approaches is considered to be additional burden to project leaders, so in order to extensively use these approaches, the project leader has to be clearly informed and understand necessities and benefits of the approaches. Otherwise, the implementation may encounter with resistance towards this change.

In addition, the case study for implementing of these approaches has to be new project since the approaches require to be applied when the project has initiated, so the project that can be used for the case study is limited.

7.3 Recommendations

The criteria of the ranking scale of FMEA (technical risk) in severity, occurrence and detection score shall be reviewed after more project leaders have used this method for managing the risk. Feedback on how the criteria is practical to use in ranking the score is necessary as the criteria of these elements need to be revised for improving the effectiveness on how the score is fit for function.

Furthermore, to ensure that these approaches will reduce amount of delay in new product development process, more sample size is required to confirm the result of the approaches that mean more projects need to be implemented by these approaches, then gather the result to measure the effectiveness of the proposed approaches from this research.

7.3.1 Further implementation

In order to increase more sample sizes or implement the proposed approaches from this research in future on more projects, the procedure for next phase of implementation is recommended in Figure 39. The procedure is developed by considering these approaches as major change in the organization.

First of all, the approaches is accounted as major change in the way of working of each project leader, so the rationale behind the necessities and benefits of these approaches must be communicated and everyone has to understand on the same page. Secondly, the coalition team that gathers one person from each section in department will be formed in order to trial these approaches with their own projects. This coalition team will attend training course about fundamental program of these approaches to gain better understanding and enable to apply it appropriately. Then, some projects will be selected to firstly implement by this coalition team. Afterwards, the results of the first implementation will be evaluated to assess the performance of these approaches, and identify the obstacles that happen during implementation. Importantly, the obstacle shall be removed in prior to extend these approaches in further step. Furthermore, it is recommended to create short-term goals to motivate the entire staffs on this change. Lastly, these approaches will be further extended to apply with all projects in the department and the coalition team will act as the team leaders to create firm guidance on this change.

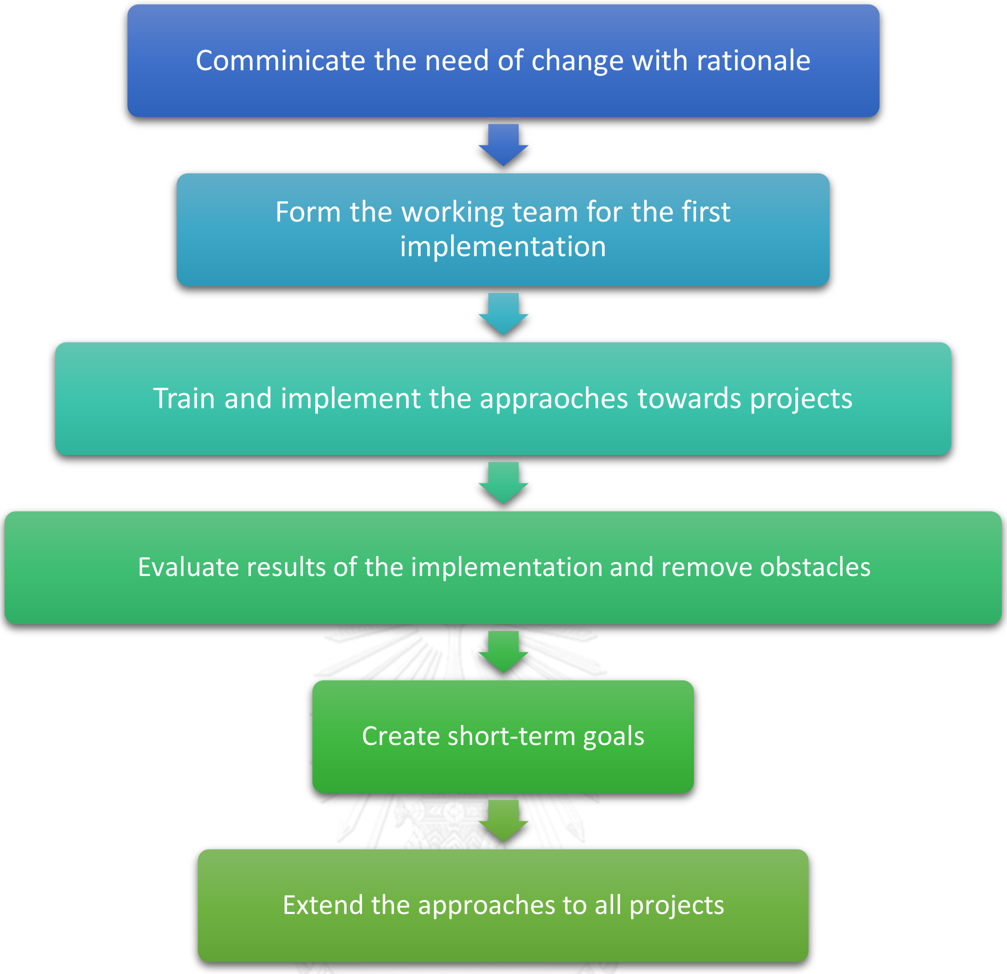


Figure 39 Process flow for further implementation

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