IMPROVEMENT OF COORDINATION SYSTEM FOR PRODUCT DEVELOPMENT PROCESS IN AUTOMOTIVE TIRE INDUSTRY

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ศิริพงษ์ ประสิทธิเม : การปรับปรุงระบบการประสานงานสำหรับกระบวนการออกแบบและพัฒนาผลิตภัณฑ์ในอุตสาหกรรมการผลิตยางรถยนต์ (IMPROVEMENT OF COORDINATION SYSTEM FOR PRODUCTDEVELOPMENT PROCESS IN AUTOMOTIVE TIRE INDUSTRY) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: ผศ. ดร. สมชาย พัวจินดาเนตร, 81 หน้า.

วิทยานิพนธ์ฉบับนี้จัดทำขึ้นเพื่อปรับปรุงระบบการประสานงานของแผนกบริการทางเทคนิคฯ ในบริษัทผลิตยางรถยนต์แห่งหนึ่งในประเทศไทย โดยมีการศึกษากระบวนการทำงานในการพัฒนาผลิตภัณฑ์สำหรับประกอบรถยนต์รุ่นใหม่และวิเคราะห์ถึงจุดเสี่ยงที่เคยทำให้เกิดปัญหาหรือมีโอกาสทำให้เกิดปัญหาขึ้นในอนาคต

การวิเคราะห์ปัญหา ปรับปรุง และป้องกันการเกิดปัญหาในวิทยานิพนธ์ฉบับนี้มีการนำทฤษฎีและเครื่องมือด้านการปรับปรุงคุณภาพหลายอย่างมาใช้ เช่น แผนภูมิกระบวนการทำงาน เทคนิคป้องกันความผิดพลาด แนวคิดความบกพร่องเป็นศูนย์ แผนภูมิพาเรโต การวิเคราะห์ด้วย 5-why แผนภูมิก้างปลา และ การวิเคราะห์ปัญหาด้วย FMEA เป็นต้น นอกจากนี้ยังมีการนำเทคนิคต่าง ๆ จากอุตสาหกรรมการผลิตรถยนต์มาใช้ด้วย เช่น APQP หรือ คู่มือจาก AIAG เป็นต้น

จากการประยุกต์ใช้เครื่องมือดังกล่าว วิทยานิพนธ์ฉบับนี้ได้ปรับปรุงกระบวนการทำงานของแผนกบริการทางเทคนิคฯ รวมถึงจัดทำเอกสารบางอย่างเพื่อลดโอกาสในการเกิดปัญหาและเพิ่มความสามารถในการตรวจจับข้อผิดพลาดขึ้นมา การปรับปรุงนี้ได้ถูกนำไปใช้ในโปรเจคการพัฒนาผลิตภัณฑ์หลายๆ โปรเจค และได้แสดงให้เห็นว่าการปรับปรุงนี้ช่วยลดปัญหาที่เคยเกิดขึ้นให้หายไป นอกจากนี้ วิทยานิพนธ์ฉบับนี้ได้วิเคราะห์ความเสี่ยงที่สามารถเกิดปัญหาขึ้นในอนาคตและแนะนำลำดับความสำคัญในการเตรียมตัวป้องกันปัญหาดังกล่าวให้แก่แผนกบริการทางเทคนิคฯ อีกด้วย

ภาควิชา	ศูนย์ระดับภูมิภาคทางวิศวกรรมระบบการผลิต	ลายมือชื่อนิสิต	....
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SIRIPONG PRASITTHIMAY: IMPROVEMENT OF COORDINATION SYSTEM FOR PRODUCTDEVELOPMENT PROCESS IN AUTOMOTIVE TIRE INDUSTRY. ADVISOR: ASST. PROF. SOMCHAI PUAJINDANETR, Ph.D., 81 pp.

This thesis was aimed to improve coordinating system of OE Technical Service (TS) department of an automotive tire manufacturer in Thailand. New product development process of TS department was studied in order to analyze and prevent root causes of existing problems and potential problem in the future.

The analysis and improvement in this thesis applied various concepts and tools in quality improvement, such as process flowchart, Poka-Yoke, zero defect concept, Pareto chart, fishbone diagram, why-why technique, and FMEA. Some framework in automotive industry, such as APQP and AIAG's manual, were also applied.

From the application of the mentioned tools, this thesis improved process flowchart and created new documents of TS department to reduce problems occurrence and increase error detectability. This improvement was implemented to product development projects of the case company, and the result showed that this improvement helped the case company to eliminate the problems. Besides, this thesis provided suggestions to TS department for potential failures prevention with priority of potential problems.

Department:	Regional Centre for Manufacturing Systems Engineering	Student's Signature	....
		Advisor's Signature	....
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CONTENTS

Page

TABLE OF TABLES

TABLE OF FIGURES

CHAPTER 1
INTRODUCTION

1.1 Background of the Case Company

The case company is an automotive tire manufacturer, located in Thailand. The case company is a subsidiary of renowned automotive tire company; its head quarter is located outside Thailand. Major products of the case company are passenger car tire, pick-up and microbus tire, SUV tire, truck & bus tire (see Figure 1-1).

Figure 1-1 Different type of tire for different type of vehicle

Organization chart of the case company consists of different departments, operating in different areas as shown in Figure 1-2.

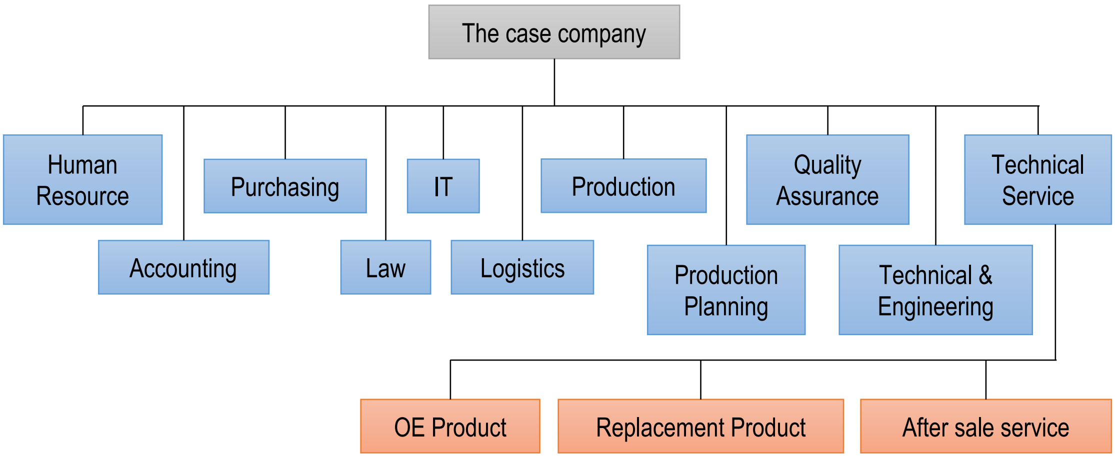


Figure 1-2 Organization chart of the case company

Major departments can be listed as below.

- Human Resource
- Accounting
- Purchasing
- Law
- IT
- Logistics
- Production
- Production Planning
- Quality Assurance
- Technical and Engineering
- Technical Service

Sales department and Tire Development functions are not working under the case company. Tires manufactured by the case company are designed by overseas Research and Development (R&D) center and sold to the market by different business units.

Markets of the case company can be divided into 2 main groups; Replacement market (REP) and Original Equipment Manufacturer (OEM) market. OE tires are developed specifically for specific vehicle model(s), the concept is usually determined by OEM customers (car manufacturers). OE tires can be sold to OEM market for vehicle assembly and to REP market (through tire dealers) as spare parts. REP tires are developed for general vehicles with a specific concept determined by the case company. Technical Service (TS) department is the department that directly communicates to customers. OE Technical Service (TS) section is responsible for OEM customers.

In the past, car manufacturers developed new vehicle at overseas R&D centers. Therefore, TS of the overseas business unit (different company but produces tire under the same brand as the case company) handled tire development projects for new vehicle by coordinating between manufacturing plant, tire R&D center, and vehicle R&D center. TS of the case company, manufacturing plant in Thailand, supported only manufacturing subjects.

However, some customers (car manufacturers) recently established R&D center in Thailand for R&D in Asia-Pacific region. Hence TS of the case company, as a member of manufacturing plant in Thailand, has to handle the development projects for new vehicle. The scope of TS jobs has been extended to cover technical subjects and activities of new tire development in order to support vehicle development programs in Thailand. New responsibility of TS of the case company is quite new and challenging. Moreover, number of projects is increasing while number of experienced staffs is limited. Thus, the discussion in this study will focus on improving coordinating and working process of OE Technical Service of the case company in order to reduce errors and encourage the product development to be completed within the plan.

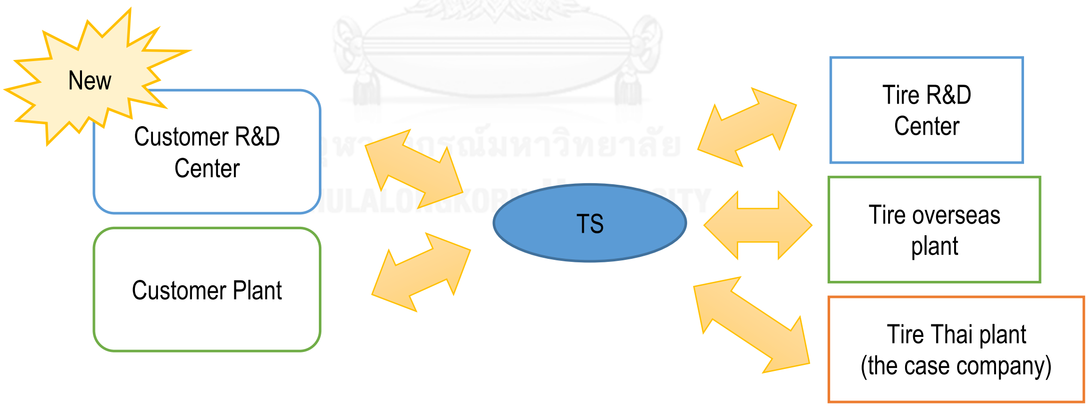


Figure 1-3 New roles of TS of the case company

1.2 Statement of Problems

1.2.1 Misinformation and miscommunication of product codes

First problem was found in February 2014 that the case company had been supplying wrong part to the customer since December 2013; Left-Hand Drive (LHD) spec was supplied to Right-Hand Drive (RHD) part number and vice versa (Figure 1-4 shows how the products were delivered incorrectly to customer). After tracing back to the cause of the problem, the case company found that OE Technical Service received incorrect information from Technical Engineering through verbal communication and could not detect this error. Consequently, product code was registered incorrectly to wrong part no. of OEM customer. Eventually, when OEM customer sent Purchasing Order (PO) to the case company, wrong products were automatically delivered to the customer as the order stated.

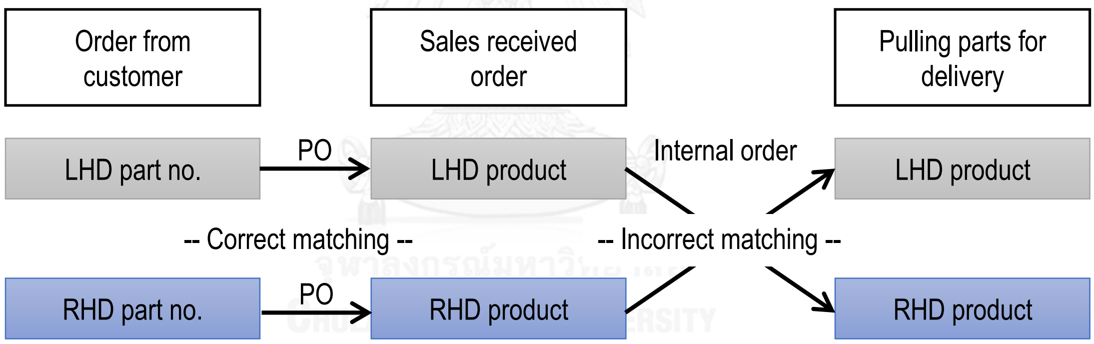


Figure 1-4 How the products were supplied incorrectly

Note: LHD = Left-Hand Drive product, RHD = Right-Hand Drive product

This kind of problem has low frequency of occurrence; it is the first case within past five years. However, the impact of this problem is huge because lots of products were supplied (see Table 1-1) as mass production spec and were already distributed to the market with high volume.

Table 1-1 Number of parts that were incorrectly supplied

Tire Spec	Number of mis-delivered parts (pieces)			
	Dec'13 (start supply)	Jan'14	Feb'14 (found problem)	Total
LHD	190	596	682	1,468
RHD	415	1,112	1,211	2,738

1.2.2 Misunderstanding of tolerance for design and unable to detect error

Second problem occurred in June 2014. A new product development was finished and the case company had submitted all product data in order to get approved Drawing from OEM customer. But just before mass production starts in July 2014, OEM customer rejected to approve this part because Dynamic Loaded Radius (DLR) - one of product characteristics – cannot meet the required target.

Table 1-2 Dynamic Loaded Radius (DLR) value doesn't meet customer requirement after including tolerance

Requirements (Include MP variance)			Actual value of prototype (Exclude MP variance)	Mass Production value (Include MP variance)
*Test with normal condition	Upper limit	303.5	303.2 →	305.2
	Center limit	300.7		303.2
	Lower limit	297.9		301.2
*Test with additional condition	Upper limit	304.8	304.9	
	Center limit	301.8		
	Lower limit	298.8		

Note: MP = Mass Production

Table 1-2 shows how DLR value was out of the target. The middle column shows actual DLR value of the prototype tire. It was within the upper limit requirement, but because it was prototype for approval, this value became center value for mass production (MP) automatically. If this prototype tire got approved, it has possibility to exceed the upper limit with MP variation. Besides, when the case company tested the prototype tire with additional condition given by customer, it was out of target.

This kind of problem is also rarely found, but its impact is very high because it makes the case company unable to get new product approval from customer. And finally the case company's sale volume was given to its competitor instead.

1.2.3 Potential failures due to lack of staff's experience

There are up to 7 persons in OE Technical Liaison team; 6 staff taking care of 3-4 car makers per person and 1 manager taking care of overall team. However, employee turnover rate is high by the reasons of either resignation or inter-department job rotation. Number of experienced and skilled employees is decreasing while number of new staffs is increasing (see Table 1 3). In this circumstance, it is difficult to control ongoing projects that were handed to new staff.

Table 1-3 Number of Technical Liaison staff VS working experience by year

	No. of staff at 1 January by year					
Working experience	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
less than 1 year	-	1	(+2)	2	2 (+1)	1 (+1)
1-2 years	-	-	1	-	1	-
2-3 years	3	1	-	1	-	1
more than 3 years	4	5	4	3	3	4
Total staff	7	7	5	6	6	6

Note: (+n) means plan of hiring n new employees

1.3 Thesis Objectives

The objective of this thesis is to improve coordination system of OE Technical Service team of the case company in new product development projects, prevent problems stated in previous section from reoccurrence, and avoid potential failures in the future.

1.4 Scope of Thesis

The study and analysis in this thesis will be done within the following scope

1. This thesis covers only Original Equipment Manufacturer (OEM) tire development, from planning phase to product and process validation phase (industrialization) only. Not include activities in mass production phase such as new tire claim, spec running change, capacity expansion, or etc.

2. Focus on activities relating to OE Technical Service (TS) section of the case company only, not including isolated operations of other departments that are out of TS control; e.g. Tire Design (TD), Technical Engineering (TE), or etc.

1.5 Expected Benefits and Contributions

Direct expected benefits and contributions from this thesis are

1. Increase work efficiency and effectiveness in OE tire development projects of OE Technical Service (TS) section of the case company.

2. Reduce re-works and prevent severe potential failures that are caused by TS during OE tire development activities.

3. Introducing quality improvement practices to TS section.

Indirect expected benefits and contributions from this thesis are

4. Reducing possibility to lose profit or business of the case company from errors caused by TS.

5. Give advantages to the case company e.g. improve professional image when co-developing new products with OEM customers, gaining trusts from OEM customers, increasing customer satisfaction, and increasing possibility to be selected as suppliers.

6. Provide general understanding of OE tire development process to readers and reference for further studies on OE tire development

CHAPTER 2
LITERATURE REVIEW

2.1 Advanced Product Quality Planning (APQP)

The Advanced Product Quality Planning (APQP) was developed by three automotive companies; Chrysler, Ford, and General Motors. This manual provides guideline to suppliers to prepare quality plans for their products, starting from design until manufacturing phase (ChryslerCorporation et al., 1994). The APQP has divided new product development into 5 phases; planning, product development, process development, and feedback after mass production (see Figure 2-1).

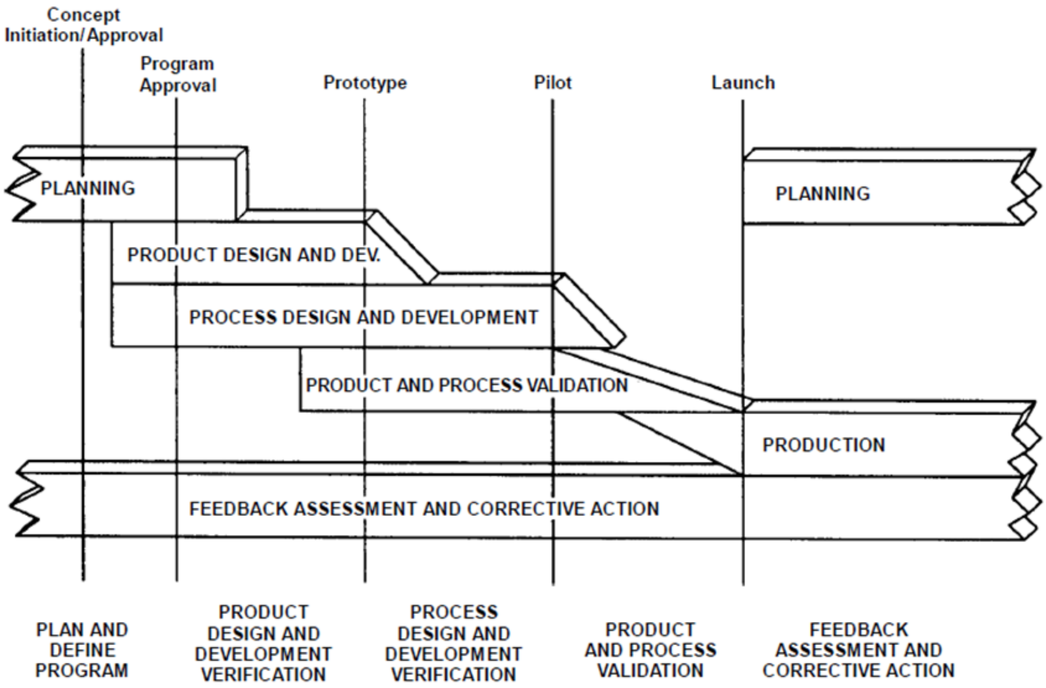


Figure 2-1 Product Quality Planning Timing Chart

From – APQP manual, (ChryslerCorporation et al., 1994)

The APQP phases can be summarized as follows.

1. Planning (plan and define program)

This phase is about collecting and understanding customer needs and expectations. Depending on each development process and customer, customer needs can be found in many forms. For example, benchmark data, voice of customers, business strategy, historical data, market research, or even experiences. And the outputs could be design targets, preliminary bill of material, product development plan, etc.

2. Product design and development

This phase is about developing new product that its features meet requirements collected in previous phase. The activities include building prototype for testing the achievement to targets. Not only product performance, APQP also mentions about achieving schedule, production demand, and cost. Besides, engineering requirements and potential problems should be reviewed as well. Outputs of this phase include material specification, design failure analysis (DFMEA), engineering drawings, list of tools and equipment for both production and testing, etc.

3. Process design and development

This phase talks about developing manufacturing process and control plans to assure that process can produce products as design. Outputs of this phase could be manufacturing process, inspection plan, including flowchart, floor plan layout, process failure mode and effects analysis (PFMEA), etc.

4. Product and process validation

This phase is to test and ensure that product and process designed from previous phases can be run without any problems. The activities include production trial run, and quality document sign-off to move to mass production phase.

5. Feedback, assessment, and corrective action

In this phase, production is finally run with normal condition. Product quality planning will be now evaluated for its effectiveness. Problems or knowledge found in this phase could help to improve quality planning in next project. Outputs from this phase might be an improved customer satisfaction, improved process variation, or improved delivery or service quality.

2.2 Failure Mode and Effect Analysis (FMEA)

Failure Mode and Effects Analysis (FMEA) is one of famous analytical tools for risk management. The users can predict potential failures and their effects of any process or system. Doing FMEA before implementing new process or new product would be the most beneficial for the user because the user can prepare preventive plan before the failures actually occur (Morris, 2011), (ChryslerCorporation et al., 2008), (Pillay and Wang, 2003), (Johnson, 2002), (Price and Taylor, 2002), (Cotnareanu, 1999). According to (Morris, 2011), (Chuang, 2007), (Sutrisno and Lee, 2011), (Rotondaro and Oliveira, 2001), and (Cohen et al., 1994), FMEA is widely applicable to not only production and product design, but also to service system.

The common procedures of the FMEA can be summarized as follows;

1. Define scope of the product or process FMEA will be applied.
2. Identify function or requirement of the system, so that you can know the expected outputs and failure modes.
3. Identify following items
    a. Potential failure modes and effects - How the product or process fails to perform its function, and what is the impact after the failure.
    b. Root causes - Analyze potential root causes that can lead to above failure modes. One failure mode might have multiple root causes.
    c. Current controls - What are current controls that prevent or detect both failure modes and root causes.
4. Set criteria to assess Severity (S) of the effect, Occurrence (O) of root causes, and Detectability (D) of current control. The range of score is normally 1-10.
5. Prioritize risks (potential failures) base on S, O, and D from previous step. Then, create action plans for countermeasure for each risk.

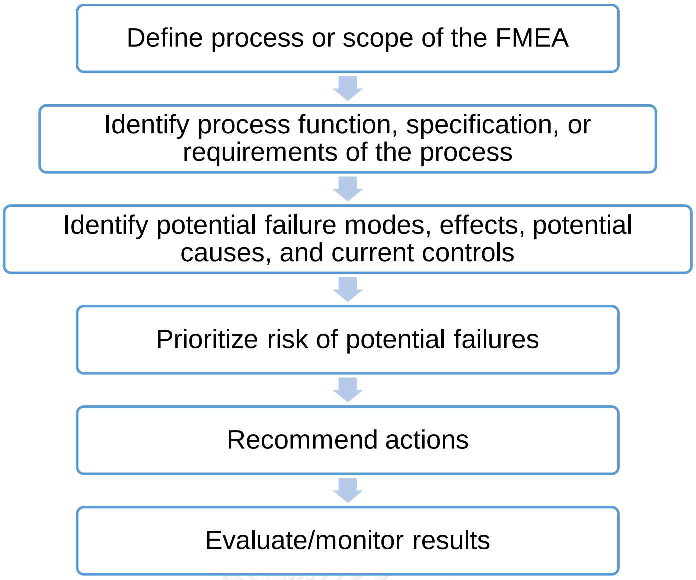


Figure 2-2 Flow of FMEA approach

2.3 Process Flowchart

Flowchart is a diagram that describes flow of a process. It has been used in many industries; e.g. manufacturing, computer and software, business planning, project management, healthcare, or even military (IHI, 2015), (Tam, 1996). (Breyfogle III, 2003) gave some examples of benefits and applications of flowchart as follows;

1. Help people understand flow of a process easier and quicker. Sometimes a written process is difficult to understand and people can understand differently.

2. It can be used to standardize procedure, create work instruction or training tools for new staff.

3. Flowchart can be used for improvement because it can break down a process into more visible steps, and let the user sees weaknesses in the process easier.

4. A process flowchart might require less space of document than a written process.

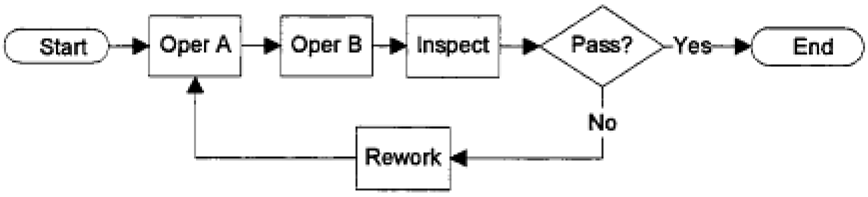


Figure 2-3 Example of process flowchart
(from - (Breyfogle III, 2003), page 104)

2.4 Zero Defect Concept and Poka-Yoke (Fail-Safe)

It could be said that zero-defect is the final goal of quality improvement that every companies want to achieve. A better quality of the operation provides less wastes which resulting in better performance of a business. Therefore, many businesses try to achieve zero-defect quality.

Shigeo Shingo is one of the most famous quality experts who developed fail-safe (or Poka-Yoke) concept to reduce defects to achieve zero defect quality. They are effective methods, especially in manufacturing, that prevent turning errors into defects (Hales and Chakravorty, 2007). Inspection is divided into 3 categories based on when defects are detected (Shingo, 1986).

1. Successive check – The operator in the next step will immediately inform the supplying operator to stop operation to correct the work.

2. Self-inspection – The operator will inspect his/her own work.

3. Source inspection – The inspection is done at the beginning before it causes the error.

There are also many types of Poka-Yoke used for either detection or prevention of the errors. For example, Poka-Yoke alarms workers when error is detected (warning type) or stops production to prevent continuous defects (control type). Poka-Yoke concept can offer inexpensive solutions, not only using complex or expensive automated technologies (Robinson and Schroeder, 1990). Moreover, Shingo classified Poka-Yoke into 3 methods.

1. Contact method – use physical property to control, such as using blocks that allow part to be placed in the proper position only (see Figure 2-4).

2. Fixed value method – use specific number(s) to control, for example counting sensor.

3. Motion step method – use motions to control, such as designing process that makes an operator works step by step.

Integrating Poka-Yoke to Process FMEA (PFMEA) can be more effective in reducing defects, reducing customer complaints, and increasing productivity (Puvanasvaran et al., 2014).

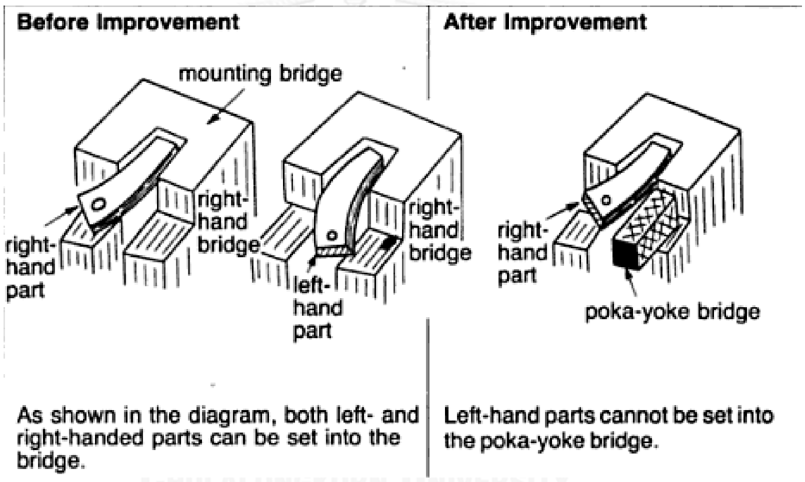


Figure 2-4 Example of contact method Poka-Yoke

(rom Zero Quality Control: Source Inspection and the Poka-Yoke System(Shingo, 1986))

Apart from manufacturing industry, the concept of Poka-Yoke has also been applied to service industry as well. Many studies showed that Poka-Yoke can improve service quality by preventing service failure (Ghasemaghaei and Shahin, 2010), (Lewis and Clacher, 2001). One study (Chase and Stewart, 1994) proposed that service Poka-Yoke should be classified by the type of error it prevents.

1. Server errors are errors from service provider, and can be divided into

a. Task errors - errors of the service functions such as the service functions incorrectly, slowly, etc. Task Poka-Yoke will be used to detect or prevent this error.

b. Treatment errors - occur when server fails to react or contact customer properly. Treatment Poka-Yoke will be used to detect or prevent this kind of error.

c. Tangible errors - errors occur on tangible parts of the service, such as air conditioner in the hotel, or dirty facilities of the hotel. Tangible Poka-Yoke will be used for this kind of error.

2. Customer errors are errors from customer, and can be divided into

a. Preparation errors – errors occur when customer don't prepare things or don't understand their role when they come to the process. Examples of preparation Poka-Yoke is reminding emails.

b. Encounter errors – errors occur during receiving the service such as not following the instruction correctly. Example of encounter Poka-Yoke is an alarm when customer do the wrong process.

c. Resolution errors – occur after the service and customers are expected to do something such as clean the restroom. Example of resolution Poka-Yoke is a poster at the door of the restroom.

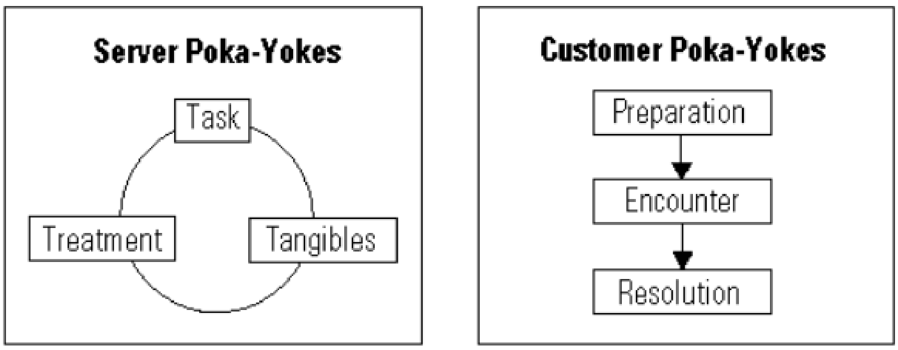


Figure 2-5 Classification of Poka-Yoke in service
(Chase and Stewart, 1994)

2.5 Fishbone Diagram

Fishbone diagram shows causes of a problems in groups. By brainstorming, the root causes are generated from the upper-layer causes or major categories. Following list is general categories that could give an idea when it is difficult to generate major headings for a problem (Montgomery and Woodall, 2008), (Breyfogle III, 2003), (ASQ, 2005).

- Methods
- Machines (equipment)
- People (manpower)
- Materials
- Measurement
- Environment

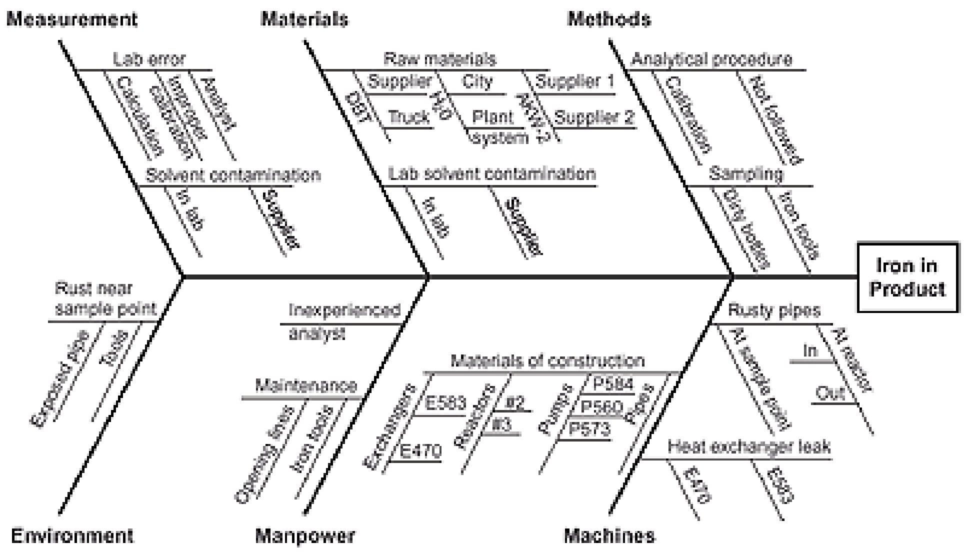


Figure 2-6 Example of Fishbone Diagram

(from - http://asq.org/learn-about-quality/cause-analysis-tools/overview /fishbone.html)

2.6 Why-why Analysis

Why-why analysis is a simple technique that leads the user to the root cause by repeatedly asking “why” to the answer of the problems. Finally, the root cause can be identified (Higgins, 1994).

CHAPTER 3
EXISTING PROBLEMS AND ANALYSIS

This chapter describes details of the existing problems stated in the first chapter. This chapter also includes analysis of the problems.

3.1 Misinformation and Miscommunication of Product Codes

The first problem was found few months after the case company started supplying 2 similar products to an OEM customer; one is for right-hand-drive vehicle (RHD) and another one is for left-hand-drive vehicle (LHD). At that time, the case company received a purchasing order for LHD tires from its parent company. Since this order came from overseas, Product Global Code (PGC) was used for communication. However, the case company and its parent company had different PGC of LHD tire, alternating with RHD spec. After checking, the case company found that its product codes were incorrect. The case company then informed the customer and corrected product codes matching.

Supplying wrong parts is basically a serious problem because it can affect to the vehicle safety and market regulations. Fortunately, in this case, the only difference between these 2 specs was direction of the Belt (see tire construction in Figure 3-1). Belt direction (left or right) affects only vehicle pulling force which is not relating to safety, regulations, or severe vehicle performance. And the case company will be responsible for market complain relating to this problem.

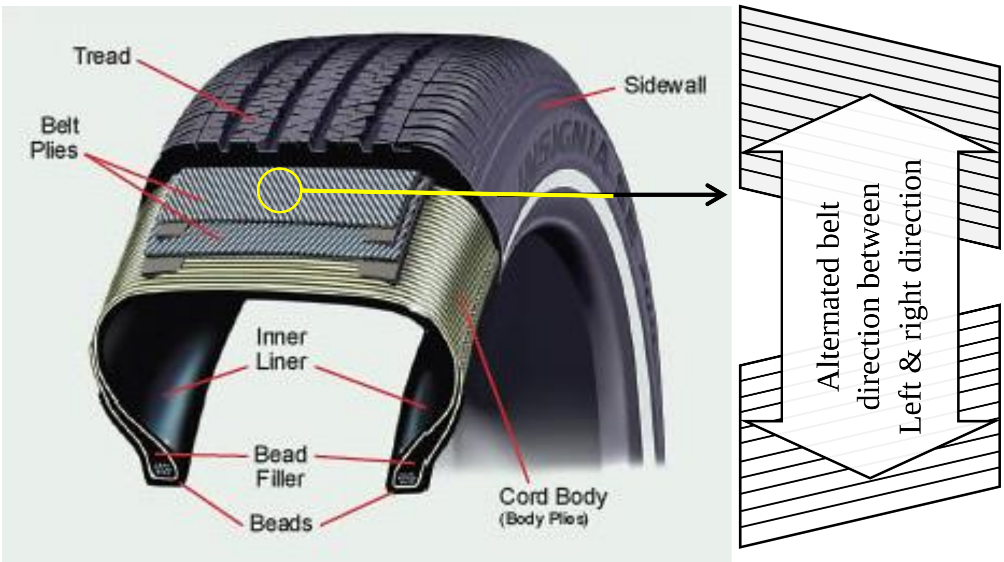


Figure 3-1 Basic tire components

(from - http://www.firestonecompleteautocare.com/cf/tires/proper-care-to-make-your-tires-last/)

<u>Error mechanism and root cause analysis</u>

Current procedures relating to Problem 1 is shown in Figure 3-3. At Process A3, OE Technical Service (TS) receives Part No. (P/N) from OE customer (or car maker). After new product approval at Process A6, TS requests Tire Design (TD) to add new product to global database. Then, TS will receive Product Global Code (PGC) at Process A9. Technical Engineering (TE) department will also receive the PGC and create Product Plant Code (PPC) for local use within the case company. After that, TS will receive PPC from TE verbally and match these 3 codes (P/N-PGC-PPC) in Product Information Sheet (PIS) at Process A12-A13. This is where the error occurred. The matching in PIS was incorrect and forwarded to OE Sales (OS) for registering new product into sales database. With wrong code matching, plant delivered wrong products to customer finally.

Figure 3-2 shows root causes of Problem 1, using Why-Why technique with related TS and TE staffs. Root causes are summarized below.

1. No appropriate communication route so far. From the past, TS acquired PPC which is an important information from TE by verbal communication. This type of communication doesn't have solid evidence and is easy to make a mistake. Eventually TE unintentionally informed incorrect PPC to TS by confusion between these 2 similar specs.

2. Official reference information wasn't shared to TS after TE had generated PPC successfully. Thus, TS didn't know the actual correct matching of product codes and couldn't detect error when TE informed incorrect PPC.

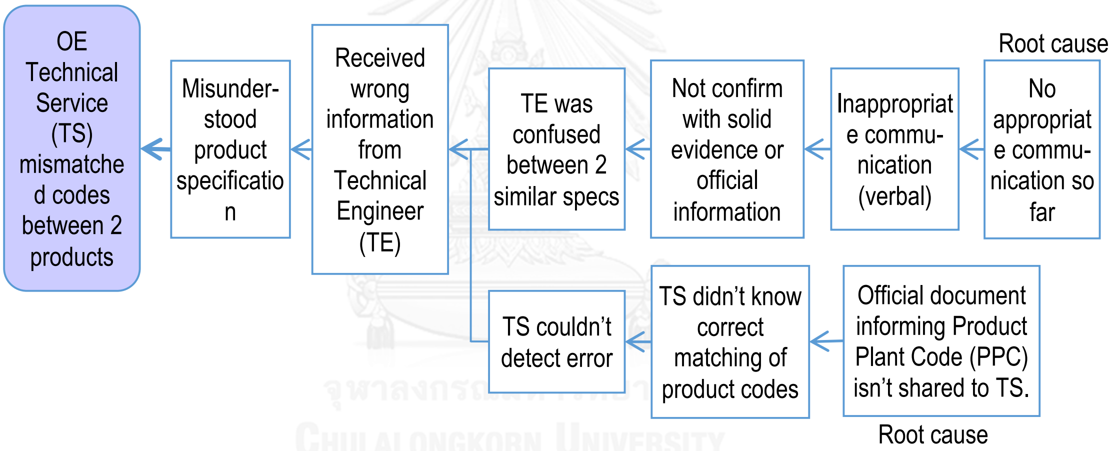


Figure 3-2 Root causes of Problem 1

Apart from the root causes above, some weaknesses are found in this problem. Product codes (PGC and PPC) are filled in Product Information Sheet (PIS) by OE Technical Service (TS) only (see Figure 3-4). There is no detection, confirmation, or approval from departments that generate both PGC and PPC.

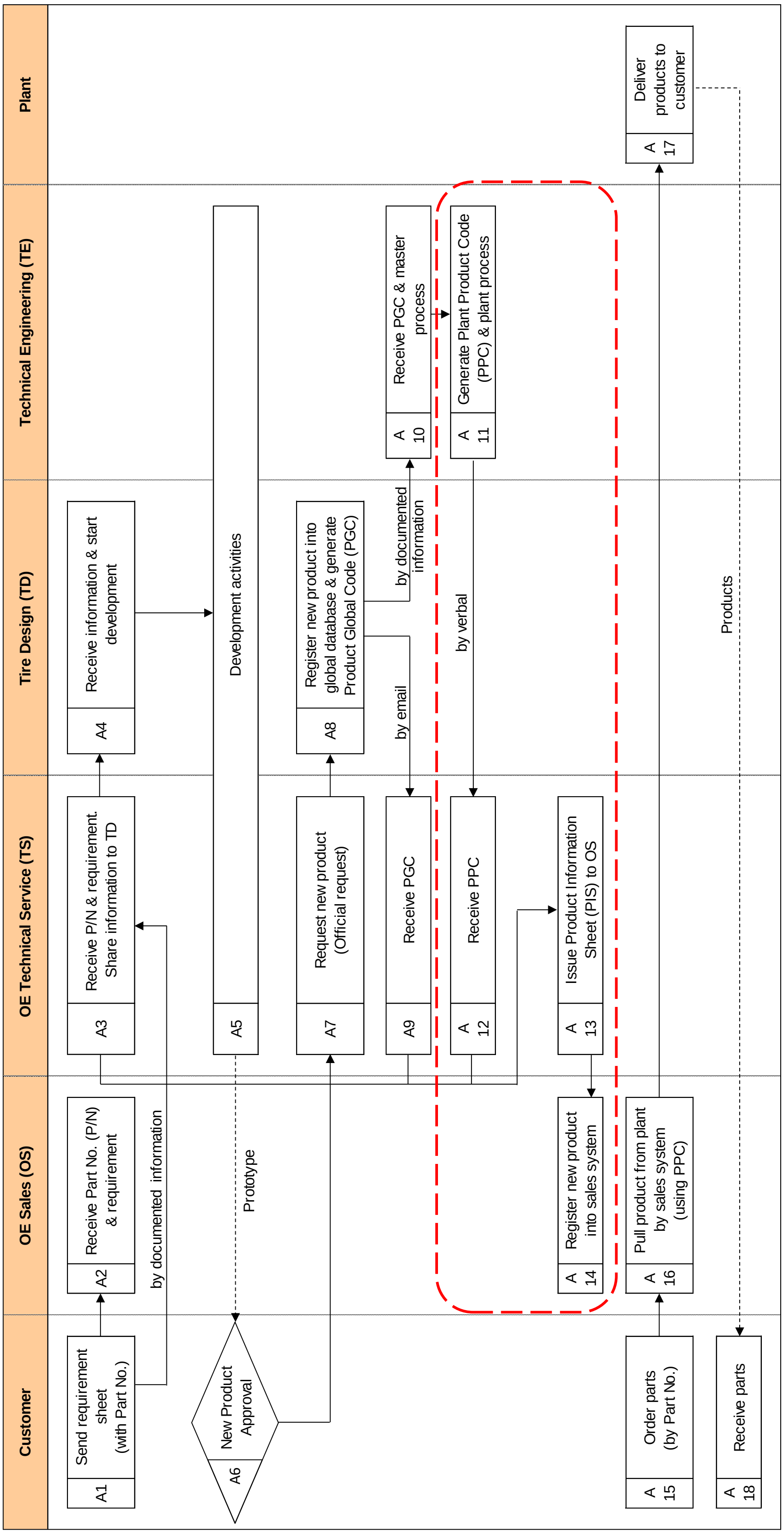
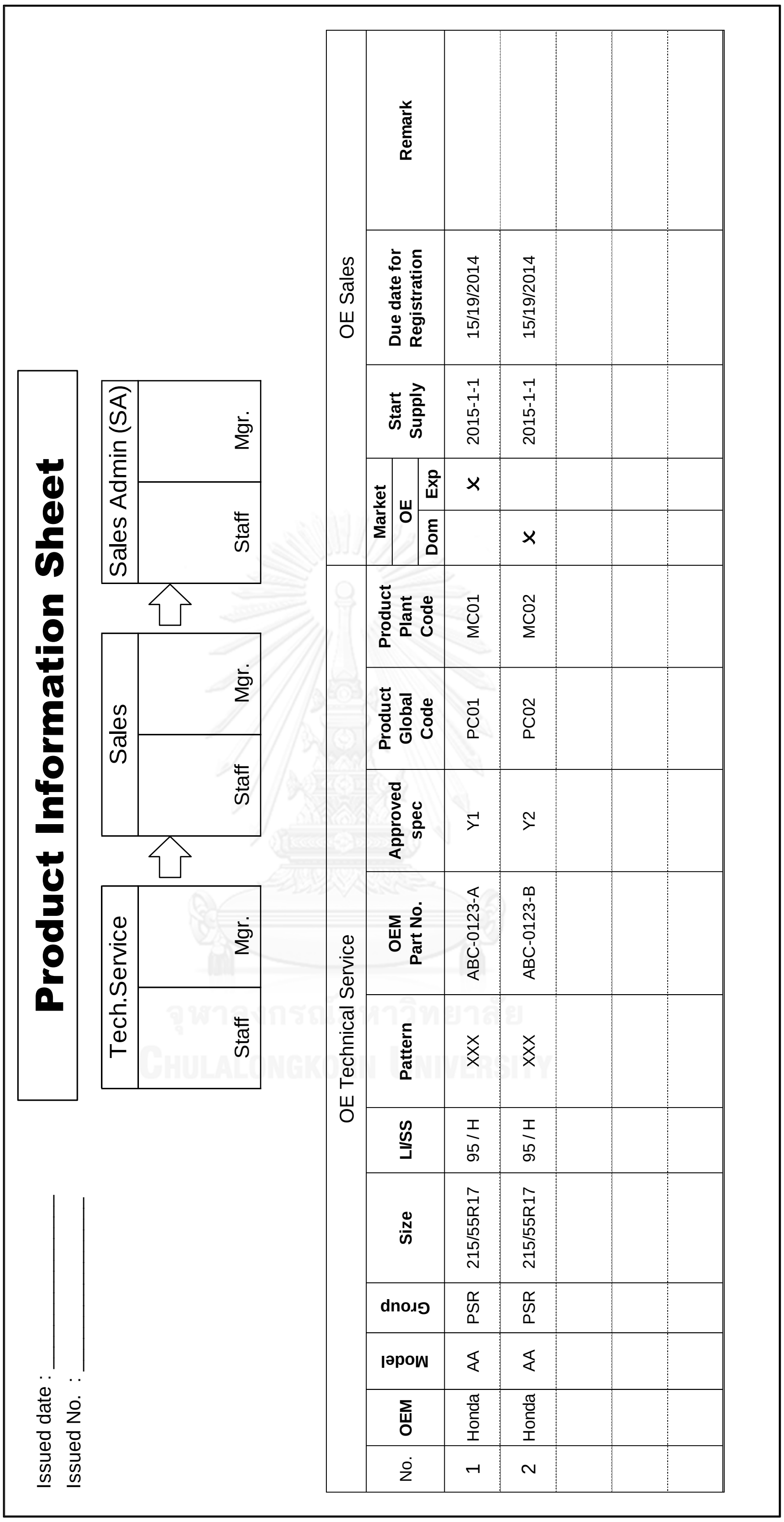


Figure 3-3 Current process flow of Problem 1



Issued date : ________
Issued No. : ________

Product Information Sheet

Tech.Service (Staff, Mgr.) → Sales (Staff, Mgr.) → Sales Admin (SA) (Staff, Mgr.)

OE Technical Service											OE Sales				
No.	OEM	Model	Group	Size	LI/SS	Pattern	OEM Part No.	Approved spec	Product Global Code	Product Plant Code	Market OE Dom	Market OE Exp	Start Supply	Due date for Registration	Remark
1	Honda	AA	PSR	215/55R17	95 / H	XXX	ABC-0123-A	Y1	PC01	MC01		X	2015-1-1	15/19/2014	
2	Honda	AA	PSR	215/55R17	95 / H	XXX	ABC-0123-B	Y2	PC02	MC02	X		2015-1-1	15/19/2014	

Figure 3-4 Current document (Product Information Sheet, PIS)

**This document was modified to protect company's confidential information*

3.2 Misunderstanding of Tolerance for Design and Unable to Detect Error

The second problem was found almost at the end of ‘product design and development phase’ of one project. After tire on-vehicle-performance was accepted, the case company prepared tire data (engineering specification and drawing) for OEM customer. This case, the new product has 1 item that doesn’t meet customer’s requirement. OE Technical Service (TS) checked the data of the new tire as usual, but couldn’t detect the error. Finally, the case company didn’t fix this error and send the data to OE customer.

Later the customer found this error. The case company, TS and Tire Design (TD), rechecked the data and found that 1 item was out of target when considering Mass Production (MP) tolerance as the requirement described. At that time, vehicle trial production was about to start, the case company couldn’t fix the error within the remaining time. As a result, the customer postponed buying parts from the case company and bought parts from the second supplier instead. The case company loses some profits from its expectation on this project.

Error mechanism and root cause analysis

Figure 3-5 shows current flow of Problem 2. After customer accepts on-vehicle-performance of a new tire, OE Technical Service (TS) will ask Tire Design (TD) to prepare engineering and data (mostly from indoor test) at Process B10. When TD finishes all testing and drawing, all data will be sent to TS for checking and submission to customer (Process B12). The error occurred here when TS failed to detect error and didn’t feedback to TD for fixing. Finally, the error was found by customer, but it was too late to fix.

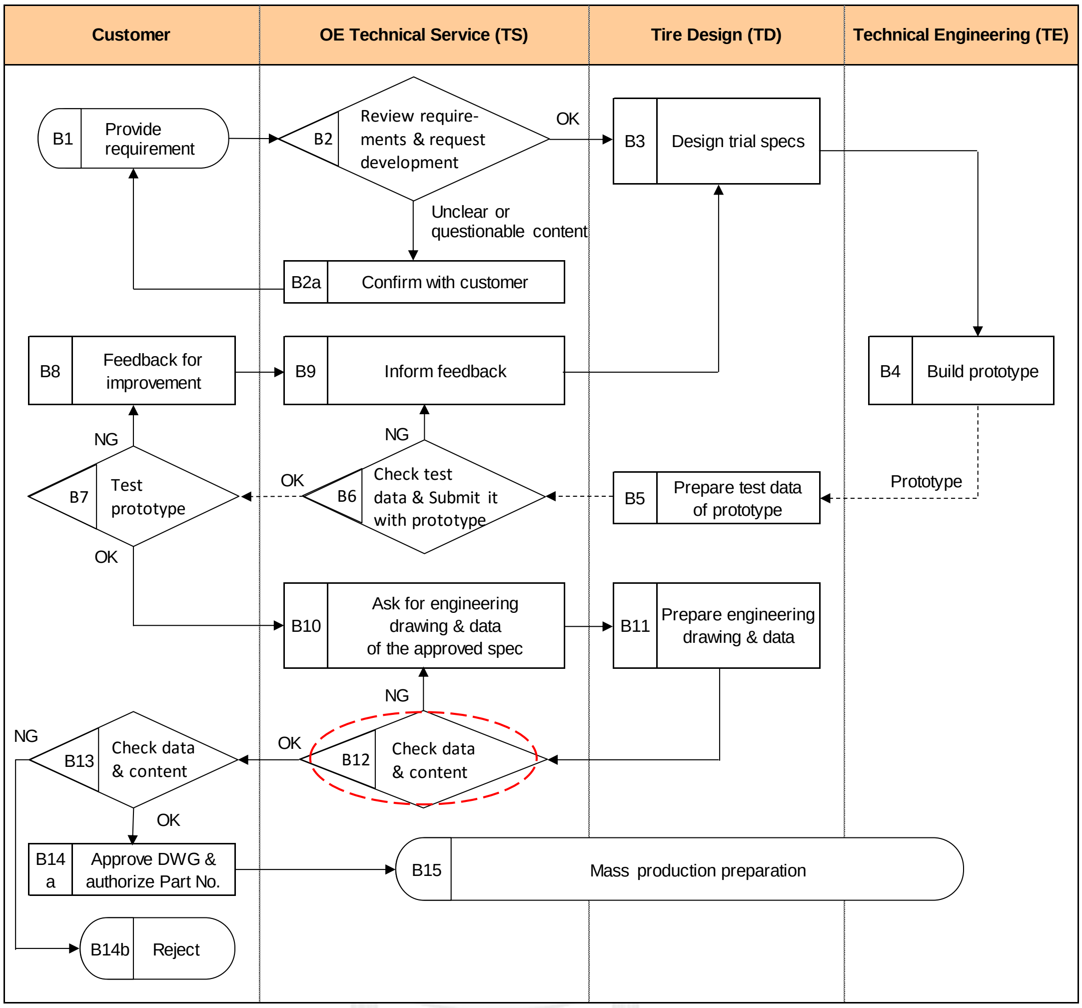


Figure 3-5 Current process flow of Problem 2

To identify root cause of Problem 2, Why-Why technique is used (see Figure 3-6). The root cause found in this problem is carelessness of TS staff who didn’t check the detail content of the requirement. Therefore, he didn’t know that mass production tolerance should be considered when reading target value in the requirement.

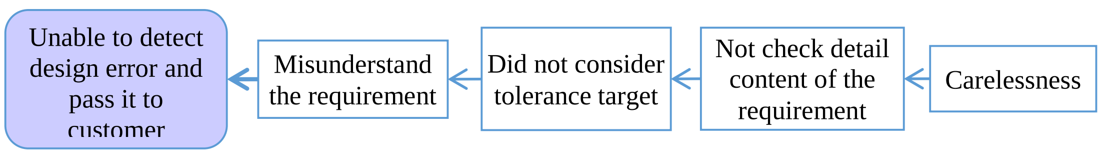


Figure 3-6 Root causes of Problem 2

3.3 Potential Failures due to Lack of Staff's Experience

The third problem, turn-over rate in OE Technical Service (TS) department is relatively high, comparing to other departments in the same company. To efficiently communication with other functions, especially to external function like OE customer, TS staff should have decent technical knowledge and experience. High turn-over rate reflects low average-experience of TS staff and results in higher possibility of errors occur in daily operations. Possible root causes of high turn-overate were showed by Fishbone Figure 3-7.

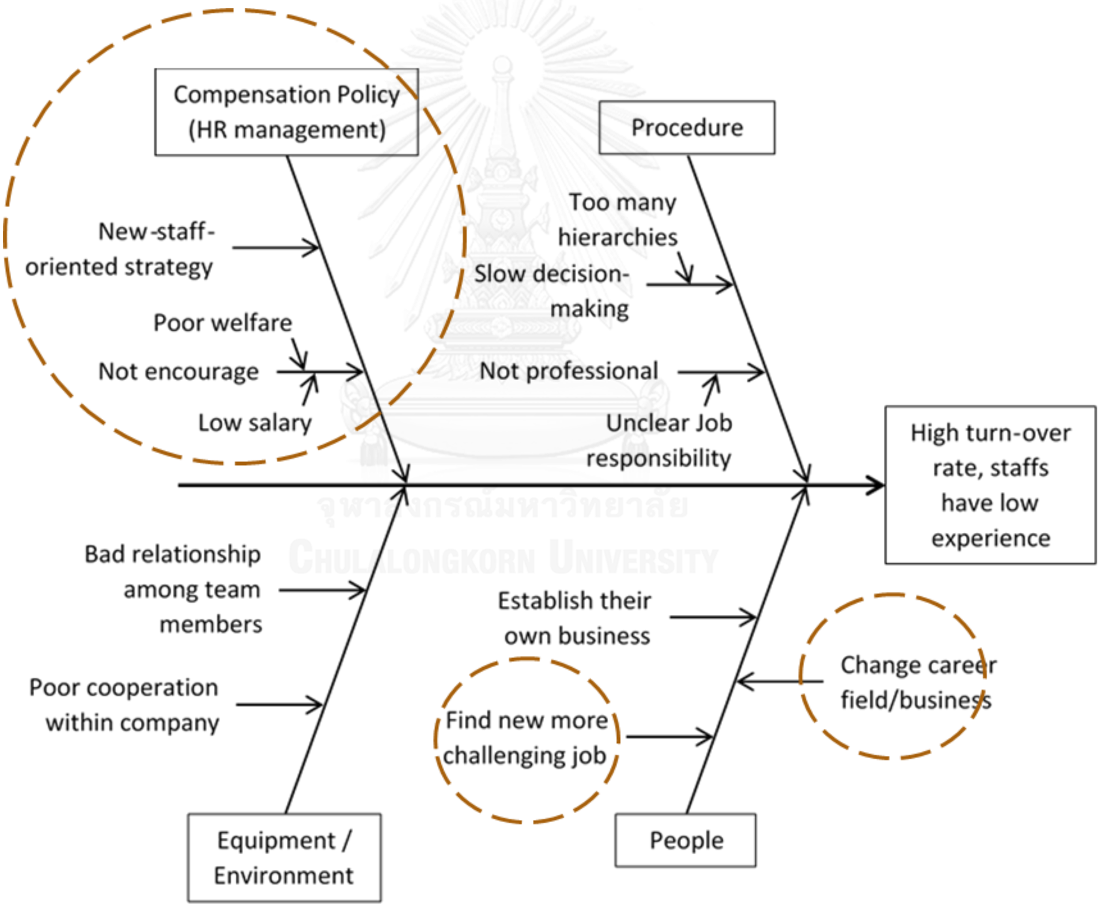


Figure 3-7 Possible root causes of high turn-over rate

The circled items are most likely root causes of high turn-overate in TS department. However, these circled root causes are external factors that TS department cannot control. And the review of Human Resource (HR) management policy requires top management involvement. Therefore, this thesis will discuss on potential failure prevention which is easier to implement by TS department solely.

3.3.1 Current process flow

Firstly, the author discussed with experienced OE Technical Service (TS) staff and develop a solid OE tire development process flow for common understanding and reference in this Thesis. Advanced Product Quality Planning (APQP) framework is applied to see purpose of each development phase, including expected role of TS of the case company.

Planning (Process 1-8)

Planning phase is to understand customer needs. From Process 1 in Figure 3-8, OE customer (or car manufacturer) sends preliminary requirement and Request for Quotation (RFQ) to the case company. At Process 3, OE Technical Service (TS) staff will review the requirement to ensure the understanding of customer needs (e.g. product concept, supplier selection criteria, schedule, etc.) and also to check missing information before sending to Tire Design (TD) department. At Process 4, TD will make a conceptual design of both development schedule and new product specification based on the given requirement for OE Sales (OS) to submit quotation price. Then Process 6-8, OS will submit quotation price and waiting for supplier selection result from OE customer.

This phase is important for planning the development schedule and conceptual specification for price quotation. TS is expected to collect as much information as possible in order to make appropriate planning. For example, if new mold is needed, the schedule will be longer. Appropriate planning can prevent delay of the schedule.

Product design and development verification (Process 9-26)

After the case company becomes one of suppliers, the case company will receive list of detailed requirements (normally including testing conditions) from customer. At Process 9, TS needs to review requirement for information checking again and then issue a document to request TD starts the development officially. Next, TD will update the schedule with the current situation and start designing trial specifications (Process 10) of new product. These trial specs will be built as prototype by Technical Engineering (TE) department at Process 11 and tested internally at Process 17. The cycles of building and testing prototypes are done until the case company has a good spec, TS then will arrange for submission (Process 18) and Joint Evaluation with customer (Process 19). Joint Evaluation events allow the case company to confirm subjective requirement on vehicle performance. If on-vehicle performance is not accepted, TS will send feedback to TD for further improvement (Process 20). If on-vehicle performance is accepted, TS will inform TD to prepare full engineering drawing including all indoor test data (Process 22). This drawing and data will be submitted to customer for final approval at Process 24.

The purpose of this phase is to develop new product and get approval in time. TS roles are

1. Collecting detailed requirements for TD as fast and accurate as possible.
2. Communicate with various parties both internal and external the case company in order to ensure the development activities are progressed in time. For example, appoint customer for Joint Evaluation and check TE to build prototype in time for this event.

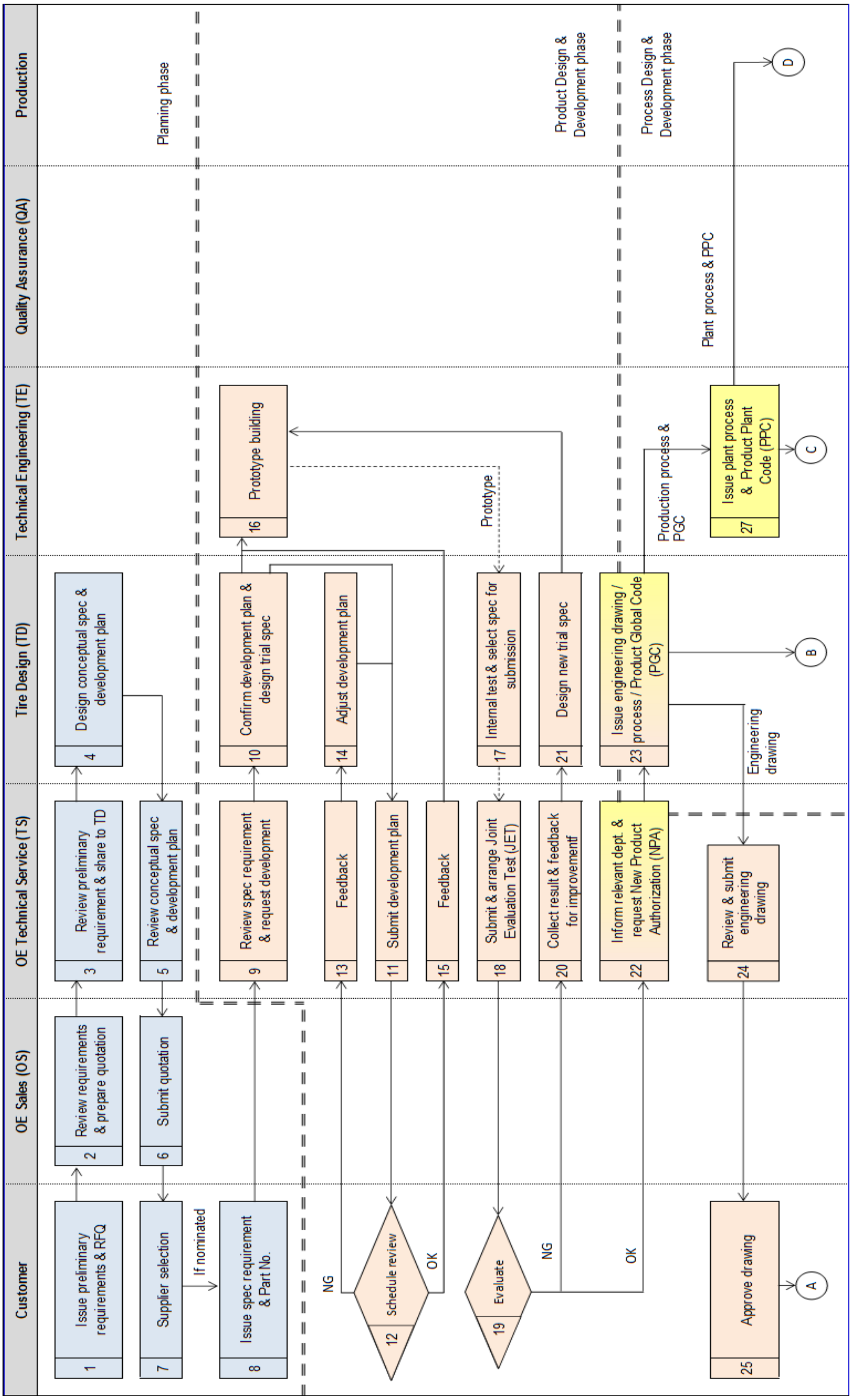


Figure 3-8 Process flow of new product development of the case company (1)

Process design and development verification (Process 23, 26-30)

At Process 23 in Figure 3-9, Tire Design (TD) staff will prepare master production process and Product Global Code (PGC) of the approved tire. Master process and PGC will be sent to Technical Engineering (TE) department and TE staff will issue plant process and Product Plant Code (PPC) at Process 27 for internal use in the case company. OE Technical Service (TS) staff needs to collect these codes in Product Information Sheet (PIS), and send to OE Sales (OS) mainly for new product registration in Sales system (Process 29-30). This activity is a preparation of selling and delivery process, PIS will show linkage between Part Number (P/N), PGC, and PPC. These 3 codes are used differently.

1. Part No. (P/N) is generated by each OEM customer (car manufacturer) and sent to TS at the A1 process together with engineering requirements. P/N will be used when TS communicates with OEM customer.
2. Product Global Code (PGC) is generated by Tire Design (TD) at the A8 process. After new product approval, TS will request TD to add this product to global database. TS receives PGC through email once the adding process completed. PGC will be used globally and internally among overseas branches or headquarters.
3. Product Plant Code (PPC) is generated by Technical Engineering (TE) at the A11 process. After TD sends PGC and master manufacturing process to TE, TE will issue PPC and plant manufacturing process for the local plant. PPC will be used locally within the local plant. For example, Thai TS uses PPC of Thai plant (the case company) when communicate within the case company.

In parallel, TS will receive approved drawing and data from customer (Process 26). The approved drawing and data will be sent to Quality Assurance (QA) department for preparing process control (Process 28).

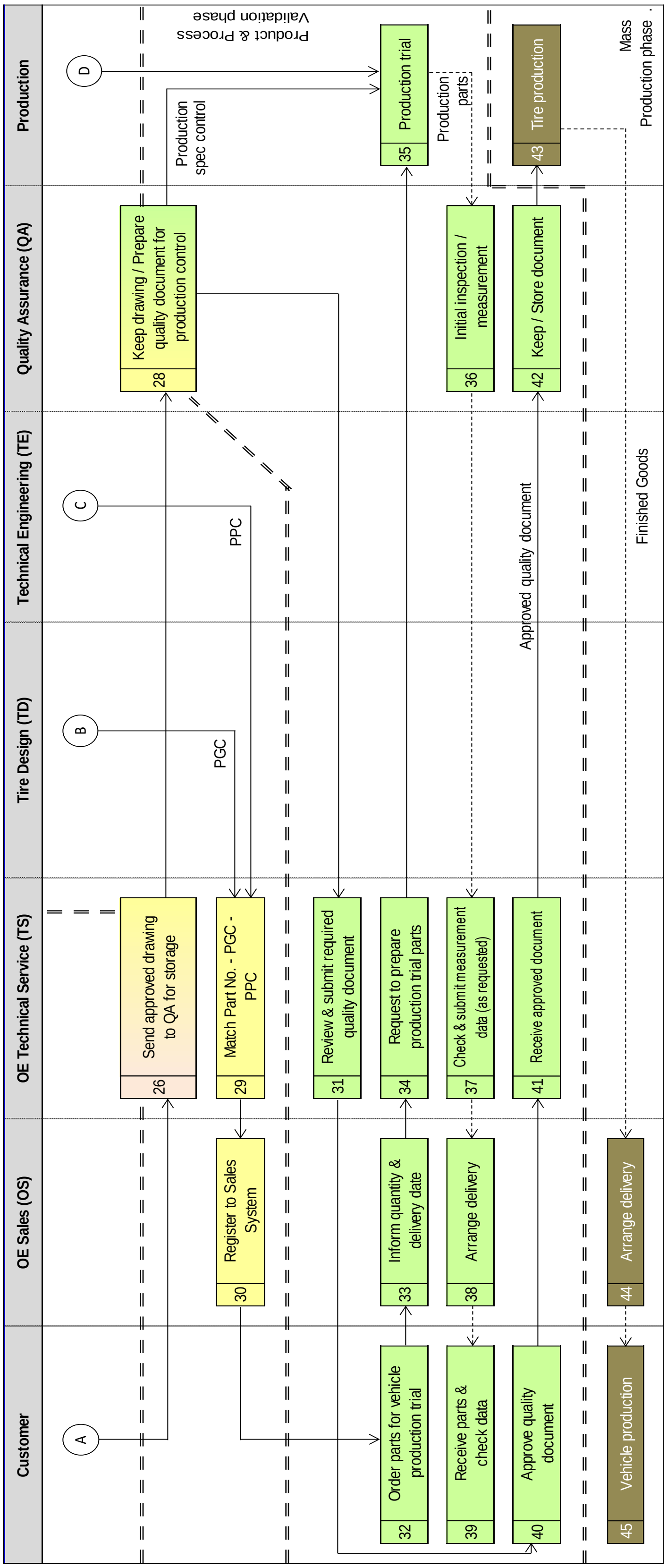


Figure 3-9 Process flow of new product development of the case company (2)

The purpose of this phase is to prepare production process, and quality control plan that provides product that meets the approved specification. TS roles are

1. Coordinate between TD and TE to ensure the activities are proceeded in time (no delay).
2. Coordinate with QA to ensure the measurement and control plan are correct as the specification approved by customer. And communicate with customer to clarify any unclear points from the case company perspectives.

Some parts of the outputs from this phase (e.g. floor plan layout, process control table, and etc.) are not need to be prepared for individual project because tire components are generally the same so production process and machines can be used commonly (see Figure 3-10). Main outputs for the case company will be standard for measurement of dimension, stamping letters, physical strength, and tire uniformity.

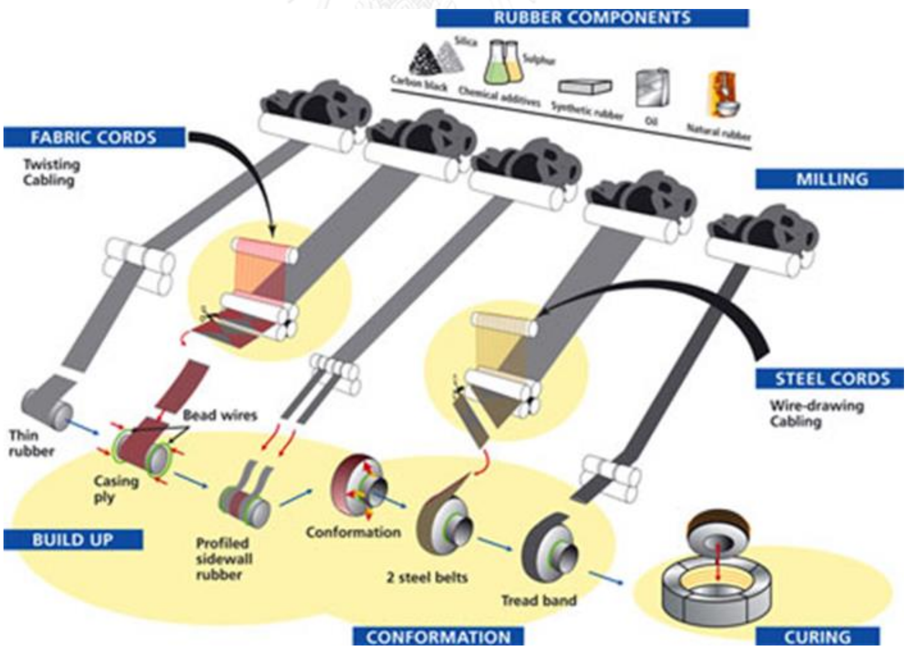


Figure 3-10 Tire manufacturing process

(from-http://www.bridgestone.com/products/speciality_tires /aircraft/products/ process/) Note: each tire component is produced at its station, which is fixed to the floor, and will be assembled before curing.

Product and process validation (Process 28, 31-42)

The validation phase starts from Process 28 in Figure 3 10 when QA department prepare document such as Production Part Approval Process (PPAP) for ensuring the quality of production system. This kind of document regularly should be required by customer, but its name and detail can be different. TS will submit this document (Process 31), and when the document has been approved, it will be returned to TS and kept as evidence by QA (Process 40-42).

Not only document, but the samples from production trial are required to submit to customer as well. Customer will order tires from the case company in order to check production tires, vehicle assembly, and delivery system before running full production (Process 32-39).

TS, in this phase, is responsible for

1. Coordinate between the case company and customer to arrange production parts and measurement data (if required) for vehicle production trial run successfully.
2. Provide customer requirements on documents (e.g. PPAP) to QA and ensure the requirements are achieved.

Product and process validation (Process 43-45)

After completing the validation phase, the case company can start mass production and supply parts to OEM customers. This phase will not be included in this study.

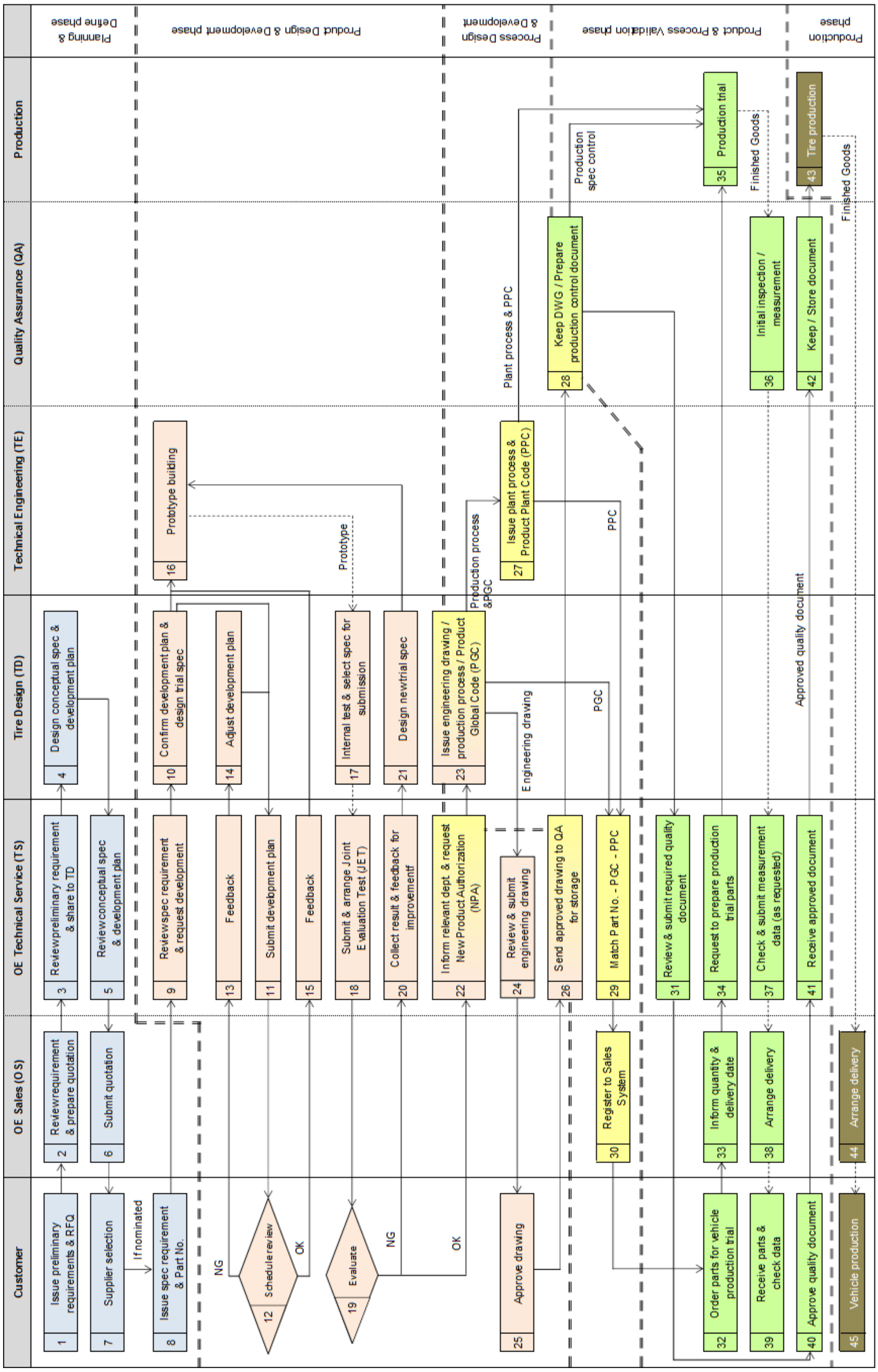


Figure 3-11 Full process flow of new product development of the case company

3.3.2 Analysis of potential failures, effects, root causes, and detection

Once we know current process flowchart and key function of OE Technical Service (TS) from previous section, the author and TS team can analyze potential failures and possible effects. We also use Why-Why technique to help identifying possible root causes as well. Code will be assigned to each failure and root cause for a shorter word.

1. Planning Phase

The planning phase starts from collecting and clearly understanding customer needs or requirements in order to create a properly product development plan. Potential failure of OE Technical Service (TS) is identified as follows.

Potential Failure PN1

Not collect all necessary project information for Tire Design (TD). This failure occurs at Process 3 of Figure 3-11. TS's role is to collect project information & product concept (preliminary requirement) for TD to make a proper development plan and conceptual design.

Potential effects - If TS doesn't collect all necessary, TD can't plan a proper schedule and can't design a decent conceptual specification of new tire. During the actual development, TD will need more adjustment of schedule and detailed specification which make the development more difficult and might take more time. For example, if TS doesn't collect all destinations of a new vehicle, TD might select inappropriate tire compound as a conceptual spec. The compound needs to be changed later, and it affects to overall tire performance. Then, the detailed specification needs to be changed as well.

Possible root causes - Figure 3-12 shows that lacking of solid guidance or work instruction encouraging this potential failure to new staff because they don't have experience and don't know what information is necessary for Tire Design (TD).

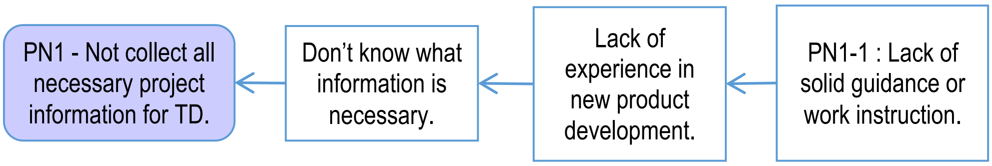


Figure 3-12 Possible root causes of PN1

2. Product Design and Development Phase

In this phase, Tire Design (TD) staff will design various specifications of trial tires. These trial tires are made and evaluated in order to verify achievement to customer's requirement. Three main activities of OE Technical Service (TS) staff in these phase are;

1. Collecting detailed requirement for TD and understanding them correctly can help TD design trial specs directly to the target. And as a result, development time can be shorter.

2. Thoroughly check data from the product development. If any error is found, TS needs to feedback to TD as soon as possible to fix the design.

3. Prepare necessary items for evaluation to facilitate the development and to prevent delay from the plan.

Based on the activities, potential failures in this phase can be listed below.

Potential Failure PD1

Not collect all requirement or target of new product for TD. At Process 9 of Figure 3-11, OE Technical Service (TS) should collect all detailed requirement or target for Tire Design (TD). Otherwise, it is considered as a failure.

Potential effects - Similar to planning phase, if TS doesn't collect all requirement or target, TD can't design a proper spec of trial tires. However, in Product Design and Development phase, remaining time of the project is shorter than Planning phase. Thus, changing the design dramatically possibly makes the approval timing delayed.

Possible root causes - Figure 3-13 shows possible root causes of this failure.

1. Lack of solid guidance or work instruction encouraging this potential failure to new staff because they don't have experience and don't know what information is necessary for Tire Design (TD).

2. Some customers are new and don't have enough experience. So they don't know what kind of information or requirement they should provide to the case company for new tire development.

3. Different style of customer (as a company) is another root cause. Some customers don't have a specific requirement for every aspect of tire, and therefore, they don't provide information to the case company.

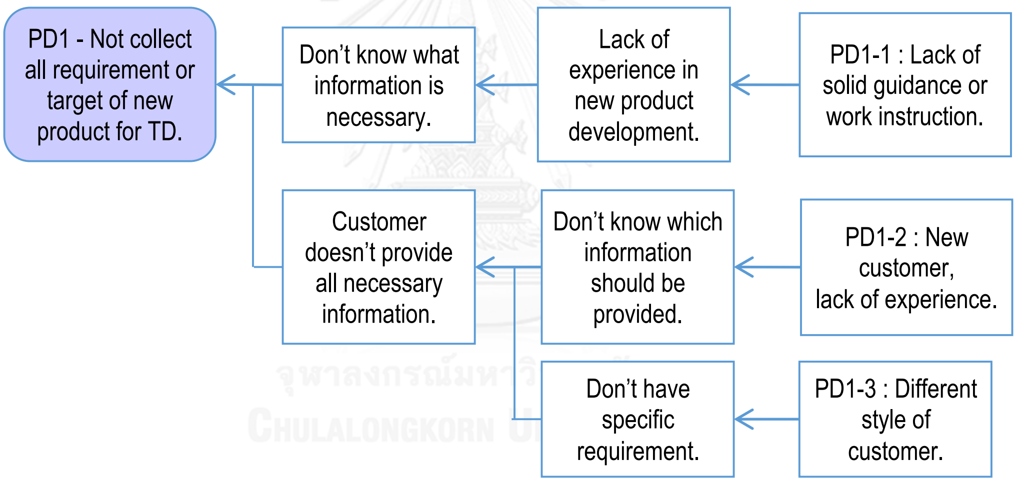


Figure 3-13 Possible root causes of PD1

Potential Failure PD2

Cannot detect error and pass it to customer. This failure is basically the second problem that is described in Section 3.2. At Process 18 and 24 of Figure 3-11, failure can occur if OE Technical Service (TS) cannot detect error from design and pass it to customer.

Potential effects - Apart from losing credibility, finding error later is risky to delay development schedule. Particularly at Process 24 where the development phase almost ends, the failure has a higher impact.

Possible root causes - Possible root causes of this problem can be summarized below.

1. First possibility is carelessness. When TS reads the requirement, TS might not check detail content of the requirement. Leading to misunderstanding the requirement and cannot detect the error.

2. Secondly, the requirement might not be written in English. There are many foreign customers (car makers) who are not using English. For example, Japanese car makers often use Japanese language. Most of the case company's employees are Thai and can't understand Japanese. Therefore, some content is not understandable and resulting in misunderstanding the requirement.

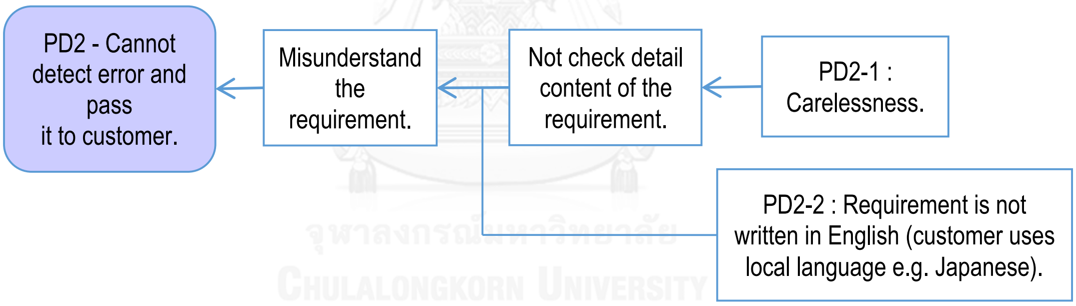


Figure 3-14 Possible root causes of PD2

Potential Failure PD3

Not prepare necessary items for evaluation in time. At Process 18 of Figure 3-11, OE Technical Service (TS) can also make a failure by not prepare necessary items for evaluation in time, such as testing vehicle, rims, or even trial tires.

Potential effects - If there are not enough necessary items for evaluation, the evaluation will be delayed, possibly a day, a week, or a month. And surely the development schedule is delayed as well.

Possible root causes - From Figure 3-15, possible root causes are

1. Lack of solid guidance or work instruction for new staff. New TS staff don't have enough experience and don't know necessary item for evaluation.

2. Lack of reminding or error-prevention tool for all TS staff. Even though old staff have enough experience, they might forget to prepare something.

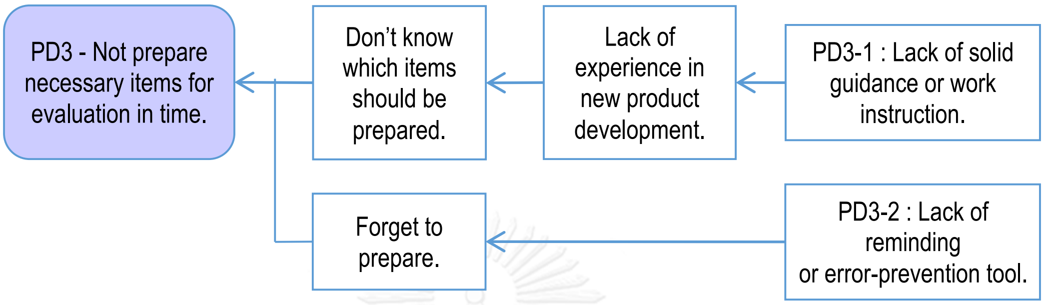


Figure 3-15 Possible root causes of PD3

3. Process Design and Development Phase

There are 2 main functions of OE Technical Service (TS) in this phase.

1. Requesting New Product Authorization (NPA) from Tire Design (TD) at the beginning of this phase to inform that new product has been approved and the case company needs process of this spec.

2. Matching all codes of the product by issue an official document called Product Information Sheet (PIS) to OE Sales (OS) at the end of this phase. OS will register new product into sales system based on information in PIS.

Possible failures in this phase are listed below.

Potential Failure PC1

Not request New Product Authorization (NPA) in time. As show in Figure 3-11 (Process 22), if OE Technical Service (TS) requests NPA late, process development will start late as well.

Potential effects - If this failure occurs, the case company probably receive process late and might not start tire production in time.

Possible root causes - Possible root causes of this problem is lack of solid guidance or work instruction for new TS staff. So the staff don't understand overall work flow and don't know what they need to do after approval.

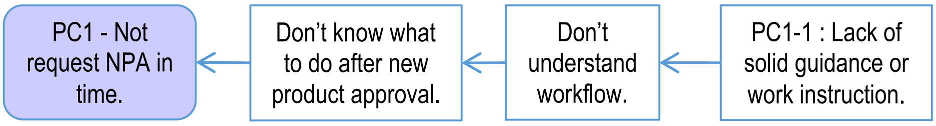


Figure 3-16 Possible root causes of PC1

Potential Failure PC2

Matching Part No. (P/N), Product Global Code (PGC) and Product Plant Code (PPC) incorrectly. This failure is basically the first problem that is described in Section 3.1. At Process 29-30 in Figure 3-11, OE Technical Service (TS) might match codes of the product incorrectly.

Potential effects - Different functions use different codes for communication. Therefore, if TS mistakenly matches the codes, the case company will deliver wrong spec to customer.

Possible root causes - Potential root causes of this problem are shown in Figure 3-17.

1. No appropriate communication between TS and Technical Engineering (TE) staff so far. They use verbal communication which is prone to be confusing and error.

2. Official document informing the Product Plant Code (PPC) isn't shared to TS. Thus TS doesn't know the correct matching and cannot detect error when TE informs wrong PPC.

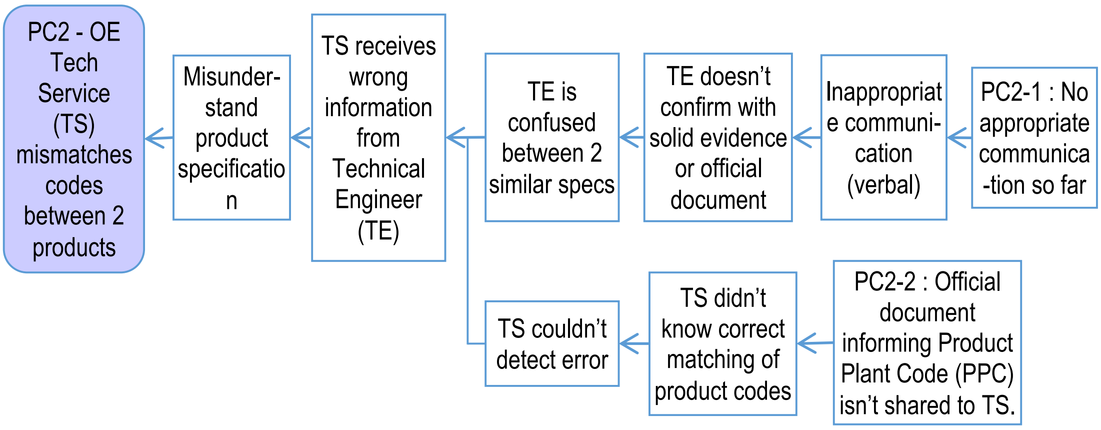


Figure 3-17 Possible root causes of PC2

4. Product and Process Validation

In this phase, the case company produces small lot of new tires using mass production and actual inspection line. Then deliver tires to customer using actual delivery system. These tires are used for vehicle trial production by customer. OE Technical Service (TS) must coordinate between the case company's plant and customer to ensure that trial production tires and the inspection data are delivered as scheduled.

Potential Failure PV1

Cannot deliver Production Trial (PT) tires and/or inspection data in time. There is possibility that TS doesn't coordinate with plant effectively, so the case company cannot prepare PT tires or inspection data by the time customer needs.

Potential effects - Production trial run usually uses actual production line and resources such as manpower, time, etc. If the case company delivers PT tires or the data late, it will impact to customer production schedule as well.

Possible root causes - Figure 3-18 shows possible root cause that lacking of solid guidance or work instruction is a possible root cause of this problem. Inexperienced TS staff usually don't understand overall procedure of development and fail to prepare PT tires or the data. Each customer has their own procedure of production trial event. For example, one tire specification can be fitted to a different sub-model of vehicle (see Figure 3-19). Some customer separates Purchasing Order (PO) by part (one tire spec one PO), some customer separates PO by sub-models or destination (one vehicle spec one PO) although those sub-models using the same part/tire. New TS staff probably don't know this and don't ask the plant to prepare inspection data based on these PO.

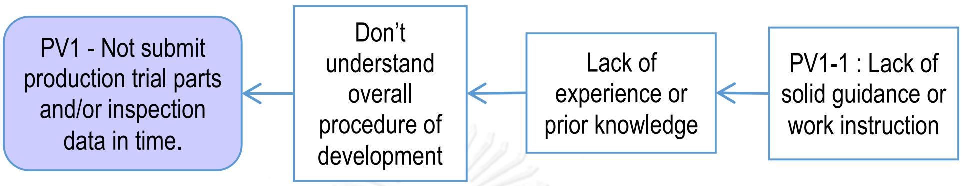


Figure 3-18 Possible root causes of PV1

Figure 3-19 Example of sub-models vehicle that can fit with same tire

a. Pick-up double-cab (from - http://carsadel-ds.com/)
b. Pick-up space-cab (from - http://www.goauto.com.au/)

3.4 Summary of Problems and Improvement Proposal

3.4.1 Root causes of the first problem

1. No appropriate communication route between OE Technical Service (TS) and Technical Engineering (TE) staffs.
2. Official reference information wasn't shared to TS after TE had generated PPC.

Improvement proposal is shown below, with application of Poka-Yoke (or mistake-prevention) concept.

1. Changing communication route from verbal to document-oriented communication in order to prevent mistake from verbal and also to share official information to TS for reference.
2. Increase detection in Product Information Sheet (PIS). The document should include Tire Design (TD) and Technical Engineering (TE) departments in the approval list in order to get official confirmation from responsible departments. PIS should also provide reference information of the new product for cross-checking by approvers.

3.4.2 Root cause of the second problem

Only root cause of this problem is carelessness of TS staff when checking detail content of the requirement. Improvement proposal are;

1. A new document called Design Review Sheet (DRS) should be created to ensure that the requirement is read carefully by TS and no misunderstanding about Mass Production (MP) tolerance will happen again. And this document should clearly show result after checking whether design values meet customer requirement or not.
2. Process flowchart should be slightly modified in order to implement the DRS sheet.

3.4.3 Potential failures and root causes

Potential failures and root causes are summarized in Table 3-1 and Table 3-2.

Table 3-1 Summary of potential failure & root causes

Phase	Key Function	Potential Failure	Potential Effect	Possible Root Cause
Planning	Collect project info. & product concept (preliminary requirement) for Tire Design (TD) to make a development plan & design conceptual product.	**PN1** Not collect all necessary project information for TD.	TD makes inappropriate plan & conceptual product in planning phase, lead to a slightly more difficulty in next because some adjustment is needed.	**PN1-1** No solid guidance or work instruction (WI)
Product Development	Collect detailed requirement of the new product for TD to set target of new design.	**PD1** Not collect all requirement of the new product for TD.	New product doesn't meet requirement, more adjustment will be needed during the development.	**PD1-1** No solid guidance or WI. **PD1-2** New customer, lack of experience. **PD1-3** Different style of customers.
	Internally check data and/or report so that design error is not delivered to customer and make amendment in time.	**PD2** Cannot detect error and pass it to customer.	Customer finds error in late timing, cannot fix it in time and supply need to be postponed.	**PD2-1** Carelessness. **PD2-2** Requirement is not written in English (Japanese, Chinese).
	Prepare prototype, vehicle, and etc. for Joint Evaluation Test (JET) with customer.	**PC3** Not prepared necessary items for JET.	JET delayed, and slightly affect to the remaining schedule (tight schedule).	**PD3-1** No solid guidance or WI. **PD3-2** No error-prevention.

Table 3-2 Summary of potential failure & root causes (cont.)

Phase	Key Function	Potential Failure	Potential Effect	Possible Root Cause
Process Development	Request new product authorization (NPA) of the approved spec to start process preparation.	**PC1** Not request NPA in time.	Process development is delayed, might affect to start of production (SOP) plan.	**PC1-1** No solid guidance or WI.
	Match Part No. (P/N) and all product codes to identify products ordered by customer.	**PC2** Match P/N and product codes incorrectly.	Supply wrong products to production vehicle, can affect safety of end users without warning.	**PC2-1** No appropriate communication route so far. **PC2-2** Official information isn't shared to OE Technical Service.
Product & Process Validation	Coordinate with concerned functions to prepare quality control document for production parts (PPAP), including to deliver production trial (PT) parts, and inspection data as required.	**PV1** Cannot submit PPAP, PT parts, and data in time.	Approval of production part and process delayed, possibly affect SOP plan slightly.	**PV1-1** No solid guidance or WI.
Mass production	Follow up feedback and/or complaint from customer after mass production.	*_Note: This phase is out of the thesis scope and*		

CHAPTER 4
METHODOLOGY

In Chapter 3, root causes of existing problems and potential failures were identified. This chapter will then show methodologies used to improve existing problems and potential failures. Methodologies for improvement used in this thesis can be categorized into 3 groups; process flow revise, document revise, prevention of potential failures (by FMEA technique).

4.1 Process Flow Revise

Similar to Motion-step method of Poka-Yoke, process flow can be added or changed to prevent errors. Figure 3-3 and Figure 3-5 in Chapter 3 show error processes of problem 1 and problem 2 respectively. Therefore, these process flowcharts will be modified in order to prevent these errors. For example, sending a document to responsible departments for data approval encourages the correctness of data.

4.2 Document Revise

The second methodology is to modify current document or making new document. This improvement can increase error-detection and/or error-prevention to current control. For example, adding information of vehicle and tire (LHD/RHD) to Request for Product Registration (RPR) document to increase its detectability of code mismatching error (Problem 1). Or, creating a new updatable document to collect customer requirements in one place. By combining it with new process flow, this can prevent information lost even if additional requirement is given separately from the original requirement (Problem 2).

The second methodology can be done through following steps

1. Identify root causes of the problem.

2. Identify opportunity to detect errors or failures based on current document or new document.

3. Modify current document or creating new document.

4.3 Prevention of Potential Failures using FMEA Technique and Pareto chart

The third methodology is to apply FMEA technique to prevent potential failures.

1. Set up FMEA team at the case company to provide detail of process flow, analyze potential failures, and create assessment criteria for Severity (S), Occurrence (O), and Detectability (D).

Since the FMEA was used specifically in OE Technical Service (TS) department of the case company, FMEA team consisted of staff from TS department.

- TS manager 1 person
- TS senior staff (more than 3-year experience) 3 persons
- TS junior staff (less than 2-year experience) 3 persons

2. Create process flow of product development process. Then identify potential failures, effects, root causes, and detection/control in (as shown in Chapter 3).

3. Set up S, O, and D assessment criteria for OE Technical Service FMEA (TSFMEA). TSFMEA criteria were adapted from criteria in AIAG's manual, in order to make the criteria more suitable for TS department.

4. Assess potential failures using TSFMEA criteria from previous step, and suggest brief preventive actions based on the root causes.

5. Prioritize importance of potential failures by their Severity level, Occurrence level, and RPN value.

CHAPTER 5
RESULT AND ANALYSIS

This chapter shows improvement result of problems described in Chapter 3 using methodology stated in Chapter 4.

The first 2 problems were recent cases in the case company and had big impacts, therefore, the improvement of these 2 problems are implemented immediately. For the potential failures, this thesis will guide how to prioritize the failures and suggests implementation ideas.

5.1 Misinformation and Miscommunication of Product Codes

To prevent misinformation and miscommunication, error-prevention concept is applied to both process flow and document. Following 2 improvements were implemented to eliminate the root causes and increase error detectability.

1. Modify current process flow (see Figure 5-1). At Process A11 to A12, after Technical Engineer (TE) generates Product Plant Code (PPC), OE Technical Service (TS) will be informed PPC of the new tire by circulating document instead of verbal information. This will help TS to know the correct matching of the PPC as well as establish an appropriate communication route between TS and TE.

2. Improve Product Information Sheet (PIS) document to enable multi-detection of codes matching by responsible departments (see Figure 5-3). This new PIS document is used at Process A13-a to A13-d of Figure 5-1.

Symbol 

shows improvement that TS department needs “checker” and “approver” to double check initial information (vehicle spec, e.g. LHD or RHD) in PIS document. Initial information will provide reference to Tire Design (TD) department and Technical Engineering (TE) department when they input their product codes. After that, “approver” of TD and TE will sign the document to approve the provided product codes.

Symbol 2 shows that new PIS provides reference information in the PIS for TE and TD to cross-check the correctness of codes matching.

These are basic improvements which are inexpensive, not much changes from the current process, and require short time for improvement. Therefore, the case company can implement them immediately with very low resistance from the related employees.

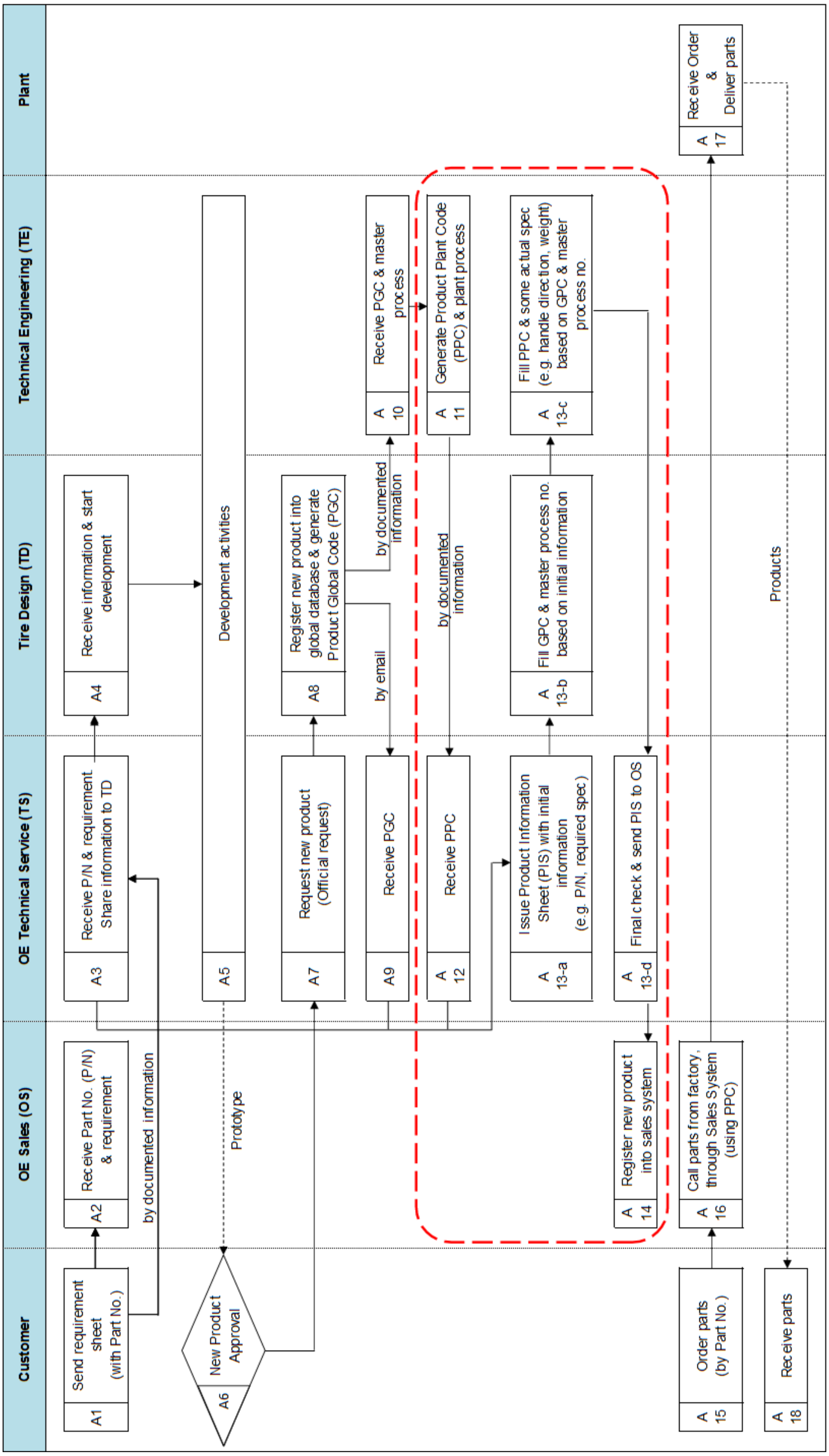


Figure 5-1 Improved process flowchart for Problem 1

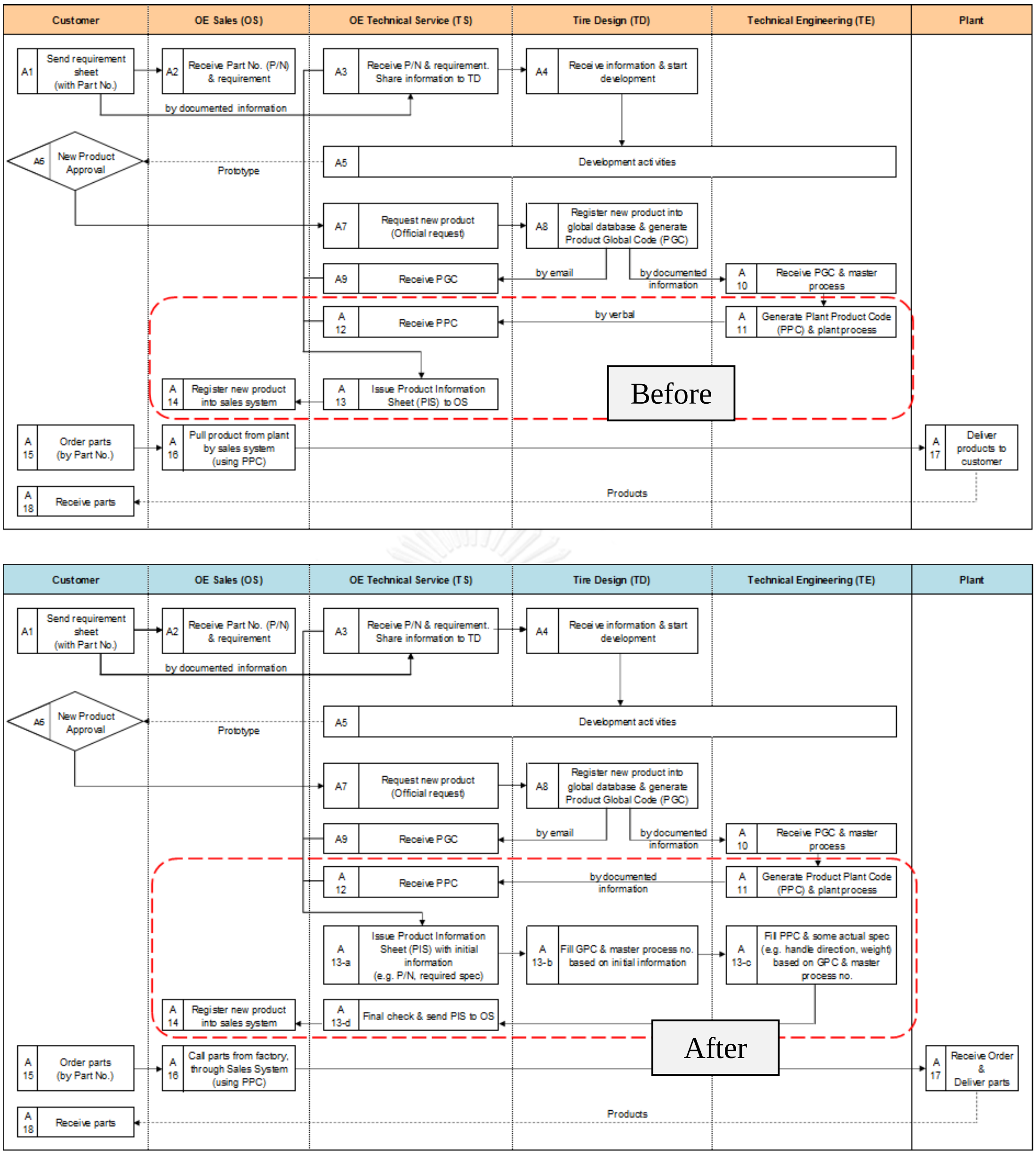
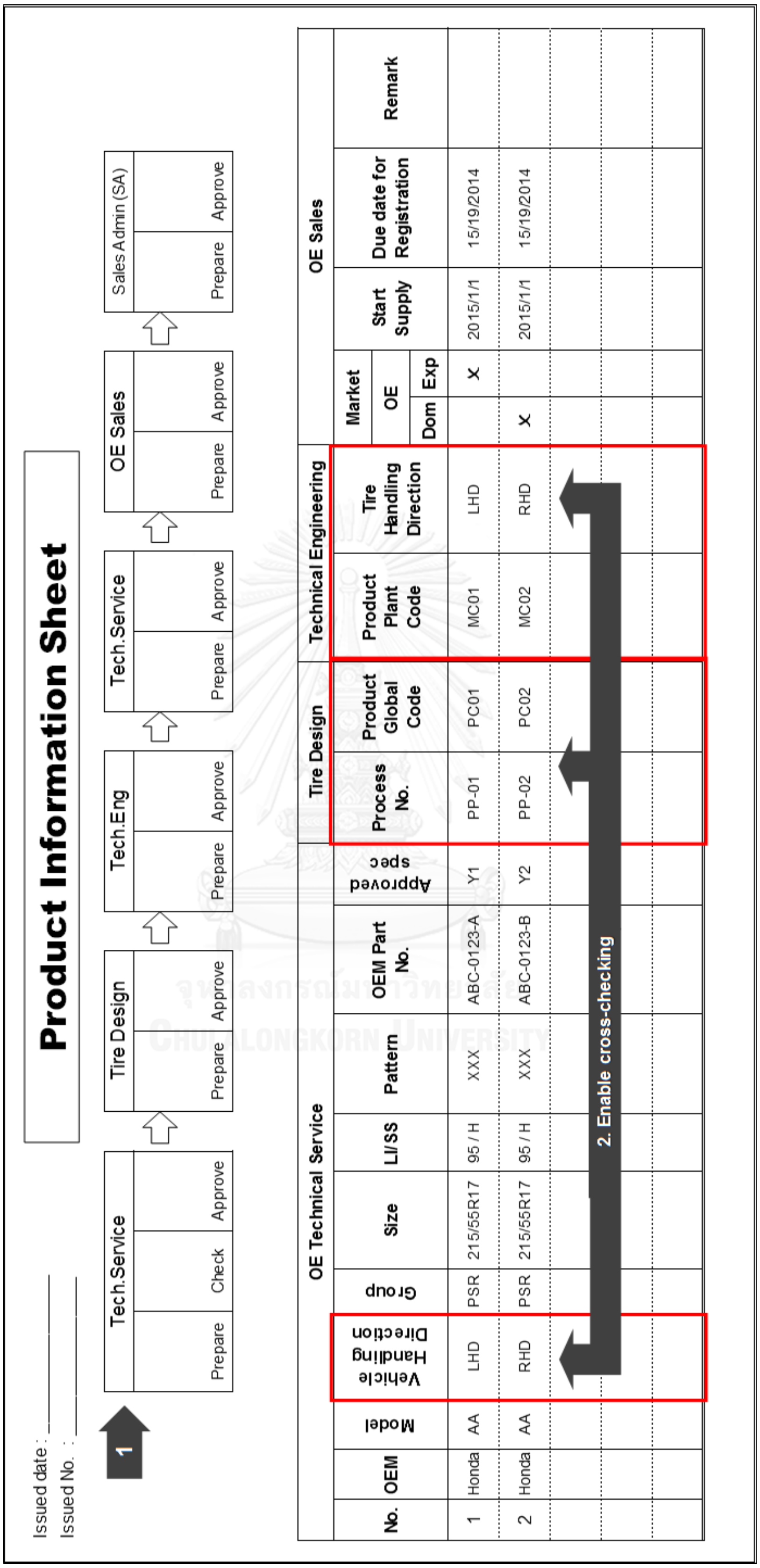


Figure 5-2 Flowchart comparison between current process and improved process of Problem 1



OE Technical Service										Tire Design		Technical Engineering		OE Sales				
No.	OEM	Model	Vehicle Handling Direction	Group	Size	LI/SS	Pattern	OEM Part No.	Approved Spec	Process No.	Product Global Code	Product Plant Code	Tire Handling Direction	Market OE Dom	Market OE Exp	Start Supply	Due date for Registration	Remark
1	Honda	AA	LHD	PSR	215/55R17	95 / H	XXX	ABC-0123-A	Y1	PP-01	PC01	MC01	LHD		X	2015/1/1	15/19/2014	
2	Honda	AA	RHD	PSR	215/55R17	95 / H	XXX	ABC-0123-B	Y2	PP-02	PC02	MC02	RHD	X		2015/1/1	15/19/2014	

Figure 5-3 New Product Information Sheet

5.2 Misunderstanding of Tolerance for Design and Unable to Detect Error

According to analysis in Chapter 3, root cause of this problem is carelessness. OE Technical Service (TS) did not check the requirement in detail which led to misunderstanding of target tolerance. Error-prevention concept is also applied to both process flow and document to eliminate root cause of this problem.

A new document called Design Review Sheet (DRS) will be developed (see Figure 5-4). Concept of DRS is to make TS review design data and compare with requirement point-by-point so that no any content in the requirement is neglected. Tolerance is also shown in this sheet. And in order to implement DRS, process flow will be adjusted as well (see Figure 5-5).

1. After review requirement and request Tire Design (TD) to develop new product, TS needs to create DRS to summarize target values (Process B2b). This process makes TS review requirement thoroughly in order to complete the DRS form.

2. After receiving data of prototype or final specs, TS needs to fill the data in DRS and compare to target values (see Process B6 and B12). If any data doesn't achieve target, TS can detect it immediately.

Project ______________

Design Review Sheet

Date ______________
Spec ______________

		Target	Production Tolerance	Actual design target	Actual (design data)	Judgement	Comment
Dimension	Condition	rim width : 6.5 inch 250 kPa			rim width : 6.5 inch 250 kPa		
	Width (mm)	212 - 230	± 5 mm	217 - 225	216.9	OK	
	Diameter (mm)	686 - 700	± 4 mm	690 - 696	698	NG	
Force & Moment	Condition	load in Z : 4782 N/ 3548 N (F/R) 230 kPa	-	-	4782 / 3548 N 230 kPa	OK	
	F(1°) slip angle	≥ 0.28 / ≥ 0.32 (F/R)	-		0.35/0.39	OK	No tolerance requirement
	F(2°) slip angle	≥ 0.51 / ≥ 0.55 (F/R)	-		0.64/0.69	OK	
	F(4°) slip angle	≥ 0.81 / ≥ 0.88 (F/R)	-		0.91/0.96	OK	
	F(6°) slip angle	≥ 0.95 / ≥ 1.01 (F/R)	-		0.99/1.02	OK	
	F(8°) slip angle	≥ 1.00 / ≥ 1.05 (F/R)	-		1.08/1.08	OK	
Aligning torque coefficient	AT(1°) slip angle	9.0 ± 1.0 (Front)	-		10.7	NG	Slightly higher than requirement. Is this acceptable?
Ply steer (SAE J670)	Condition	load in Z : 4782 N 230 kPa			load in Z : 4782 N 230 kPa		
	RAT mean (NM)	-2.5 ± 1.5			-0.73	OK	
Rolling Resistance (ISO 28580)	Condition	load in Z : 568 kg 210 kPa 80 kph			Load : 5.57 kN 210 kPa 80 kph		
	RRC @ average	0.0083 kg / ton			0.0092 N/kN	NG	Is this level acceptable?

Figure 5-4 Sample of Design Review Sheet

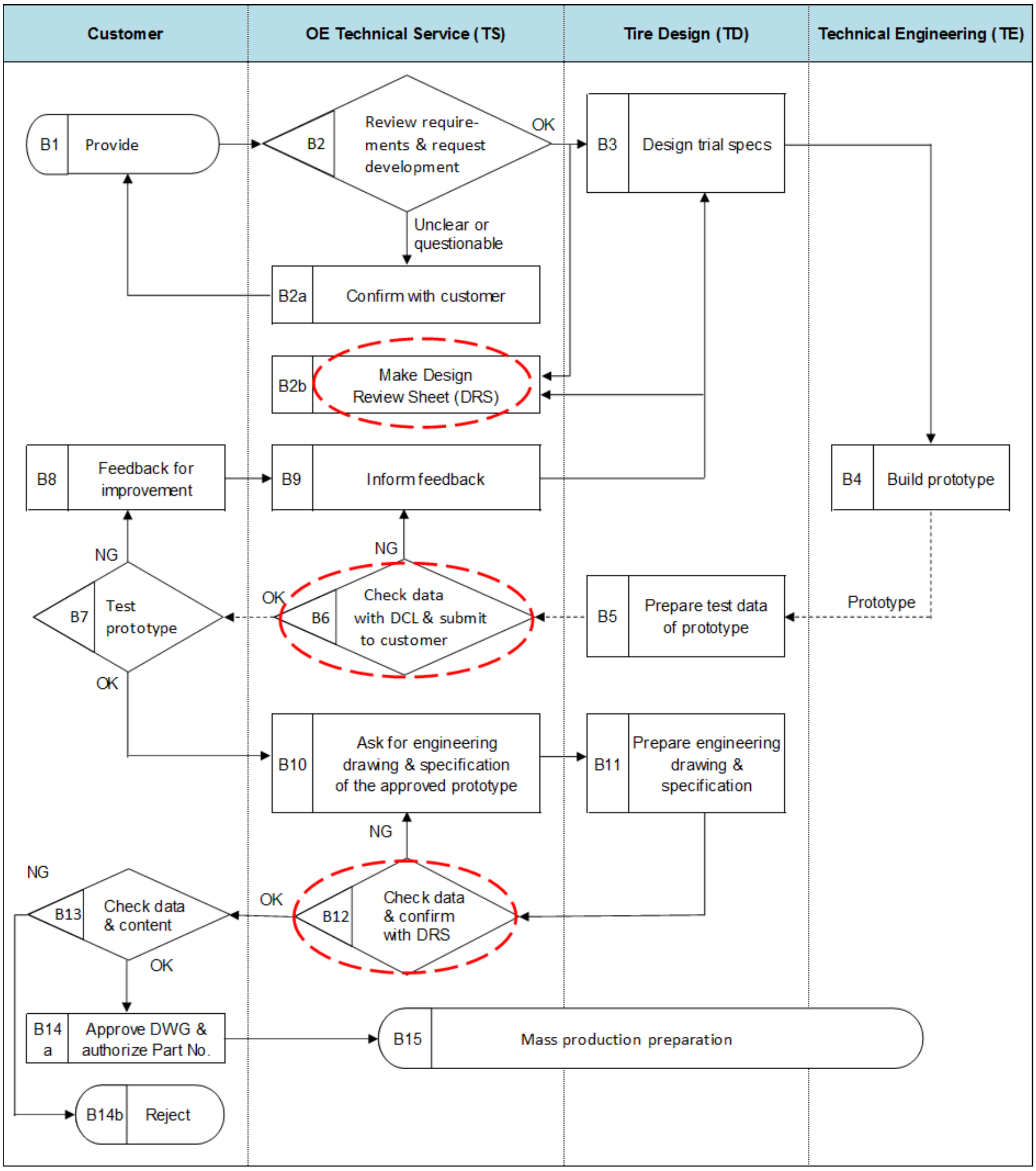


Figure 5-5 Improved process flow chart for Problem 2

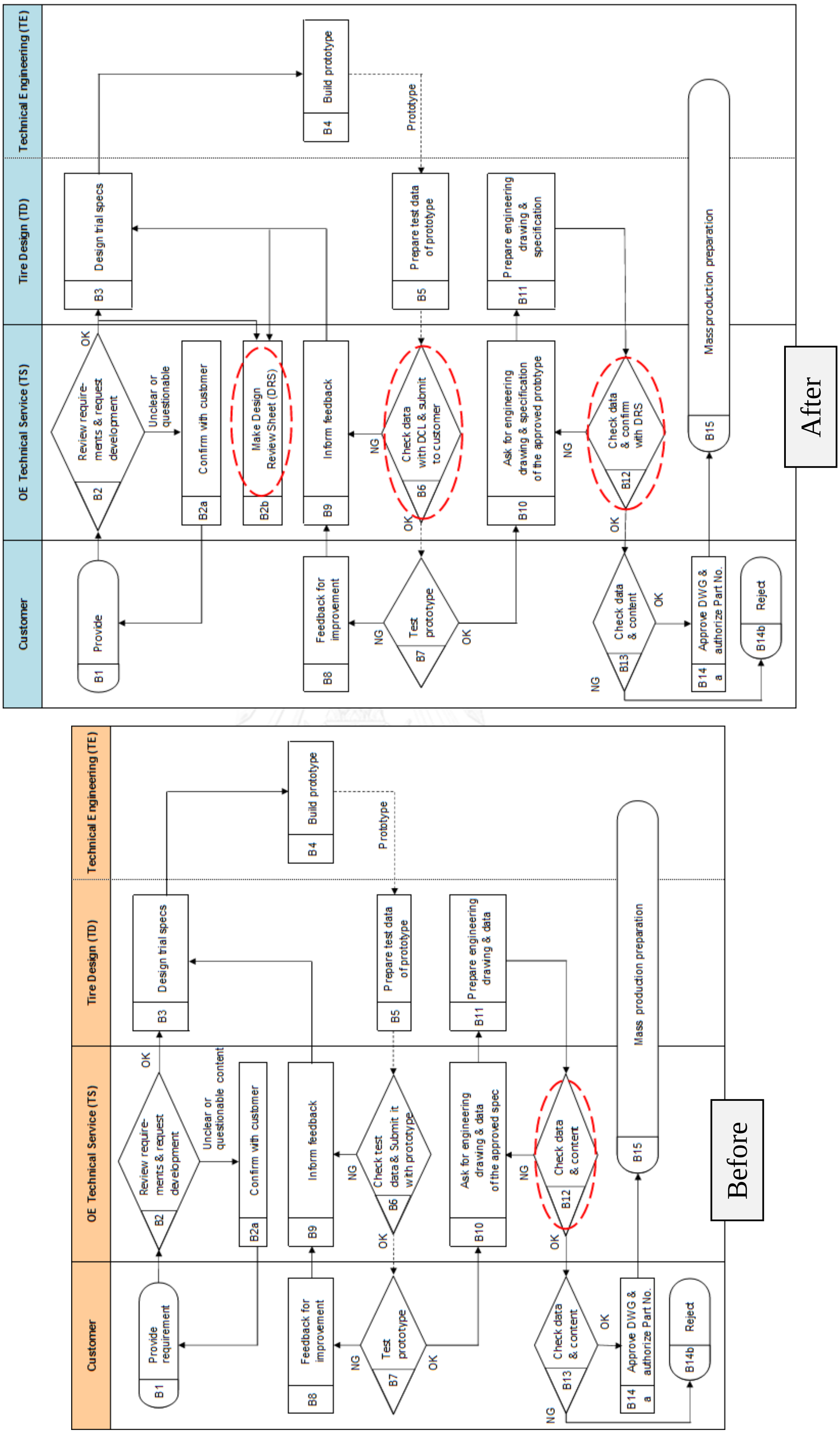


Figure 5-6 Flowchart comparison between current process and improved process for Problem 2

5.3 Potential Problems Analysis and Proposal of Prevention

After identifying potential failures in Chapter 3, FMEA technique was applied to evaluate failures and give them priority to be handled first. Other techniques, such as Pareto Chart, were applied in this section as well.

5.3.1 OE Technical Service FMEA (TSFMEA) Criteria

Automotive Industry Action Group (AIAG) gives examples of FMEA criteria to evaluate Severity (S), Occurrence (O), and Detectability (D) of failures in both processing/manufacturing function (called Process FMEA or PFMEA) and designing function (called Design FMEA or DFMEA). However, OE Technical Service (TS) is not production or designing function. Thus, original AIAG's criteria are not applicable to TS function directly.

A new FMEA criteria, OE Technical Service FMEA (TSFMEA) Criteria, was created from discussion with FMEA team of the case company, based on concept of AIAG FMEA criteria. Following description will explain the detail of TSFMEA.

Severity

AIAG divided FMEA into 2 categories based on the area that its context focuses; Process FMEA (PFMEA) and Design FMEA (DFMEA). Just as their names, Severity level in PFMEA focuses on effect of failures on the process continuity or production line whereas Severity level in DFMEA focuses on effect of design failures on product (vehicle) functions. However, TS is a service-based function that does not relate to production line or product design directly. Thus, Severity of TSFMEA was agreed by FMEA team of the case company to focus on impact on activities of the project.

From TS business strategy, failure that affects to customer's activities is considered a severe problem because it damages relationship between the case company and customer. Also, impact to market quality or safety of end users is the most severe problem. Thus, the criteria were defined as follow.

Level 9 to 10 relate to end user's safety, which is the highest concern (similar to PFMEA and DFMEA top levels).

Level 6 to 8 relate to customer's activities, namely vehicle production trials and start of production (VSOP) and/or the whole business/project of the case company.

Level 2 to 5 relate to the case company's internal activities.

Level 1 is no or very low impact.

Table 5-1 shows detail description of Severity at each level, and comparing Severity of TSFMEA and AIAG's FMEA.

Table 5-1 Comparison of Severity by AIAG (PFMEA, DFMEA) and TSFMEA

Rating	Severity					
	PFMEA		DFMEA		TSFMEA	
	Effect	**Criteria = Severity of effect on process**	**Effect**	**Criteria = Severity of effect on product and customer**	**Effect**	**Criteria = Effect on project schedule, customer, and/or the case company**
10	Failure to meet Safety and/or Regulatory Requirements	May endanger operator (machine or assembly) without warning.	Failure to meet Safety and/or Regulatory Requirements	Affect safe vehicle operation and/or involves noncom-pliance with government regulation without warning	Affect end users and/or regulations	Affect regulatory requirements and/or safety of end users without warning.
9		May endanger operator (machine or assembly) with warning.		Affect safe vehicle operation and/or involves noncom-pliance with government regulation with warning		Affect regulatory requirements and/or safety of end users with warning.
8	Major Disruption	100% of product may have to be scrapped. Line shutdown or stop ship.	Loss or Degradation of Primary Function	Loss of primary function (vehicle inoperable, does not affect safe vehicle)	Affect customer's production plan and/or business of the case company	Affect to customer's VSOP and/or the case company loses share of the specific model.
7	Significant Disruption	A portion of the production may have to be scrapped. Deviation from primary process including decreased line speed or added manpower.		Degradation of primary function (vehicle operable, but at reduced level of performance)	Affect external (customer's) activities	Affect customer's production trial run and may slightly delay VSOP schedule (delay no more than 1 week).
6	Moderate Disruption	100% of production run may have to be reworked off line and accepted.	Loss or Degradation of Secondary Function	Loss of secondary function (vehicle operable, but comfort and/or convenience functions inoperable)		Delay approval plan and/or may affect vehicle first production trial run. VSOP is not affected.
5		A portion of the production run may have to be reworked off line and accepted.		Degradation of secondary function (vehicle operable, but comfort and/or convenience are reduced)	High impact to internal (the case company's) activities	Affect internal activities shortly before approval plan, limited time to find counter measures (CM) or rework. Might delay approval plan slightly.
4	Moderate Disruption	100% of production run may have to be reworked in station before it is processed.	Annoyance	Vehicle operable but appearance or audible noise does not conform and noticed by most customers (> 75%)	Medium impact to internal (the case company's) activities	Affect internal activities in the middle of project and have less time to fiind counter measures (CM) or rework.
3		A portion of the production run may have to be reworked in station before it is processed.		Vehicle operable but appearance or audible noise does not conform and noticed by many customers (> 50%)	Low impact to internal (the case company's) activities	Affect internal activities in the beginning of project, still have plenty of time to find counter measures (CM) or rework.
2	Minor Disruption	Slight inconvenience to process, operation or operator.		Vehicle operable but appearance or audible noise does not conform and noticed by sensitive customers (> 25%)		Show difficulties to internal activities before start the project (planning phase). Have time to adjust plan.
1	No effect	No discernible effect.	No effect	No discernible (detectable) effect	No effect	No discernible effect.

Occurrence

PFMEA rates Occurrence level (O) based on proportion of defects from the process (e.g. 1 in 10 or 1 in million) whereas DFMEA rates O based on likelihood of failures and how fresh/reliable the design is. The common concept between PFMEA and DFMEA is frequency or likelihood of failure occurrence. Therefore, Occurrence criteria of TSFMEA was created based on the same concept, which is a frequency of failures in last 5 years (P) instead. Below equation shows how P is calculated.

$$P = \frac{\text{Number of cases actually occured}}{\text{Maximum number of cases can occur in last 5 years}} \times 100\%$$

Table 5-2 shows calculation of P value for each root cause.

Table 5-2 "P" value calculation table

Failure	PN1	PD1			PD2		PD3		PC1	PC2		PV1
Root Cause	PN1-1	PD1-1	PD1-2	PD1-3	PD2-1	PD2-2	PD3-1	PD3-2	PC1-1	PC2-1	PC2-2	PV1-1
Number of actual cases	11	0	6	7	1	2	0	0	0	1	1	3
Maximum no. of cases	43	42	42	42	42	42	42	42	39	39	39	41
P	25.6%	0.0%	14.3%	16.7%	2.4%	4.8%	0.0%	0.0%	0.0%	2.6%	2.6%	7.3%

From discussion and agreement with OE Technical Service (TS) department, Occurrence level 5 should represent a significant value of P. Thus, Pareto Chart was applied to select a significant P value (around 80% of total P from every failures). Firstly, root causes (in codes) were sorted by P value, from largest to smallest. Then cumulative P value and its percentage are calculated as in Table 5-3. Finally, Pareto Chart could be created as Figure 5-7.

Table 5-3 "P" value ordering for Occurrence Pareto

Root Cause	*P* (by ordered)	Cumulative *P*	Cumulative *P* (in %)
PN1-1	25.6%	0.26	33.6%
PD1-3	16.7%	0.42	55.5%
PD1-2	14.3%	0.57	74.3%
PV1-1	7.3%	0.64	83.9%
PD2-2	4.8%	0.69	90.1%
PC2-1	2.6%	0.71	93.5%
PC2-2	2.6%	0.74	96.9%
PD2-1	2.4%	0.76	100.0%
PD1-1	0.0%	0.76	100.0%
PD3-1	0.0%	0.76	100.0%
PD3-2	0.0%	0.76	100.0%
PC1-1	0.0%	0.76	100.0%

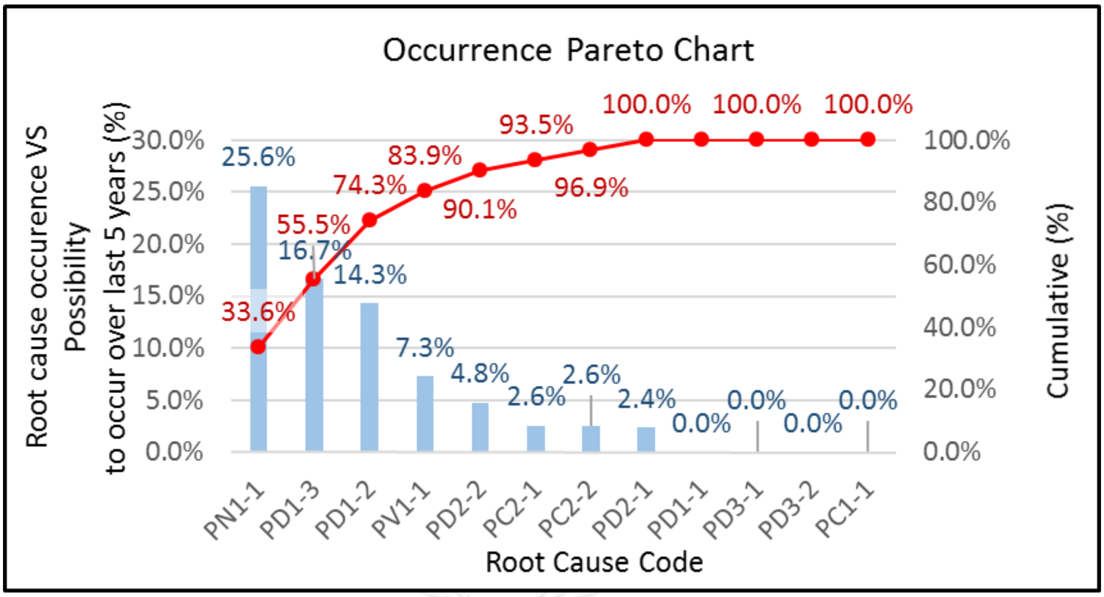


Figure 5-7 Occurrence Pareto chart

From Figure 5-7, P value of root cause PV1-1 and above (P value ≥ 7.3%) are accounted for around 84%. Thus, Occurrence level 5 was set by P value, around 7.3%. Finally, we set Occurrence level of TSFMEA as Table 5-4.

Table 5-4 Comparison of Occurrence by AIAG (PFMEA, DFMEA) and TSFMEA

Occurrence of Cause					
Rating		PFMEA (AIAG)	DFMEA (AIAG)	TSFMEA (AIAG)	
	Likelihood of Failure	**Criteria = Occurrence of Cause (Incidents per items/vehicles)**	**Criteria = Occurrence of Cause (Design life/reliability of item/vehicle)**	**Criteria = frequency of failure occurrence in last 5 years (P)**	**Likelihood of failure**
10	Very High	≥ 100 per thousand ≥ 1 in 10	New technology / new design with no history.	13.5% ≤ P	Very High
9	High	50 per thousand 1 in 20	Failure is inevitable with new design, new application or change in duty cycle/operating conditions.	12% ≤ P < 13.5%	
8		20 per thousand 1 in 50	Failure is likely with new design, new application or change in duty cycle/operating conditions.	10.5% ≤ P < 12%	High
7		10 per thousand 1 in 100	Failure is uncertain with new design, new application or change in duty cycle/operating conditions.	9% ≤ P < 10.5%	
6	Moderate	2 per thousand 1 in 500	Frequent failures associated with similar designs or in design simulation and testing.	7.5% ≤ P < 9%	Moderate
5		0.5 per thousand 1 in 2,000	Occasional failures associated with similar designs or in design simulation and testing.	6% ≤ P < 7.5%	
4		0.1 per thousand 1 in 10,000	Isolated failures associated with similar designs or in design simulation and testing.	4.5% ≤ P < 6%	Low
3	Low	0.01 per thousand 1 in 100,000	Only isolated failures associated with almost identical design or in design simulation and testing.	3% ≤ P < 4.5%	
2		≤ 0.001 per thousand 1 in 1,000,000	No observed failures associated with almost identical design or in design simulation and testing.	1.5% ≤ P < 3%	Very Low
1	Very Low	Failure is eliminated through preventive control	Failure is eliminated through preventive control.	0% ≤ P < 1.5%	

Detectability

Detectability is an ability of current controls to detect errors or failure modes. PFMEA evaluates Detectability of a process control whereas DFMEA evaluates Detectability of a control in the design (before production) phase. From PFMEA and DFMEA detectability criteria, there are 2 common concepts to evaluate Detectability; first is how early or fast the control can detect errors or failures, and second is reliability or effectiveness of methodology of the control/detection.

The first factor, a better control or detection can detect failures earlier and is ranked at lower-end score. This is because if you find failure modes or errors earlier (before design freeze or in-process.), you can correct them easier (change design or fix the process) and have less opportunity to turn these mistakes into defective deliverables to customer.

The second factor, a more reliable methodology of control has less variation and is ranked at lower-end score. This is clearly reasonable, automated detections are generally more reliable and hardly make mistake, unlike human's detection (visual check or etc.).

Above of all, the best control (level 1) of PFMEA and DFMEA is a control that can prevent the failure from occurrence. These concepts were applied to create Detectability criteria of TSFMEA (see Table 5-5).

Table 5-5 Comparison of Detectability by AIAG (PFMEA, DFMEA) and TSFMEA

Detection							
Rating	PFMEA (AIAG)		DFMEA (AIAG)		TSFMEA		Likelihood of detec-tion
	Opportunity for Detection	**Criteria: Likelihood of detection by process control**	**Opportunity for Detection**	**Criteria: Likelihood of detection by design control**	**Opportunity to Detect**	**Criteria: Likelihood of detection by information control**	
10	No detection opportunity	No current process control; Cannot detect or is not analyzed.	No detection opportunity	No current design control; Cannot detect or is not analyzed.	No detection at any stage	The case company cannot detect	Impossible to detect
9	Not likely to detect at any stage	Failure modes (FM) and/or error is not easily detected (e.g. random audits).	Not likely to detect at any stage	Design analysis/detection controls have a weak detectability; Virtual Analysis (e.g. CAE, FEA, etc.) is not correlated to expected actual operating conditions.	Low opportunity : Error can be detected post-processing (by other departments)	Detect by other departments after TS processing, need thorough inspection	Very unlikely
8	Problem detection post-processing	FM detection post-processing by operator through visual / tactile / audible means.	Post Design Freeze and prior to launch	Product verification/validation after design freeze and prior to launch with pass/fail testing (testing with accep-tance criteria such as ride and handling, shipping evaluation, etc.).		Detect by other departments after TS processing, almost immediately	
7	Problem detection at Source	FM detection in-station by operator through visual/tactile/audible means or post-processing through use of attribute gauging (go/no-go, manual torque check, etc.).		Product verification/validation after design freeze and prior to launch with test to failure testing (testing until failure occurs, testing of system interactions, etc.).	Low opportunity : Error can still be detected within TS department	Well-trained or high experienced TS staff can detect by thorough inspection	Unlikely
6	Problem detection post-processing	FM detection post-processing by operator through use of variable gauging or in-station by operator through use of attribute gauging.		Product verification/validation after design freeze and prior to launch with degradation testing (testing after durability test, e.g., function check).		Well-trained or high experienced detect immediately	
5	Problem detection at Source	FM or Error detection in-station by operator through use of variable gauging or by automated controls in-station that will detect discrepant part and notify operator (light, buzzer, etc.). Gauging performed on setup and first piece check (for set-up causes only).	Prior to Design Freeze	Product validation (reliability testing, development or validation tests) prior to design freeze using pass/fail testing (e.g. acceptance criteria for performance, function checks, etc.).	High opportunity : Error can be detected within TS department	Moderate experienced TS staff can detect by thorough inspection	Likely
4	Problem detection post-processing	FM detection post-processing by automated controls that will detect discrepant part and lock part to prevent further processing		Product validation (reliability testing, development or validation tests) prior to design freeze using test to fail testing (e.g. until leaks, yields, cracks, etc.).		Moderate experienced TS staff can detect immediately	
3	Problem detection at Source	FM detection in-station by automated controls that will detect discrepant part and automatically lock part in-station to prevent further processing		Product validation (reliability testing, development or validation tests) prior to design freeze using degradation testing (e.g. data trends, before/after values, etc.).		Inexperienced TS staff can detect by thorough inspection	Very likely
2	Error detection and/or problem prevention	Error detection in-station by automated controls that will detect error and prevent discrepant part from being made	Virtual Analysis - Correlated	Design analysis/detection has a strong detectability. Virtual Analysis prior to design freeze highly correlated with expected or actual operating conditions.		Inexperienced TS staff can detect immediately	
1	Detection not applicable; Error prevention	Error prevention as a result of fixture design, machine design or part design. Descrepant parts cannot be made because item has been error-proofed by process / product design	Detection not applicable; Failure prevention	Error or FM can not occur because it is fully prevented through design solutions (e.g. proven design standard, best practice or common material, etc.).	Error prevented at the source	Failure or error is prevented or detected automatically and instantly (e.g. value calculated automatically in excel, detection by excel formula).	Almost certain

Table 5-6 Summary of TSFMEA criteria

Rating	Severity		Occurrence		Detection	
	Effect	**Criteria = Effect on project schedule, customer, and/or the case company**	**Likelihood of failure**	**Criteria = % of occurrences in projects completed in last 5 years (P)**	**Opportunity to Detect**	**Criteria: Likelihood of detection by information control**
10	Affect end users and/or regulations	Affect regulatory requirements and/or safety of end users without warning.	Very High	13.5% ≤ P	No detection at any stage	The case company cannot detect
9		Affect regulatory requirements and/or safety of end users with warning.		12% ≤ P < 13.5%	Low opportunity : Error can be detected post-processing (by other departments)	Detect by other departments after TS processing, need thorough inspection
8	Affect customer's production plan and/or business of the case company	Affect to customer's VSOP and/or the case company loses share of the specific model.	High	10.5% ≤ P < 12%		Detect by other departments after TS processing, almost immediately
7	Affect external (customer's) activities	Affect customer's production trial run and may slightly delay VSOP schedule (delay no more than 1 week).		9% ≤ P < 10.5%	Low opportunity : Error can still be detected within TS department	Well-trained or high experienced TS staff can detect by thorough inspection
6		Delay approval plan and/or may affect vehicle first production trial run. VSOP is not affected.	Moderate	7.5% ≤ P < 9%		Well-trained or high experienced detect immediately
5	High impact to internal (the case company's) activities	Affect internal activities shortly before approval plan, limited time to find counter measures (CM) or rework. Might delay approval plan slightly.		6% ≤ P < 7.5%	High opportunity : Error can be detected within TS department	Moderate experienced TS staff can detect by thorough inspection
4	Medium impact to internal (the case company's) activities	Affect internal activities in the middle of project and have less time to fiind counter measures (CM) or rework.	Low	4.5% ≤ P < 6%		Moderate experienced TS staff can detect immediately
3	Low impact to internal (the case company's) activities	Affect internal activities in the beginning of project, still have plenty of time to find counter measures (CM) or rework.		3% ≤ P < 4.5%		Inexperienced TS staff can detect by thorough inspection
2		Show difficulties to internal activities before start the project (planning phase). Have time to adjust plan.	Very Low	1.5% ≤ P < 3%		Inexperienced TS staff can detect immediately
1	No effect	No discernible effect.		0% ≤ P < 1.5%	Error prevented at the source	Failure or error is prevented or detected automatically and instantly (e.g. value calculated automatically in excel, detection by excel formula).

5.3.2 TSFMEA implementation result

After TSFMEA criteria was created and agreed, FMEA team which consisted of OE Technical Service (TS) members rated Severity (S), Occurrence (O), and Detectability (D) of all potential failures and root causes. Table 5-7 and Table 5-8 show results after rating.

Table 5-7 Summary of TSFMEA

Phase	Key Function	Potential Failure	Potential Effect	Severity	Possible Root Cause	Occurrence	Current Control	Detectability	Recommended action
Planning	Collect project info. & product concept (preliminary requirement) for Tire Design (TD)	**PN1** OE Technical Service (TS) doesn't collect all necessary information for TD.	TD makes inappropriate plan & conceptual product in planning phase, lead to a slight difficulty in next phase, need some adjustment	2	**PN1-1** Lack of solid guidance or work instruction (WI)	10	Senior staffs specially follow up new staffs	5	Develop a solid work instruction, together with closely training during working
Product Development	Collect detailed requirement of the new product for TD to set target of new design.	**PD1** OE Technical Service (TS) doesn't collect all requirement of the product for TD.	New product doesn't meet requirement; more adjustment will be needed during the development.	4	**PD1-1** Lack of solid guidance or WI	1	TS input requirement in the existing check sheet, and can detect missing information	4	Develop a solid work instruction, together with closely training during working
					PD1-2 New customer, lack of experience	10	Confirm missing information with customer can understand their expertise and/or style	4	Provide training to customers
					PD1-3 Different style of customer	10		4	Try to get official agreement to be reference for development
	Internally check data and/or report so that design error is not delivered to customer and make amendment in time.	**PD2** OE Technical Service (TS) cannot detect error and pass it to customer.	Customer finds error in late timing, cannot fix it in time and supply need to be postponed.	8	**PD2-1** Carelessness	2	No standard checking process	10	Develop check sheet and standard checking process
					PD2-2 Requirement is not written in English (customer uses local language e.g. Japanese)	4	Inexperienced staffs can detect unfamiliar language immediately after reviewing requirement	1	Encourage staff to ask experts of those language (usually customer or mangers)
	Prepare prototype, vehicle, and etc. for Joint Evaluation Test (JET) with customer.	**PD3** Not prepared necessary items for JET.	JET delayed, and slightly affect to the remaining schedule (tight schedule).	4	**PD3-1** Lack of solid guidance or WI	1	Senior staffs specially follow up new staffs	5	Develop a solid work instruction & training
					PD3-2 Lack of reminding or error-prevention tool.	1	Reminding from related departments	9	Develop a check list

Table 5-8 Summary of TSFMEA (cont.)

Phase	Key Function	Potential Failure	Potential Effect	Severity	Possible Root Cause	Occurrence	Current Control	Detectability	Recommended action
Process Development	Request new product authorization (NPA) as scheduled.	**PC1** Not request NPA in time.	Process development is delayed, might affect to start of production (SOP) plan.	7	**PC1-1** Lack of solid guidance or WI	1	Senior staffs provide guidance or reminds after new product approval	4	Develop a solid work instruction, together with closely training during working
	Match Part No. (P/N) and all product codes to identify products ordered by customer.	**PC2** Match P/N and product codes incorrectly.	Supply wrong products to production vehicle, can affect safety of end users without warning.	10	**PC2-1** No appropriate communication standard so far (use verbal communication)	2	No current control	10	Develop an official or document-based communication
					PC2-2 Official document informing Product Plant Code (PPC) isn't shared to TS.	2		10	Sharing official document to TS
Product & Process Validation	Coordinate with concerned functions to prepare production trial (PT) parts, and inspection data as required.	**PV1** Cannot submit PT parts and/or inspection data in time.	Affect vehicle production trial run schedule, possibly affect SOP plan only slightly.	7	**PV1-1** Lack of solid guidance or WI	5	Senior staffs specially follow up new staffs	5	Develop a solid work instruction, together with closely training during working
Mass Production	Follow up feedback and/or complaint from customer after mass production.	*Not include in thesis scope*							

Then, all failures and root causes are prioritized into groups by their Severity and Occurrence (see Figure 5-8). OE Technical Service was suggested to prepare action plan based on following sequences.

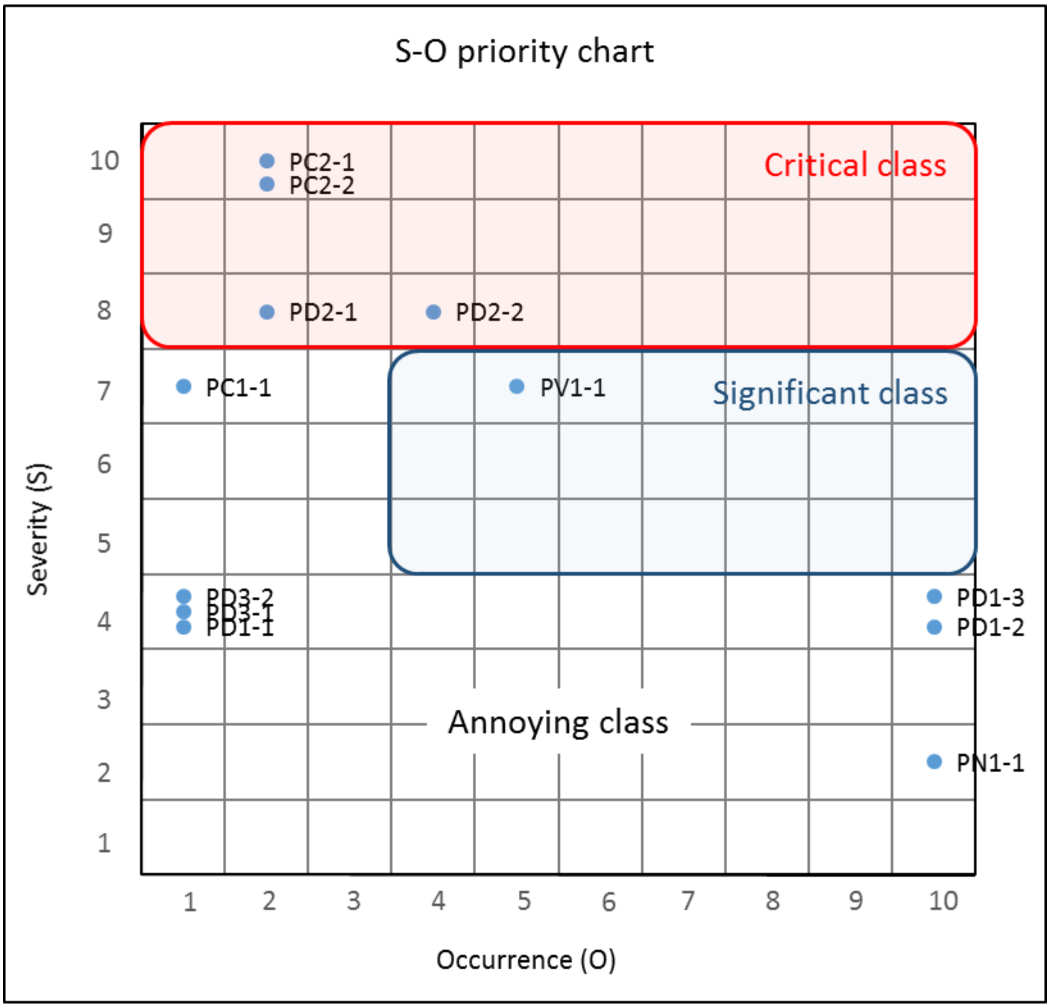


Figure 5-8 Severity versus Occurrence

1. The first group, Critical class, are failures that have the most severe effects and, regardless their Occurrence level, must be handled first and immediately. AIAG manual consider Severity (S) level 9 and 10. However, S level 8 impacts to the case company business and customer's production schedule significantly. Thus, it is not acceptable and S level 8 was included in this group as well. Failures in this group; namely

PC2-1, PC2-2, PD2-1, and PD2-2, are actually the 2 problems we have described in Section 5.1 and 5.2.

2. The second group, significant class, are failures that have Severity level 5-7 with Occurrence level 4 and above. Severity of these failures are slightly less severe than Critical class. However, Occurrence level that are relatively too high for TS department makes them important failures. Therefore, failures PV1-1 in this group will be the second priority.

3. The third and final group, the Annoying class, are failures that have less relatively low impact and/or lower occurrence rate than the above 2 groups. Thus, this group are relatively less important than the other two. However, when TS department considers failures in this group, Pareto Chart could be applied to help TS department prioritizes annoying failures by their RPN (see Figure 5-9).

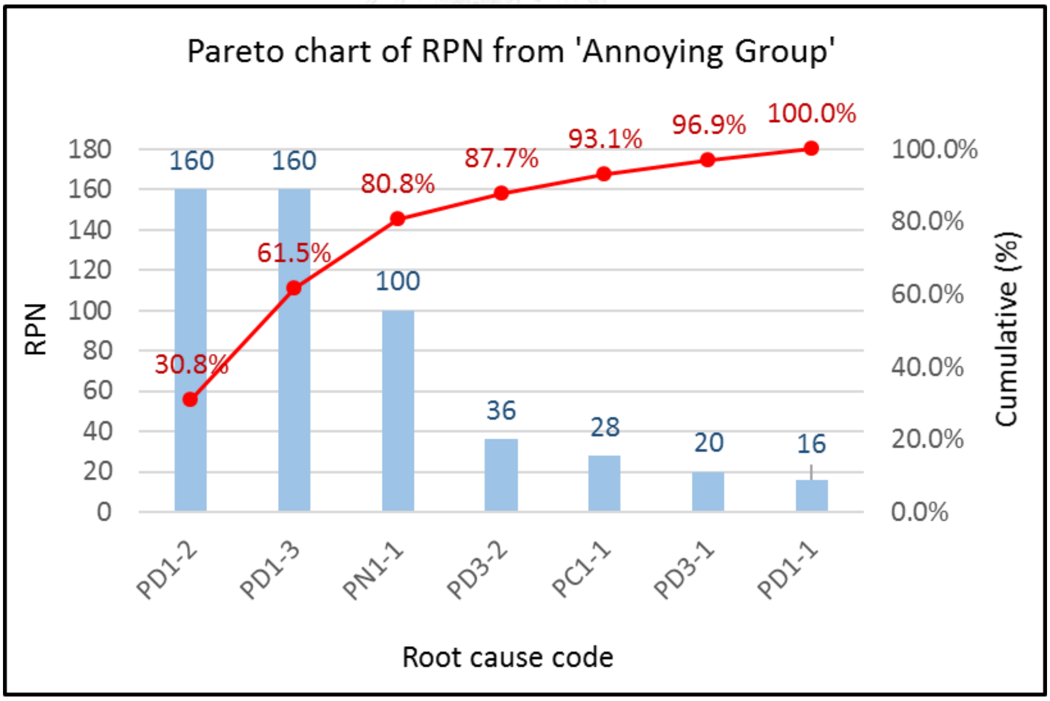


Figure 5-9 Pareto Chart of Annoying Group

5.4 Measurement of Result

New process flows and documents were introduced in the case company in order to prevent the stated problems in product development phase and process development phase. From Figure 5-10, Project A had implemented the new Product Information Sheet (PIS) and new process to prevent mismatching product codes. The result from Project A shew no failure as expected. However, the results of Project B to Project E haven't been collected and measured yet because of the project schedules are depended on agreement with customers.

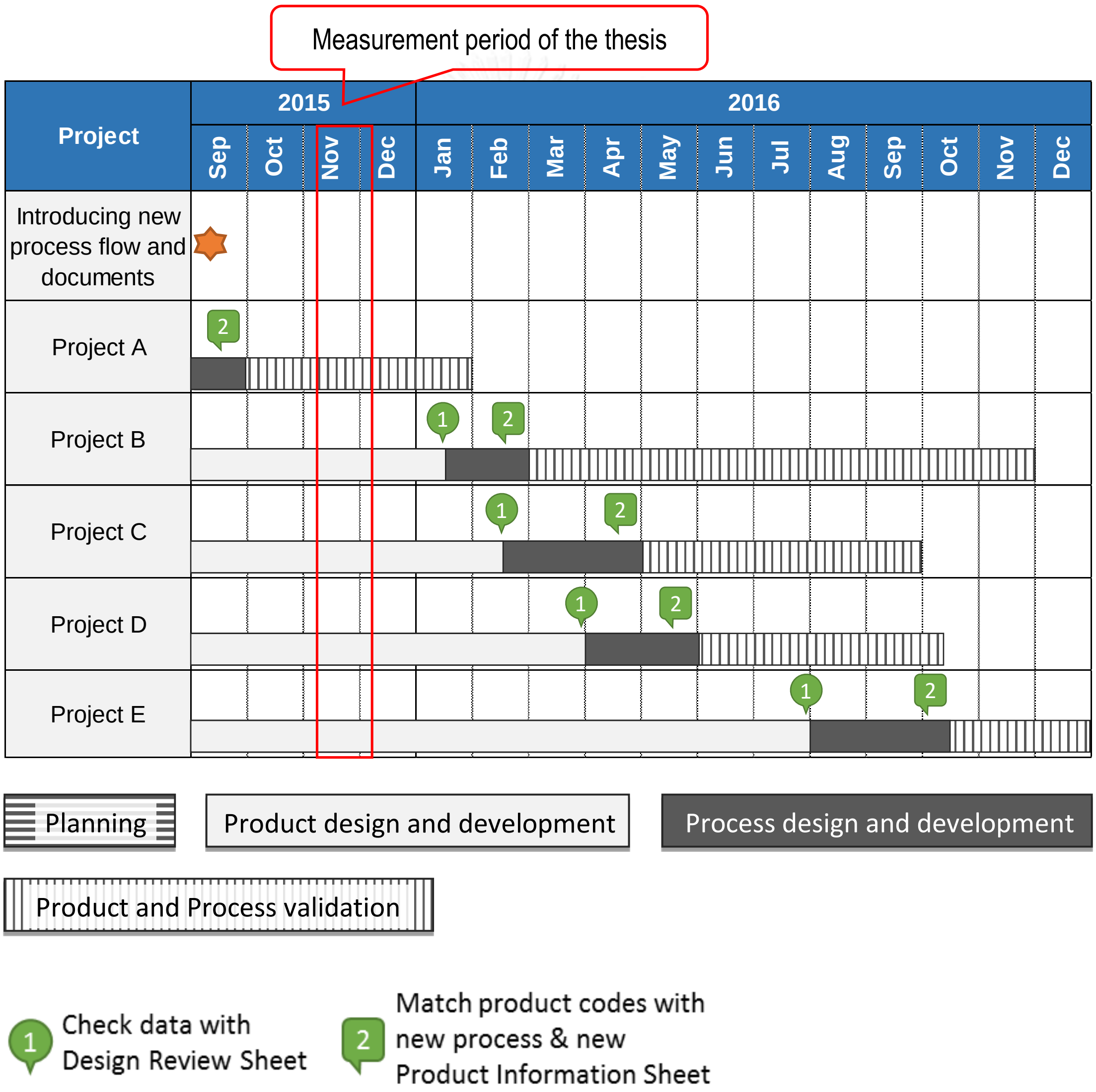


Figure 5-10 Result measurement plan from projects that end within2016

From Table 5-9, the solved problems were re-assessed again by OE Technical Service members (TS). After implementing solutions, Detectability level was decreased because the solutions will let TS members detect error if it occurs.

For PC2-1 and PC2-2, before improvement, TS staff verbally communicated with Technical Engineering (TE) staff to acquire Product Plant Code (PPC) and issue Product Information Sheet (PIS) for register new product to sales and delivery system. And TE didn't circulated official document to TS when PPC was created. Thus, TS couldn't detect the failure and no other department can detect after TS. After improvement, TS will receive PPC from circulated official document and have pre-knowledge to detect errors. Also product codes will be input to PIS by each department to enable cross-checking of information before TS finally forward to sales' registration.

For PD2-1, the Design Review Sheet (DRS) requires TS to check data in detail by comparing with the requirement. So the Detectability level is decreased. While PD2-2 wasn't modified anything because the staff can detect language that they don't know automatically. Consequently, Occurrence level should be reduced as well because the solutions are expected to block root causes.

Table 5-9 Comparison between before and after implementation

	Inappropriate communicatio n so far (using verbal)		**Official information isn't shared to OE Technical Service (TS) from the beginning for detection**		**Carelessness of staff when checking data**		**Requirement is not written in English and not understandable**	
	PC2-1		PC2-2		PD2-1		PD2-2	
	Before	After	Before	After	Before	After	Before	After
S	10	10	10	10	8	8	8	8
O	2	1	2	1	2	1	4	4
D	10	2	10	2	10	5	1	1
RPN	200	80	200	80	160	40	32	32
RPN reduction		-60%		-60%		-75%		0%

CHAPTER 6
DISCUSSION AND CONCLUSION

6.1 Discussion

1. OE Technical Service (TS) department of the case company has many problems in new product development process. This thesis studied 2 recent major problems including risks in overall process of new product development. The root causes can be summarized in to 3 major categories.
    a. Human-error from new staff, experienced staff, or even customer.
    b. Insufficient and ineffective controls in the process. For example, lack of work instruction for new staff, lack of document or process control, etc.
    c. Old working system that might not be suitable for current business environment where number of product line-up and development projects is increasing. Particularly, product code system should have classification system to provide more detail of product specification in the code.
2. To permanently improve the coordination system, time and investment might be needed for
    a. Change the working system or database system
    b. Change the organization

    Therefore, this thesis reduced opportunity to create error and increases detection to the process instead, which was much cheaper and easier to implement.
3. Figure 5-10 showed that the problem did not occur again after the improvement. There might be other implications of the result, such as
    a. The problems have low possibility of occurrence, so it is hard to see the failures occur.
    b. Staff were more cautious because of awareness of the problems.

However, the improvement is necessary to ensure that these problems won't occur again. Because they can generate huge impact to the case company, as follows.

1) Impact from mismatching product codes

From Table 6-1, actual parts were misdelivered to customer for 3 months. The total value of misdelivery in 3 months was around 6.7 million THB. It can be estimated to around 31 million THB for 1 year.

The improvement in the thesis was inexpensive and also easy to implement, yet it could prevent problems that cost so much to the case company.

Table 6-1 Mismatching problem impact

Mismatching Problem				
	No. of months mis-delivered	No. of parts misdelivered (pcs)	Sales price (THB/unit, rounded)	Total value (THB)
Actual	3	4,206	1,600.00	6,729,600.00
Estimation per year	12	19,200	1,600.00	30,720,000.00

2) Impact from misunderstanding requirement

From Table 6-2, the problem about misunderstanding of requirement caused the case company lost business of one vehicle model for 2 years. Total value was around 40 million THB, excluding development cost that the case company had paid. Thus the improvement developed in this thesis should be necessary.

Table 6-2 Misunderstanding requirement (tolerance for design) impact

No. of years expected to supply	Estimated annual sales volume (piece)	Sales price (THB/unit, rounded)	Revenue lost (THB)
2	18,000	1,100.00	39,600,000.00

4. From Table 5-9, Detectability was a main improvement in this thesis because OE Technical Service (TS) department cannot change the impact of the problem

and the impact is out of control of TS department such as safety of end users or customer's need of parts.

6.2 Limitation of This Thesis

1. Only one project could show implementation result so far. Due to limitation of project schedule, the rest of the projects will be able to provide result after completion of product development phase and process development phase. The project schedules are beyond the research timeline. Thus, it is impossible to monitor results within thesis period.
2. This study only focused on new product development process of OE Technical Service (TS) of the case company. Other phase and other companies were not included in the scope of study.
3. TS department cannot easily change the core operating system (such as product code identification, IT system, etc.), the design of the product, or the schedule of the project. Thus, the result mostly improved only detectability.

6.3 Conclusion

The study, analysis, and result in this thesis are summarized in following points.

1. This thesis used why-why technique and process flowchart to determine root cause of the 2 major problems. The following items are root causes found after analysis.
    1.1. Lack of standard communication route between OE Technical Service (TS) staff and Technical Engineering (TE) staff. Verbal communication was used which is easy to have a mistake.
    1.2. TE didn't share official information of Product Plant Code to TS, so TS didn't have pre-knowledge to detect wrong codes matching.

1.3. Carelessness of TS staff made the staff overlook some detail content in the requirement. Resulting in misunderstanding of tolerance for design and TS cannot detect error before sending data to customer.

2. By application of Poka-Yoke (error-prevention) concept, current process flow and documents were improved to eliminate root causes and increase ability to detect error.

3. One project was in an appropriate phase to implement the new process and document. The problem wasn't found as expectation. And the assessment by FMEA technique shows that the improvements help in reducing Detectability and Occurrence level of the case problems instead of Severity level.

4. For high turn-over rate that makes TS staff experience low, the thesis proposed to prevent potential failures as a quick countermeasure. FMEA technique was applied to evaluate and prioritize importance of each failure. Criteria for evaluation are modified to fit with the work of TS department. Apart from root causes of the case problems, other possible root causes can be grouped and listed below.

    4.1. Lack of Work Instruction or solid guidance for new staff

    4.2. Requirement are not understandable (not in English)

    4.3. Carelessness of TS staff

    4.4. New customers or different style of customers

5. Potential failures were prioritized by their Severity, Occurrence, and Detectability level in order to show sequences to take actions. Brief actions are recommended for each failure.

6.4 Recommendations and Further Study

Following recommendations are listed for the case company and readers to continue or improve results from this thesis, based on results and findings in this thesis.

1. The case company should continue to monitor the result and continuously update solutions periodically. Because each project takes time to achieve the implemented phase and some factors might be changed in near future (e.g. new information system might be installed).

2. Support from management is important because some solutions, for example, integrating separate information system of all branch companies to one global system, needs decisions from authorized personnel.

3. Cooperation from other departments are also important because TS roles is essentially to coordinate between departments.

4. Further study should be done in different phase, such as mass production phase, to cover all the jobs of TS department.

5. Study in a different tire manufacturer should make root cause analysis again because different companies have different systems, strategies, and environments. The result of analysis might be different and, thus, require different solutions. However, similar concept and procedure could be adapted.

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APPENDIX

VITA

Siripong Prasitthimay was born on March 3rd, 1988 in Bangkok, Thailand. He had been living in Nonthaburi province with his family since then. After graduating with his high school diploma in 2006 from Mahidol Wittayanusorn School (MWITS), he attended Chulalongkorn University for his undergraduate degree in Bangkok, Thailand.

He graduated with his Bachelors of Engineering in Industrial Engineering in March 2010 and joined Thai Bridgestone Company in May 2010 for his work. More than 5 years of working at Thai Bridgestone, he had opportunities to work in various fields; Replacement-market Technical Service, OE-market Technical Service, and OE tire development.

In November 2012, he started his graduate dual-degree in Engineering Management, collaborating programme between the University of Warwick and Chulalongkorn University. His thesis focused on improvement on product development process in automotive tire industry, where he was working at. He was advised by Asst. Prof. Somchai Puajindanetr, Ph.D.