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SAFETY MANAGEMENT FOR MAINTENANCE OF PETROL STATION

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การุณย์ ภู่ธนะพิบูล : การจัดการความปลอดภัยในงานซ่อมบำรุงสถานีน้ำมัน (SAFETY MANAGEMENT FOR MAINTENANCE OF PETROL STATION) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: รศ.ดร. ปารเมศ ชุติมา, 120 หน้า.

วิทยานิพนธ์นี้มีวัตถุประสงค์เพื่อพัฒนาขั้นตอนการจัดการความปลอดภัยสำหรับงานซ่อมบำรุงสถานีน้ำมัน บริษัทที่ใช้เป็นกรณีศึกษาเป็นหนึ่งในผู้นำทางด้านการให้บริการ Facility Management ในระดับนานาชาติ สำหรับประเทศไทยบริษัทที่ใช้เป็นกรณีศึกษาได้ทำการให้บริการงานซ่อมบำรุงสถานีน้ำมันกับบริษัทน้ำมันชื่อดังแห่งหนึ่งนับตั้งแต่ปี พ.ศ. 2544 อย่างไรก็ตาม ในช่วง 6 ปีที่ผ่านมา ทางบริษัทที่ใช้เป็นกรณีศึกษาต้องเผชิญกับอุบัติเหตุหรือเหตุการณ์ที่เกี่ยวข้องกับงานซ่อมบำรุงมาโดยตลอด แม้อัตราการเกิดอุบัติเหตุหรือเหตุการณ์จะไม่สูงมากนัก แต่การเกิดซ้ำของอุบัติเหตุหรือเหตุการณ์เดิม เป็นสัญญาณแสดงถึงข้อบกพร่องของระบบการจัดการความปลอดภัย

วิทยานิพนธ์นี้แบ่งเป็น 3 ส่วน โดยเริ่มจากการศึกษาอุบัติเหตุหรือเหตุการณ์ต่างๆในอดีตและภาพรวมของอุปกรณ์หรือเครื่องมือต่างๆที่ใช้ในสถานีน้ำมัน รวมทั้งงานซ่อมบำรุงที่เกี่ยวข้องกับอุปกรณ์หรือเครื่องมือนั้นๆ จากนั้นจะเป็นการวิเคราะห์งานซ่อมบำรุงของแต่ละอุปกรณ์ เพื่อสรุปเป็นเป็นภาพรวมตามลักษณะของงานซ่อมบำรุง

ลำดับต่อไปเป็นการนำข้อมูลจากการศึกษาข้างต้นมาวิเคราะห์ โดยการประยุกษ์ใช้วิธีวิเคราะห์อาการขัดข้องและผลกระทบ Failure Modes and Effects Analysis (FMEA) เพื่อค้นหาสาเหตุและแนวทางป้องกันการเกิดซ้ำ นอกจากนี้ ผู้ทำการศึกษาได้ใช้หลักการ Pareto ในการคัดเลือกสาเหตุหลักของอุบัติเหตุหรือเหตุการณ์ เพื่อทำการเสนอแนวทางป้องกันต่อไป

ขั้นตอนสุดท้ายเป็นการนำเสนอแนวทางป้องกันและแก้ไขตามผลการวิเคราะห์ เนื่องจากเวลาที่ค่อนข้างจำกัด ทำให้ทางผู้ทำการศึกษาไม่สามารถนำผลลัพธ์ที่ได้จากวิทยานิพนธ์นี้ไปประยุกต์ใช้ทั้งหมด อย่างไรก็ตามแนวทางป้องกันที่ได้นำไปประยุกต์ใช้แล้วนั้น แม้ว่าค่า RPN ที่ได้จะไม่เป็นไปตามที่คาดหวังไว้ แต่ผลตอบรับจากผู้รับเหมาเกี่ยวกับแนวทางป้องกันที่ได้ประยุกต์ใช้พบว่า สามารถช่วยลดโอกาสการเกิดอุบัติเหตุจากการทำงานได้ โดยการเฝ้าสังเกตพฤติกรรมการทำงานของพนักงาน

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KARUN PUTHANAPIBOOL : SAFETY MANAGEMENT FOR MAINTENANCE OF PETROL STATION. THESIS PRINCIPAL ADVISOR: ASSOC. PROF. PARAMES CHUTIMA, Ph.D., 120 pp.

The purpose of this thesis is to develop the standard safety procedure for maintenance of petrol station. The selected case company is one of the international leading service providers in facility management. In Thailand, the company has provided maintenance service for a big name petrol company since 2001. However, during six years, the case company has persistently experienced accidents/incidents related to maintenance tasks. Even the recordable incident rate may not be so high, the recurrence of some incidents shows the weakness of safety system and the incident impact is always ruined the company and client reputation.

This thesis is comprised of three parts. Firstly, the author reviewed in the past incident and the big picture of equipments together with their related maintenance tasks. And then, the potential failure modes were listed and classified into groups by considering the nature of failures.

Next, the information from the study was analyzed further by applying Failure Modes and Effects Analysis (FMEA) in order to find to root cause of each failure together with the recommended action. And then, Pareto principle was applied for determining the major root causes to be focused.

Finally, the proposals to cope with the potential root causes were implemented practically. Due to time constraint, there is only one recommended action was implemented. Even there is no incident occurred during implementation, the result in term of RPN did not meet the expectation and need to be improved. However, the feedback from sample contractor showed that the implemented action can help to mitigate risk in maintenance service by observing the working behavior of operators.

The Regional Centre for Manufacturing System Engineering Student's signature: .....
Field of Study: ..Engineering Management... Thesis Principal Advisor's signature: .....
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CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

Page

CHAPTER I

INTRODUCTION

1.1 Background of Research

Nowadays, every business has high competitive pressure, so every company has to set business strategy and follow such strategy in order to maintain its position in business. One strategy which is quite useful and effective is Outsourcing strategy. This strategy is to assign some tasks which company may not be good in, to the service provider. The reason for outsourcing is to save cost by getting better work quality and also to mainly focus on company's core competence. This kind of thing has no exception for Petrol Retail business. Currently, big companies such as Shell, Exxonmobil have outsourced some functions to the service provider especially engineering function which is consisted of construction team and maintenance team. It is always found that the first tier service provider does not perform the work at site itself but it hires subcontractors to do field work.

This research is based on the case company which has provided facility management service in Thailand for six years and it will focus on the maintenance part of Petrol station which has a lot of equipments. Generally, all equipment at Petrol station can be categorized into three major groups:

1.) Mart Equipments: At the present, mart seems to be the part of Petrol station. Once the sign of petrol station is noted, the sign of mart is seen, as well. For example, in Thailand, PTT petrol station is always opened with Seven-Eleven, Shell petrol station with Select mart, ESSO with Tiger mart, etc. For maintenance work, there are so many equipments as listed below:

- Walk-in cooler/Four-door cooler
- Fast Food show case
- Low/Medium Temperature cooler
- Juice dispenser
- Microwave oven
- Hot dog Griller
- Coffer Brewer, Grinder & Maker
- Frozen soft drink
- Pop corn machine

- Bun warmer
- Ice cube freezer
- Cup dispenser
- Ice maker

2.) General Equipments: For this kind of equipment, most of them are located in forecourt of station which is mostly in the hazardous area. The hazardous area is area in 5 meters around Dispenser Pump and 8 meters around Petrol loading point. So, to perform maintenance work in such area needs to be consciously and carefully. Moreover, some equipments in this group is in the high level above the ground such canopy, yard light, etc. Then, working at height is totally expected to have no mistake with operator. The list of general equipment is illustrated as following:

- Signage consisting of Highway sign, ID sign, Major Sign, Price sign, Sign on canopy, Spreader sign, End-sign, Backlit sign, etc.
- Lighting and Electrical system: Down light, Yard light, Sign lighting, Voltage protection cabinet.
- Others: Auto car wash machine, Air compressor, Air Condition, Generator, Building, etc.

3.) Petrol System: The equipment in this group is quite sensitive because all of them connect directly to petrol. The equipment list is shown as below:

- Dispenser Pump
- Under ground petrol tank & Pipe
- Ventilation Pipe
- Petrol loading point
- Fiber Lite /Flow guard sump
- Tank Monitoring system (Veeder Root)

These are all equipments which are in each petrol station. It can be imagined that the maintenance work will be very busy due to the huge number of equipment. However, to do maintenance work at petrol station is not quite similar to others because in this field, safety issue must come first. So, service provider/subcontractor who performs work at site need to concern about safety very much.

As mentioned above, most of big companies outsource maintenance function to service provider which mostly does not perform field work itself but hires subcontractors to do it. Also, there is no subcontractor to maintenance all equipment at site, so company has to hire many subcontractors who are expertise in each equipment group. However, in Thailand, there is limitation of subcontractor capacity. There is no subcontractor who can support all area of country, so each single group of equipment, company has to hire subcontractor at least two companies.

By this information, it can be seen that it is very tough to manage subcontractors in terms of safety and quality because a lot of subcontractors involve. Furthermore, to award maintenance work to any subcontractor, there is process of contract bidding which normally is two-year contract. Therefore, it is more likely that there will be the new subcontractor who comes in to join this work. And this may be the critical point because new subcontractor may be not familiar with safety of petrol station.

In the past six year, the case company has dealt with many subcontractors which always changed by every contract period. Currently, there are around 15 subcontractors who perform maintenance work at Client petrol station in Thailand. For safety issue, so far, there is no standard safety procedure for all subcontractors to comply when working at site. Every subcontractor, who join with the case company, need to conduct such procedure herself and submit to the company for review. Consequently, the safety procedure from subcontractors who maintenance the same group of equipment is always different. However, the usual way that such difference can be noted is when incident occur. And this is quite unacceptable and inspires the researcher to do this study.

1.2 Statement of Problems

As previously stated in the section of background, so far, the company has no standard safety procedure for subcontractor to comply while working at site. But subcontractors have to conduct the procedure themselves. So each subcontractor has different procedure, even they maintenance the same equipment. This gap of safety procedure is always seen when incident occur. There is one of recent incident (June 2007) which illustrates the weakness of this gap:

"A foreman working at site to remove u/g tanks. While lifting the latest tank suddenly one side of hook which fixed with the tank was torn and causes the sling swang and hit the stomach of the foreman."

This incident occurred while subcontractor was lifting the underground tank by using crane and sling. Unfortunately, the hook of underground tank was deformed and broken. Consequently, the hung underground tank swing and hit operator. This shows that risk plan of this subcontractor is not completely effective because they do not concern about the deformed hook of tank. Also, the position of operator during lifting process needs to be concerned. On the other hand, other subcontractor, who do the same task, use backhoe to remove tank instead of crane and sling. By this case, it can be concluded that each contractor do safety procedure in different way.

The below incident was occurred in 2006:

"A contractor was carrying out cleaning and relamping exercise. A worker who was working on the canopy near the manager office slipped and had a fall into the office."

In this case, after investigation, it was found that operator did not wear completely set of personal protection equipment (PPE) required for this kind of work.

Another recent accident which occurred in July 2007 is the car got fired due to the leak nozzle during filling petrol.

Figure 1-1: Incident

Source: www.nan.go.th

These sample cases obviously illustrate that the hazardous in working at petrol station is quite high. To avoid or even get rid of such hazardous, the standard safety procedure must be established and make sure that all potential hazardous are identified together with the best suited control actions.

1.3 Objective of the Research

The main objective of this research is to identify all potential hazardous in maintenance tasks of petrol station and provide control actions to cope them. Furthermore, all findings from this research will be developed as the standard safety procedures for all subcontractors to comply when performing work at site.

1.4 Scope of the Research

As already mentioned in the first section, the petrol station is consisted of the various equipments which can be classified into three major categories: Mart equipments, General equipments and Petrol system. However, this research will focus on just two categories: General equipments and Petrol system which have many related incident in the past. On the other hand, in last two years, there is no major incident related to Mart equipments which most of them are quite similar to electrical equipment at home. Also, all mart equipments are located inside building which is not in the hazardous area (5 meters around dispenser pump or 8 meters around petrol loading point)

1.5 Methodology

The research will be carried out by following steps as illustrated below:

1. Study the related literatures

2. Collect the relevant information such as;
   - The manual of equipment in Petrol station
   - The history of incident occurred in Petrol station

3. Study and Analyze the information in order to:
   - Classify equipments into groups
   - Identify maintenance tasks for each equipment group
   - Find the gap/cause of occurred incident in the past

4. Survey at service station and observe subcontractors performing maintenance work.

5. Do the analysis (By brainstorm with subcontractors and apply FMEA)
   - Identify the potential hazardous and its effect
   - Evaluate the hazardous
   - Find out the root cause of hazardous
   - Decide on precaution/control action

6. Summarize all findings

7. Implement the safety procedures

8. Review and update if necessary

9. Prepare the presentation and write thesis

10. Present the thesis

1.6 Research Schedule

The research is planned as following schedule:

Table 1-1: The schedule of Research

Procedures	2007						2008			
	Oct		Nov		Dec		Jan		Feb	
1. Study the related literatures										
2. Collect the relevant information										
3. Study and Analyze the information										
4. Survey at Site & observe subcontractors										
5. Do the analysis										
6. Summarize all findings										
7. Implement the safety procedures										
8. Review and update if necessary										
9. Prepare the presentation and write thesis										
10. Present the thesis										

1.7 Expected Result

By the end of this research, it is expected that all hazardous in maintenance work of Petrol station have been identified together with control actions to cope them. All findings are also expected to be further developed as the standard safety plan for all subcontractors who perform maintenance work in Petrol station.

Moreover, by the contribution of existing subcontractors, this research is expected to be the key mechanism to motivate their safety awareness especially in term of Personal Protective Equipment (PPE). Last but not least, the safety performance of each subcontractor is expected to be significantly improved once the findings are implemented.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

In this chapter, theories, tools and techniques that are applied to this thesis are introduced. The chapter begins with the introduction of Failure Mode and Effect Analysis (FMEA) which is the main tool of this research. Next, Brainstorming and Group Decision Making which are the key activities are introduced. Lastly, it is literature surveys which are taken from academic papers and past thesis works.

2.2 Failure Modes and Effects Analysis (FMEA)

Failure Mode and Effect Analysis (FMEA) was originally developed by the US military. It was used as a reliability evaluation technique to determine the effect of system and equipment failures. In the 1960s, FMEA has been used in Apollo space missions. Ford Motor company introduced FMEA to automotive industry in the late 1970's for safety and regulatory consideration after they suffered by a design flaw.

The following are some definition of FMEA from academic books and published papers:

"Failure Modes and Effects Analysis (FMEA) is a systematic technique for assessing the risks associated with defective products reaching the market. Whilst going through the exercise, one should be able to learn the chances of a particular failure occurring and what caused it. This can then be used to make decisions as to what action should be taken to reduce the risk associated with some of the more serious findings from the study." (Burns)

"Failure mode and effect analysis (FMEA) is a disciplined procedure that recognizes and evaluates the potential and actual effects of failure of a product or a process and identifies actions that reduce the chance of a potential failure occurring." (Yang & El-Haik)

"Failure mode and effect analysis (FMEA) is an analytical technique (a paper test) that combines the technology and experience of people in identifying foreseeable failure modes of a product or process and planning for its elimination." (Besterfield)

"FMEA is a design discipline and a quality-planning tool used to investigate the sources and the consequences of failures on the operation of a system. FMEA is a systematic and analytical process that combines top down and bottom up analysis. From the top, the system functional goals are decomposed into sub-system goals and, from the bottom, the component behaviors are expresses as the functions required to realize the goals of each sub-system. Failure modes are then defined, and the resulting behavioral changes are classified according their effect on goal achievement." (Barkai)

From the several definitions, it can be summarized that FMEA is the procedure for identifying of potential failure modes within system and the consequences of those failures, along with actions to prevent potential failures.

To conduct FMEA, there are so many approaches that are proposed in academic books and published papers. In this thesis, the approach that is applied is conducted by SEQ Group in 2001. This approach is consisted of nine processes as following: *(From: SEQ Group, Snap-On Incorporated Standard on FMEA Process for Quality Problem Solving (Failure Mode & Effect Analysis))*

Step 1: Review the process

To ensure that everyone on the FMEA team has the same understanding of the process that is being worked on, the team should review a blueprint (or engineering drawing) of the product if they are conducting a product FMEA, or a detailed flowchart of the operation if they are conducting a process FMEA.

If a blueprint or flowchart is not available, the team will need to create one prior to starting the FMEA process.

With the blueprint or flowchart in hand, the team members should familiarize themselves with the product or process. For a product FMEA, they should physically see the product or a prototype of the product. For a process FMEA, the team should physically walk through the process exactly as the process flows.

It is helpful to have an "expert" on the product or process available to answer any questions the team might have.

Step 2: Brainstorm Potential Failure Mode

Once everyone on the team has an understanding of the process (or product), team members can begin thinking about potential failure modes that could affect the manufacturing process or the product quality. A brainstorming session will get all of those ideas out on the table. Team members should come to the brainstorming meeting with a list of their ideas. In addition to the ideas members bring to the meeting, others will be generated as a result of the synergy of the group process.

Because of the complexity of some manufactured products and manufacturing processes, it is best to conduct a series of brainstorming sessions, each focused on a different element (for example; people, methods, equipment, materials and the environment) of the product or process. Focusing on the elements one at a time may result in a more thorough list of potential failure modes.

It is not unusual to generate dozens of ideas from the brainstorming process. In fact, that's the objective. Once the brainstorming is completed, the ideas should be organized by grouping them into like categories. Your team must decide the best categories for grouping, as there are many different ways to form groups with failure modes. You can group them by the type of failure (e.g., electrical, mechanical, user-created), where on the product or process the failure occurred, or the seriousness (at least the team's best guess at this point) of the failure. Grouping the failures will make the FMEA process easier to work through.

Without the grouping step, the team may invest a lot of energy jumping from one aspect of the product to a completely different aspect of the product and then back again. An easy way to work through the grouping process is to put all of the failure modes onto self-stick notes and post them on a wall so they are easy to see and move around as they are being grouped.

The grouping also gives the team a chance to consider whether some failure modes should be combined, because they are the same or very similar to

each other. When the failure modes have been grouped and combined, if appropriate, they should be transferred onto the FMEA sheet.

Step 3: List Potential Effects of Each Failure Mode

With the failure modes listed on the FMEA worksheet form, the FMEA team reviews each failure mode and identifies the potential effects of the failure should it occur. For some of the failure modes, there may be only one effect while there may be several effects for other failure modes.

This step must be thorough, because this information will feed into the assignment of risk ratings for each of the failures. It is helpful to think of this step as an ***if-then*** process: ***If*** the failure occurs, ***then*** what are the consequences.

Step 4, 5 and 6 – Assigning Severity, Occurrence and Detection Ratings

Each of these three ratings is based on a 5-point scale, with 1 being the lowest rating and 5 being the highest.

It is important to establish clear and concise descriptions for the points on each of the scales, so that all team members have the same understanding of the ratings. The scales should be established before the team begins the rating process. The more descriptive the team is when defining the rating scale, the easier it should be to reach consensus during the rating process.

A generic rating system for each of the scales is provided in Tables 2-1, 2-2 and 2-3. This system should be customized by the team for their specific FMEA project.

Even if the rating system is clear and concise, there still may be a disagreement about the rating for a particular item.

Table 2-1: Sample of Severity Rating

Rating	Description	Definition
10	Hazardous without warning	Very high severity ranking when a potential failure mode effects safe system operation without warning
9	Hazardous with warning	Very high severity ranking when a potential failure mode affects safe system operation with warning
8	Very High	System inoperable with destructive failure without compromising safety
7	High	System inoperable with equipment damage
6	Moderate	System inoperable with minor damage
5	Low	System inoperable without damage
4	Very Low	System operable with significant degradation of performance
3	Minor	System operable with some degradation of performance
2	Very Minor	System operable with minimal interference
1	None	No effect

Table 2-2: Sample of Occurrence Rating

Rating	Description	Definition
10	Very High: Failure is almost inevitable	>1 in 2
9		1 in 3
8	High: Repeated failures	1 in 8
7		1 in 20
6	Moderate: Occasional failures	1 in 80
5		1 in 400
4		1 in 2,000
3	Low: Relatively few failures	1 in 15,000
2		1 in 150,000
1	Remote: Failure is unlikely	<1 in 1,500,000

Table 2-3: Sample of Detection Rating

Rating	Description	Definition
10	Absolute Uncertainty	Design control **cannot** detect potential cause/mechanism and subsequent failure mode
9	Very Remote	**Very remote** chance the design control will detect potential cause/mechanism and subsequent failure mode
8	Remote	**Remote** chance the design control will detect potential cause/mechanism and subsequent failure mode
7	Very Low	**Very low** chance the design control will detect potential cause/mechanism and subsequent failure mode
6	Low	**Low** chance the design control will detect potential cause/mechanism and subsequent failure mode
5	Moderate	**Moderate** chance the design control will detect potential cause/mechanism and subsequent failure mode
4	Moderately High	**Moderately High** chance the design control will detect potential cause/mechanism and subsequent failure mode
3	High	**High** chance the design control will detect potential cause/mechanism and subsequent failure mode
2	Very High	**Very high** chance the design control will detect potential cause/mechanism and subsequent failure mode
1	Almost Certain	Design control **will** detect potential cause/mechanism and subsequent failure mode

Step 4: Assign a Severity Rating for Each Effect

The severity rating is an estimation of how serious the effects would be if a given failure did occur. In some cases it is clear, because of past experience, how serious the problem would be. In other cases, it is necessary to estimate the severity based on the knowledge and expertise of the team members.

Because each failure may have several different effects, and each effect can have a different level of severity, it is the effect, not the failure that is rated. Therefore, each effect should be given its own severity rating, even if there are several effects for a single failure mode.

Step 5: Assign an Occurrence Rating for Each Failure Mode

The best method for determining the occurrence rating is to use actual data from the process. This may be in the form of failure logs or even process capability data. When actual failure data are not available, the team must estimate how often a failure mode may occur. The team can make a better estimate of how likely a failure mode is to occur and at what frequency by knowing the potential cause of failure. Once the potential causes have been

identified for all of the failure modes, an occurrence rating can be assigned even without failure data.

Step 6: Assign a Detection Rating for Each Failure Mode and/or Effect

The detection rating looks at how likely we are to detect a failure or the effect of a failure. We start this step by identifying current controls that may detect a failure or effect of a failure. If there are no current controls, the likelihood of detection will be low, and the item would receive a high rating, such as a 9 or 10. The current controls should be listed first for all of the failure modes or the effects of the failures and then the detection ratings assigned.

Step 7: Calculate the Risk Priority Number for Each Failure Mode

The risk priority number (RPN) is simply calculated by multiplying the severity rating times the occurrence rating times the detection rating for all of the items.

Risk Priority Number = Severity x Occurrence x Detection

The total risk priority number should be calculated by adding all of the risk priority numbers. This number alone is meaningless, because each FMEA has a different number of failure modes and effects. However, it will serve as a gauge to compare the revised total RPN against the original RPN once the recommended actions have been instituted.

Step 8: Prioritize the Failure Modes for Action

The failure modes can now be prioritized by ranking them in order from the highest risk priority number to the smallest. A Pareto diagram is helpful to visualize the differences between the various ratings.

The team must now decide which items to work on. Usually it helps to set a cut-off RPN, where any failure modes with an RPN above that point are attended to. Those below the cut-off are left alone for the time being.

Step 9: Take Action to Eliminate or Reduce the High-Risk Failure Modes

Using an organized problem-solving process, identify actions to eliminate or reduce the high-risk failure modes and make recommendations to the appropriate management level.

The following Table 2-4 is the form of Failure Mode and Effects Analysis that is used in this study.

Table 2-4: Template of Failure Mode and Effects Analysis

FMEA Number:	
Page	of
Prepared by:	
FMEA Date (Orig.)	(Rev.)

Process Name:_____ Design Responsibility:_____

Core Team:_____

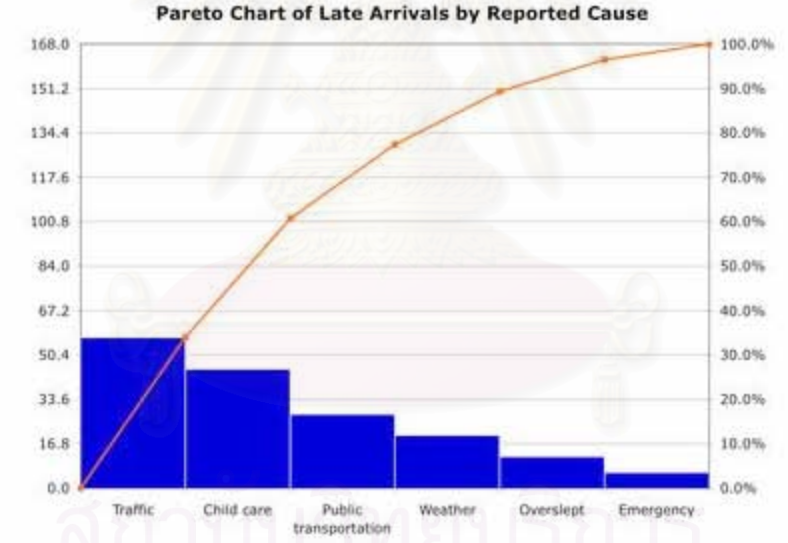
Item / Process / Function	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Potential Cause(s)/ Mechanism(s) of Failure	Occur	Current Design Controls	Detec	R.P.N.	Recommended Action(s)	Responsibility & Target Completion Date	Expected Sev	Expected Occur	Expected Detec	Expected R.P.N.

In this study, the rating criterion of Severity, Occurrence and Detection is based on rating scale of five which was applied by Kittipong (2005) in the study of "Safety Management System for Hazardous Substance Transportation based-on Risk Analysis" and it went well. The criterion for each rating scale will be demonstrated in the chapter of Analysis.

2.3 Pareto Principle

The idea of Pareto principle is to do 20% of work which can generate 80% of the advantage of doing the entire work. Pareto analysis is a formal technique for finding the changes that will give the biggest benefits. It is useful where many possible causes of action are competing for attention.

Figure 2-1: Example of Pareto Chart



"This principle is sometimes called the 80/20 rule: 80% of the trouble comes from 20% of the problems. Through named for turn-of the-century economist Vilfredo Pareto, it was Dr. Juran who applied the idea to management. Dr. Juran advises us to concentrate on the "vital few" sources of problems and not be distracted by those of less importance."

Source: The Team Handbook, Peter R. Scholtes, Joiner Associates 1992

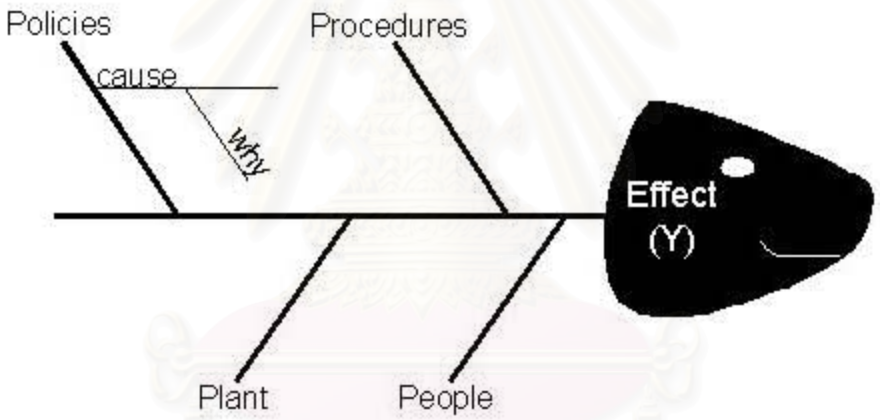
In this study, Pareto principle will be applied when FMEA was completed. The purpose of implement this principle is to sort out the trivial issues and keep focusing on the major ones.

2.4 Fishbone Diagram

Fishbone diagram invented by Dr. Kaoru Ishikawa, a Japanese quality control statistician, is an analysis tool that provides a systematic way of looking at effects and the causes that create or contribute to those effects. This diagram is sometimes called a cause-and-effect diagram due to its function.

This tool is very useful when utilizing a team approach to problem solving, there are often many opinions as to the problem's root cause. One way to capture these different ideas and stimulate the team's brainstorming on root causes is to conduct the fishbone diagram. Figure 2-2 shows the example of fishbone diagram.

Figure 2-2: Example of Fishbone Diagram



2.5 Brainstorming

Brainstorming, a powerful technique for generating new ideas, is the name that is given to a situation when a group of people meet together and develop new ideas around a specific area of interest. Originally, Brainstorming was developed by Alex Osborn, an advertising executive, in 1941. At that time, he found that the creation of new ideas was inhibited during conventional business meetings. Then, he set some rules designed to remove inhibitions and make people able to think more freely. He also described the definition of Brainstorming as:

"Brainstorming is a conference technique by which a group attempts to find a solution for a specific problem by amassing all the ideas spontaneously by its members"

The rules of Brainstorming that can reduce peoples' natural inhibitions are consisting of:

- **Postpone and withhold your judgment of ideas:** This rule is to generating ideas without any judgment on ideas until the completion of the brainstorming session. All ideas are potentially good so the sudden judgment is prohibited.

- **Encourage wild and exaggerated ideas:** The more wild and exaggerated ideas, the more possibility of inhibition loss. It is hard for normal ideas to stimulate good solutions.

- **Quantity counts at this stage, not quality:** It is easier to select good ideas from a large list than a small one. If the number of ideas at the end of Brainstorming session is very huge, there is a great chance in finding the best ideas. In this case, quantity brings quality.
- **Build on the ideas put forward by others:** This rule is for encouraging people to build and expand on the ideas of others. The combination of several suggested ideas can lead to an exploration of new possibilities.

- **Every person and every idea has equal worth:** Every person has a unique viewpoint and perspective. The idea from one person may not be the final solution, but it will spark off and inspire other people. Every single idea proposed belongs to the group, not the one who generated it.

The following are the process of conducting Brainstorming session which can be summarized as below:

- Define the problem and agree the objective
- Select and invite participants
- Present and agree the rules of Brainstorming
- Brainstorming, present and record ideas
- Analyze, assess and rank list of ideas
- Find out and agree action with timescale

- Control and monitor

2.6 Group Decision Making

When working in team, the key activity that can lead the team direction is "Decision making". Team can reach decisions in many difference ways. At the present, there are many Decision making models introduced by expertise are available for being applied in each situation. The understanding of Decision making models influences team in making the best decision. There are six models of Decision making that are described, along with its strengths and weaknesses as following:

2.6.1 Decision made by authority without group discussion

The nature of this model is that the designated leader makes all decision without consulting group members.

Strengths

- Take minimal time in making decision
- Commonly used in organizations (So people familiar with method)

Weaknesses

- No group interaction
- Team may not understand decision or be unable to implement decision

2.6.2 Decision made by expert

This model is to select expert of group and let expert consider the issue and make a decision.

Strength

- Useful when one person on the team has the overwhelming expertise

Weaknesses

- Unclear how to determine who the expert is (Members may have difference opinions)
- No group interaction
- May become popularity issue or power issue

2.6.3 Decision made by averaging individuals' opinions

This is to separately ask each team members for his/her opinion and then, average the result

Strengths

- Extreme opinions cancelled out
- Error typically cancelled out
- Group members consulted
- Useful when it is difficult to get the team together to talk
- Urgent decisions can be made

Weaknesses

- No group interaction, team members are not truly involved in the decision
- Opinions of least and most knowledgeable members may cancel
- Commitment to decision may not be strong
- Unresolved conflict may exist or escalate
- May damage future team effectiveness

2.6.4 Decision made by authority after group discussion

This model is team creates ideas and has discussion but finally; the designated leader makes a decision.

Strengths

- Team interaction
- Listening to the team increases the accuracy of the decision

Weaknesses

- Team is not part of decision
- Team may compete for the leader's attention

2.6.5 Decision made by minority vote

This is in case of limited time preventing the meeting arrangement for the entire team members. So, a minority of the team, two or more members who constitute less than 50% of the team, make team's decision.

Strengths

- Method often used by executive committees
- Method can be used by temporary committees

- Useful for large number of decisions and limited time

Weaknesses

- May not have full team commitment to decision
- May create an air of competition among team members

2.6.6 Decision made by majority vote

This model is the common used method. The decision is made when 51% or more of team members have the same opinion.

Strengths

- Useful when there is insufficient time to make decision by consensus
- Useful when the complete team-member commitment is unnecessary for implementing a decision

Weaknesses

- Taken for granted as the natural, or only, way for teams to make a decision
- Team is viewed as the "winners and the losers"; reduces the quality of decision
- Minority opinion not discussed and may not be valued
- May have unresolved and unaddressed conflict
- Full group interaction is not obtained

2.6.7 Decision made by consensus

This is to see the collective decision arrived through an effective and fair communication process. All team members have chances to speak and listen.

Strengths

- Most effective method of team decision making
- All team members express their thoughts and feelings
- Team members "feel understood"

Weaknesses

- Takes more time
- Takes psychological energy and high degree of team-member skill (can be negative if individual team members not committed to the process)

2.7 Literature Survey

As a result of survey, there are several studies about risk management which have been previously carried out by applying FMEA. So, all of them are very useful to be utilized as guidance for organizing this research.

During 2003, Thanchuda has done the feasible study in "Risk Management system development in Supplies Division Office of Planning and Finance". This study began with establishing the objective of the section and identifying the possible risks that could affect section not to meet the objective. Then, Risk evaluation was conducted by applying Failure Mode and Effect Analysis (FMEA) technique. Finally, Fault Tree Analysis (FTA) was used as a tool to analyze root causes of all risks in order to establish Risk Management Plans.

In 2004, "An application of risk management for establishing a shoe factory" was done by Israpol. This study was aimed to managing project risks in order to achieve 85% of operation time. The process of this study was divided into six phases: Project goals and objective, Identifying and assessing project risks, Developing project risk management strategy, Implementing project risk control, Monitoring project risk management and Improving risk management. During this study, there are various analysis tools being applied such as 6W, Risk map, Checklist, Tree diagram and Stepwise multiple regression. As the result of implementing project risk plan, it shown that the shoe factory in this study can achieve the target (85% operation time).

In the same year, there is another study related to risk management. This one was done by Varaporn, is for Advisability and Installation Information System (AIIS) project. The aim is to generate the risk information and preventive plan. The study process is quite similar to others which is consisted of Define and scope the AIIS project, Identify internal risks, Explore external risks, Analyze risk factors, Set risk management plans and Develop check sheet to monitor risk factors.

Last but not least, during 2005, Kittipong had studied "Safety Management System for Hazardous Substance Transportation based-on Risk Analysis". This study is aimed to develop the safety management system (SMS) for Hazardous chemical transportation company which experienced persistently accidents/incidents rate in past few years. The study started by setting up SMS working team. And then, some potential tools and techniques such as Brainstorming, FMEA were applied in order to identify risks and their consequences, along with the actions to cope such risks. As the result of the study, even the recommended actions might not be able to reduce incident rate/

financial impact significantly; SMS working team still remains in the company in order to keep monitor the incident and find out the way to close the gaps/risks.

CHAPTER III

OVERVIEW OF CASE ORGANIZATION

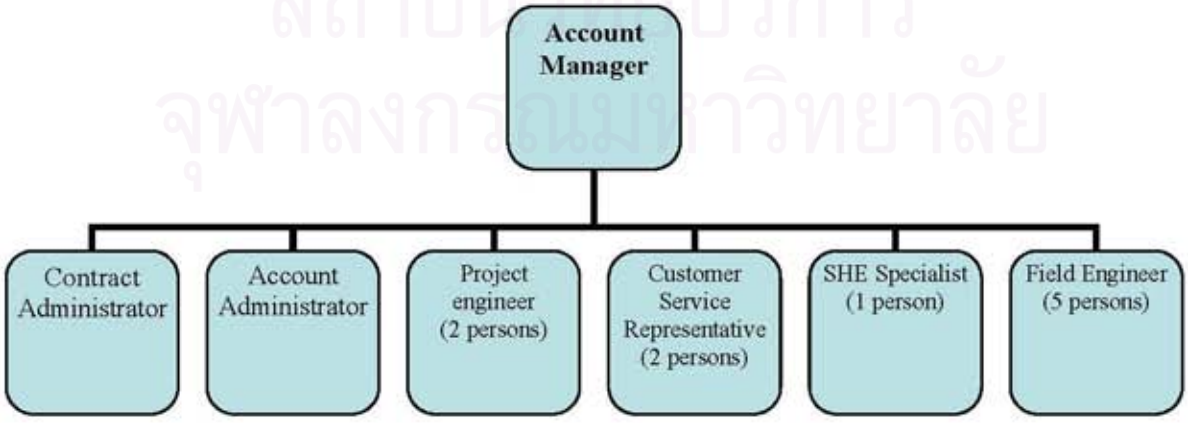
3.1 Introduction

In this chapter, the information about the case organization/project team will be provided such as core business activity, role and responsibility of this project team, safety policy and procedure, etc. Also, the incidents which occurred in past few years will be mentioned, along with their root causes. This is like an inspiration for conducting this thesis in order to minimize the incident rate. Lastly, the equipments of petrol station will be listed along with their related maintenance tasks in order to set the boundary of this thesis and being studied and analyzed further in the next chapter.

3.2 Company Background

The case organization/project team is the outsourcing service provider which provides maintenance service for Retail-fuel service station. The project team is also responsible for monitoring and handling on behalf of client all Safety, Health and Environmental issues, insurance claims, warranties and carry out periodic audits to ensure the continuity of business. This team is consisted of 13 persons. The organization chart is illustrated as following:

Figure 3-1: Organization Chart



The role and responsibility of each position is stated as following:

- ***Account Manager***: To oversee all aspects of team works and ensure all projects related issues are handled properly and managed the overall relationship with the client management team.

- ***Contract Administrator***: To maintain assigned segments of the finance system and ensure accurate and timely. Processing and assist in producing the annual budgets.

- ***Account Administrator***: To provide sub-contract administration and supervision of material purchasing in support of account activity.

- ***Project engineer***: Responsible for planning and coordinating all significant maintenance and repair projects.

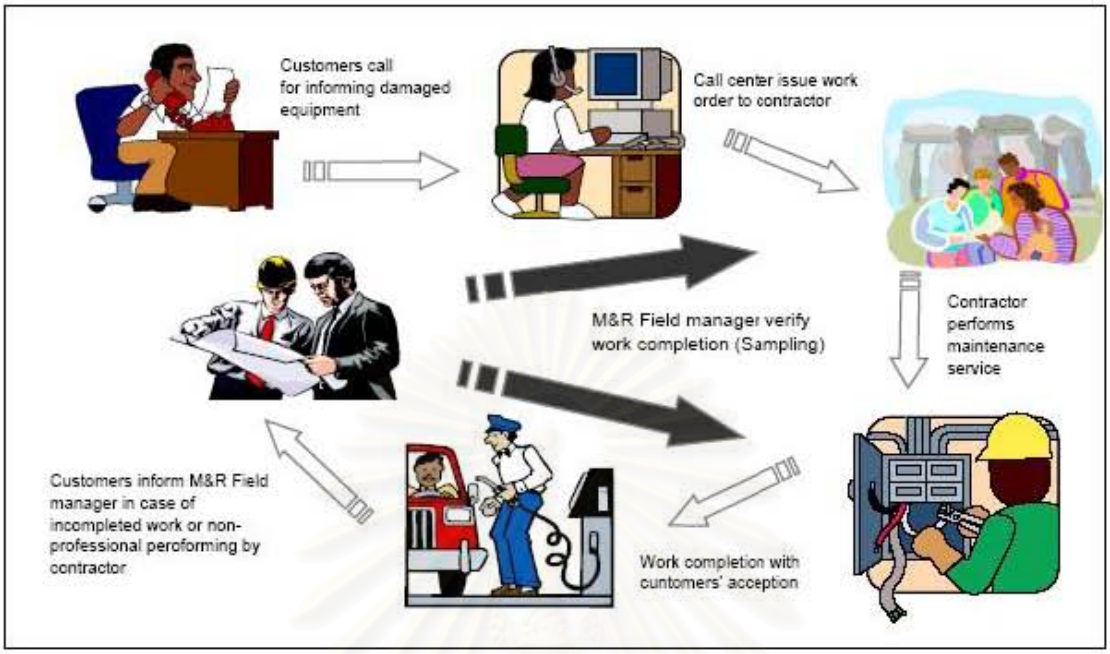
- ***Field Engineer:*** Responsible for performing all operational work at the property level.

- ***SHE Specialist***: To organize, administer, conduct and measure individual and group safety programs with the Account.

- ***Customer Service Representative (CSR)***: To coordinate customer service activities at sites to provide consistent support and service, input information into and maintain the computerized maintenance management system database.

Generally, the maintenance work starts by site operator who calls call center in order to inform the damaged equipment. Then, CSR will record work order into system and issue work order to contractor, accordingly. Once contractor receives work order, quotation will be generated and submitted to Field engineer who is responsible in the area where damaged equipment occurs. After quotation is reviewed in terms of cost and technical, Field engineer may reject such quotation is not technically/costly reasonable. Once quotation is approved, contractor can start to perform maintenance service. While performing maintenance service at site, contractor will be occasionally observed by FM or SHE specialist in order to inspect the quality of work and also to ensure that contractor performs professionally and safely.

Figure 3-2: Work Flow



3.3 Safety, Health & Environment Management System

For Company's SHE Policy, it has been always reviewed by SHE specialist and client's SHE team to order to ensure that existing SHE policy to meet client's objective.

Company's SHE Policy is consisted of 4 portions as following:

- Company Safety Objective
- Health & Safety Policy Statement
- Organization & Responsibilities
- SHE Procedures

For SHE Policy Statement, it is provided with full details in Appendix A

3.3.1 Company Safety objectives

- To be recognized as best by our employees, business partners, customers and competitors;

- Safety, Health & Environment to be one of the most important part of our business;
- To have knowledgeable, trained and competent staff and partners;
- Performance justifying the reputation.

3.3.2 Organization & Responsibilities

The role and responsibility for each position in term of safety perspective for each position are:

- **Account Manager**

Account Managers is responsible for the safety, health and environment of the contractor staff and the work areas. He is also responsible for the safety, health and environment of visitors within the area of work.

Account Managers must identify hazards and assess the risks to ensure appropriate and adequate controls are implemented to minimize the risk. Emphasis must be on the elimination of risk where reasonably practicable but where this is impractical, appropriate procedures, information, instruction, education and training must be provided.

Account Managers must meet with contractors on a regular basis to discuss safety and ensure safety awareness in an on-going and integrated activity. When visiting the Contractor offices, he shall also examine the Contractor management commitment to Safety by viewing the policies on Safety, Drug & Alcohol and records of in-house briefings and training provided to their employees.

Account Managers must monitor safe systems, inspect work places, measure performance and report where appropriate. Reporting will include the reporting of accidents and near-miss incidents. Serious incidents must be reported immediately to the Client Services Director.

Account Managers must investigate all accidents and incidents and implement remedial actions to eliminate the risk reoccurrence.

- **SHE Specialist**

SHE specialist will act on behalf of the Account Manager to assist with the responsibilities:

- Ensure SHE processes are in place and maintained,
- Monitor compliance with safety and health processes and standards,
- Communicate with the client and contractors to ensure co-ordination of activities in safety and health,
- Communicate any issues and concerns promptly to the Account Manager,
- Ensure all accidents and incidents are reported promptly and keep local records on behalf of the Account Manager.

- **Project Staff / Contractors' Employee**

- Work safely and follow SHE policies, procedures, instructions, and standards
- Use personal protective equipment (PPE) -- hardhat, gloves, safety glasses, hearing protection, respirator, appropriate footwear, fall protection
- Immediately report work-related injuries, illnesses, unsafe conditions, unsafe acts, environmental hazards, and pollution incidents to the supervisor using the standard forms
- Inspect tools and equipment before use and refuse to use defective items

3.3.3 SHE Procedures

In order to achieve the objective set as in SHE Policy, SHE procedures need to be established for everyone in project team including subcontractors to follow accordingly. SHE procedures applied in this project are consisted of portion developed by client and portions that company developed itself. SHE procedures are composed of 6 elements as below:

- **Training**

All contractors must be provided training on Safety, Health and Environment periodically to up-date them on procedures. As a minimum this must consist of emergency procedures, essential local site rules, contacts and accident reporting. It is the Account Manager's responsibility to ensure adequate training takes place.

- **Site Safety**

Site safety rules and processes may be exclusively those of our client. The subsequent, agreed SHE processes will be documented in a Company Local Process. Staff must ensure they are familiar with all relevant aspects of the SHE Local Process and related documentation and must ensure they abide by them at all times.

- **Accident & Incident Reporting**

It is essential that all accidents and incidents accidents are reported promptly. This will permit proper recording, allowing statutory reporting where required, ensure investigations to eliminate the potential for reoccurrence and provide data for trend analysis.

The client accident reporting process must also be adhered to. It is essential that staff comply with this requirement.

- **Company Safety, Health & Environmental Manual**

Whilst company's staff working on the client account will comply with client's SHE requirements, company also has a Safety, Health & Environmental Guideline which contains the detailed SHE requirements for the proper management of the risks we are likely to encounter in the wide range of our business activities. It can be used for training and reference and the elements of this SHE Guideline include:

- Crane Operation Program
- Injury Reporting & Investigation Program
- Electrical Safe Work Practices Program
- Employee Safety Training Program
- Ladder/Scaffold Safety Program
- Asbestos Awareness Program
- Lockout/Tagout Program
- Personal Protective Equipment Program
- Lead Safety Program
- Flammable & Combustible Liquids Program

- Compressed and Liquefied Gases Program
- First-Aid Program
- Medical Recordkeeping Program
- Respiratory Protection Program
- Employee Emergency & Evacuation Program
- Driver Safety Program
- Trenching Program
- Confined Space Entry Program
- Materials Handling Program
- Welding/Cutting/Brazing Safety Program
- Managing Contractor Safety Program

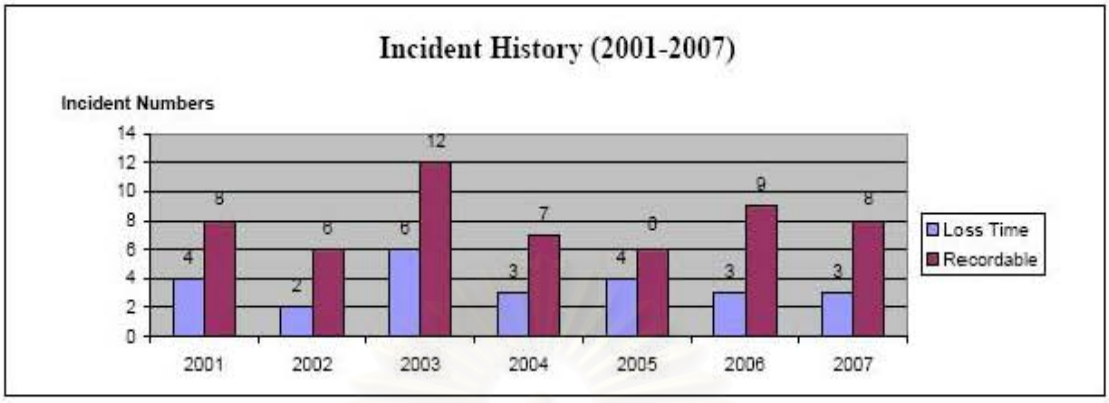
- **Drug & Alcohol Policy** (See the details in Appendix B)

3.4 Past Incidents/Accidents

The case company has serviced maintenance works for fuel service station since 2001. Every year, the company had to face various accidents/incidents which always ruin company's and client's reputation even some cases may not hurt company and client so much in term of financial. Also, every time, when accident/incident occurred, company did an immediately response by investigating the root cause and came up with preventive action. However, some cases were closed but some still recurrences sometimes.

Here below is Figure 3-3 which illustrated the case company's Incident History during 2001 – 2007.

Figure 3-3: Incident History (2001-2007)



According to Figure 3-3, it found that each year, the number of incidents was not significant, only one digit except year 2003. However, each incident always hurt company's reputation, customers' brand loyalty and feeling.

In this section, the example of incidents occurred in past few years are demonstrated:

- Unidentified object exploded while operator was grasping it
- Electrical short circuit at Dispenser pump
- Fired incident at store room
- Fired incident at water pump
- Sling torn while lifting underground tank
- Fired incident at signage

From the above incidents, it can be summarized that the past incidents were not only caused by improper behavior of maintenance operator but also deteriorated equipment itself.

3.5 Maintenance Tasks

Regarding to the scope of research in Chapter 1, this study will be focused on only two categories of equipment consisting of:

- General Equipments
- Petrol System

Both equipment groups have been found that there are many related incidents during past few years and also, most of them are located in the hazardous area. To find out the gaps of maintenance work and close them as much as possible, all equipments and their maintenance tasks related are defined as following:

3.5.1 General Equipments

As already mentioned that this group contains a lot of equipments and most of them are located in forecourt area where the fuel vapour is around. Therefore, it is quite risky when performing maintenance which a flash may occur. Even there are various equipments; the maintenance tasks are quite similar. Table 3-1 shows the related maintenance tasks of General Equipment Group.

Table 3-1: Maintenance Tasks for General Equipments

Equipment	Maintenance Task related
Price Sign / Highway Sign	• Cleaning, Painting & Relamping
	• Repair electrical system (CB, wire, etc.)
	• Repair corroded/damaged pole
	• Demolition/Removal
Product Sign (Spreader & End sign)	• Repair electrical system (CB, wire, etc.)
	• Repair plastic plate
	• Installation/Demolition
Yard Light	• Painting & Relamping tasks
	• Repair electrical system (CB, wire, etc.)
	• Repair corroded/damaged pole
	• Demolition/Removal
Down Light	• Repair (changing lamp, Ballast, etc.)
Voltage Protection Cabinet	• Repair failed Voltage Protection (Changing Magnetic relay, Time Relay Pilot lamp, CB, Fuse, etc.)
	• Infrared Scan
	• Demolition/Removal
CCTV	• Installation
	• Repair failed CCTV system (monitor, recorder, signal cable)
	• Demolition/Removal
Air Tower	• Repair (changing valve, hose, belt, etc.)
	• Repair leaked pipe
	• Demolition/Removal
Air Compressor	• Repair (replace parts such as filter, valve, etc.)
	• Demolition/Removal

Table 3-1: Maintenance Tasks for General Equipments (Con't)

Equipment	Maintenance Task related
Hoist	• Repair (changing hydrolic lubricant, etc.)
	• Safety leg installation
	• Painting
	• Demolition/Removal
Aboveground Water Tank	• Repair leaked tank & pipe
	• Repair water pump (change float valve, etc.)
	• Cleaning & Painting
	• Demolition/Removal
Building	• Rapair leaked roof & replace broken tiles
	• Repair lighting system (change lamp, etc.)
	• Painting
Canopy	• Raplace vinyl/sticker
	• Rapair backlit
	• Painting
Pavement	• Repair broken/subsided pavement
	• Repair U-drain
Septic tank	• Repair Broken tank
	• Remove waste in septic tank
Bumper	• Repair dameged bumper (By car crashed)
	• Installation
Other Equipments	• Repair Time recorder
	• Repair High pressure water pump
	• Repair/Refill fire extinguisher
	• Repair/install air ventilation fan
	• Repair portable air tank
	• Repair FAX machine
	• Repair intercom system

3.5.2 Petrol System

In this group, most of equipments contact directly with petrol such as underground tank, underground pipe and dispensing pump, etc., so any maintenance tasks performed need to be done correctly, carefully and safely. The maintenance tasks related of these equipments are identified as in Table 3-2.

Table 3-2: Maintenance Tasks for Petrol System

Equipment	Maintenance Task related
Dispensing Pump (D/P)	• Repair (Changing motor, Belt, Hose, Pulley, Valve, Display board, Nozzle, Filter etc.)
	• Repair corroded D/P basement
	• Meter Verification & Calibration
	• Cleaning & repainting D/P skirt
	• Replace product sticker
	• Installation & Removal
Underground Tank	• Cleaning & Degassing
	• Switch Product
	• Pressure Test (Leak)
	• Pump out the water
	• Demolition
Underground pipe	• Repair pipe leaked
	• Pressure Test (Leak)
	• Installation/Demolition
Remote Fill (Loading pipe)	• Repair pipe leaked
	• Pressure Test (Leak)
	• Installation/Demolition
Air Ventilation Pipe	• Repair pipe leaked
	• Pressure Test (Leak)
	• Installation/Demolition
Tank Sump	• Pump out the water
	• Repair (Sump leaked, Motor, lift up the level etc.)
	• Installation/Demolition
Automation Tank Guage (ATG	• Repair (Changing indicating lamp, sensor, signal cable, etc.)
	• Preventive Maintenance (Check probe, monitor, etc)
	• ATG Calibration

From above Table 3-1 and Table 3-2, they show there are so many and various maintenance tasks related to both equipment groups. In next chapter, these maintenance tasks will be brought to analysis in order to find out the solutions for safety performance enhancement.

CHAPTER IV

ANALYSIS

4.1 Introduction

In this chapter, it is starting point to analyze the potential risks for all maintenance tasks identified in previous chapter. First of all, the potential risks of all maintenance works will be identified and then, they will be brought into analysis process. The analysis tools are applied in this study consisted of Fishbone diagram, Failure Modes and Effects Analysis (FMEA) and Pareto Chart widely used and very powerful. The data used in this analysis is based on the recordable past incident and the experience of contractors who have been working in this field for years.

4.2 Failure Modes and Effects Analysis (FMEA)

According to the steps to perform FMEA mentioned in Chapter II, first of all, the potential failure modes for each maintenance task need to be identified. Regarding to Table 3-10 and Table 3-11, the potential risks for each tasks can be listed as following Table 4-1 and Table 4-2 which are for General equipment and Petrol system, respectively.

Table 4-1: Potential Failures for General Equipments

Equipment	Maintenance Task	Potential Failures
Price Sign / Highway Sign	• Cleaning & Painting	- Basket of Cherry picker hits signage pole
		- Tools fall down from scaffold
		- Operator falls down from scaffold
		- Scaffold collapsed
		- Paint/Cleaning substance gets into body
	• Repair electrical system (CB, wire, etc.)	- Electrical short circuit
		- Tools fall down from scaffold
		- Operator falls down from scaffold
		- Scaffold collapsed
	• Repair corroded/damaged pole	- Spark/Ignition from welding/grinding metal pole
		- Crane collpsed
		- Sling torn during lifting
		- Pole swing & hit building/operator nearby
		- Paint gets into body
	• Demolition/Removal	- Electrical short circuit
		- Spark/Ignition from trenching concrete basement
		- Spark/Ignition from welding/grinding metal pole
		- Crane collpsed
		- Sling torn during lifting
		- Pole swing & hit building/operator nearby

Table 4-1: Potential Failures for General Equipments (Con't)

Equipment	Maintenance Task	Potential Failures
Product Sign (Spreader & End sign)	• Repair plastic plate	- Plastic plate fall down from scaffold
		- Scaffold collapsd
		- Operator fall down from scaffold
	• Repair corroded frame	- Spark/Ignition from welding/grinding frame
		- Operator falls down from scaffold
		- Tools fall down from scaffold
		- Paint gets into body
	• Repair electrical system (CB, wire, etc.)	- Electrical short circuit
		- Tools fall down from scaffold
		- Operator falls down from scaffold
		- Scaffold collapsed
	• Installation/Demolition	- Spark/Ignition from knocking/Drilling frame
		- Metal frame swing & hit D/P
		- Sling torn during hanging
Yard Light	• Painting & Cleaning	- Paint/Cleaning substance gets into body
		- Tools fall down from scaffold
		- Operator falls down from scaffold
		- Scaffold collapsed
	• Repair electrical system (CB, wire, lamp, etc.)	- Electrical short circuit
		- Tools fall down from scaffold
		- Operator falls down from scaffold
		- Scaffold collapsed

Table 4-1: Potential Failures for General Equipments (Con't)

Equipment	Maintenance Task	Potential Failures
Yard Light	• Repair corroded/damaged pole	- Spark/Ignition from welding/grinding metal pole
		- Crane collpsed
		- Sling torn during lifting
		- Pole swing & hit building/operator nearby
		- Paint gets into body
	• Demolition/Removal	- Spark/Ignition from trenching concrete basement
		- Spark/Ignition from welding/grinding task metal pole
		- Crane collpsed during lifting
		- Sling torn during lifting
		- Pole swing & hit building/operator nearby
Down Light	• Repair (changing lamp, Ballast, etc.)	- Electrical short circuit
		- Scaffold collapsd
		- Operator fall down from scaffold
		- Tools fall down from scaffold
Voltage Protection Cabinet	• Repair failed Voltage Protection (Changing Magnetic relay, Time Relay Pilot lamp, CB, Fuse, etc.)	- Electrical short circuit
	• Infrared Scan	- Electrical short circuit
	• Demolition/Removal	- Electrical short circuit
		- Spark/Ignition from knocking/welding cabinet
CCTV	• Repair failed CCTV system (monitor, recorder, signal cable)	- Electrical short circuit
	• Installation/Demolition/Removal	- Electrical short circuit
		- CCTV fall down from scaffold
		- Operator falls down from scaffold
		- Scaffold collapsed

Table 4-1: Potential Failures for General Equipments (Con't)

Equipment	Maintenance Task	Potential Failures
Air Tower	• Repair (changing valve, hose, belt, etc.)	- Spark/Ignition from knocking/drilling air tower leg
		- Remained air blow into eyes
	• Repair leaked pipe	- Spark/Ignition from trenching concrete
		- Spark/Ignition from welding pipe
		- Saw blade broken during cutting joint concrete
	• Demolition/Removal	- Electrical short circuit
		- Remained air blow into eyes
		- Spark/Ignition from trenching concrete
		- Saw blade broken during cutting joint concrete
Air Compressor	• Repair (replace parts such as filter, valve, etc.)	- Electrical short circuit
		- Remained air blow into eyes
	• Demolition/Removal	- Electrical short circuit
		- Spark/Ignition from knocking air tower leg
		- Remained air blow into eyes
		- Sling torn during lifting
Hoist	• Repair (changing hydrolic lubricant, repair corroded frame,etc.)	- Lubricant/paint gets into body
		- Spark/Ignition from welding/grinding metal frame
	• Safety leg installation	- Spark/Ignition from trenching/drilling concrete
		- Spark/Ignition from welding/grinding metal frame
	• Painting	- Paint gets into body
		- Spark/Ignition from polishing/grinding metal frame
		- Hoist fall down

Table 4-1: Potential Failures for General Equipments (Con't)

Equipment	Maintenance Task	Potential Failures
Hoist	• Demolition/Removal	- Crane collpsed during lifting
		- Sling torn during lifting
		- Spark/Ignition from trenching/drilling concrete
		- Steel core swing & hit building/operator nearby
Aboveground Water Tank	• Repair leaked/corroded tank & pipe	- Oxygen in tank is run out
		- Spark/Ignition from welding/grinding connector
	• Repair water pump (change float valve, etc.)	- Electrical short circuit
		- Oxygen in tank is run out
	• Cleaning & Painting	- Oxygen in tank is run out
		- Paint gets into body
		- Tools fall down from scaffold
		- Operator falls down from scaffold
		- Scaffold collapsed
	• Demolition/Removal	- Tank swing & hit building
		- Sling torn during lifting
		- Crane collapsed during lifting
		- Spark/Ignition from welding task
Building	• Rapair leaked roof & replace broken tiles	- Scaffold collapsed
		- Operator fall dow from roof
		- Operator fall dow from scaffold
	• Repair lighting system (change lamp, etc.)	- Electrical short circuit
		- Operator fall dow from ladder

Table 4-1: Potential Failures for General Equipments (Con't)

Equipment	Maintenance Task	Potential Failures
Building	• Painting	- Paint gets into body
		- Scaffold collapsed
		- Operator falls dow from scaffold
		- Tools fall dow from scaffold
Canopy	• Raplace vinyl/sticker	- Car hits scaffold
		- Scaffold collapsed
		- Operator falls dow from scaffold
		- Tools fall dow from scaffold
	• Rapair backlit	- Electrical short circuit
		- Car hits scaffold
		- Scaffold collapsed
		- Operator falls dow from scaffold
		- Tools fall dow from scaffold
	• Painting	- Paint gets into body
		- Car hits scaffold
		- Scaffold collapsed
		- Operator falls dow from scaffold
		- Tools fall dow from scaffold
Pavement	• Repair broken/subsided pavement	- Saw blade broken during cutting joint concrete
		- Car hits operator
		- Spark/Ignition from trenching/drilling concrete

Table 4-1: Potential Failures for General Equipments (Con't)

Equipment	Maintenance Task	Potential Failures
Pavement	• Repair U-drain	- Saw blade broken during cutting joint concrete
		- Spark/Ignition from trenching/drilling concrete
		- Spark/Ignition from welding metal sheet
Septic tank	• Repair Broken tank	- Spark/Ignition from knocking concrete cover
	• Remove waste in septic tank	- Spark/Ignition from electrical device (pump)
Bumper	• Repair dameged bumper (By car crashed)	- Spark/Ignition from knocking/welding bumper
		- Spark/Ignition from trenching concrete basement
	• Installation	- Spark/Ignition from trenching concrete basement
Other Equipments	• Repair Time recorder	- Electrical short circuit
	• Repair High pressure water pump	- Electrical short circuit
		- Remain water injects to hands
	• Repair/Refill fire extinguisher	- Chemical substance gets into body
	• Repair/install air ventilation fan	- Electrical short circuit
		- Spark/Ignition from knocking concete wall
		- Operator fall from ladder
	• Repair portable air tank	- Remain air blows into eyes
	• Repair FAX machine	- Electrical short circuit
		- Operator fall from ladder
	• Repair intercom system	- Electrical short circuit
		- Car hits scaffold
		- Scaffold collapsed
		- Operator falls dow from scaffold

Table 4-2: Potential Failures for Petrol System

Equipment	Maintenance Tasks	Potential Failures
Dispensing Pump (D/P)	• Repair (Changing motor, Belt, Hose, Pulley, Valve, Display board, Nozzle, Filter etc.)	- Product spilled
		- Electrical short circuit
		- Spark/Ignition from knocking task (to remove motor, nozzle)
		- Spark/Ignition from static electricity
	• Repair corroded D/P basement	- Product spilled
		- Spark/Ignition from knocking/drilling task
		- Sling torn during lifting by crane
		- Crane collapsed during lifting
		- D/P swing & hit column during lifting
	• Meter Verification & Calibration	- Spark/Ignition from static electricity
		- Product spilled
	• Cleaning & repainting D/P skirt	- Spark/Ignition from knocking task
		- Paint gets into body
	• Replace product sticker	- Spark/Ignition from knocking task
	• Installation & Removal	- Electrical short circuit
		- Spark/Ignition from static electricity
		- Product spilled
		- Spark/Ignition from knocking/drilling task
		- Sling torn during lifting by crane
		- Crane collapsed during lifting
		- D/P swing & hit column during lifting

Table 4-2: Potential Failures for Petrol System (Con't)

Equipment	Maintenance Tasks	Potential Failures
Underground Tank	• Cleaning & Degassing	- Oxygen in tank is run out
		- Product spilled
	• Switch Product	- Spark/Ignition from electrical device (pump)
		- Product spilled
	• Pressure Test (Leak)	- Spark/Ignition from trenching concrete (manhole)
		- Spark/Ignition from knocking (scew of manhole cover)
		- Product spilled
	• Pump out the water	- Contaminated water is released into environment nearby
		- Spark/Ignition from electrical device (pump)
		- Product spilled
	• Demolition	- Saw blade broken during joint cutting
		- Spark/Ignition from trenching concrete (above tank)
		- Spark/Ignition from knocking (to disconnect tank & pipes)
		- Sling torn during lifting by crane
		- Crane collapsed during lifting
		- Tank swing & hit building
		- Contaminated water is released into environment nearby
		- Product spilled
Underground pipe	• Repair pipe leaked	- Saw blade broken during joint cutting
		- Spark/Ignition from trenching concrete (above pipe)
		- Product spilled

Table 4-2: Potential Failures for Petrol System (Con't)

Equipment	Maintenance Tasks	Potential Failures
Underground pipe	• Pressure Test (Leak)	- Spark/Ignition from trenching concrete (manhole)
		- Spark/Ignition from knocking (to disconnect tank & pipes)
		- Product spilled
	• Installation/Demolition	- Saw blade broken during joint cutting
		- Spark/Ignition from trenching concrete (above pipe)
		- Spark/Ignition from knocking (to disconnect tank & pipes)
		- Product spilled
Remote Fill (Loading pipe)	• Repair pipe leaked	- Saw blade broken during joint cutting
		- Spark/Ignition from trenching concrete (above pipe)
		- Product spilled
	• Pressure Test (Leak)	- Spark/Ignition from trenching concrete (manhole)
		- Spark/Ignition from knocking (to disconnect tank & pipes)
		- Product spilled
	• Installation/Demolition	- Saw blade broken during joint cutting
		- Spark/Ignition from trenching concrete (above pipe)
		- Spark/Ignition from knocking (to disconnect tank & pipes)
		- Product spilled
Air Ventilation Pipe	• Repair pipe leaked	- Saw blade broken during joint cutting
		- Spark/Ignition from trenching concrete (above pipe)
		- Operator falls from scaffold
		- Scaffold collasped
		- Product spilled

Table 4-2: Potential Failures for Petrol System (Con't)

Equipment	Maintenance Tasks	Potential Failures
Air Ventilation Pipe	• Pressure Test (Leak)	- Saw blade broken during joint cutting
		- Spark/Ignition from knocking (to disconnect tank & pipes)
		- Spark/Ignition from trenching concrete (above pipe)
		- Operator falls from scaffold
		- Scaffold collasped
		- Product spilled
	• Installation/Demolition	- Saw blade broken during joint cutting
		- Spark/Ignition from knocking (to disconnect tank & pipes)
		- Spark/Ignition from trenching concrete (above pipe)
		- Product spilled
Tank Sump	• Pump out the water	- Spark/Ignition from electrical device (pump)
		- Saw blade broken during joint cutting
		- Oxygen is run out
		- Spark/Ignition from trenching concrete (manhole)
		- Contaminated water is released into environment nearby
	• Repair (Sump leaked, Motor, lift up the level etc.)	- Electrical short circuit during repair motor/pump
		- Oxygen is run out
		- Spark/Ignition from trenching concrete (manhole)
		- Saw blade broken during joint cutting
		- Product spilled
		- Contaminated water is released into environment nearby

Table 4-2: Potential Failures for Petrol System (Con't)

Equipment	Maintenance Tasks	Potential Failures
Tank Sump	• Installation/Demolition	- Electrical short circuit during remove motor/probe
		- Oxygen is run out
		- Spark/Ignition from trenching concrete (manhole)
		- Saw blade broken during joint cutting
		- Contaminated water is released into environment nearby
		- Product spilled
Automation Tank Guage (ATG)	• Repair (Changing indicating lamp, sensor, signal cable, etc.)	- Electrical short circuit during remove probe
		- Oxygen is run out
	• Preventive Maintenance (Check probe, monitor, etc)	- Spark/Ignition from knocking (to open pipe cap)
		- Spark/Ignition from electrical device (probe)
		- Product spilled
	• ATG Calibration	- Electrical short circuit during setting calibration function

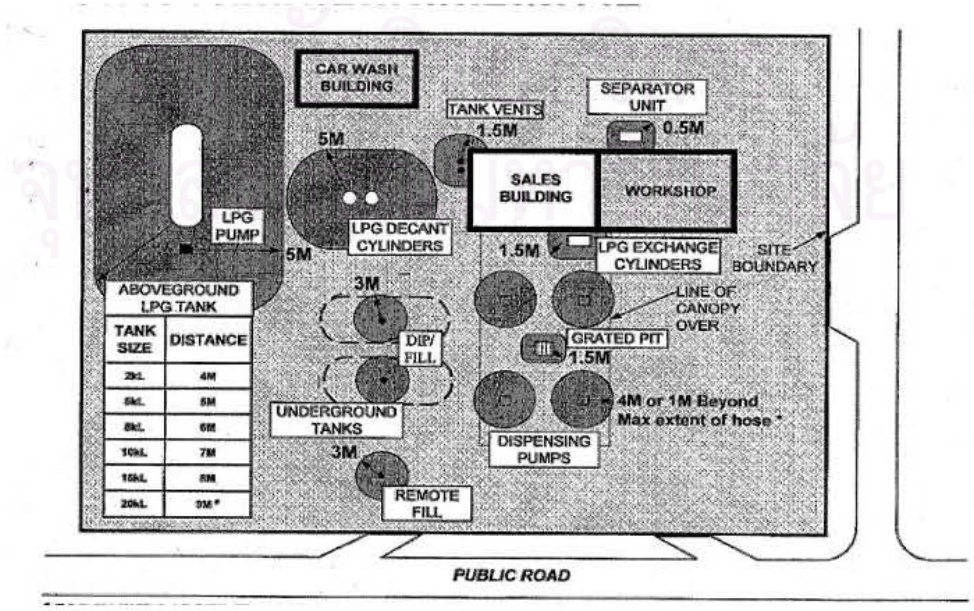
From above Tables, there are dozens of potential failures generated by gathering information from various level people who have experienced in this field such as contractors, safety officers, site person, etc. Even more than a hundred failures are listed; in fact, most of them are quite similar to each other in term of the nature of failures. In order to prevent time wasted in repeating analysis the similar failures, grouping step is performed. By grouping the failures, it also gives a chance to consider whether some failure modes should be combined due to the similar. All potential failures can be grouped into seven categories as following:

- **Failures related to working at height**: In petrol station, there are so many equipments which are located above ground level such as lighting equipment, roof, signage, etc. To perform maintenance service, operator has to use scaffold or ladder in order to reach such equipments.

- **Failures related to electrical work**: The majority of equipments run by electricity. So, most of maintenance tasks are related to electricity. The historical data also shows that the big loss from past incident was caused by electrical problem. (Fired incident at Nakornpathom)

- **Failures related to hot work**: Hot work is the sort of work resulted heat or ignition occurrence. The maintenance tasks related are consisted of welding, demolition, installation, etc. The failure of this kind of work can cause the big impact once it is perform in hazardous area where fuel vapour is spread. See Hazardous zone as following Figure 4-1:

Figure 4-1: Hazardous Zone



- **Failures related to trenching/excavation work**: Trenching concrete tasks are mostly performed in order to access equipments which are located underground or equipment held with concrete as basement.

- **Failures related to working with chemical substance**: To perform maintenance service in petrol station, there are some chemical substances which operator has to deal with such as petrol product, lubricant, fungi-resistance substance, etc. The effect from failure can be ranged from loss of organ by getting chemical substance into body to explosion once product spilled.

- **Failures related to working in confined space**: Some equipment like tank sump, tank which is quite tough for operator to service. Working under this condition, operator needs to concern about respiration issue, oxygen volume and fuel vapour.

- **Failures related to working with crane**: Crane operation is mostly related to installation and demolition tasks. This equipment needs to be controlled by specialised and trained person. Otherwise, the big loss/impact will be apparent once failure occurs.

Regarding to seven categories, their potential related failures can be combined and grouped as following Table 4-3. Also, this table illustrated the potential effects for each failure mode.

Table 4-3: Failure Modes and Effects Identification

Type of Maintenance Task	Potential Failure	Potential Effect
1.) Working at Height	1.1) Scaffold/Ladder collapsed	1.1.1) Operator fall down and hit the ground caused the dead
	1.2) Tools/Equipments fall from scaffold/ladder	1.2.1) Fallen stuff hit customer vehicle caused damage/ hit operator under caused injury
	1.3) The basket of cherry picker hit building/signage	1.3.1) Property damaged/ Operator on basket get electricution (fall down & hit the ground)
2.) Working related electrical system	2.1) Spark/Ignition from electrical short-circuit	2.1.1) Operator get electrocution/ Propertu damaged (Station get burn)
3.) Working related hot work	3.1) Spark/Igmition from welding/grinding/knocking metal pole/frame	3.1.1) Explosion causes property damaged/ operator get burn (lost organ)
4.) Working related trenching/excavation	4.1) The saw blade broken during joint cutting	4.1.1) Broken saw blade hit operator caused lost organ
	4.2) Spark/Ignition from trenching concrete pavement	4.2.1) Explosion causes property damaged/ operator get burn (lost organ)
5.) Working related chemical substance	5.1) Chemical substance/product spilled during cleaning tank/demolition	5.1.1) Spilled product released to environment nearby (need to remediation)/ Explosion
	5.2) Static electrical discharge in form of spark during perform meter calibration	5.2.1) Explosion/Dispensing pump get burn and damaged
	5.3) Chemical substance (Paint) gets into body	5.2.1) Loss the organ

Table 4-3: Failure Modes and Effects Identification (Con't)

Type of Maintenance Task	Potential Failure	Potential Effect
6.) Working in confined space	6.1) Spark/Ingition within tank sump	6.1.1) The fire/explosion within tank sump, operator is stuck in sump and dead eventually/ Property damaged
	6.2) Oxegen in confined space is run out	6.2.1) Operator lose consciousness and dead eventually
7.) Working related crane operation	7.1) Sling is torn during removing U/G tank	7.1.1) U/G tank swing & hit people nearby and caused the dead/ Property damaged
	7.2) Crane collapsed while lifting U/G tank	7.2.1) Crane/tank fall down & hit people under and caused the dead/ Property damaged
	7.3) Tank/signage pole swing during lifting	7.3.1) Tank swing & hit build/operator caused property damaged/death

After the potential failure modes and their effects identified, next is to find out the potential root cause and solutions. All potential and possible causes for each failure modes were listed by applying the Fishbone Diagram.

"The fishbone diagram is an analysis tool that provides a systematic way of looking at effects and the causes that create or contribute to those effects. Because of the function of the fishbone diagram, it may be referred to as a cause-and-effect diagram. The design of the diagram looks much like the skeleton of a fish. Therefore, it is often referred to as the fishbone diagram."
http://quality.enr.state.nc.us/tools/fishbone.htm

This analysis tool works well and efficiently with brainstorm activity. In this study, the potential root causes came from brainstorm activity among experienced people in maintenance field such as SHE manager, Account Manager, Contractors' owner, etc. All potential root causes are classified into five groups as following:

- Man
- Machine
- Material
- Method
- Environment

According to fifteen potential failures illustrated in Table 4-3, the potential root causes for each failure are demonstrated by applying Fishbone diagram as following:

Figure 4-2: Fishbone Diagram of Scaffold Collapsed

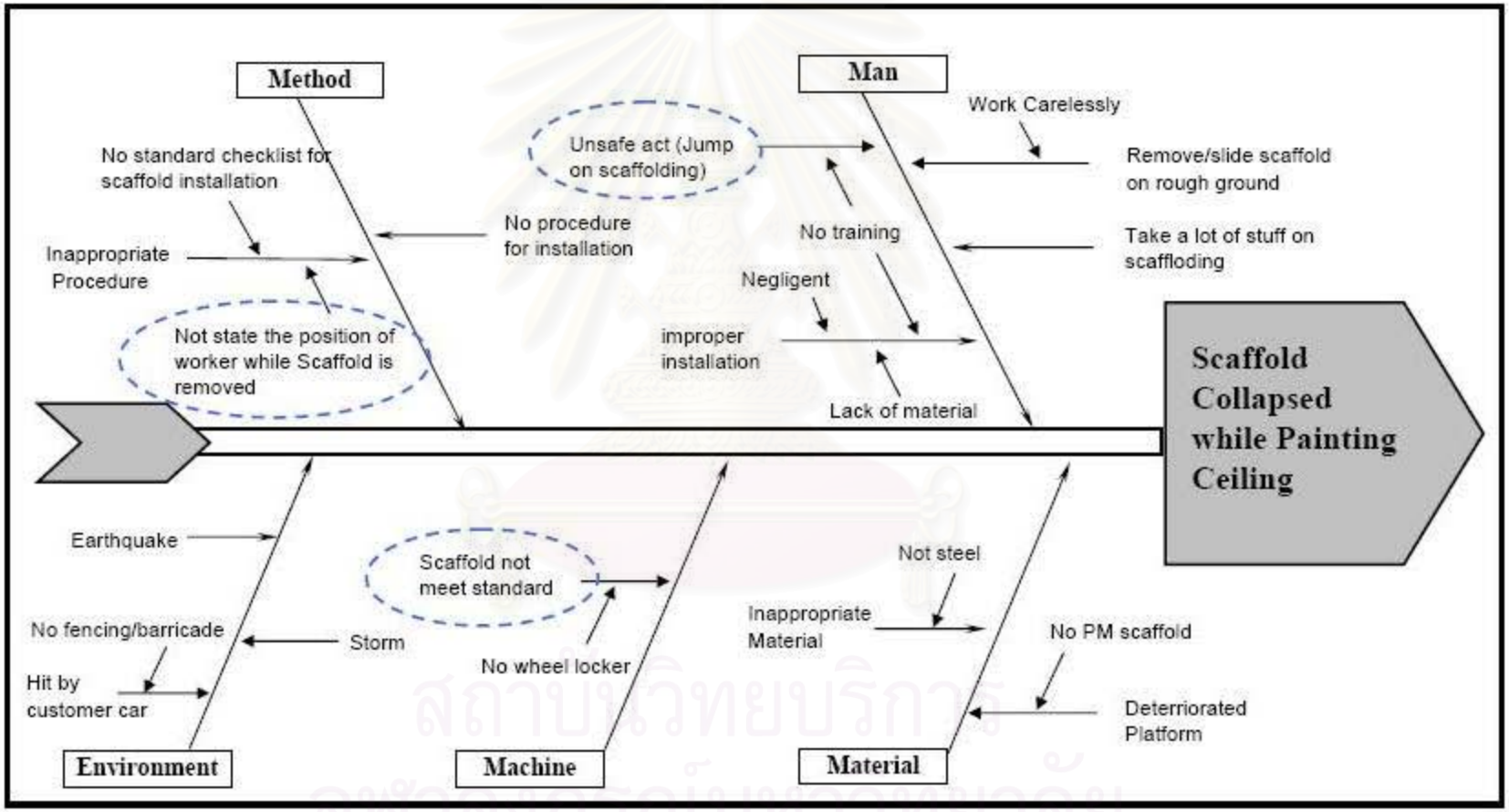


Figure 4-3: Fishbone Diagram of Tool Fallen from Scaffold

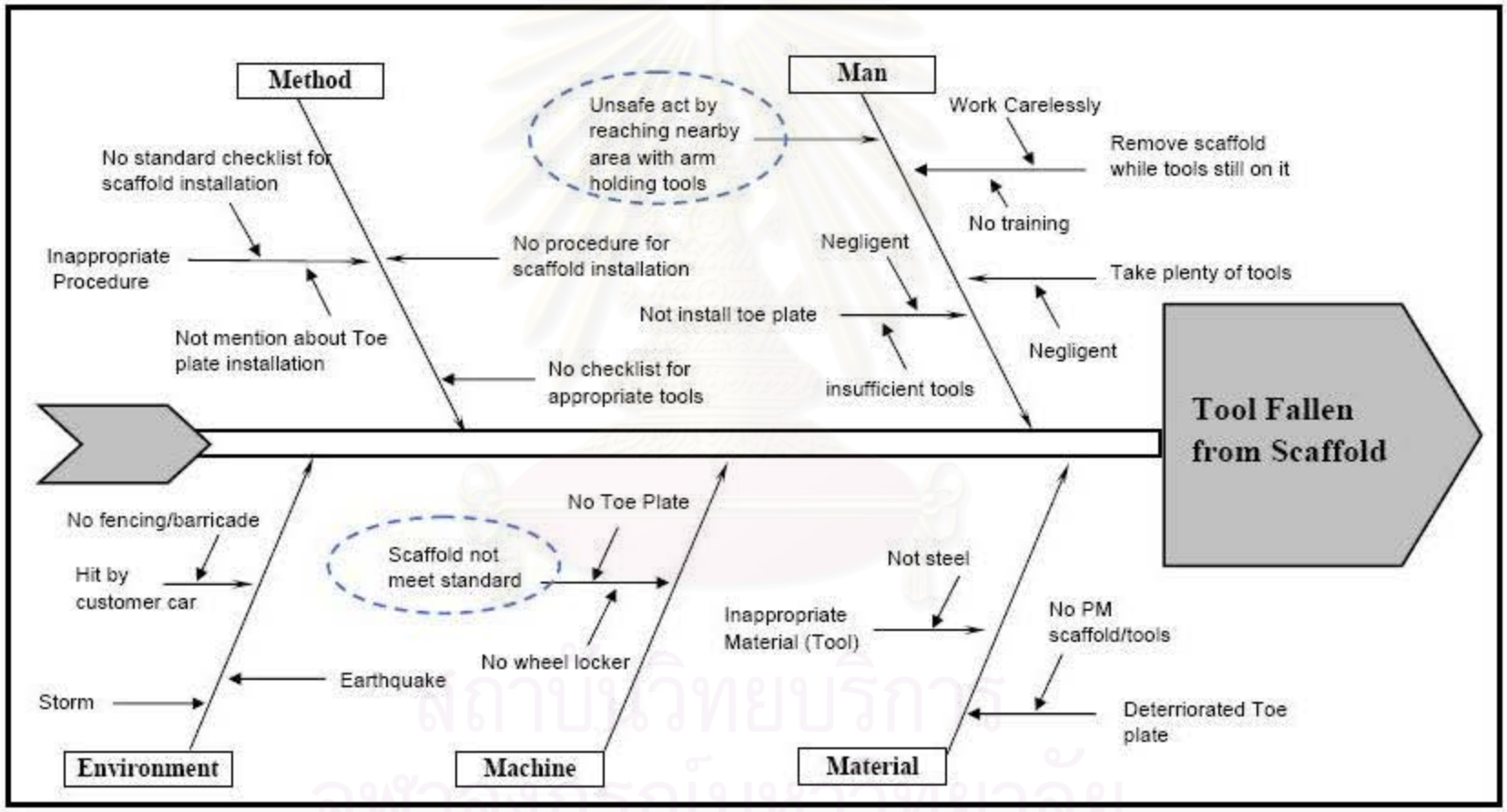


Figure 4-4: Fishbone Diagram of Basket of Cherry Picker Hit Building/Signage

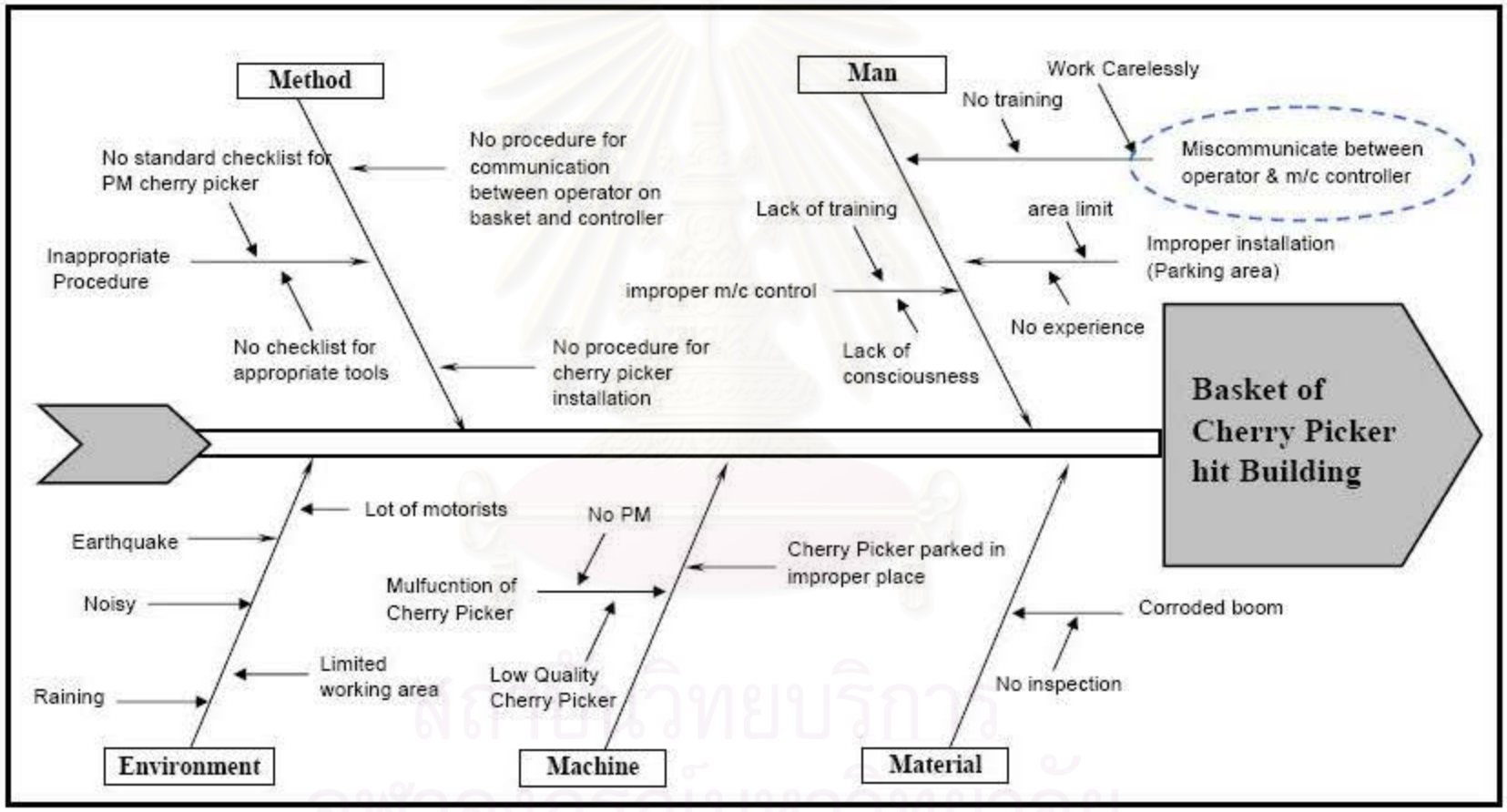


Figure 4-5: Fishbone Diagram of Spark from Electrical Short-circuit

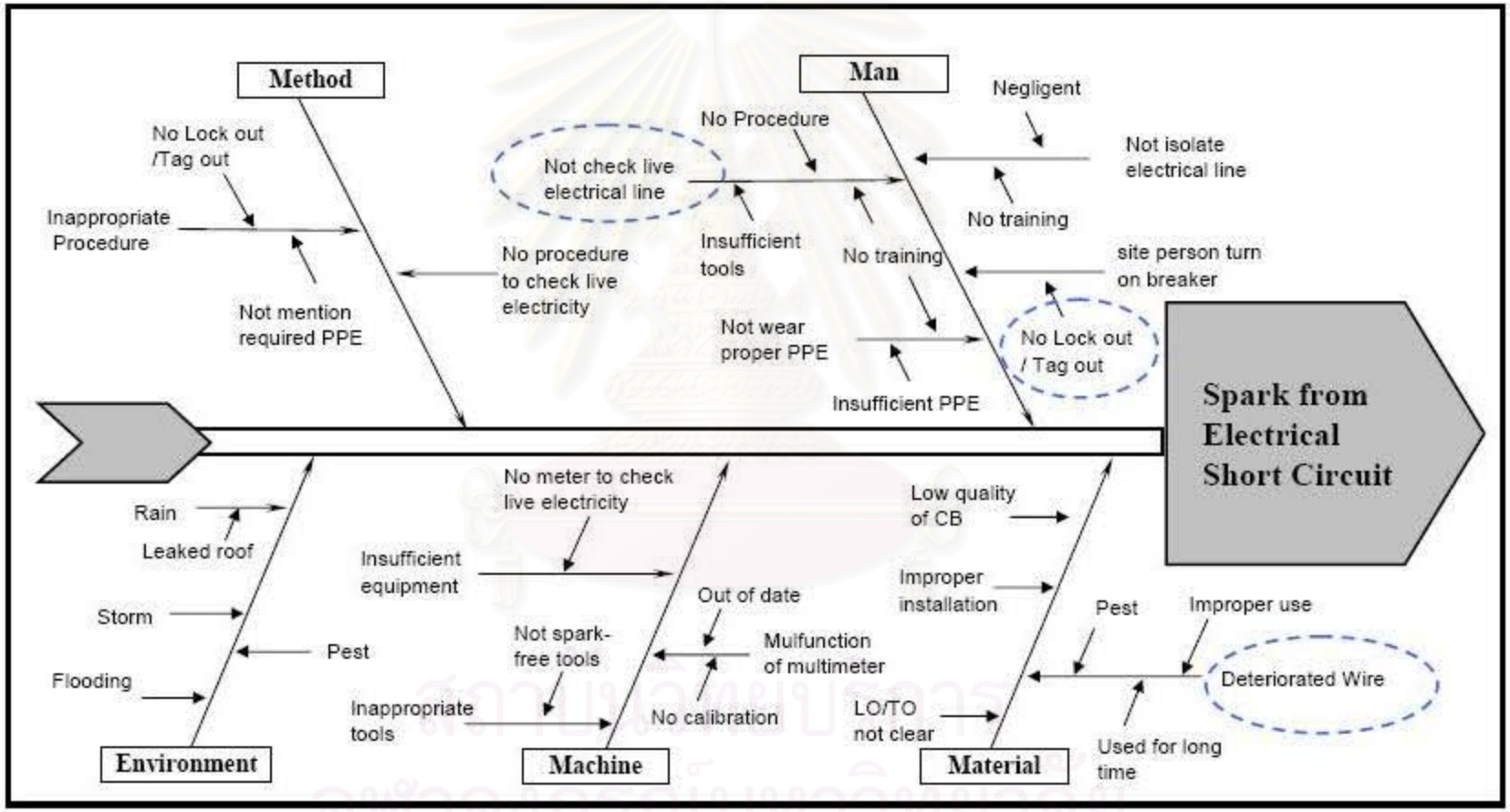


Figure 4-6: Fishbone Diagram of Spark from Knocking/Grinding tasks

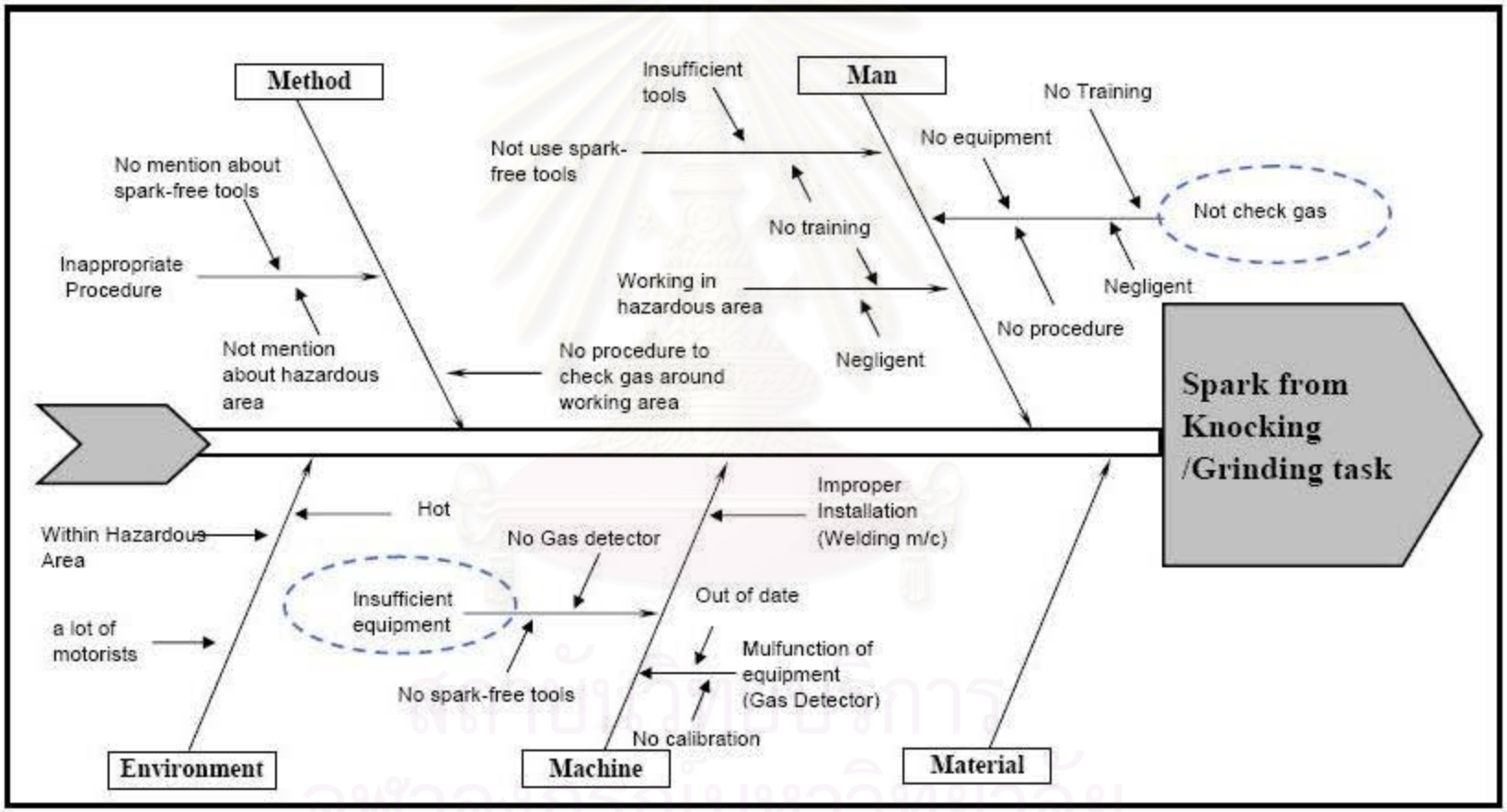


Figure 4-7: Fishbone Diagram of Spark from Trenching/Excavation

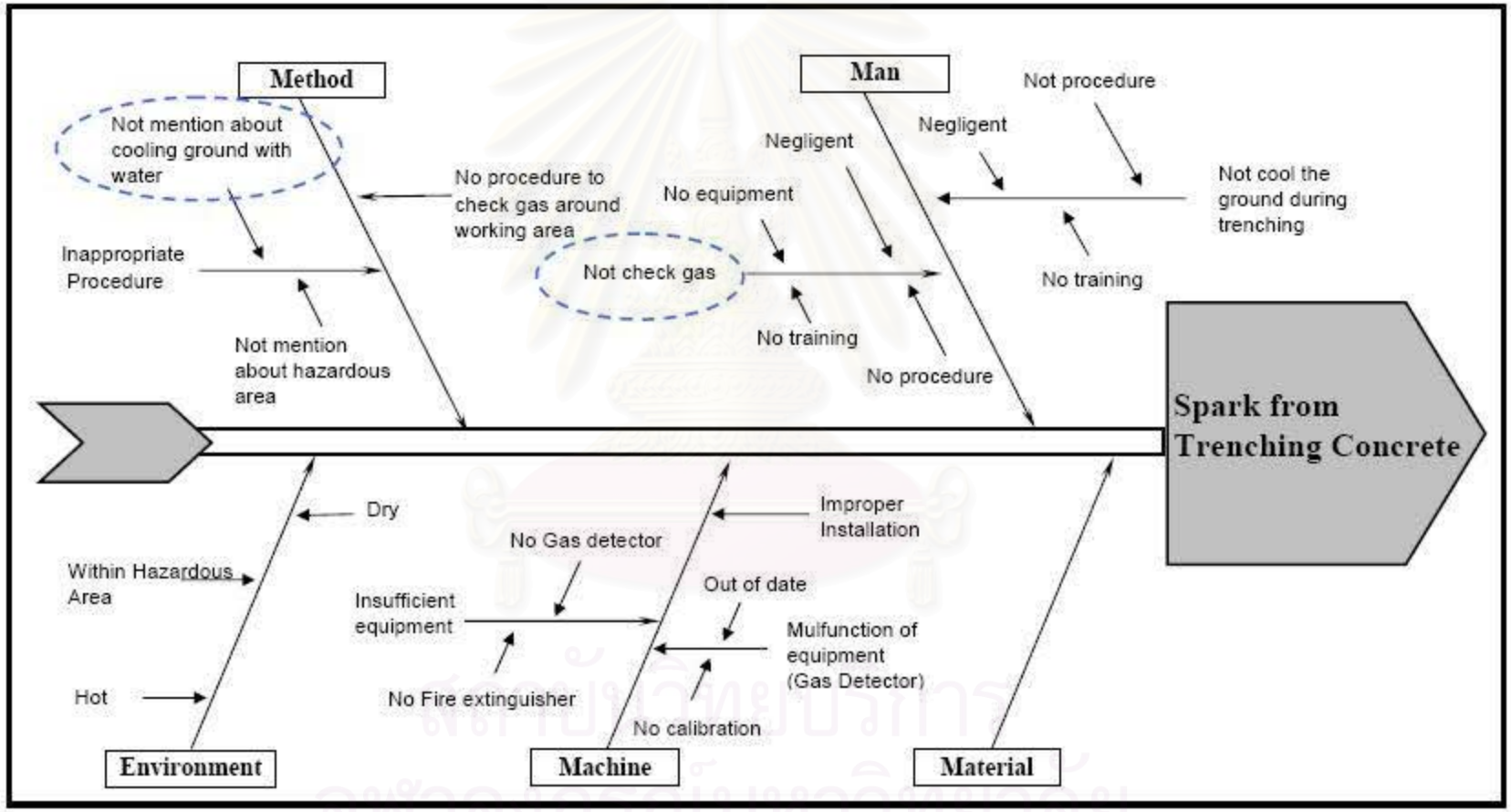


Figure 4-8: Fishbone Diagram of Saw Blade Broken

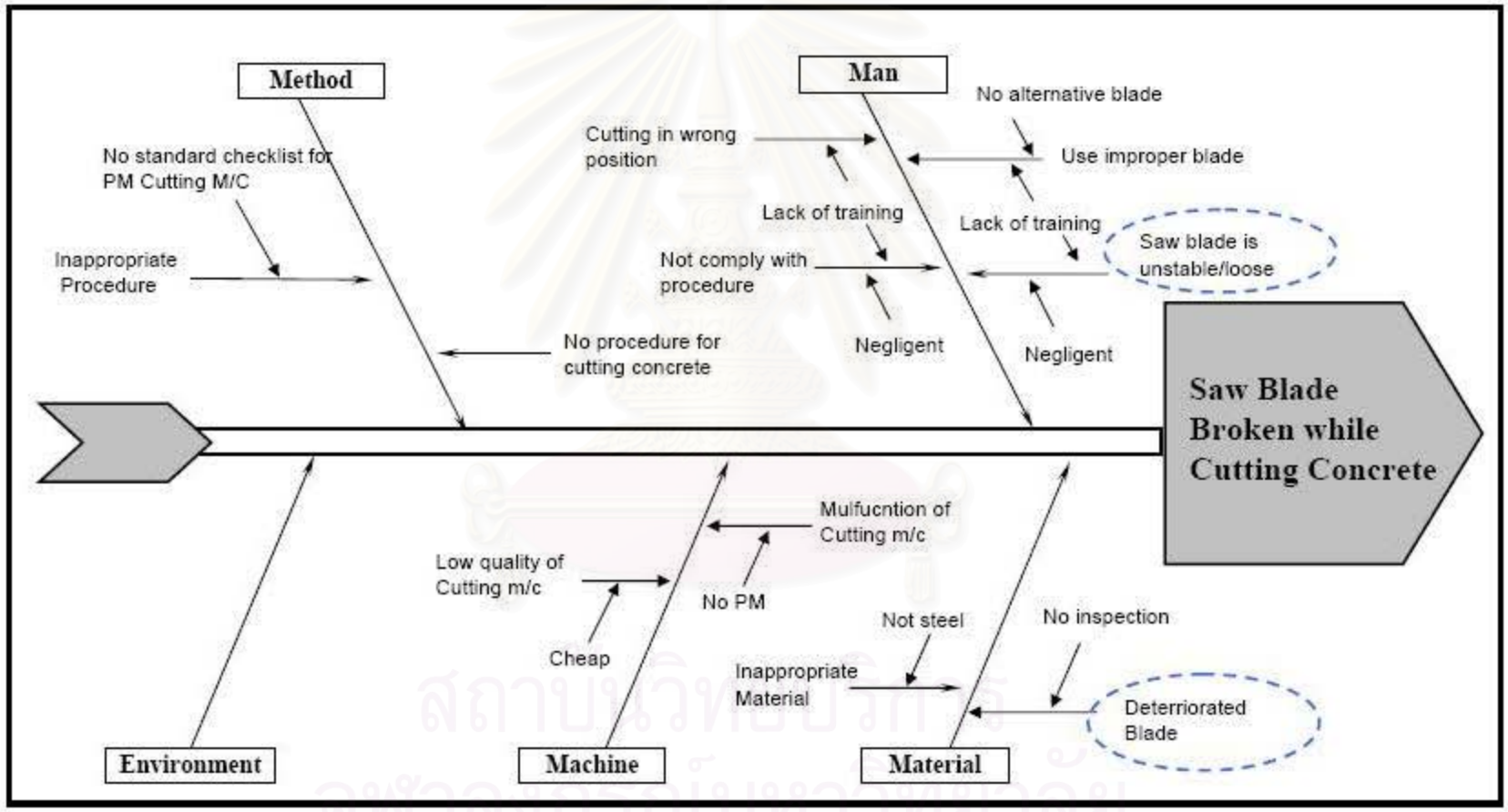


Figure 4-9: Fishbone Diagram of Product Spilled while cleaning U/G Tank

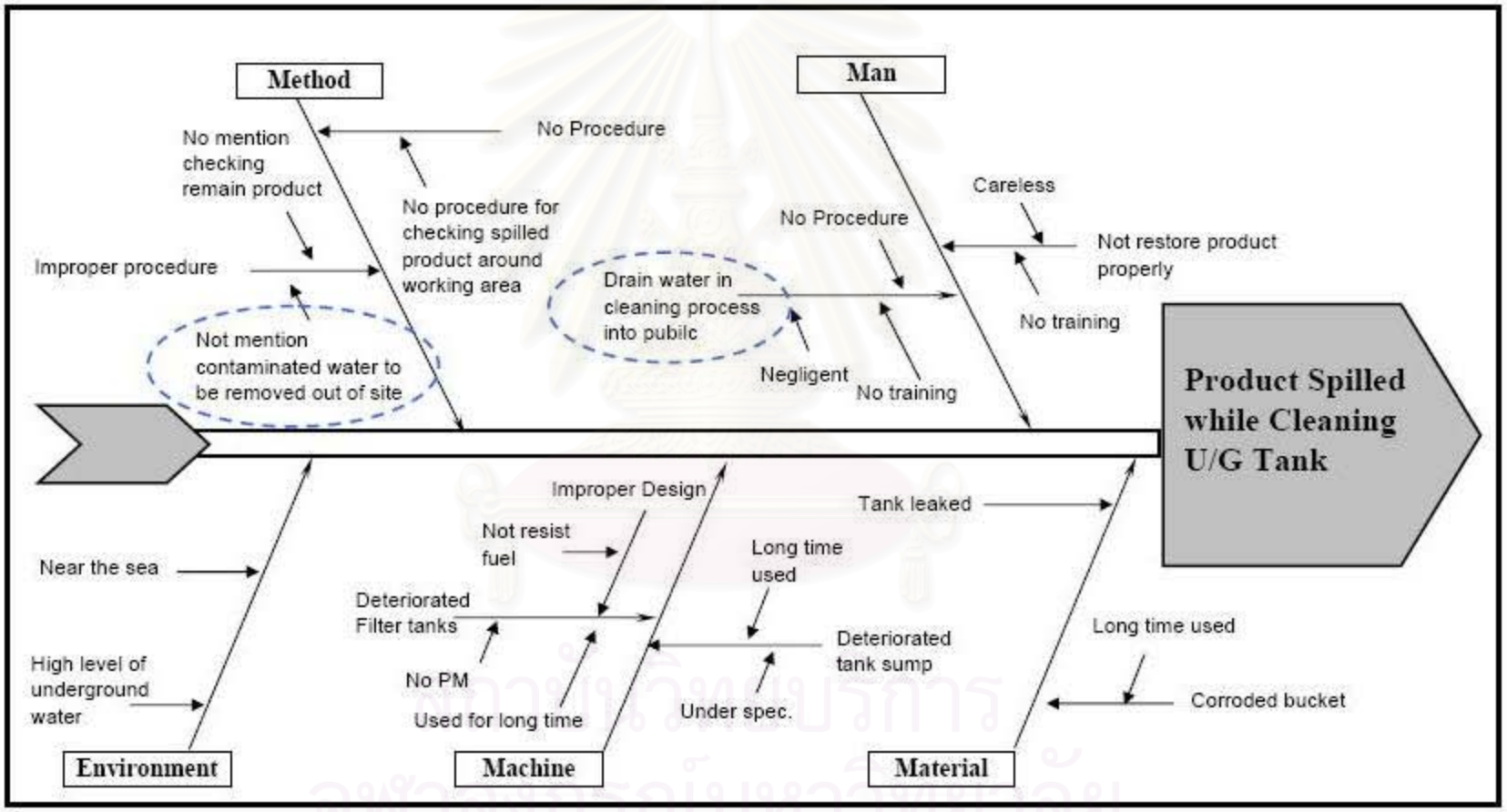


Figure 4-10: Fishbone Diagram of Spark from Static Electricity

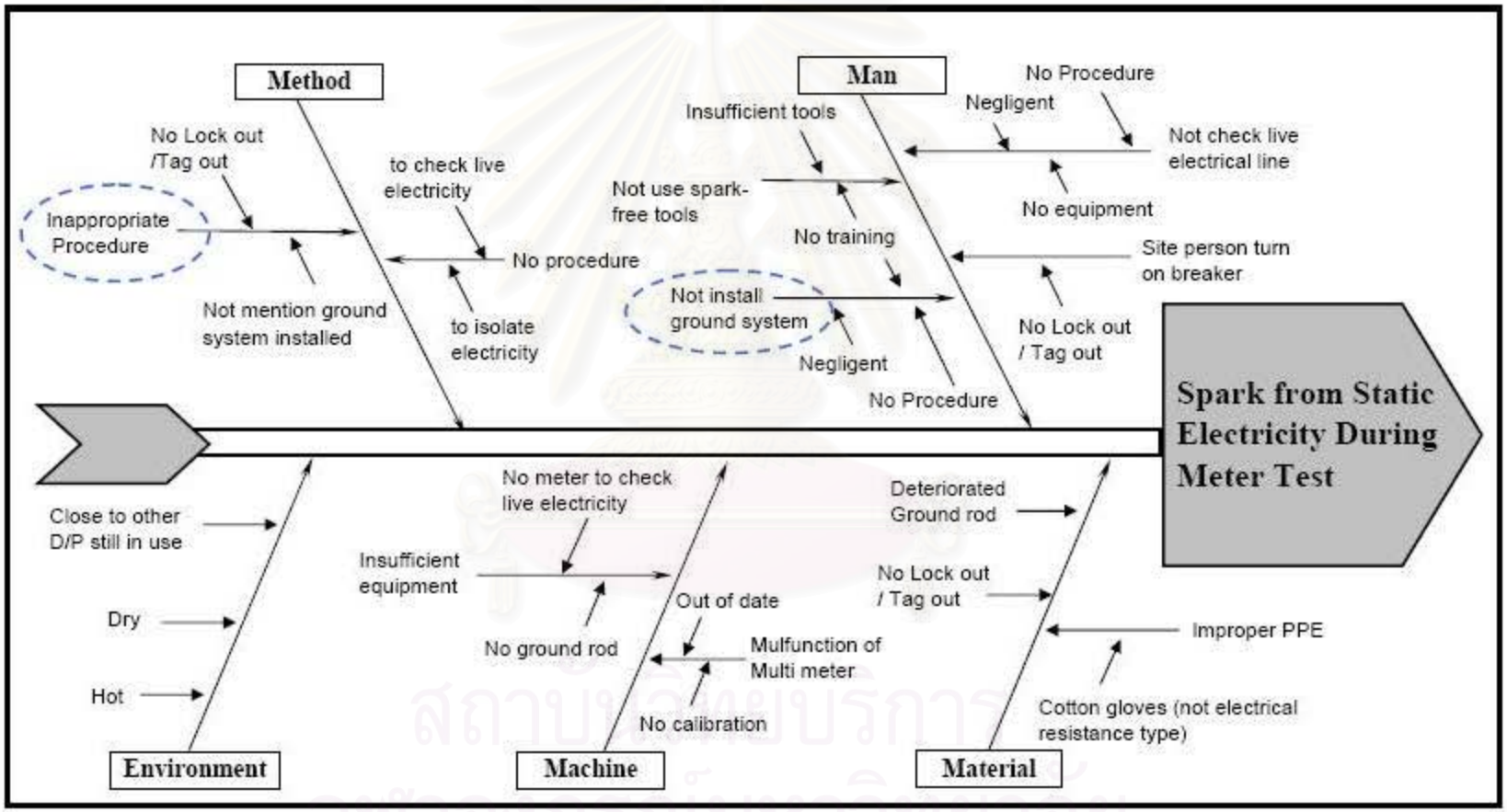


Figure 4-11: Fishbone Diagram of Paint Gets into Body

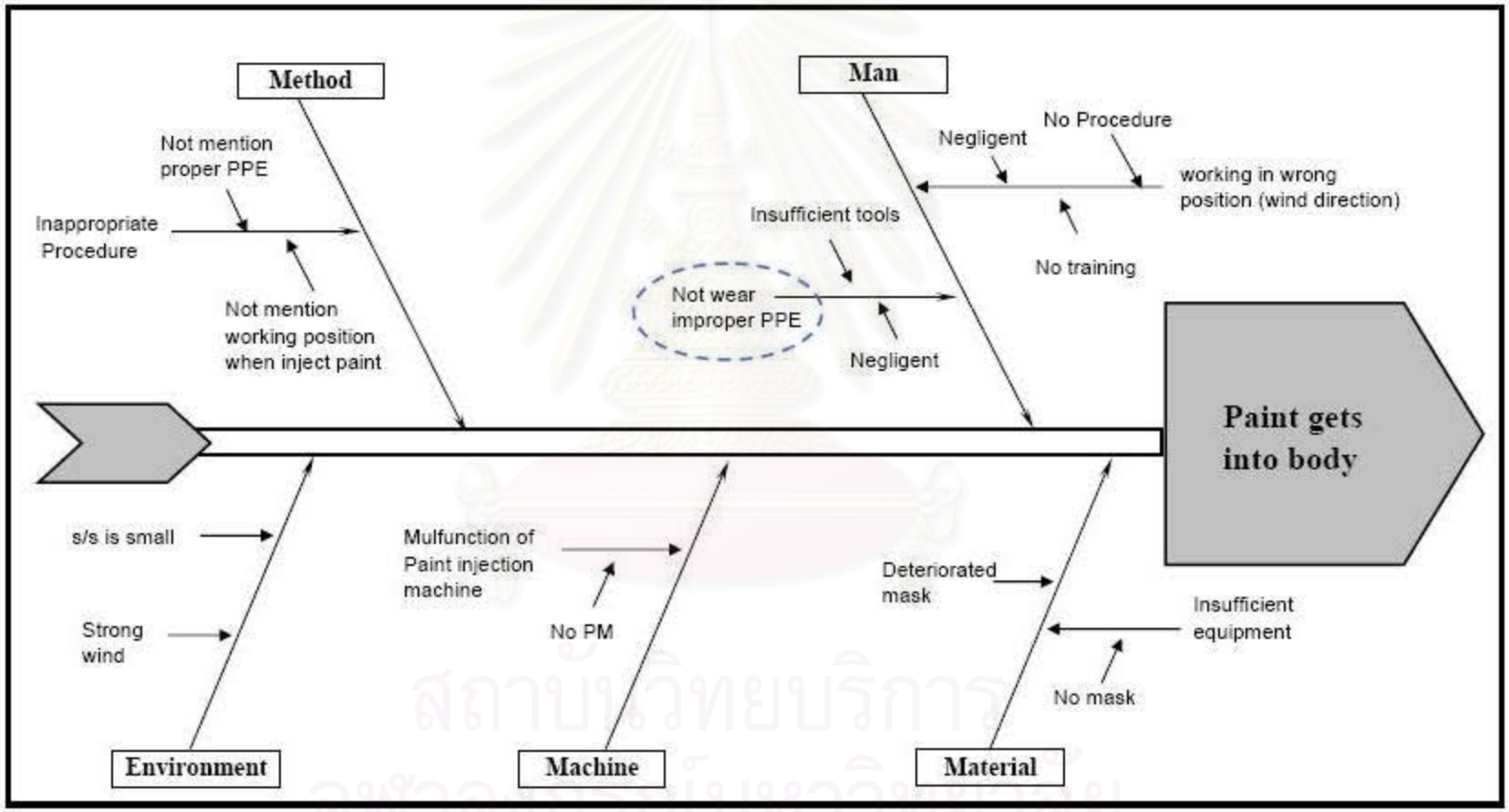


Figure 4-12: Fishbone Diagram of Spark within Tank Sump

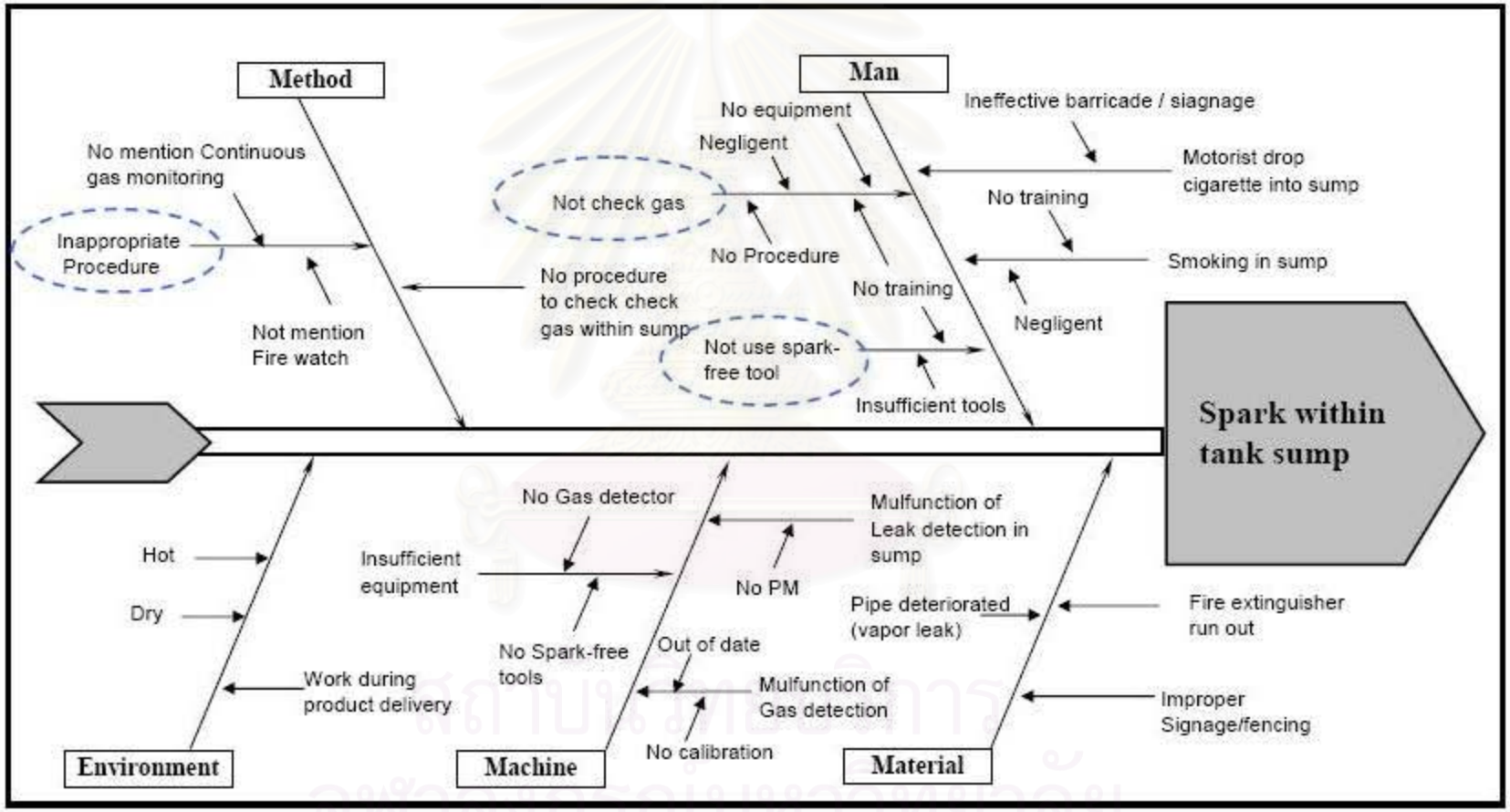


Figure 4-13: Fishbone Diagram of Oxegen in Tank Sump runs out

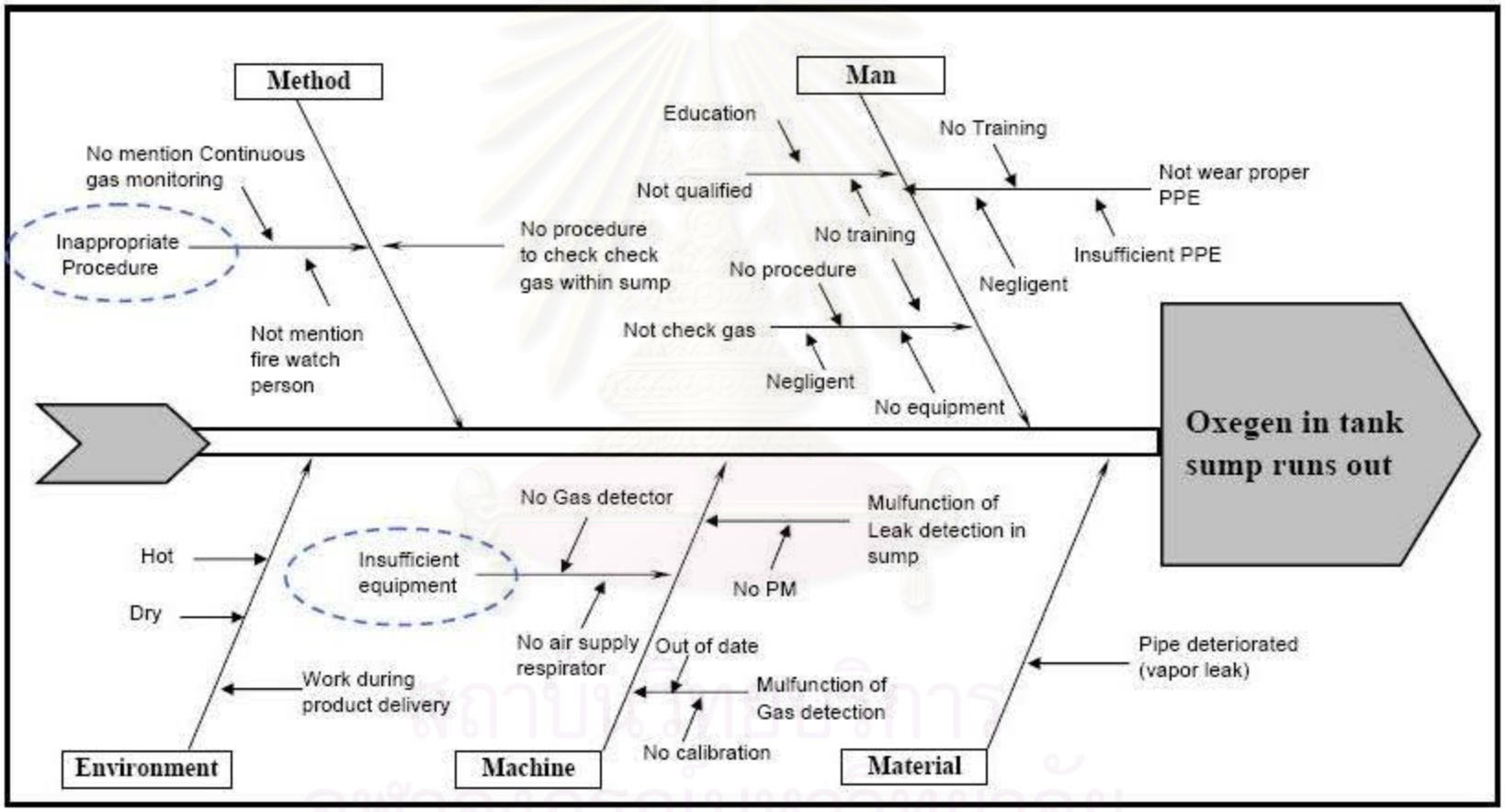


Figure 4-14: Fishbone Diagram of Sling Torn while lifting U/G Tank

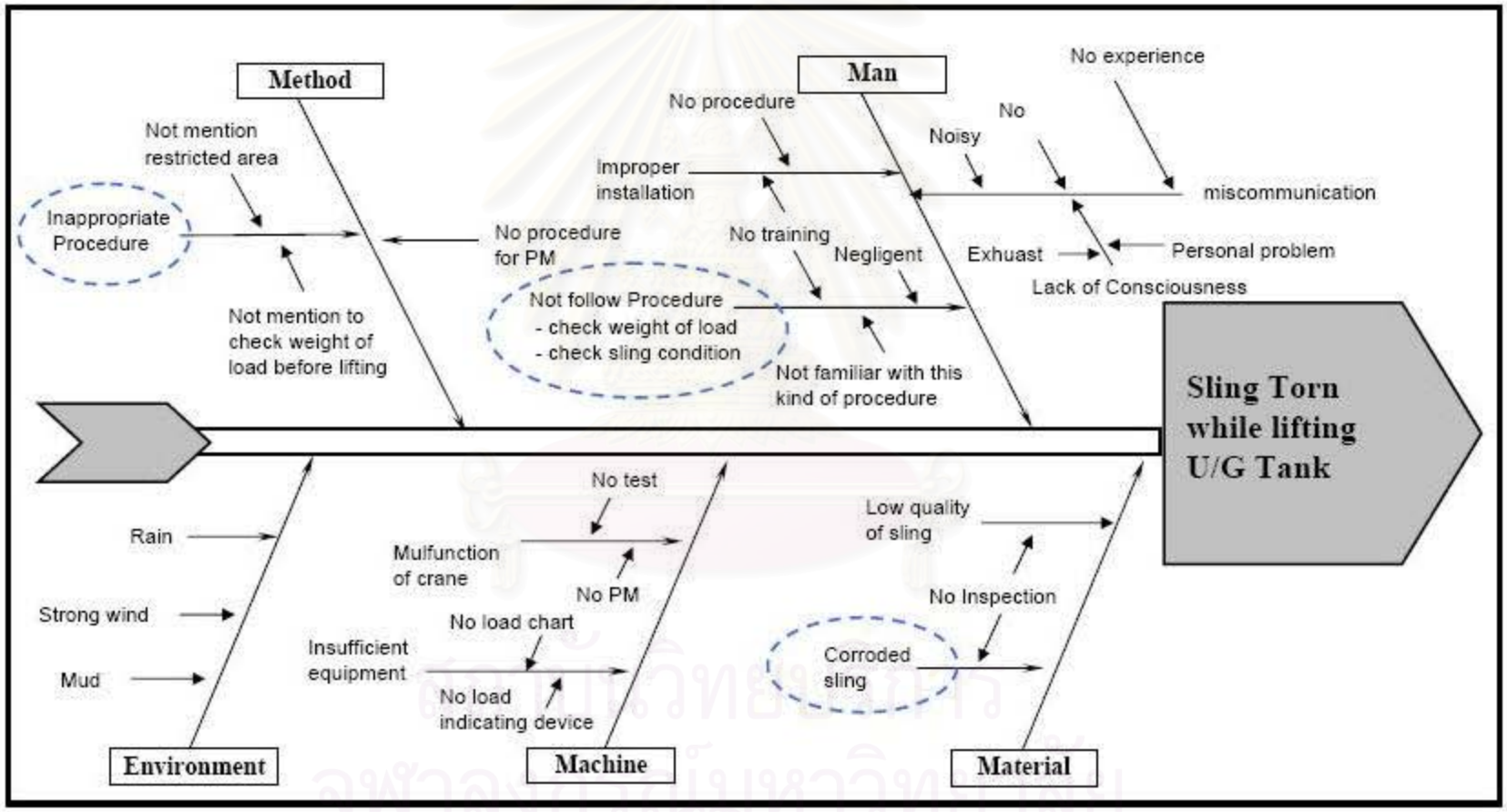


Figure 4-15: Fishbone Diagram of Crane Collapsed while lifting U/G Tank

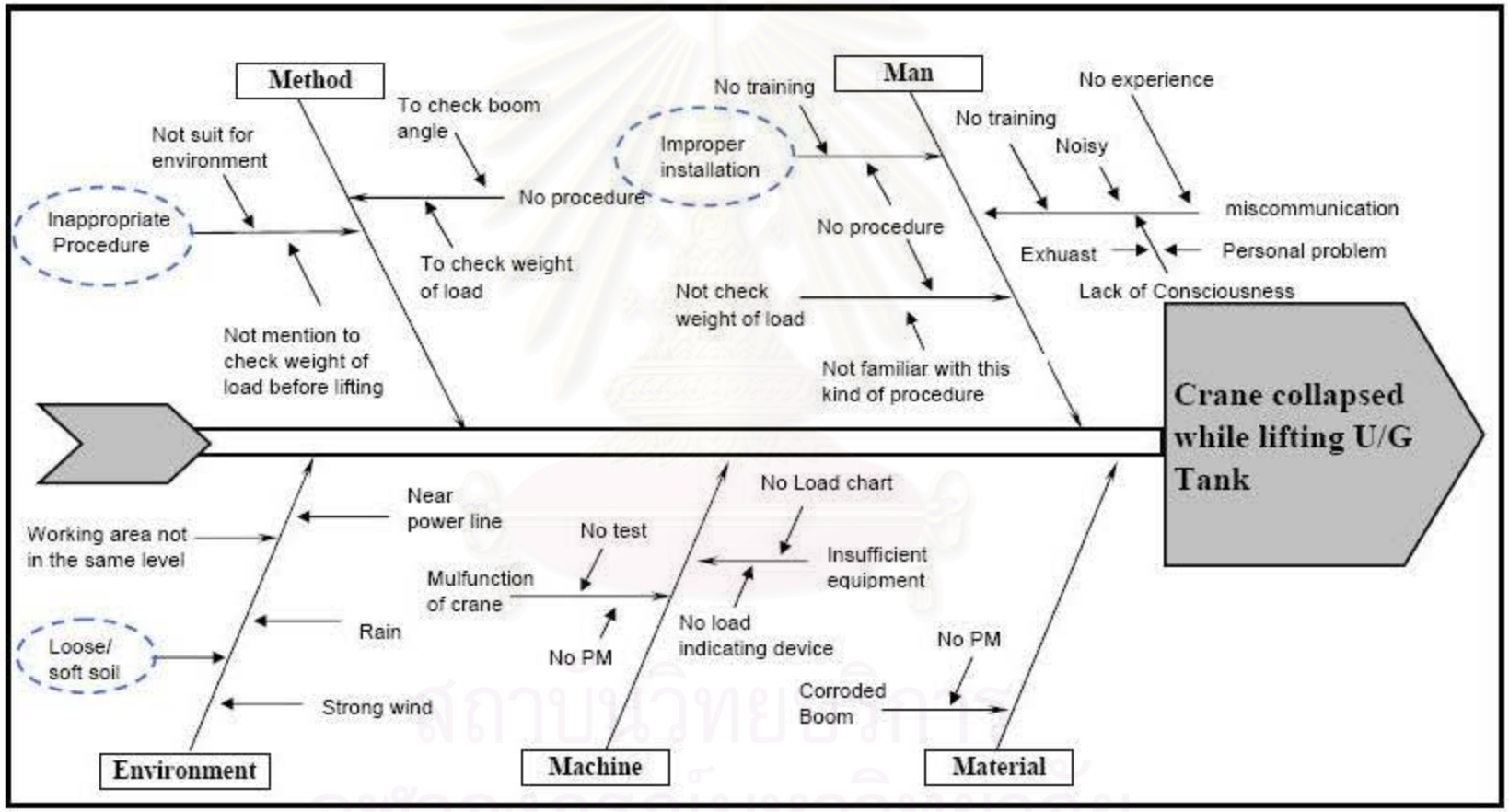
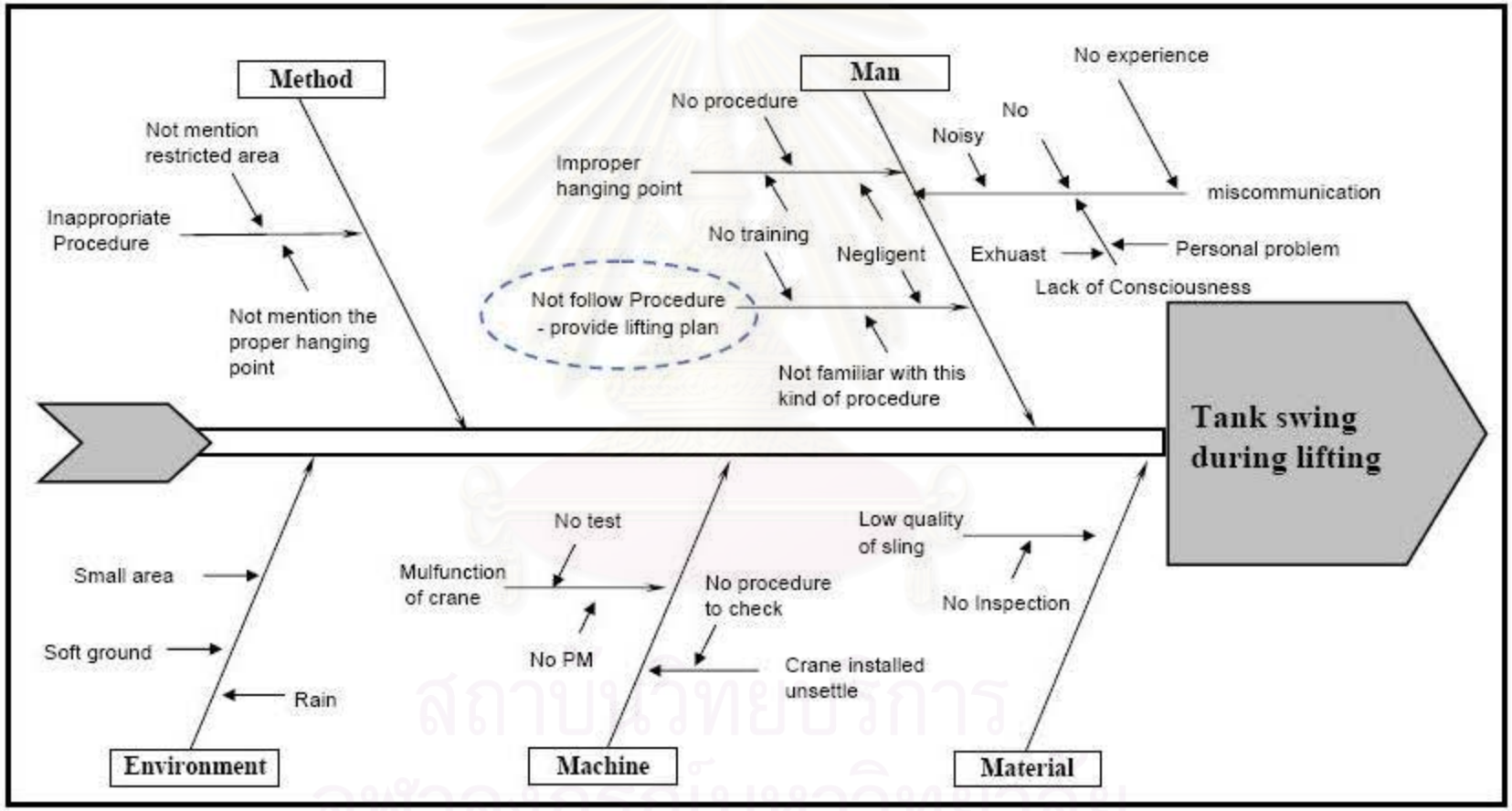


Figure 4-16: Fishbone Diagram of Tank Swing During Lifting



According to Fishbone diagram of seven maintenance tasks, all potential root causes of each were screened out in order to keep focus on the key potential root causes. The criterion for screen out the weak root causes is to consider the severity, occurrence of its effect. Finally, team came up with thirty-two potential root causes from fifteen failures modes.

These failure modes and their potential root causes were processed in further analysis process by applying Failure Modes and Effects Analysis technique (FMEA). By this technique, the level of severity, occurrence and detection will be rated in order to evaluate the risk priority of each potential root cause.

Before conducting Failure Modes and Effects Analysis, rating criterion needs to be established. Generally, rating scale of ten is widely applied in FMEA. However, there are some studies which applied different criterion of rating scale. For example, in 2005 Kittipong applied FMEA with rating scale of five in his study of "Safety Management System for Hazardous Substance Transportation based-on Risk Analysis". In this study, after considering the incident data (See Table 3-1) and found the five categories of incident severity which are generated customer are composed of:

- Near Miss
- First Aid
- Worse than First Aid (Medical treatment)
- Lost Time
- Fatality

Then, in order to match with criterion established by customer, rating scale of five seems to be the most appropriate with this study. The criterion for each rating scale is illustrated as following Table 4-4, 4-5 and 4-6.

Table 4-4: Rating Criterion of Severity

Ranking	Description	Definition
1	Very Minor	No injury or Financial loss is less than 1000 THB
2	Minor	Minor injury (First Aid Treatment) or Financial loss is between 1000 THB and 5000 THB
3	Moderate	Injury (Medical Treatment), Leave from work less than 24 hours or Financial loss is between 5000 THB and 20000 THB
4	Major	Injury (Medical Treatment), Leave from work more than 24 hours or Financial loss is between 20000 THB and 50000 THB
5	Very Major	Injury with loss of organ,death or Financial loss is more than 50000 THB

Table 4-5: Rating Criterion of Occurrence

Ranking	Description	Definition
1	Very Low	0 occurrence within past 3 years
2	Low	1 occurrence within past 3 years
3	Moderate	2 occurrences within past 3 years
4	High	3 occurrences within past 3 years
5	Very High	more than 4 occurrences within past 3 years

Table 4-6: Rating Criterion of Detection

Ranking	Description	Definition
1	Very High	The defect is obvious detected
2	High	Controls in place and small chance for undetected defect
3	Moderate	Controls in place but small chance to detect defect
4	Low	Controls in place but not generally detect the defect
5	Very Low	The defect is not detectable

For rating criterion of Severity, team decided to take financial issue into account even so far the case company did not focus on financial impact so much, just emphasis in impact to operator. However, with this criterion, it went well with case which does not have any impact to operator but have significant impact in property damaged like the incident at Nakornpathom.

For rating criterion of Occurrence, even the case company has provided maintenance service for the case client since 2001, the data related to incidents for the first four years is not completed and not kept as formal format. Therefore, incident data for this study is based on incident occurred during year 2005 – 2007. Also, regarding to Table 3-1, the incident rate since 2001 is not big number, so the criterion as in Table 4-5 was found as the best suit for this study.

The Failure Mode and Effect Analysis for five failure modes and their twenty potential root causes are illustrated as following Table 4-7

Table 4-7: Failure Modes and Effects Analysis

FMEA Number:	XXXXX
Page	1 of 10
Prepared by:	Karun P.
FMEA Date (Orig.)	15-May-08 Rev. 0

Process Name: Working at Height

Design Responsibility: SHE Manager, Contractor's Safety Officer & Safety Committee

Core Team: SHE Manager, M&R Field Managers, Site person & Contractors' safety officer

Process / Function	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Potential Cause(s)/ Mechanism(s) of Failure	Occur	Current Design Controls	Detec	R.P.N.	Recommended Action(s)	Responsibility	Expected Sev	Expected Occur	Expected Detec	Expected R.P.N.
Working at Height	Scaffold Collapsed	Worker fall down and die	5	Unsafe Act of Worker on scaffold	4	Unannounced Site Visit & Loss Prevention Observation by M&R Field managers	3	60	Provide training to ensure getting qualified worker & Implement Internal Loss Prevention Observation (ILPO) & Reorganize Work Authority System	SHE Manager, FMs & Safety Officers	5	2	2	20
			5	Improper Procedure (During removing scaffold)	2	Working Procedure/JSA conducted by contractor & revied by SHE Manager	3	30	Conduct safety committee to review working procedure/JSA generated by contractor and set as standardizd procedure	Safety Committee & contractor's Safety officer	5	1	1	5
			5	Scaffold not meet standard (No wheel locker)	4	Checklist for working at height	2	20	Provide training to ensure getting qualified worker & Implement Internal Loss Prevention Observation (ILPO)	SHE Manager & Contractor's Safety officer	5	2	1	10

Table 4-7: Failure Modes and Effects Analysis (Con't)

FMEA Number:	XXXXX
Page	2 of 10
Prepared by:	Karun P.
FMEA Date (Orig.)	15-May-08 Rev. 0

Process Name: Working at Height

Design Responsibility: SHE Manager, Field Manager & Contractor's Safety Officer

Core Team: SHE Manager, M&R Field Managers, Site person & Contractors' safety officer

Process / Function	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Potential Cause(s)/ Mechanism(s) of Failure	Occur	Current Design Controls	Detec	R.P.N.	Recommended Action(s)	Responsibility	Expected Sev	Expected Occur	Expected Detec	Expected R.P.N.
Working at Height	Tools fallen from Scaffold	Fallen stuff hit people nearby caused injury	4	Unsafe Act of Worker on scaffold	5	Unannounced Site Visit & Loss Prevention Observation by M&R Field managers	3	60	Provide training to ensure getting qualified worker & Implement Internal Loss Prevention Observation (ILPO) & Reorganize Work Authority System	SHE Manager, FMs & Contractors' safety officer	4	2	2	16
			4	Scaffold not meet standard (No Toe plate)	5	Checklist for working at height	1	20	Provide training to ensure getting qualified worker & Implement Internal Loss Prevention Observation (ILPO)	SHE Manager, FMs & Contractors' safety officer	4	1	1	4
	Basket of Cherry picker hit building	Worker fall down and die	5	Miscomunication between worker on scaffold & M/C controller	3	Work Authorization System (Only for supervisor)	3	45	Provide training to ensure getting qualified worker & Implement Internal Loss Prevention Observation (ILPO) & Reorganize Work Authority System	SHE Manager, FMs & Contractors' safety officer	5	2	2	10

Table 4-7: Failure Modes and Effects Analysis (Con't)

FMEA Number:	XXXXX
Page	3 of 10
Prepared by:	Karun P.
FMEA Date (Orig.)	15-May-08 Rev. 0

Process Name: Working related to Electricity

Design Responsibility: Account Manager, Project Manager, SHE Manager & Contractors' Safety officer

Core Team: SHE Manager, M&R Field Managers, Site person & Contractors' safety officer

Process / Function	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Potential Cause(s)/ Mechanism(s) of Failure	Occur	Current Design Controls	Detec	R.P.N.	Recommended Action(s)	Responsibility	Expected Sev	Expected Occur	Expected Detec	Expected R.P.N.
Working related to Electricity	Spark from Electrical short circuit	Explosion/Fire incident	5	Deteriorated Wire/Electrical devices	4	No control	5	100	Conduct Preventive Maintenance for electrical system in Petrol station	Account Manager & Project Manger	5	2	2	20
			5	Not check live electrical line & isolate it	5	Unannounced Site Visit & Loss Prevention Observation by M&R Field managers	4	100	Provide training to ensure getting qualified worker & Implement Internal Loss Prevention Observation (ILPO) & Reorganize Work Authority System	SHE Manager, FMs & Safety Officers	5	3	3	45
			5	Insufficient Equipment (No Lock out/Tag out device)	2	No control	5	50	Identify the required equipments in working procedure/JSA	SHE Committee & contractor's Safety officer	5	1	1	5

Table 4-7: Failure Modes and Effects Analysis (Con't)

FMEA Number:	XXXXX
Page	4 of 10
Prepared by:	Karun P.
FMEA Date (Orig.)	15-May-08 Rev. 0

Process Name: Working related to Hot Work

Design Responsibility: SHE Manager, Field Manager & Contractor's Safety Officer

Core Team: SHE Manager, M&R Field Managers, Site person & Contractors' safety officer

Process / Function	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Potential Cause(s)/ Mechanism(s) of Failure	Occur	Current Design Controls	Detec	R.P.N.	Recommended Action(s)	Responsibility	Expected Sev	Expected Occur	Expected Detec	Expected R.P.N.
Working related to Hot Work	Spark from Knocking / Grinding work	Explosion/Fire incident	5	Insufficient Equipment (No Gas Detector)	1	No control	5	25	Revise Working Procedure/JSA by identify the required equipments for such work	SHE Committee & contractor's Safety officer	5	1	1	5
			5	Not check gas before working	3	Unannounced Site Visit & Loss Prevention Observation by M&R Field managers	4	60	Provide training to ensure getting qualified worker & Implement Internal Loss Prevention Observation (ILPO) & Reorganize Work Authority System	SHE Manager, FMs & Safety Officers	5	2	3	30

Table 4-7: Failure Modes and Effects Analysis (Con't)

FMEA Number:	XXXXX
Page	5 of 10
Prepared by:	Karun P.
FMEA Date (Orig.)	15-May-08 Rev. 0

Process Name: Working related to Trenching

Design Responsibility: SHE Manager, Field Manager & Contractor's Safety Officer

Core Team: SHE Manager, M&R Field Managers, Site person & Contractors' safety officer

Process / Function	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Potential Cause(s)/ Mechanism(s) of Failure	Occur	Current Design Controls	Detec	R.P.N.	Recommended Action(s)	Responsibility	Expected Sev	Expected Occur	Expected Detec	Expected R.P.N.
Working related to Trenching / Excavation	Spark from Welding / Grinding	Explosion/Fire incident	5	Not check gas before working	2	Unannounced Site Visit & Loss Prevention Observation by M&R Field managers	3	30	Provide training to ensure getting qualified worker & Implement Internal Loss Prevention Observation (ILPO) & Reorganize Work Authority System	SHE Manager, FMs & Safety Officers	5	1	2	10
			5	Improper Procedure (Not state Cooling ground process)	2	Working Procedure/JSA conducted by contractor & revied by SHE Manager	3	30	Conduct safety committee to review working procedure/JSA generated by contractor and set as standardizd procedure	Safety Committee & contractor's Safety officer	5	1	1	5
	Saw Blade Broken	Injury / Loss of Organ	5	Deteriorated Blade	1	No Control	5	25	Revise Working procedure /JSA by state the process of equipment check	Safety Committee & contractor's Safety officer	5	1	1	5
			5	Saw blade was loosely installed	1	No Control	5	25	Revise Working procedure /JSA by state the process of equipment check	Safety Committee & contractor's Safety officer	5	1	1	5

Table 4-7: Failure Modes and Effects Analysis (Con't)

FMEA Number:	XXXXX
Page	6 of 10
Prepared by:	Karun P.
FMEA Date (Orig.)	15-May-08 Rev. 0

Process Name: Working related to Chemical substance
Design Responsibility: SHE Manager, Field Manager & Contractor's Safety Officer
Core Team: SHE Manager, M&R Field Managers, Site person & Contractors' safety officer

Process / Function	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Potential Cause(s)/ Mechanism(s) of Failure	Occur	Current Design Controls	Detec	R.P.N.	Recommended Action(s)	Responsibility	Expected Sev	Expected Occur	Expected Detec	Expected R.P.N.
Working related to Chemical / hazardous substance	Product spilled & released into Public	Explosion/Fire incident	5	Drain comtaminated water directly into public	4	Unannounced Site Visit & Loss Prevention Observation by M&R Field managers	4	80	Provide training to ensure getting qualified worker & Implement Internal Loss Prevention Observation (ILPO) & Reorganize Work Authority System	SHE Manager, FMs & Safety Officers	5	1	1	5
			5	Improper Porcedure (No mention about removing contaminated water)	2	Working Procedure/JSA conducted by contractor & revied by SHE Manager	3	30	Conduct safety committee to review working procedure/JSA generated by contractor and set as standardizd procedure	Safety Committee & Contractor's Safety officer	5	1	1	5
	Spark from static electricity during Meter Test	Explosion / Electrocution	5	Improper Procedure (No mention about installing ground system)	2	Working Procedure/JSA conducted by contractor & revied by SHE Manager	3	30	Conduct safety committee to review working procedure/JSA generated by contractor and set as standardizd procedure	Safety Committee & Contractor's Safety officer	5	1	1	5
			5	Not install ground system	3	Unannounced Site Visit & Loss Prevention Observation by M&R Field managers	4	60	Provide training to ensure getting qualified worker & Implement Internal Loss Prevention Observation (ILPO) & Reorganize Work Authority System	SHE Manager, FMs & Safety Officers	5	2	3	30

Table 4-7: Failure Modes and Effects Analysis (Con't)

FMEA Number:	XXXXX
Page	7 of 10
Prepared by:	Karun P.
FMEA Date (Orig.)	15-May-08 Rev. 0

Process Name: Working related to Confined space & Chemical substance

Design Responsibility: SHE Manager, Field Manager & Contractor's Safety Officer

Core Team: SHE Manager, M&R Field Managers, Site person & Contractors' safety officer

Process / Function	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Potential Cause(s)/ Mechanism(s) of Failure	Occur	Current Design Controls	Detec	R.P.N.	Recommended Action(s)	Responsibility	Expected Sev	Expected Occur	Expected Detec	Expected R.P.N.
Working related to Chemical / hazardous substance	Paint gets into body	Loss of organ	4	Operator not wear proper PPE (Unsafe act)	2	Unannounced Site Visit & Loss Prevention Observation by M&R Field managers	3	24	Provide training to ensure getting qualified worker & Implement Internal Loss Prevention Observation (ILPO) & Reorganize Work Authority System	SHE Manager, FMs & Safety Officers	4	1	2	8
Working related to Confined space	Spark within tank sump	Explosion/Fire incident	5	Not check gas	2	Unannounced Site Visit & Loss Prevention Observation by M&R Field managers	3	30	Provide training to ensure getting qualified worker & Implement Internal Loss Prevention Observation (ILPO) & Reorganize Work Authority System	SHE Manager, FMs & Safety Officers	5	1	2	10
			5	Improper Porcedure (No mention about continually check gas)	2	Working Procedure/JSA conducted by contractor & revied by SHE Manager	3	30	Conduct safety committee to review working procedure/JSA generated by contractor and set as standardizd procedure	Safety Committee & contractor's Safety officer	5	1	1	5
			5	Not use spark-free tools (not available)	2	Unannounced Site Visit & Loss Prevention Observation by M&R Field managers	3	30	Provide training to ensure getting qualified worker & Implement Internal Loss Prevention Observation (ILPO) & Reorganize Work Authority System	SHE Manager, FMs & Safety Officers	5	1	2	10

Table 4-7: Failure Modes and Effects Analysis (Con't)

FMEA Number:	XXXXX
Page	8 of 10
Prepared by:	Karun P.
FMEA Date (Orig.)	15-May-08 Rev. 0

Process Name: Working related to Confined space

Design Responsibility: SHE Manager, Field Manager & Contractor's Safety Officer

Core Team: SHE Manager, M&R Field Managers, Site person & Contractors' safety officer

Process / Function	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Potential Cause(s)/ Mechanism(s) of Failure	Occur	Current Design Controls	Detec	R.P.N.	Recommended Action(s)	Responsibility	Expected Sev	Expected Occur	Expected Detec	Expected R.P.N.
Working related to Confined space	Oxegen in tank sump run out	Unconcious and death	5	No Air supply respirator	1	No control	5	25	Revise Working Procedure/JSA by identify the required equipments for such work	SHE Committee & contractor's Safety officer	5	1	1	5
			5	Improper Procedure (No fire watch person)	3	Working Procedure/JSA conducted by contractor & revied by SHE Manager	3	45	Conduct safety committee to review working procedure/JSA generated by contractor and set as standardizd procedure	Safety Committee & contractor's Safety officer	5	1	1	5

Table 4-7: Failure Modes and Effects Analysis (Con't)

FMEA Number:	XXXXX
Page	9 of 10
Prepared by:	Karun P.
FMEA Date (Orig.)	15-May-08 Rev. 0

Process Name: Working related to Crane Operation

Design Responsibility: SHE Manager, Field Manager & Contractor's Safety Officer

Core Team: SHE Manager, M&R Field Managers, Site person & Contractors' safety officer

Process / Function	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Potential Cause(s)/ Mechanism(s) of Failure	Occur	Current Design Controls	Detec	R.P.N.	Recommended Action(s)	Responsibility	Expected Sev	Expected Occur	Expected Detec	Expected R.P.N.
Working related to Crane operation	Sling torn during lifting U/G tank	Tank swing and hit worker nearby caused death	5	Corroded Sling	2	No Control	5	50	Revise Working procedure /JSA by state the process of equipment check	Safety Committee & contractor's Safety officer	5	1	1	5
			5	Improper Porcedure (No mention about restricted area	2	Working Procedure/JSA conducted by contractor & revied by SHE Manager	3	30	Conduct safety committee to review working procedure/JSA generated by contractor and set as standardizd procedure	Safety Committee & contractor's Safety officer	5	1	1	5
			5	Not check weight of load	2	Unannounced Site Visit & Loss Prevention Observation by M&R Field managers	3	30	Provide training to ensure getting qualified worker & Implement Internal Loss Prevention Observation (ILPO) & Reorganize Work Authority System	SHE Manager, FMs & Safety Officers	5	1	1	5

Table 4-7: Failure Modes and Effects Analysis (Con't)

FMEA Number:	XXXXX
Page	10 of 10
Prepared by:	Karun P.
FMEA Date (Orig.)	15-May-08 Rev. 0

Process Name: Working related to Crane Operation

Design Responsibility: SHE Manager, Field Manager & Contractor's Safety Officer

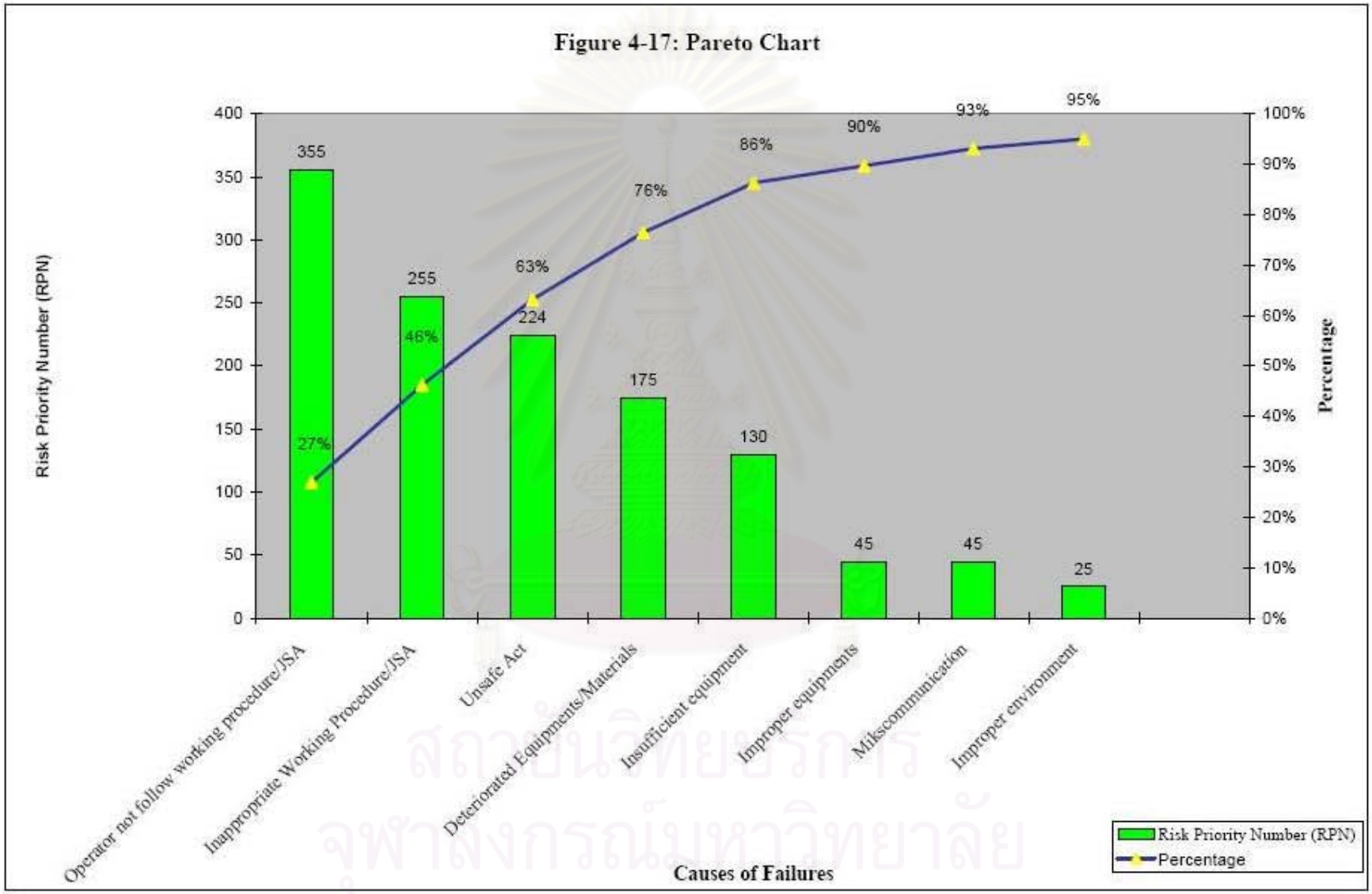
Core Team: SHE Manager, M&R Field Managers, Site person & Contractors' safety officer

Process / Function	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Potential Cause(s)/ Mechanism(s) of Failure	Occur	Current Design Controls	Detec	R.P.N.	Recommended Action(s)	Responsibility	Expected Sev	Expected Occur	Expected Detec	Expected R.P.N.
Working related to Crane operation	Crane Collapsed during lifting A/G water tank	Crane damaged & hit operator caused death	5	Improper installation	2	Checklist for Crane operation	2	10	Provide training to ensure that getting qualified worker & Identify checklist for crane operation as the working process in JSA	SHE Manager & Contractors' safety officer	5	1	1	5
			5	Improper Porcedure (No mention about load check)	2	Working Procedure/JSA conducted by contractor & revied by SHE Manager	3	30	Conduct safety committee to review working procedure/JSA generated by contractor and set as standardizd procedure	Safety Committee & contractor's Safety officer	5	1	1	5
			5	Improper Environment (Loose / soft soid)	1	No Control	5	25	Revise Working procedure /JSA by state the process of working area/environment check	Safety Committee & contractor's Safety officer	5	1	1	5
	Tank/DP/Sign pole swing during lifting	Tank hits building (property damaged) or hit operator nearby (death)	5	No lifting plan	3	Unannounced Site Visit & Loss Prevention Observation by M&R Field managers	3	45	Provide training to ensure getting qualified worker & Implement Internal Loss Prevention Observation (ILPO) & Reorganize Work Authority System	SHE Manager, FMs & Safety Officers	5	1	1	5

According to Table 4-7, it demonstrates the failure modes and their effects. The table also, provides the potential root causes, current controls, recommended actions, along with the Risk Priority Number (RPN). Even the case company would like to take all recommended action into account; it seems to take a lot of time and can not be finished during the period of this study. Therefore, some trivial issues were sorted out and the majorities were focused.

The principle that is applied for sorting the outstanding issues is Pareto principle. By Pareto diagram, the RPN data from FMEA are converted to be the bar chart as demonstrated in the following Figure 4-17.

Figure 4-17: Pareto Chart



According to Pareto chart in Figure 4-17, it obviously shows that there are four major potential root causes for seven categories of M&R tasks, consisting of:

- Operator not follow working procedure
- Inappropriate working procedure
- Unsafe act
- Deteriorated Equipment/Materials

Therefore, in this study these four potential causes will be focused and the potential actions to cope such causes will be developed in order to enhance safety performance. In next chapter, the recommended actions will be proposed. However, for the proposed action related to preventive maintenance program, this study will not go to the deep details of its scope due to time constraint. So, it will be left for responsible person like Account manager and Project engineer to study further about scope of preventive maintenance program.

Moreover, there are some concerned issues which seem to be the weak point such as incident investigation procedure and training system. Even these issues were not resulted from the analysis, it is obviously found as obstacle for safety performance enhancement. So, the recommended incident investigation procedure and training system will be proposed in next chapter in order to in order to make this study more effective.

CHAPTER V

PROPOSED SOLUTIONS AND IMPLEMENTATION

5.1 Introduction

In this chapter, the results/gaps from analyzing both current safety management system and past incidents will be converted to the recommended actions and procedures which the study team would like to propose in order to minimize or even close such gaps and enhance safety performance of the case company, client and contractors, as well.

5.2 Work Authorization System

- **Objective**

  To ensure that all operators who perform maintenance service at petrol service station are qualified according to mandatory safety requirement. (Safety for operation level & Safety for supervisory level)

- **Scope**

  Work Authorization System shall be implemented to all subcontractors' operators who perform maintenance service at Client's petrol service station.

- **Definition**

  a. Work Authorization card (Level I) refers to a license for person who is qualified according to safety requirement for operation level. The holder is allowed to perform maintenance service at petrol service station.

  b. Work Authorization card (Level II) refers to a license for person who is qualified according to safety requirement for supervisory level. The holder is allowed to perform maintenance service at petrol service station and able to conduct safety training program (Operation level) for subordinates.

- **Responsibility**

  a. SHE specialist is responsible for conducting the paper tests for both operation level and supervisory level and evaluating the testing result.
  b. Account administrator is responsible for preparing place and materials for safety paper test.
  c. Subcontractors' safety officers are responsible for updating the operators' name list to SHE specialist and monitoring the valid period of each work authorization card, as well.
  d. All subcontractors' operators who perform maintenance service at petrol service station shall be qualified according to safety requirement for operation level as minimum.

- **Procedures**

  The procedures for issuing work authorization card (Level I) and (Level II) are shown as following Figure 5-1 and Figure 5-2, respectively:

  a. For operation level (Level I), subcontractors' safety officers shall notify SHE specialist to request for safety examination for new operators or card-expired operators. Basically, new operators should get the safety training from their supervisor or Safety officer.
  b. For supervisory level (Level II), subcontractors' safety officers shall notify SHE specialist to request for safety training program for the new employed supervisor/safety officer or the refresh program for card-expired supervisor.
  c. Account Administrator shall contact subcontractors at least one week in advance to notify the training date (Level II) or the examination date (Level I) and prepare place and related materials.
  d. SHE specialist conducts training program/examination and evaluates the result for both levels.
  e. Once the testing result was announced, the one who fail the test shall attend retraining program (Level II) or retest (Level I) until pass.

f. For the one who pass the test, SHE specialist shall issue Work authorization card which is valid for two years.

- **Related document**

a. Work Authority Card (Figure 5-3)

Figure 5-1: Process of Issuing Work Authorization Card (Level I)

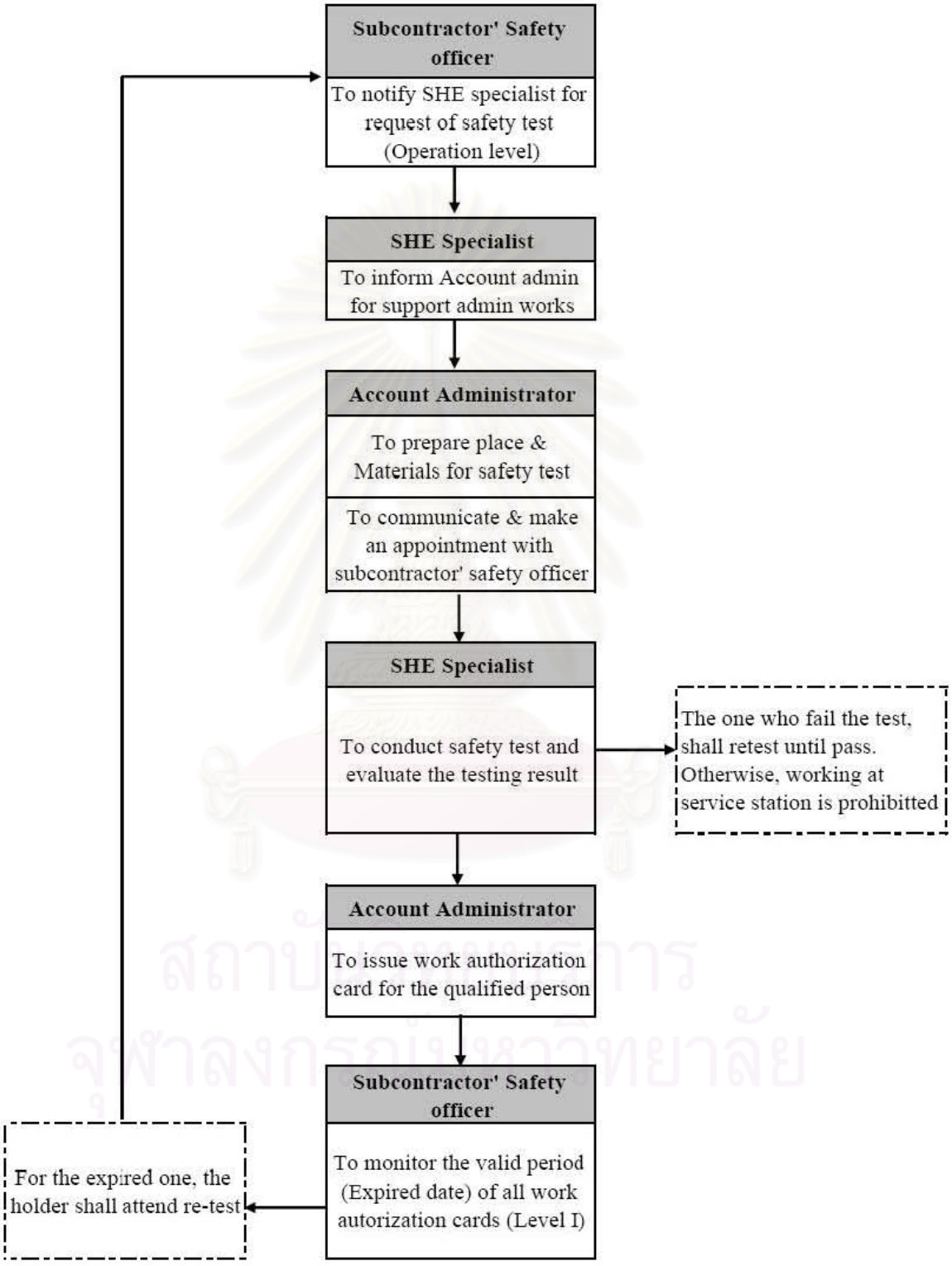


Figure 5-2: Process of Issuing Work Authorization Card (Level II)

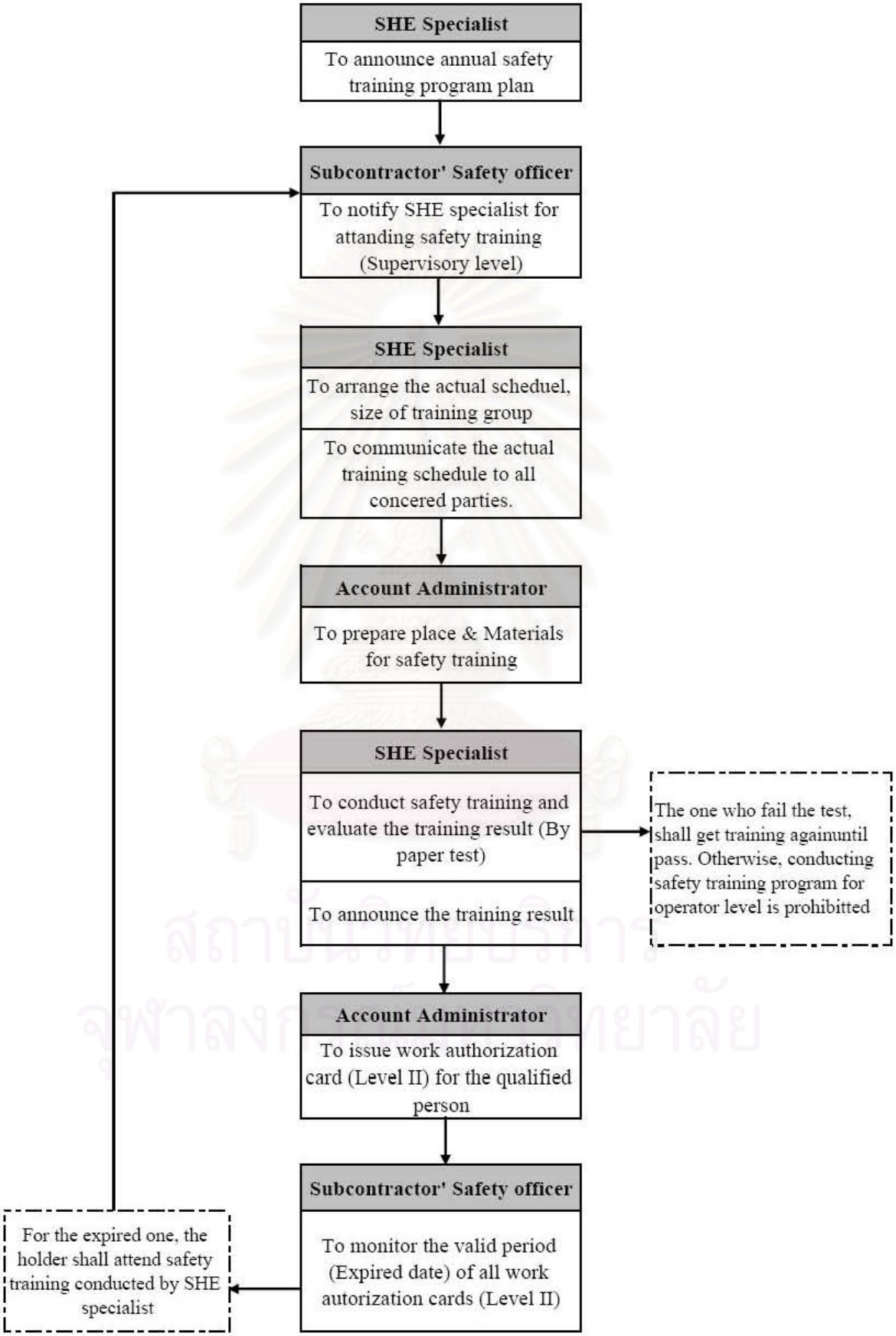


Figure 5-3: Work Authorization Card

5.3 Safety Training System

Form the result of past incident analysis, Safety training is the crucial issue which shall be provided appropriately for both direct employees and subcontractor. In this section, safety training system is revised in order to be proposed and implemented, accordingly.

- **Objective**

  To ensure that all levels from subcontractor to employees involved in maintenance of petrol service station are equipped with the knowledge, skills and regulatory requirements to eliminate work-related injuries and illness and to promote a safe and healthy environment.

- **Scope**

  Safety training system is provided for all project members and subcontractors who involve in maintenance of petrol service station.

- **Definition**

  b. Subcontractors who participate in safety training conducted by the case company shall be in the supervisory level such as safety officer, supervisor, etc.
  c. Safety training program refers to program for training the trainer, not operator.

- **Responsibility**

  a. Account manager is responsible for specifying the safety training requirement for all project members and subcontractors and ensuring that adequate training takes place.
  b. SHE specialist is responsibility for conducting the annual safety training plan and keep update the information for reporting to Account manager. SHE specialist also plays the role in conducting safety orientation for new project member and safety training program.

c. Account administrator is responsibility for contacting and making appointment with all concerned parties, preparing place and materials for safety training program.

d. All project members and subcontractors are responsible for participate the safety training programs according to safety training requirement for each position.

- **Procedures**

Safety training procedures shall be in compliance as per Figure 5-4.

a. SHE specialist conducts annual safety training plan regarding to safety training requirement set by Account manager

b. The safety training plan shall be reviewed and endorsed by Account manager in order to ensure that the adequate training programs are provided.

c. After endorsement, SHE specialist shall communicate the annual safety training plan to all concerned parties in advance.

d. All concerned parties who are interested in attending safety training course shall notify their intention to SHE specialist.

e. After consolidating list of attendees, SHE specialist shall arrange the actual schedule of training course and communicate to all concerned parties.

f. Then, Account administrator shall support SHE specialist by preparing place and materials for training program.

g. SHE specialist conducts the training program. After the completion of each program, trainees shall be evaluated by paper test.

h. The evaluation result shall be reported to Account manager and trainees' supervisor (For subcontractors). Also, the result shall be updated into individual training record by SHE specialist (only project member)

i. For attendees who failed the test, shall re-attend safety training course and re-test until pass the test.

In case of additional request for safety training program, the requester shall notify SHE specialist with some detail. And then, issue is raised to Account manager for review and endorsement.

- **Related Documents**

  a. Individual Training Record Form (Table 5-1)
  b. Training courses (Table 5-2)

Figure 5-4: Safety Training Process

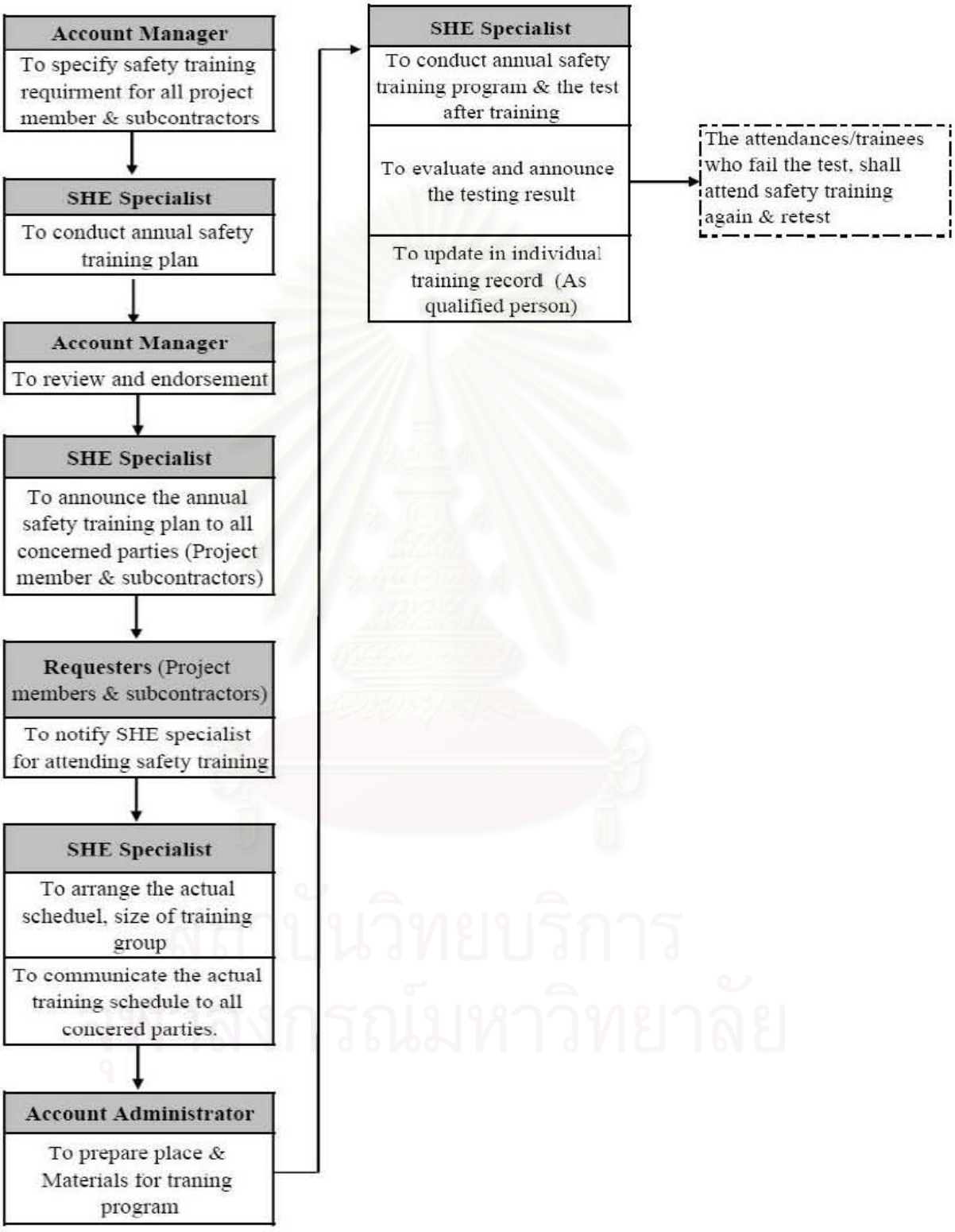


Table 5-1: Individual Training Record Form

	Individual Training Record

Name _____ Department _____

Position _____ Employment Date _____

Training Program	Evaluated Result	Date Training Completed	Trainers Signature/ Supervisor Signature	Remark
			....	
			....	
			....	
			....	
			....	

Table 5-2: Training Courses

Training Course	Organizer	Refresher Frequency	Attendees	
			Project Staff	Subcontractor
Defensive Driving (Client's Requirement)	Client	3 yrs.	Yes	Some of staff (*)
Work Authorization System	SHE Specialist	2 yrs.	Yes	Some of staff
Safety Regulation in Petrol Station	SHE Specialist	2 yrs.	Yes	Some of staff
Emergency Response (Including First Aid, Fire Extinguisher Using)	SHE Specialist	2 yrs.	Yes	Some of staff
Incident Investingation & Reporting Guideline	SHE Specialist	2 yrs.	Yes	Some of staff
Working at Height	SHE Specialist	-	Yes	Some of staff
Operation of Crane	SHE & Specialist	-	Yes	Some of staff
Hot Work	SHE & Specialist	-	Yes	Some of staff
Electrical Work	SHE & Specialist	-	Yes	Some of staff
Confined Space Entry	SHE & Specialist	-	Yes	Some of staff
Working with Chemical Substance	SHE & Specialist	-	Yes	Some of staff

(*) Couse is conducted by SHE specialist

5.4 Internal Loss Prevention Observation

Loss Prevention Observation (LPO) is one key activity which purposes to observe the way operator performs maintenance task at service station and then, discuss with operator about improper things and the improvement. So far, this activity has been implemented in between project member and subcontractor. Due to workload, project members sometimes can not perform LPO as it should be especially when subcontractor perform at service station far away from the case company office. By this gap, it is more likely for operator to feel more comfortable and not comply with the designed work procedure. Consequently, the unsafe act may lead to the occurrence of incident.

- **Objective**

  To ensure that all maintenance operators act safely and comply with the designed working procedure properly during performing maintenance tasks in service station.

- **Scope**

  Internal Loss Prevention Observation (ILPO) shall be implemented to all subcontractors who perform high risk/medium risk tasks within service station.

- **Definition**

  a. Internal Loss Prevention Observation (ILPO) refers to activity for observing the working behavior of subordinates/colleagues while performing maintenance tasks at service station. This activity is conducted by subcontractor itself.
  b. High risk tasks defined by client refer to tasks related to confined space entry, hot work within hazardous zone, trenching & excavation and lifting by crane operation.
  c. Medium risk tasks defined by client refer to tasks related to working at height (more than 1.8 m.), electrical, hot work outside hazardous area and wasted oil removal.

- **Responsibility**

  a. SHE specialist is responsible for setting ILPO target for each subcontractor. Once ILPO report with questionable issue submitted, SHE specialist shall bring it into meeting with safety committee.
  b. Safety officer is responsible for assigning supervisor/operators to perform ILPO as per target given and also, consolidating report and submit to SHE specialist.
  c. Subcontractor is responsible to perform ILPO.
  d. Safety committee is responsible for review ILPO report regularly and find out the solution for questionable issue.

- **Procedures**

  The ILPO process shall be compliance with the following Figure 5-5

  a. SHE specialist shall set the ILPO target for all subcontractors who perform high/medium risk tasks and communicate this set target to all concerned parties.
  b. Safety officer shall assign supervisors/operators who have been trained in LPO course to perform ILPO. On the other hand, safety officer may perform by herself.
  c. In performing ILPO, the observer shall make appoint with the observed operator in advance. When ILPO completion, observer shall discuss and summaries the good things and questionable issue with the observed operator. And then, observer conducts report to safety officer.
  d. Safety officer consolidates the ILPO report and submits to SHE specialist regularly.
  e. SHE specialist shall review the submitted report and sort out the report with questionable issue and then, bring it to meeting with safety committee.
  f. Safety committee shall review the ILPO report with questionable issue and find out the root cause along with potential solution.
  g. SHE specialist shall communicate and implement the solution to all concerned parties and keep record.
  h. After implement the solution, Safety officer shall keep observe the operator who caused the questionable issue and then, report the new ILPO to SHE specialist.

- **Related Document**

  a. Hazardous zone (Figure 4-1)
  b. Loss Prevention Observation Form (Figure 5-6)

Figure 5-5: Internal Loss Prevention Observation Process

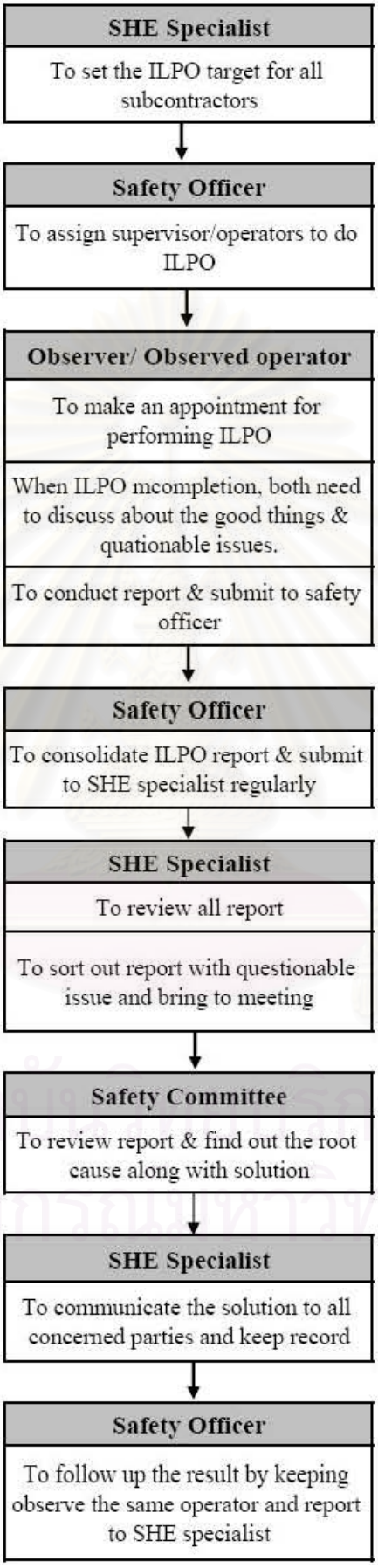


Figure 5-6: Internal Loss Prevention Observation Form

แบบฟอร์มการตรวจสอบการทำงาน

สถานที่/ชื่อสถานี	อำเภอ	จังหวัด	วันที่ตรวจสอบ	เวลา

ผู้ตรวจสอบ	ผู้ถูกตรวจสอบ
ชื่อ:	ชื่อ:
ชื่อบริษัท:	ชื่อบริษัท:
ตำแหน่ง:	ตำแหน่ง:
ประเภทงาน:	

ประเภทงานที่สังเกต:

	การค้นพื้นที่ทำงาน		งานรื้อถอน/กำจัด		งานตัดแยกระบบไฟฟ้า		งานการยกของโดยใช้เครื่องมือยก			
	งานปรับแต่ง/วัดค่า		การขับขี่รถอย่างปลอดภัย		งานจัดเก็บ/ขนย้ายผลิตภัณฑ์		งานขุดดิน			
	การเข้าที่อับอากาศ		งานที่มีความร้อน/ประกายไฟ		งานใช้เครื่องจักร/อุปกรณ์เกี่ยวกับแอร์		การทำงานบนที่สูง			

อุปกรณ์ที่เกี่ยวข้อง

	การทำงานในอาคาร - ร้านขายของหรือที่ล้างรถ		ตู้แช่อาหาร		ระบบท่อ		อุปกรณ์เติมลม		อื่นๆ	
	หลังคาคลุมปั๊ม		ตู้จ่ายน้ำมัน		ระบบการขายอัตโนมัติ		ถังน้ำมัน			
	บริเวณที่ล้างรถ - อุปกรณ์		อุปกรณ์ตกแต่งภายใน เช่น สี, อุปกรณ์ตกแต่ง		ปั๊มแรงดันสูง (Pressure Pumps)		พื้น/วัสดุปูพื้น			
	ฝ้า/เพดาน		งานระบบเครื่องทำความเย็น		ป้าย		สาธารณูปโภค (รางระบายน้ำ, ระบบสุขาภิบาล)			
	เสาไฟฟ้า		ถังก๊าซ LPG/NGV/		บ่อ/หลุม		ระบบดูดไอน้ำมันกลับ			

ลักษณะงานที่ปฏิบัติและข้อมูลต่างๆ ที่เกี่ยวข้อง เช่น สภาพแวดล้อมในการทำงาน

การปฏิบัติงานที่ถูกต้องเหมาะสม

การปฏิบัติงานที่ไม่เหมาะสม (หรือคาดว่าไม่เหมาะสม)

ความคิดเห็นของพนักงาน (ผู้ปฏิบัติงาน) เกี่ยวกับสิ่งที่เกิดขึ้น

ข้อสรุปเกี่ยวกับสิ่งที่เกิดขึ้น (รวมทั้งแนวทางการแก้ไข)

สาเหตุที่ทำให้เกิดการปฏิบัติงานที่ไม่เหมาะสม

หัวข้อ	การกระทำ/สิ่งที่ไม่เหมาะสม	สาเหตุที่แท้จริงของการกระทำที่ไม่เหมาะสมนั้น	แนวทางการป้องกัน	ผู้รับผิดชอบในการแก้ไข	ลายเซ็นผู้รับผิดชอบ	วันที่คาดว่าจะเสร็จ	ดำเนินการเสร็จเรียบร้อยในวันที่

สรุปผลการสังเกตการณ์

วันที่ทำการสรุปผล :	เวลาที่ทำการสรุปผล:
วันที่ตรวจสอบความถูกต้อง:	วันที่อนุมัติ:
วันติดตามผลโดยหัวหน้างาน:	วันที่ตรวจสอบคุณภาพ:

5.5 Safety Operation Procedure Issuance System

Safety Operation procedure is the one which its gap is shown in both analysis of current Safety Management system and past incidents. It was found that the potential root cause is from an inappropriate system in conducting safety operation procedure for each task. As already mentioned in previous chapter, the existing system is to allow subcontractors generate the safety operation procedure by themselves, and then, submit procedure to SHE specialist for review and approval. Therefore, it is more likely to find subcontractors perform the same task in the different ways.

- **Objective**

  To provide a system for generating Safety Operation procedure in order to ensure that subcontractors perform maintenance task by following the standard procedure.

- **Scope**

  Safety operation procedure issuance system shall cover all high risk maintenance tasks such as tasks related hot work, electrical, confined space, excavation and working at height.

- **Definitions**

  a. Job Safety Analysis (JSA) refers to safety operation procedure which is provided for the specific task. JSA for high risk tasks shall be reviewed by safety committee and endorsed by Account manager.

  b. Safety committee is responsible for review JSA. The committee shall be consisted of SHE specialist, Field engineer, subcontractors' representative. In some cases, the specialist in some specific area of work may be invited to involve the meeting.

- **Responsibility**

  a. Subcontractors are responsible for drafting the JSA for new task and completely comply with all implemented JSA.

b. SHE specialist is responsible for sorting JSA for high risk tasks and communicating the endorsed JSA to all concerned parties.
c. Safety committee is responsible for reviewing and correcting the proposed JSA.
d. Account manager is responsible for review and endorse JSA which is reviewed and corrected by Safety committee.

- **Procedures**

The safety operation procedure issuance system can be followed as Figure 5-7.

a. When the new maintenance program is planned to implemented, subcontractor must draft JSA and submit it to SHE specialist.
b. In case, subcontractor would like to propose the new way to perform task, subcontractor shall draft JSA and submit it to SHE specialist.
c. Once SHE specialist got the submitted draft JSA, she shall review the potential risk. If high risk, she shall call safety committee for the meeting.
d. Safety committee reviews the submitted draft JSA. If they find some unsafe steps, they may adjust or even reject JSA. Also, if they believe the existing JSA is better than the proposed one, the change will not be allowed.
e. Once safety committee agreed with JSA proposed by subcontractor, SHE specialist shall pass it to Account manager for review and endorsement.
f. After endorsement, the new JSA must be documented and communicated to all concerned parties by SHE specialist.
g. After the endorsement JSA is communicated, subcontractor can perform task by following new JSA.

- **Related Document**

a. Job Safety Analysis, (JSA) form (See Figure 5-8)

Figure 5-7: JSA Issuance Process

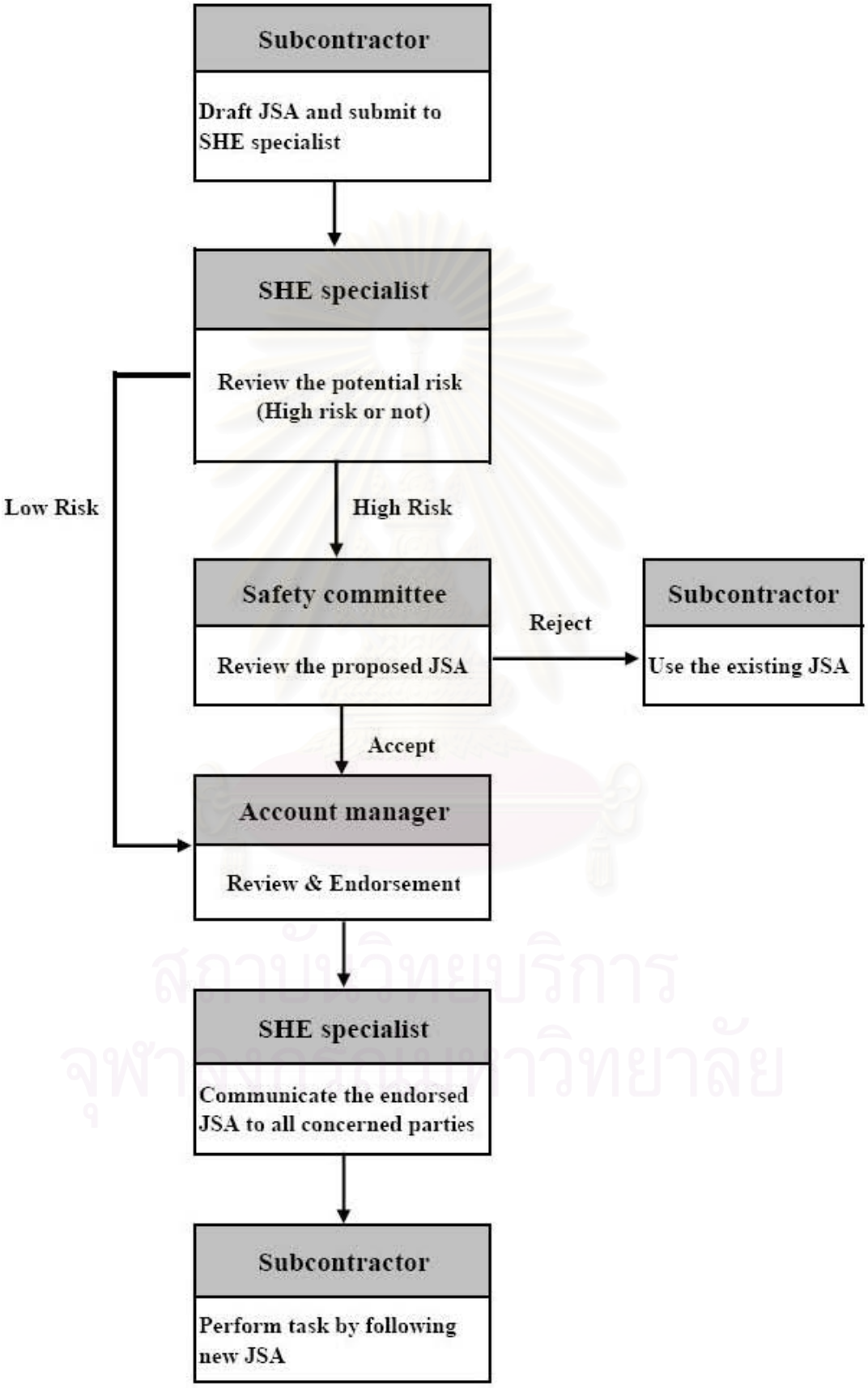


Figure 5-8: Job Safety Analysis Form (JSA)

Type of Work:			Revision: Page No.
Development Team		Reviewed By Safety Committee:	
Position / Company		Effective Date:	
Personal Protection Equipment and Tools for this job			
HARD HAT	WORK VEST / LIFE VEST	BARRICADES	HEARING PROTECTION
SAFETY SHOES / BOOTS	SAFETY HARNESS	FIRE EXTINGUISHER	SAFETY BELT
SAFETY GLASSES	FACE SHIELD	LOCKOUT / TAGOUT	RESPIRATOR / GAS DETECTOR
LEATHER / COTTON GLOVES	GOGGLES	WORK PERMIT	OTHER _____

No.	Working Steps	No.	Potential Hazards	No.	Hazard Elimination Actions

5.6 Preventive Maintenance Program

According to Pareto chart in Chapter IV and past incident, it illustrated obviously that the another cause of failure which had the high impact to client in terms of financial and reputation is equipment deterioration. To minimize this kind of cause, the improvement/change of work procedure may not be the right solution. Therefore, the recommended action is to conduct the preventive maintenance program for site equipments. However, there are a lot of equipments are available at service station, so it may take a huge investment on maintenance program. Regarding to past incident and the analysis, the one which highly required preventive maintenance program is Electrical system especially electrical wire. The impact of deteriorated electrical wire can range from short period of equipment shut down to Fire accident like the case at Nakornpathom.

Last but not least, the equipment which may not be experienced the big impact in the past but is very sensitive in term local regulation is underground petrol system. So far, client has experienced the petrol leak case but the leaked amount may not significant and not out of site area. However, if petrol leaks into environment nearby without the notification of site person, people around service station who get an effect from the leak may raise issue to local government. Consequently, client may be punished by paying fine and its reputation is ruined as well.

Therefore, electrical wire and underground petrol system are two groups of equipments that are proposed for getting preventive maintenance program. However, the scopes of maintenances programs are not detailed in this study. It will be left for Account manager who shall coordinate with Project engineer in order to find out the scope of programs.

5.7 Implementation

This section is to illustrate the result from the implementation of proposed solution. However, during this study period, there is only one action was implemented which is Internal Loss Prevention Observation because of uncomplicated and easy to understand. In order to get more efficiency of the implementation, only one contractor was selected for this two-month implementation.

During the implement period, sample contractor was assigned to perform ILPO 4 times a week or 16 times a month. However, the result showed that contractor did not meet the target by done only 15 ILPO for the first month and 13 for the second month. The Table 5-3 below demonstrated the number of work orders and the number of ILPO which were classified into groups of maintenance tasks related.

Table 5-3: Number of Work Order and ILPO during Implementation

	Maintenance Task						
	Height	**Electrical**	**Hot work**	**Trenching**	**Chemical**	**Confined**	**Crane**
Number of WO	227	421	517	159	164	52	18
Number of ILPO	15	15	21	11	10	1	5
% Detection	6.6%	3.6%	4.1%	6.9%	6.1%	1.9%	27.8%
Detection rating	4	4	4	4	4	4	4

During two month implementation, there is no incident occurred. However, above table showed that the number of ILPO seems to be less than what it should be. The portion between the number of ILPO and the number of work order can be demonstrated as Detection ratio which estimated around rating-4 regarding to Table 4-6. Nevertheless, the feedback from sample contractor shows that most of ILPO done during two month came up with questionable issues as following:

- Unsafe Act 18 cases
- Not follow procedure 6 cases
- Deteriorated equipment 1 case
- Insufficient equipment 1 case
- N/A 2 cases

From above list, it implies that this proposed action can help to mitigate risk in incident occurrence. On the other hand, this feedback also demonstrates that most of observed operators are still unqualified due to their unsafe behavior.

CHAPTER VI

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

To perform maintenance tasks within petrol station is quite risky and complicated for operator who is not familiar with working among petrol vapor. It is always found that many incidents related to M & R works occurred by unqualified persons. However, even the qualified and experienced person sometimes made mistake which causes the big loss to petrol station and operator himself. The objective of this study is to develop Standard safety procedure for maintenance of petrol station by applying Failure Mode and Effects Analysis (FMEA).

This study was done by gathering the valuable information from so many experienced people such as SHE specialist, Field engineer, subcontractors' supervisor, etc. These people have the same goal which is to raise the safety performance in maintenance service for petrol station.

The study was started by review the past incidents in order to see the potential root cause of each. And then, all maintenance tasks related to targeted equipment groups were listed. In this study, the focus was on two equipment groups:

1.) General equipments
2.) Petrol System

From both groups, it found that there is plenty of maintenance tasks related and more than a hundred failure modes can be listed. After review in detail of all maintenance tasks and their related failure modes, there are many failures which are similar to each other. All failures were grouped into seven categories as following:

1.) Failures related to working at height
2.) Failures related to electrical work
3.) Failures related to hot work (welding/Grinding/Knocking)
4.) Failures related to concrete trenching/excavation
5.) Failures related to working with chemical/hazardous substance
6.) Failures related to working in confined space

7.) Failure related to working with crane

Then, risk analysis of these seven types of maintenance tasks was conducted by applying FMEA. First of all, the potential failures and their most powerful effect were identified. Then, the potential root causes were listed and properly classified into groups by using Fishbone diagram. After the completion of root cause identification, some weak root causes which has low potential and may not occurred more often were screened out. Finally, the focus of seven failure modes was on thirty-two root causes, and then these failure modes and causes were put into FMEA worksheet in order to evaluate the risk priority number (RPN) of each.

After RPN of each potential cause was evaluated, Pareto principle was applied in order to sort out the low RPN and keep the high RPN for further propose the recommend action. Finally, team decided to focus on top four issues ranked by RPN:

- Inappropriate working procedure
- Operator not follow with working procedure
- Unsafe act by operator
- Deteriorated Materials

According to result from the analysis, the recommended actions to cope above potential root causes are as following:

- Safety Operation Procedure Issuance System
- Internal Loss Prevention Observation
- Work Authorization System
- Safety Training System
- Preventive Maintenance Program
  - Electrical System
  - Underground Petrol System

For implementation, the proposed action which was firstly applied is Internal Loss Prevention Observation (ILPO), even it took a little bit time for selecting sample contractor and communicating the idea to them. During two-month of ILPO implementation, the selected contractor can complete twenty-eight ILPO. However, when compare between the number of ILPO and the number of work order, it demonstrated as detection rate which is quite disappointing figure. Nevertheless, the feedback from observers showed that there are so many cases which the operators/observees did unsafe act or not follow procedure. So, from the feedback, it

can be summarized that this action helps to mitigate the potential risks which may cause the incident.

However, the rest proposed actions are still within the process of Management review because most of such actions require official cooperation among many parties which may affect to their manpower and financial. Nevertheless, people who made their contribution on this study strongly believe that once the rest actions are implemented, the safety performance will be obviously raised up. The action like "Safety operation procedure issuance system" will totally clean up the inappropriate working procedure which was always found as failure cause in the past. By group of experienced people, the process of working procedure review will be more efficient than only SHE manager's review.

Last but not least, the recommended work authorization system will help to guarantee that all operators who perform maintenance service in petrol station are qualified and have got training in both safety and operation.

6.2 Recommendation

Due to time constraint of the thesis, Internal Loss Prevention Observation (ILPO) is the only one proposed action which was implemented in practical. Even the feedback from sample contractor who was assigned to perform ILPO is quite positive; there is still a question about detection rate which resulted from the implementation. In the probation period, selected contractor was assigned to perform ILPO 4 times a week. However, the result showed that this target seems to be less than what it should be. Therefore, to improve safety performance further, the proper target of ILPO needs to be set. Even contractor was expected to perform ILPO in every work order, in fact, it is impossible because of the huge number of work order.

One of the key proposed actions, which have potential in enhancing safety performance are Work Authorization System and Training System. From analysis, the result shows that most of incidents/failures are came from unqualified operators. These solutions are expected to clean up nonprofessional worker. Therefore, to improve safety performance of this case company, these proposed actions need to be treated as top priority for further implementation.

Time limitation also affects in minimizing scope of the study. For example, this study focused on two equipment groups: General equipment and Petrol system, even

Mart equipment group was found some related incidents in the past. However, once the proposed actions were proved that they are effective in enhancing safety performance, Mart equipment group need to be taken into account for analysis.

In addition, the financial issue is another one which is recommended for being studied further in order to ensure that the recommended action which will be implemented costs reasonably when comparing to the financial impact of incident. Due to the objective of this study is to develop safety procedure; the financial part is not much focused as it should. However, once the recommended action was proposed to management level, the financial impact must be completely studied and provided to management level for review.

Finally, the one thing that highly influences to the success of the study is the teamwork. This study required many support from various parties, so it is inevitably to done the study by working as a team. However, this study was done by gathering information from various experienced people who were not assigned by management, so it was quite hard to conduct meeting regularly. It was always found that most of time when meeting /brainstorming activity was arranged, some expected attendants missed. Therefore, the author would recommend establishing the certain team to perform the study which will make it done efficiently and effectively.

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APPENDICES

APPENDIX A

Company's Health & Safety Policy Statement

As a company which regards people as its primary asset, we will provide a safe and healthy working environment for its employees, customers and others. This is achieved as a minimum standard by compliance with legislation.

We and our customers are leaders in our businesses, dealing with new and changing processes and techniques. Therefore, safety, health and environmental matters require constant assessment and review of risks. We must make absolutely certain that all measures necessary are taken to protect the safety, health and environment of our employees, customers, contractors and others, including the prevention of occupational health risks and the potential for environmental impact.

The best-intentioned practices will fail unless managers take a personal interest in and a leadership role for safety, health and environment.

The above statement underlines the Company's fundamental belief in and the importance it places on:

- Its concern to maintain health,
- Provision of a safe working environment, and
- Elimination or control of safety, health and environmental hazards.

We will be responsible for our safety, our colleagues and others whom we may encounter in the course of our work. It is, therefore, to our mutual benefit that we strive constantly to achieve these objectives.

Customer Services Director

APPENDIX B

Company's Drug & Alcohol Policy

It is the policy of the Head Office, the company that any employee found working under the influence of drug and alcohol entails ground for termination.

To ensure a safe, healthy, and productive work environment for all employees, to protect the public, property and assets, and to ensure efficient operations, all company and Contractors employees shall be prohibited from the following:

1). Using, possessing, selling, manufacturing, distributing, concealing, or transporting while on or handling Client Property.

- Any Prohibited Substance;
- Illicit drug equipment or paraphernalia.

2). Using or possessing while on or handling Client Property or performing Services prescription drugs or over-the-counter medication that may cause impairment except when all of the following conditions have been met:

- Prescription drugs have been prescribed by a licensed physician for the person in possession of the drugs.
- The prescription was filled by a licensed pharmacist for the person possessing the drugs.
- The individual notifies their supervisor that they will be in possession of or using, impairment-causing prescription drugs or over-the-counter medication and appropriate steps are taken to accommodate the possibility of impairment, including but not limited to, removal from work for the period of possible impairment.

3). Being under the Influence of Prohibited Substances while performing any work or Services for Client.

4). Upon reasonable suspicion of contractor that their employee is Under the Influence of a Prohibited Substance while on Client Property, the contractor shall remove the individual from Client Property and surrender his/her site credentials to company. It shall be the contractor responsibility to sent the employee for a medical examination and/or refer the employee to the relevant authorities.

5). Any Contractor employee found in violation of the Contractor's Policy shall be permanently removed by Contractor from Client Property and shall be reassigned to other work not involving work or Services for Client. The Contractor must immediately notify company that the individual has become "disqualified". The Contractor will also immediately review with company the nature of the work previously performed by the individual. At company request Contractor shall, at its sole cost and risk, inspect all work in which the individual may have participated, and submit a written report to Company that documents the inspection, any findings, and the actions taken to assure all deficiencies have been corrected.

6) The Contractor shall have a Drug & Alcohol Policy incorporating the above conditions and the Contractor employees shall be fully informed of the requirements of this the Drug & Alcohol Policy, and agree to be bound by those requirements.

BIOGRAPHY

The son of a merchant and a housewife, Karun Puthanapibool was born in Rayong, 1979. He is the youngest of Puthanapibool family, together with one brother and three sisters.

Karun was first educated at Rayong primary school and then in 1992 went to Samsen Wittayalai School completing junior high school (M3). While studying high school (M4) at Samsen Wittayalai School, he simultaneously studied the non-formal education program and gained senior high school (M6) qualification in the following year.

At the age of 18, he attended the engineering degree program at Kasetsart University, majored in Electrical engineering. Having spent four years at Kasetsart University, he was eventually graduated the Bachelor's Degree in Electrical engineering in 2001. Currently, he is pursuing a Master degree in Engineering Business Management at Regional Centre for Manufacturing Systems Engineering, Chulalongkorn University, Thailand and University of Warwick, England.