The Use of Quality Improvement Tools for Continual Improvement : A Case of Silapat's Aggregate Rock Quarry

by

Ms. Chantana Sirivesmas

A Final Report of the Six-Credit Course
CE 6998 - CE 6999 Project

Submitted in Partial Fulfillment
of the Requirements for the Degree of
Master of Science
in Computer and Engineering Management
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Academic Year	March 2004

The Graduate School of Assumption University has approved this final report of the six-credit course, CE 6998 — CE 6999 PROJECT, submitted in partial fulfillment of the requirements for the degree of Master of Science in Computer and Engineering Management.

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ABSTRACT

This project investigates each production process in Silapat Quarry which produces Aggregate rocks for construction industry. The operation problems occur from an inappropriate mining plan which leads to other problems, that is, more use of accessories, waste time for operation and increase of production cost.

Tools of Continual Improvement are used to determine the problems in the quarry and analyze the root causes. First of all, I start with studying the existing process, collecting the data and finding the problems of each process. Next, I analyze and develop to accomplish the quarry's objective. The study of the project includes interviewing the relevant persons from top to bottom line, observing the operation, collecting the data and analyzing the improvement plan.

Improving the mining plan, enhancing knowledge of workers and setting the machinery maintenance planning are the methods that are chosen to solve the problem. It can enhance productivity by increasing output and decreasing the cost and time of production.

ACKNOWLEDGEMENTS

I am indebted to the following people and organizations. Without them, this project would not have been possible.

I wish to express my sincere gratitude to my advisor, Dr. Akajate Apikajornsin. His patience, assistance, guidance and constant encouragement have led me to accomplish the research project. I would like to thank many instructors in the Computer and Engineering Management (CEM) faculty for all the knowledge they imported to me.

Besides, I would like to thank Silapat Quarry for giving me a chance to research this project. Special appreciation goes to my family for their fervent and continuous encouragement. Above all, I am forever grateful to my parents, whose willingness to invest in the future has enabled me to achieve my educational goal.

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I. INTRODUCTION

1.1 Overview

A quarry is a factory that converts solid bedrock into crushed stone. The excavated rock is crushed, screened, washed and separated into different sizes, for subsequent sale and use. The amount of fines should be kept to a minimum. The final products are used as raw material for chemical plants, such as limestone for cement manufacturing, paper and steel industries, and clay shales for building materials, or as raw material for concrete aggregates, highway construction, or other civil engineering projects.

Silapat Quarry is one of the leading companies in the Quarry industry in Thailand, which mainly produces Aggregate Rock for Construction Industry such as constructing roads, building houses, etc. This company has been in operation since 1976, which is accounted for more than 20 years in this business.

Currently, the production capacity is 150,000 — 200,000 tons per month or approximately 1,800,000 — 2,400,000 tonnage per annum. The company's operation is divided into 4 main departments : Purchasing, Crushing, Quarry Site and Machinery Maintenance.

Purchasing : This department is controlled by the purchasing manager. The purchasing officer will receive purchase orders from all departments and purchase raw materials such as drilling accessories, explosive and so on.

Crushing : The crushing manager will control all crushing process which is operated by crushing operators. This process is the last process before selling to the users.

Quarry Site : This department will cover most of the production process whiFh can be divided into : Upper site, Lower site, Drill and Blast, Haul and Load.

Machinery Maintenance : This department is controlled by the engineer and is divided into 2 sections, that is, in quarry and work shop. In Quarry, the drill operator carries out daily check and maintenance his machine. For the main parts break down, they will send to the work shop for repairing.

The steps of rock production are shown in Figure 1.1.

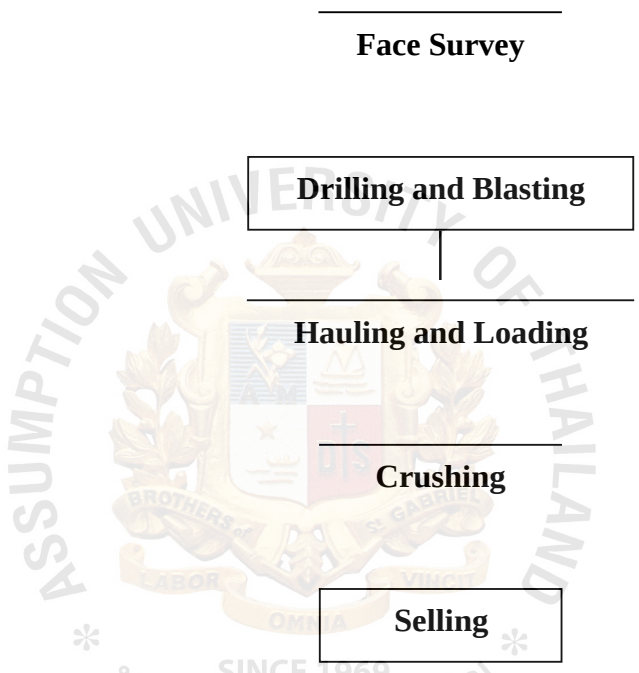


Figure 1.1. Rock Production Flowchart.

Due to the Economic Crisis in 1997 and the economic slow down worldwide, the industries hard hit are construction materials (both cement and steels), motor vehicle and transport equipment. Both government and private construction projects have slowed down or stopped. There are many quarries that have shut down, less production, or temporary closed especially in Southern Thailand. Silapat is the one of surviving companies. Now construction materials have continued to grow considerably from the end of last year corresponding to rising domestic demand for cements caused by the

upturn of residential construction, which partly resulted from not only effective Government measures to boost real estate sector, but also low interest rate credits and low cement prices.

Table 1.1. Manufacturing Production Index.

Manufacturing Production Index

(Unit : % ___ voy)

	2000	2001	Jan-Jun	
			2001	2002
Food	2.5	-3.5	-8.5	6.8
Beverage	-41.7	13.8	8.2	20.0
Tobacco	-1.3	-3.0	-3.9	-0.3
Textiles & Textiles Products	3.2	0.6	3.2	-1.0
Petroleum Products	-0.9	2.2	4.3	1.5
Construction Materials	0.1	9.9	1.9	21.0
Iron & Steel Products	15.8	1.7	1.3	23.6
Vehicles and equipments	25.5	23.4	21.3	9.8
Electronic & Electrical Products	31.6	-26.8	-21.9	16.7
Jewellery	28.5	3.9	4.9	-0.3
Others	14.9	0.7	1.0	-8.1
Total	**3.3**	**1.3**	**1.2**	**6.1**
(Excluding Liquor)	**10.9**	**0.6**	**1.0**	**4.4**

Note : * covering 62.4% of overall value added in the Manufacturing sector

Source : www.bot.or.th

The business of rock production has become popular. There are many entrepreneurs who increase the market. If businesses stand still they will loose their competitive edge, so improvements must be made to keep pace and stay in business. To compete in today's global market, Silapat wants to increase the productivity with minimum cost. According to our study, I found out how the company can increase productivity by improving the efficiency of machineries, production methods and labor utilization.

This project will use the tools of quality improvement for continual improvement to solve the problem. Continual Improvement is a type of change that is focused on increasing the effectiveness and/or efficiency of an organization to fulfill its policy and objectives. It is not limited to quality initiatives. Improvement in business strategy, business results, customer, employee and supplier relationships can be subject to continual improvement. From the report, I will analyze how to implement Continual Improvement in the aspect of increasing the effectiveness and productivity to fulfill the company's objective. It will show the factors which effect toward the capacity of production, and before and after result of Continual Improvement implementation. This project will help the company use the operation resources effectively. The result will be increasing the productivity and minimizing cost.

1.2 Project Objectives

(1) To study the productivity improvement.

(2) To find the factors that decrease the productivity.

(3) To analyze the improvement after Continual Improvement implementation.

1.3 Project Scope

(1) This study covered Silapat Quarry's Operation.

(2) The period of study was between October and December.

(3) The study is concentrated on Continual Improvement within the Quality Management Systems toward Aggregate Rock Quarry only.

II. LITERATURE REVIEW

In today's turbulent business environments everyone is looking for continuous improvements in the products and services which they offer and the ways in which they produce them. Whether these come through the occasional 'big bang' breakthrough innovation, or through the more typical incremental improvements and adjustments, constant change is essential, not just to remain competitive but often for the survival of the business itself.

Faced with this challenge we need to rethink our views on innovation and how it is carried out. In particular, we need to think again about *who* can be involved in the process. Whilst innovation used to be the responsibility of a few specialists in R&D or production engineering, there is no reason why most people in the organization should not be able to participate in thinking of — and implementing — small changes on a regular basis. After all, most of the innovation task is about incremental problem-solving, getting the 'bugs' out of the system or product. And everyone in the firm comes fully equipped for the task — 'with every pair of hands you get a free brain' !

2.1 The definition of Continual Improvement

Continual Improvement is a type of change that is focused on increasing the effectiveness and/or efficiency of an organization to fulfill its policy and objectives. It is not limited to quality initiatives. Improvement in business strategy, business results, customer, employee and supplier relationships can be subject to continual improvement. Put simply, it means 'getting better all the time'.

Continual improvement should focus on enablers such as leadership, communication, resources, organization architecture, people and processes — in other words, everything in the organization, in all functions at all levels.

Continual improvement should also lead to better results such as price, cost, productivity, time to market, delivery, responsiveness, profit and customer and employee satisfaction. There has been a tendency in total quality management (TQM) programmes to focus on departmental improvement which does not improve business results overall. Departmental improvements may merely move the constraints or problems somewhere else in the process chain.

Improvement is not about using a set of tools and techniques. Improvement is not going through the motions of organizing improvement teams and training people. Improvement is a result, so it can only be claimed after there has been a beneficial change in an organization's performance.

2.2 Types of improvement — Gradual, incremental or breakthrough

There are three types of improvement. Continuous improvement is a gradual never-ending change, whereas continual improvement is incremental change. Both types of improvements are what the Japanese call Kaizen. Breakthroughs are improvements but in one giant leap — a step change. However, the method of achievement is the same but breakthroughs tend to arise out of chance discoveries and could take years before being made (see illustration).

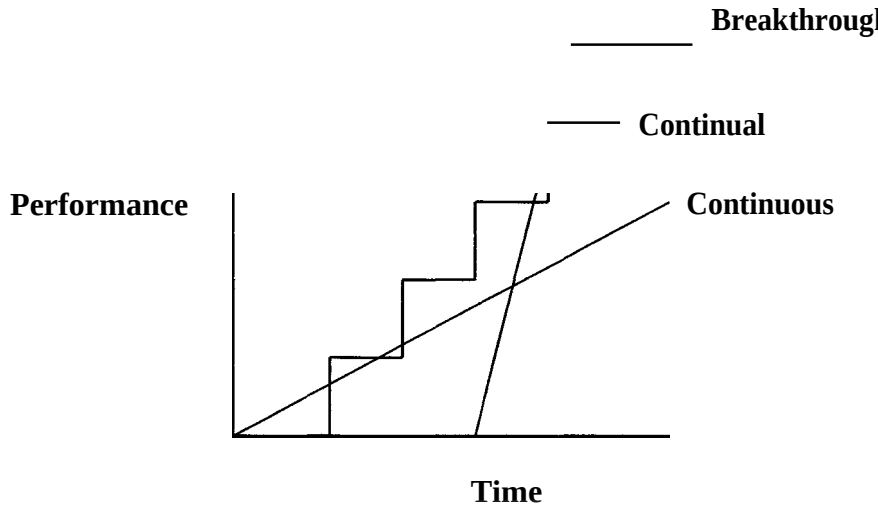


Figure 2.1. Three types of Improvement — Gradual, Incremental and Breakthrough.

2.3 Relationship with TQM and ISO 9000

Continual improvement is one aspect of a TQM philosophy. It can also be an element of an ISO 9000 quality system. The ISO 9000:2000 will in fact include requirements for continual improvement

2.4 Importance of continual improvement to an organization

All managerial activity is either directed at control or improvement. Managers are either devoting their efforts at maintaining performance, preventing change or creating change, breakthrough or improvement. If businesses stand still they will loose their competitive edge, so improvements must be made to keep pace and stay in business.

2.5 When should continual improvement be started?

Every system, programme or project should have provision for an improvement cycle. Therefore when an objective has been achieved, work should commence on identifying better ways of doing it.

2.6 How should continual improvement be undertaken?

(a) Measurement

There is no improvement without measurement. An organization must establish current performance before embarking on any improvement. If it does not, it will have no baseline from which to determine if its efforts have yielded any improvement.

(b) A ten step sequence

There are ten steps to undertaking continual improvement:

(1) Determine current performance

(2) Establish a need to improve

(3) Obtain commitment and define the improvement objective

(4) Organize the diagnostic resources

(5) Carry out research and analysis to discover the cause of current performance

(6) Define and test solutions that will accomplish the improvement objective

(7) Produce improvement plans which specify how and by whom the changes will be implemented

(8) Identify and overcome any resistance to the change

(9) Implement the change

(10) Put in place controls to hold new levels of performance and repeat step one

2.7 Where do the ideas come from?

If the organization has identified its critical success factors (that handful of things at which it must be supremely good in order to succeed), then to focus the attention of the continual improvement process onto one or more of these for a defined period might give rise to major improvements.

2.8 Whose responsibility is it?

No one in the organization, from top to bottom, is exempt from the responsibility for improvement. It is a normal component of all employees' jobs to search out ways of

improving performance. Furthermore, no one is expected to do this without help and support from others.

2.9 How does a company organize improvement?

Most continual improvement programmers are executed by teams that either diagnose problems, search for solutions or implement changes. These teams may be within departments or cross functional. However, there needs to be a steering group of managers, which directs the teams towards their goal, and above all provides the environment for success.

2.10 Tools for continual improvement

The proper use of analytical and statistical tools can often mean the difference between success and failure; the screen tools are proper for the quality improvement. In this project, we select Flowchart to describe the process of operation of quarry, the form of problems to be the collecting data, then the Pareto Diagram as a tool for categorizing the type and percentage of problems in the production line. After that we verify the root cause by using the Cause and Effect Diagram.

The portfolio of tools used for continual improvement should be those, which enable an organization to execute the ten steps above. These include:

(a) Cause and Effect Diagram

The cause and effect diagram is also called the fishbone chart because of its appearance and the Ishakowa chart after the man who popularized its use in Japan. Its most frequent use is to list the cause of particular problems. The lines coming off the core horizontal line are the main causes and the lines coming off those are sub causes.

Constructing a Cause and Effect Diagram

2 7 2 Li

(1) Establish what the problem, or effect, is. It must be stated in clear and concise terms, agreed by everyone.

(2) Write the effect (problem) in a box on the right and draw a long line pointing to the box.

(3) Decide the major categories of causes. This may be done in several ways:

(a) Brainstorming

(b) Using standard categories such as the 4Ms (Machines, Materials, Methods, Manpower) or PEMPEM (Plant, Equipment, Materials, People, Environment, Methods).

(c) When the effect results from a recognizable process or set of activities, the major steps in the process can be used.

(4) Write the major categories in boxes parallel to, and some distance from, the main line. Connect them to the main line with slanting arrows.

(5) Brainstorm for possible causes.

(a) Add the causes to the diagram clustered around the major causes they influence. Divide and sub-divide the causes to show how they interact, and draw links between causes that are related. If the diagram becomes too crowded, move one or more categories to a new sheet of paper.

(6) Evaluate and analyze the possible causes.

(7) Decide and act.

(a) This will probably involve using other tools. For example, in order to verify some of the possible causes identified you may

need to collect data (using checksheets) and analyze it (Pareto Analysis, graphs, etc.).

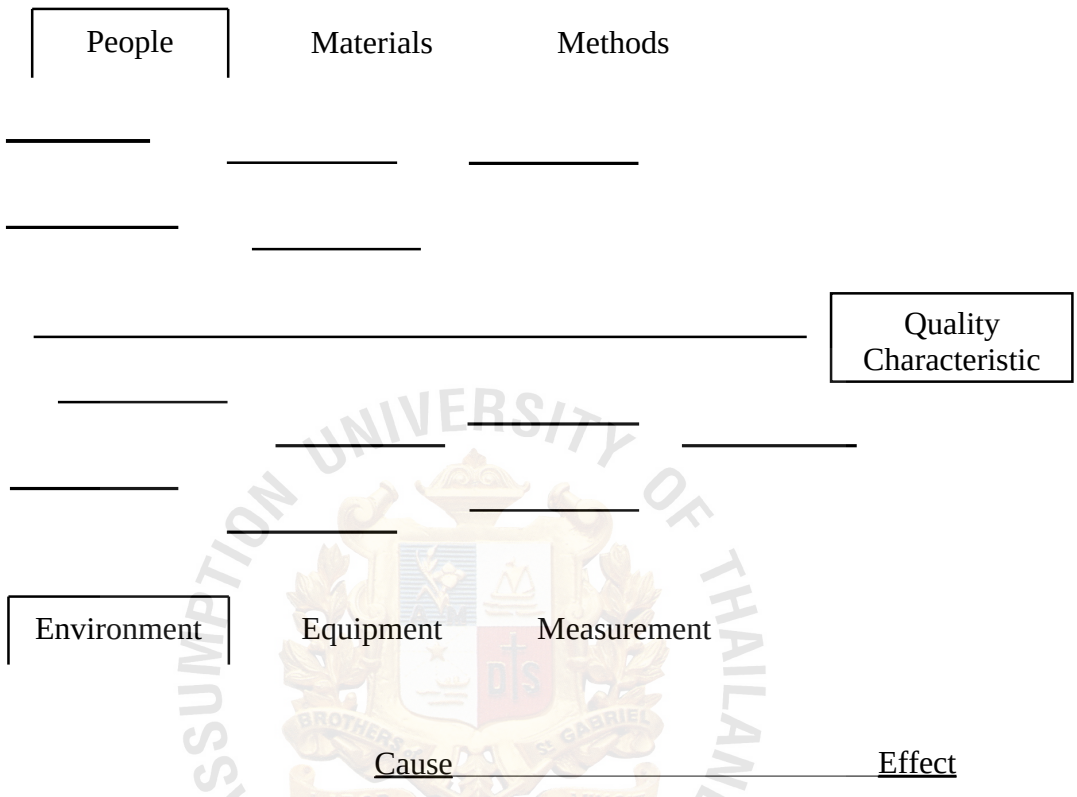


Figure 2.2. Example of Cause and Effect Diagram.

(b) Run Chart

The run chart shows the history and pattern of variation. It is helpful to indicate on the chart whether up is good or down is good. This tool is used at the beginning of the change process to see what the problems are. It is used at the end (check) part of the change process to see whether the change has resulted in a permanent improvement.

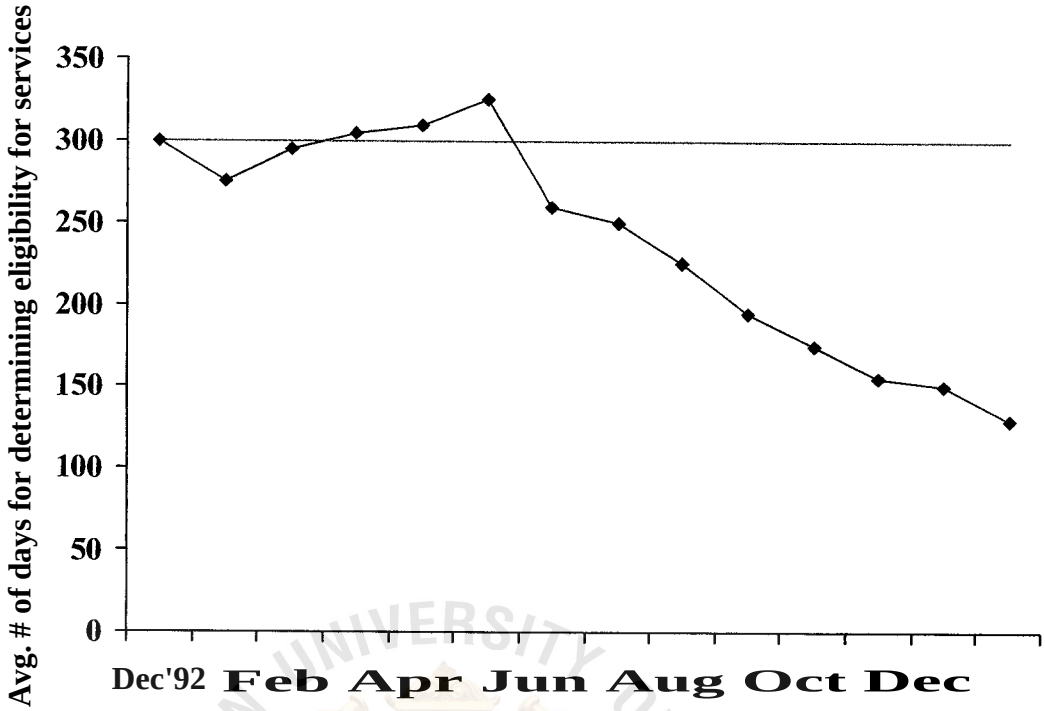


Figure 2.3. Example of Run Chart.

(c) Scatter Diagram

The scatter diagram shows the pattern of relationship between two variables that are thought to be related. For example is their a relationship between outside temperature and cases of the common cold? As temperatures drop, do colds increase? The closer the points hug a diagonal line the more closely there is a one to one relationship.

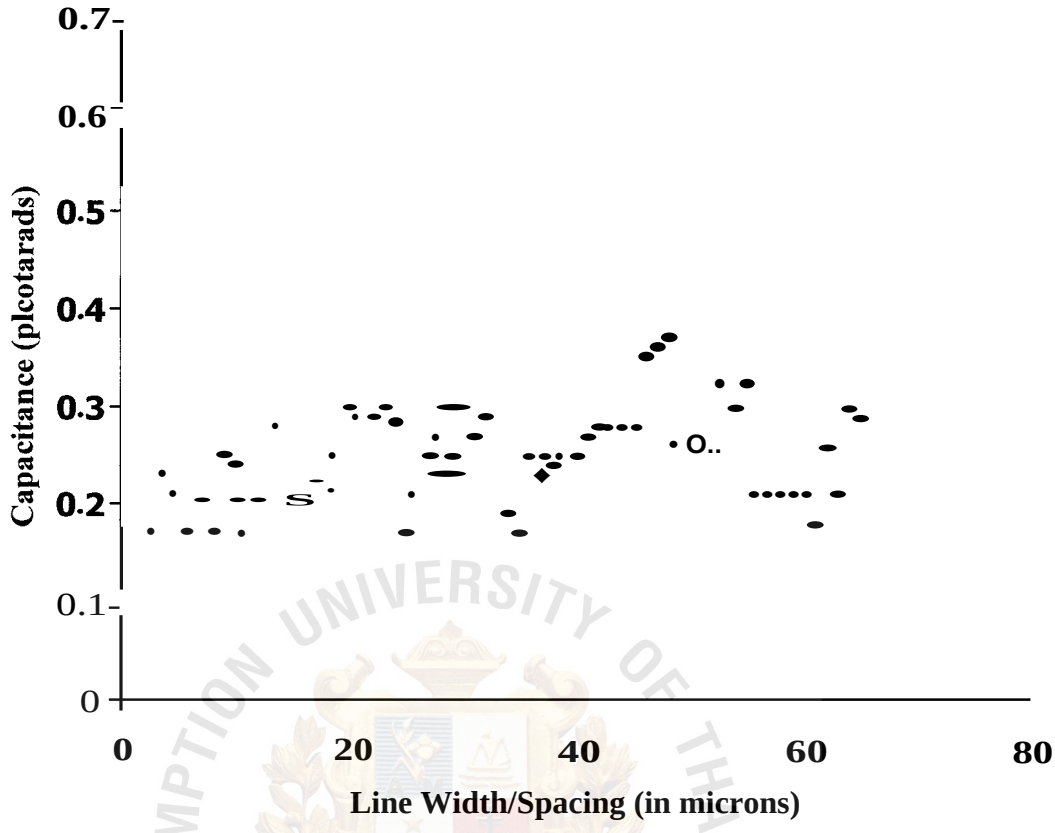


Figure 2.4. Example of Scatter Diagram.

(d) Flowchart

The flowchart lists the order of activities. The circle symbol indicates the beginning or end of the process. The box indicates action items and the diamond indicates decision points. A beneficial technique is to map the ideal process and the actual process and identify the differences as targets for improvements.

Constructing a flowchart

(1) Decide what level of detail the flowchart is to represent.

(2) This will depend on the purpose for constructing the flowchart. On a higher level flowchart several tasks which make up an activity will be

shown as one activity whereas on a lower level flowchart each task will be shown separately.

List the activities in the process.

Draw the flowchart.

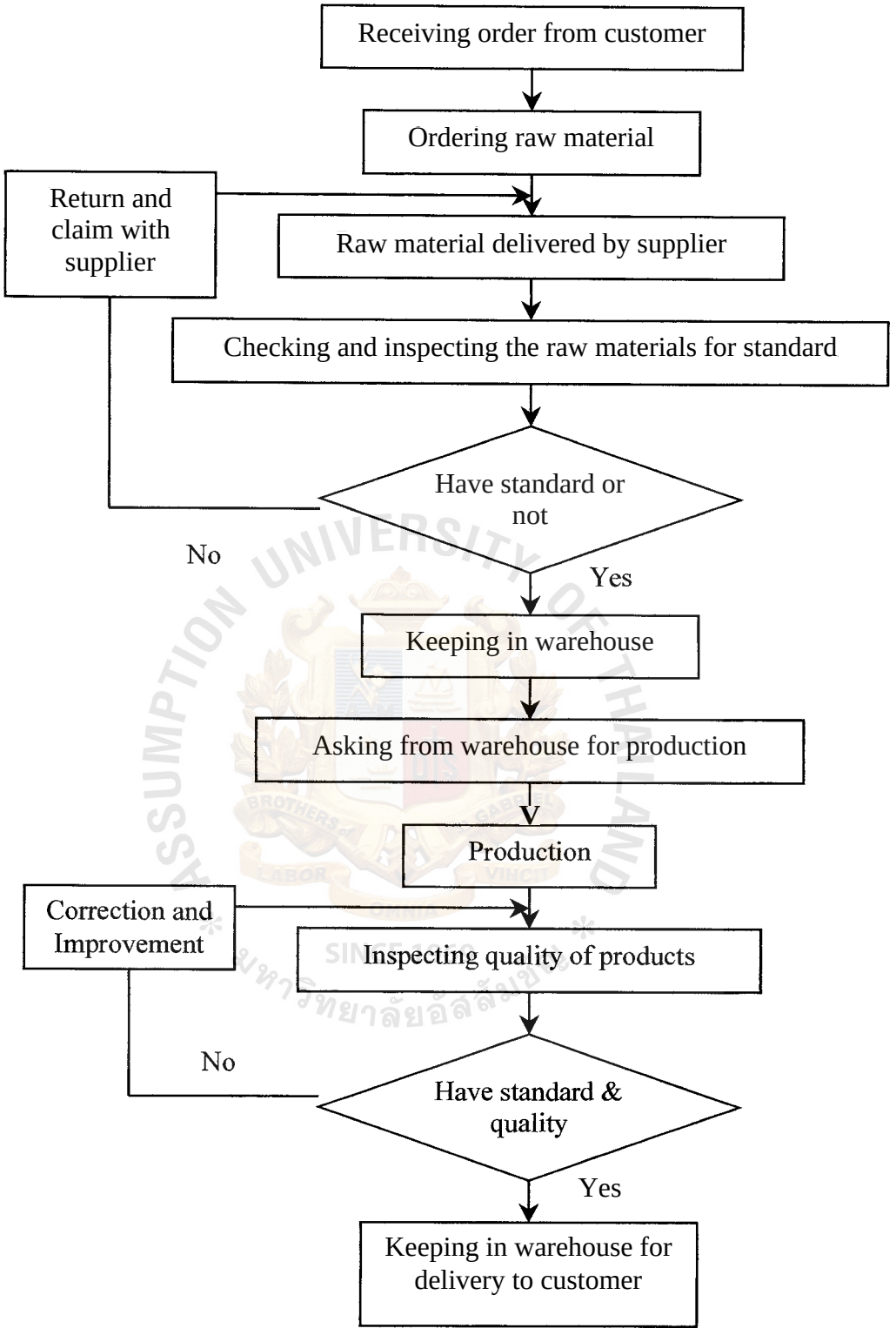


Figure 2.5. Example of Flow Chart.

(e) Pareto Chart

The Pareto Chart shows the distribution of items and arranges them from the most frequent to the least frequent with the final bar being misc. The tool is named after Wilfredo Pareto, the Italian economist who determined that wealth is not evenly distributed. Some of the people have most of the money. This tool is a graphical picture of the most frequent causes of a particular problem. It shows where to put your initial effort to get the most gain.

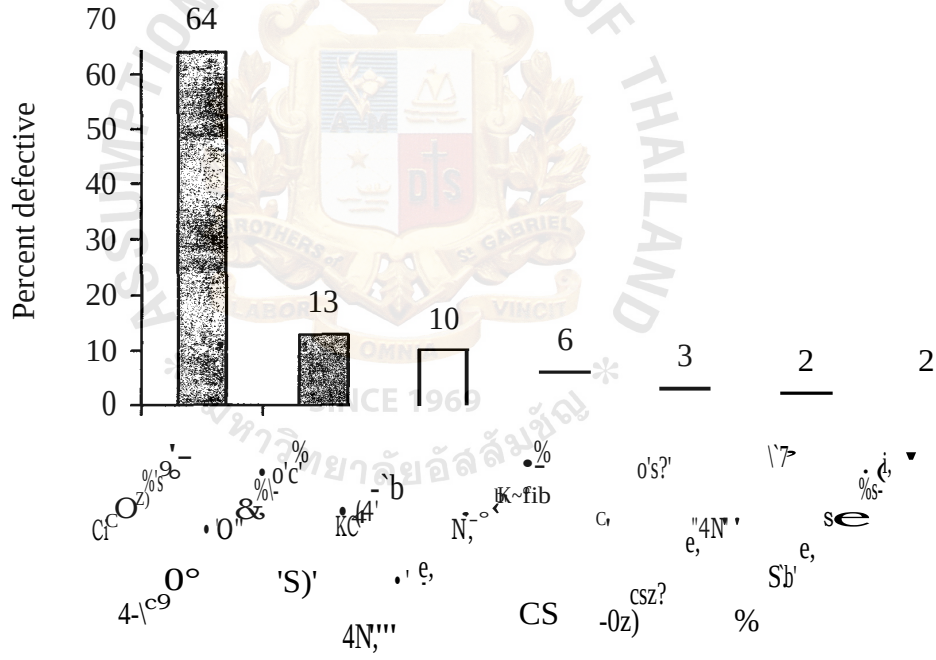
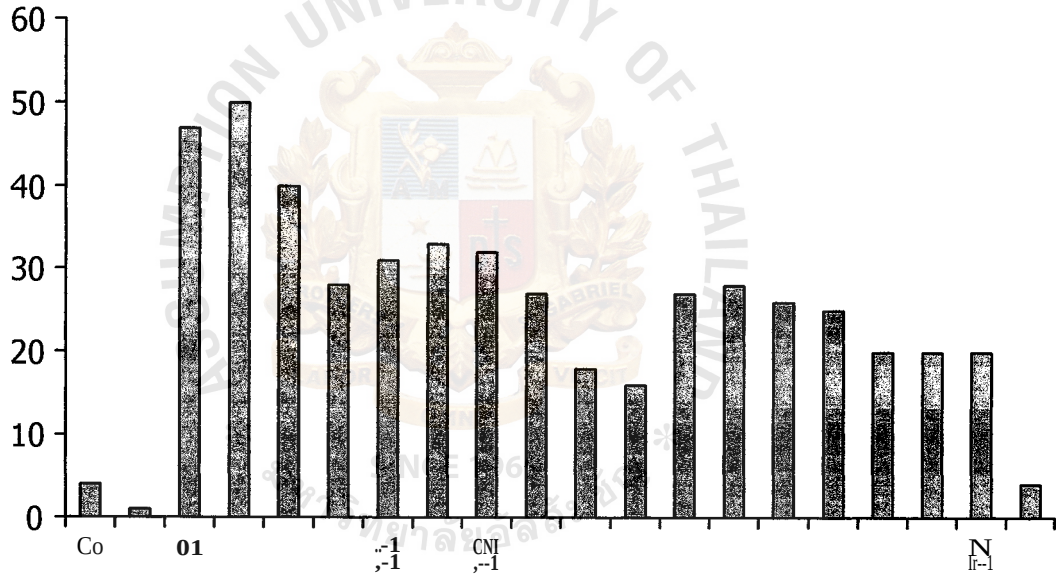


Figure 2.6. Example of Pareto Chart.

(f) Histogram

The histogram is a bar chart showing a distribution of variables. An example would be to line up by height a group of people in a course. Normally one would be the tallest and one would be the shortest and there would be a cluster of people around an average height. Hence the phrase "normal distribution". This tool helps identify the cause of problems in a process by the shape of the distribution as well as the width of the distribution.



HOTrep data May 22 to August 24

Figure 2.7. Example of Histogram.

(g) Control Chart

The control chart is a line chart with control limits It is based on the work of Shewhart and Deming. By mathematically constructing control limits at 3 standard deviations above and below the average, one can

determine what variation is due to normal ongoing causes (common causes) and what variation is produced by unique events (special causes). By eliminating the special causes first and then reducing common causes, quality can be improved.

Table 2.1. Table of constants for variables control charts.

Week #	R	X-bar	Week #	R	X-bar
1	1.01	3.76	14	1.21	4.18
2	1.27	4.21	15	1.33	4.02
3	0.48	4.29	16	0.78	3.71
4	1.32	4.36	17	1.21	4.08
5	1.52	4.13	18	1.23	4.23
6	1.03	3.77	19	1.08	3.98
7	1.15	4.17	20	1.64	4.46
8	1.07	4.21	21	1.20	3.96
9	0.70	4.22	22	0.98	3.63
10	2.05	4.00	23	0.91	4.48
11	0.95	4.30	24	1.19	4.30
12	0.99	4.20	25	1.03	4.29
13	1.06	4.32	**Avg.**	**1.14**	**4.13**

n = 10 evaluations randomly sampled each week

1-not at all 2-not very 3-moderately 4-very 5-extremely

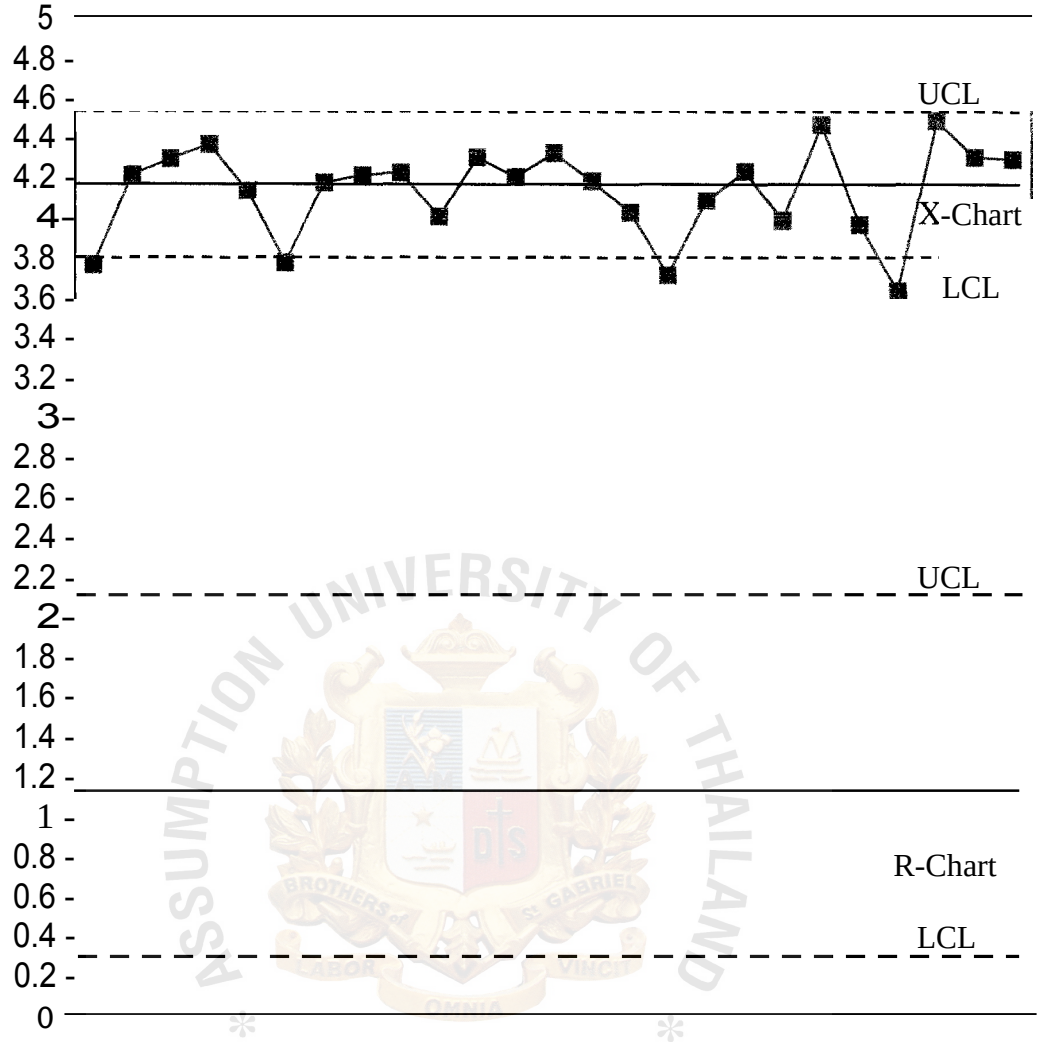


Figure 2.8. Example of Control Chart.

(h) Check Sheet

A Check Sheet is a list of causes of quality problems with the number of defects resulting from each cause. The main purpose of the check sheet is to ensure that the data is collected carefully and accurately by the operating personnel. Data should be presented in such a form that it can be quickly and easily used and analyzed. The form of the check sheet is individualized for each situation and is designed by the project team.

Checks are made on a daily and weekly basis, and some checks, such as temperature, are measured.

Check sheets are used to record data. They are therefore used in every project stage that includes data collection so we could have put them anywhere in our sequence and be correct. The best check sheets are simple to use and visually display the data in a format that can reveal underlying patterns. It should be user-friendly and, whenever possible, include information on time and location.

Items	A	B	C	D	E	F
	- - -✓✓✓✓		✓			✓✓✓
	- - - -✓✓			✓✓✓✓	✓✓	
		✓✓✓✓				✓✓✓✓

Figure 2.9. Example of Check Sheet.

2.11 Changing the culture of organization

Continual improvement is far more than a set of techniques. For many organizations, it involves a radical change in attitudes. The defense of the status quo, and resistance to innovation, cannot be treated as normal management behavior. A fear of reprisals for reporting problems has to be replaced by congratulating people for identifying an opportunity to improve. Hoarding of good ideas within departmental walls must be a thing of the past as people share their knowledge and experience in the search for greater collective success.

2.12 The importance of commitment

Continual improvement is about the entire organization and everything it does. It has to be a prime concern of executive management and its success depends upon commitment from the top. The commitment must also be highly visible. It is not enough to have a quality policy signed by the chief executive. If executive management does not demonstrate its commitment by doing what it says it will do, it cannot expect others to be committed to the policy.

2.13 Reward success

The encouragement of people who have initiated improvements, however small, is an important component. This can be done in many ways, from displays on special improvement notice boards to the awarding of prizes. This is an area in which the culture and style of the organization has to be considered. The sudden introduction of a show business style into a staid environment may lead to cynicism rather than effective promotion of improvement. Rewards may, but need not, have a financial component.

2.14 Dealing with failure

It is very common to find that about 12 to 18 months into a continual improvement programme it is felt that it is not delivering what was expected. This is just the time to redouble efforts. It is a long-term haul to change behavior, therefore persistence and extra imaginative effort is the key.

III. OVERVIEW OF OPERATIONS OF ROCK PRODUCTION

From the introduction, the company background and production process will be known briefly. Knowing the process and background of the company clearly is the first point lead to understand the problem in each process. The following are the company profile, the quarry's actual status and working condition, operation of rock manufacturing and rock production process in order to know the quarry's statement of problem and the important reasons of the project's objectives about continual improvement of processes.

3.1 Company Profile

Name	Silapat Quarry
Location	Saraburi Province
Area of Quarry	100 Rai
Type of business	Production of Aggregate Rock
Number of employees :	About 60 persons
Quarry Layout	See Appendix A

Production Facilities

(a) Drilling Machines

There are 6 machines and 4 breakers for drilling. All machines are imported from Japan : 1 for HCR 9, 1 for HCR 180 and 4 for HCR 300, 1 for Breaker Topa and 3 for Breaker Furukawa 20G.

(b) Clearing Machines

There are 4 Clearing Machines : 1 for Wheel loader 966, 1 for Grader D7, 1 for CAT 320 and 1 for CAT325.

(c) Hauling and Loading Machines

There are 30 machines for Hauling and Loading : 1 for CAT988, 2 for CAT966, 2 for Hydraulic Shovel, 1 for Back Hoe, 2 for Terex 35T, 7 for 10 Wheels Trucks and 15 for 6 Wheel Trucks.

Strategic Objective of the Quarry is the continual improvement of process. It helps to enhance the organization's performance and benefit its interested parties. This is the reason why the quarry can compete in today's global market for an increasing market share. Now the business of rock production has become popular, so the quarry uses the continual improvement in case of increasing productivity and minimum cost which appear in the next section.

3.2 **Organization**

The quarry is divided into 4 main departments as follows (see Figure 3.1 for Organization Chart) :

(1) Purchasing Department consists of a purchasing manager and 2 officers.

(2) Crushing Department consists of a crusher manager and 4 crusher operators.

(3) Quarry Site Department is divided into 4 sections : Upper Site, Lower Site, Drill and Blast, and Load and Haul. Each section consists of a foreman and workers.

(4) Machinery Maintenance Department is divided into 2 parts : work shop and at site. Each part consists of 4 mechanicals and controlled by a mechanical engineer.

SILAPAT OUARRY

Purchasing Department	Crushing Department	Quarry Site Department	Maintenance Department
	Crushing Manager		Mechanical Engineer
Purchasing Officers	Crusher Operators	Mechanical Team (Work Shop)	Mechanical Team
		Drill and Blast	Load and Haul
	Foreman	- Foreman	Foreman
	Workers	- Workers	Workers

Organization Chart.

3.3 **The Process of Operation of the Quarry**

3.3.1 Ordering Raw Materials

This section is the responsibility of the purchasing department. The purchasing manager is the leader of this department who signs and approves the purchase order. Before production, the purchasing officer receives the purchase order from the Quarry Site Department to order drilling accessories such as drilling bit, drilling rod, coupling, shank, and explosives, detonators, spare parts or sometimes buys the new machine instead of the old one.

3.3.2 Production

When raw material is ready, the production process will start. It starts from face survey, drill and blast, load and haul, crush and sell to the end users or stock in warehouse.

3.3.3 Inspection of quality of finished goods

After finishing production, the quarry will check the size and classify the rock to be standard. If it is not standard, the rock will be sent back for correction and improvement. After that, they will pass into the next step.

3.3.4 Selling or Stocking

The aggregate rocks are separated for selling or stocking. Because of selling hard items, the customers visit the site to buy the rock according to their purpose. The rocks have many sizes depending on their use. For stocking, the rocks are kept in warehouses tell they are sold. Figure 3.2 shows the process of operation of the Quarry.

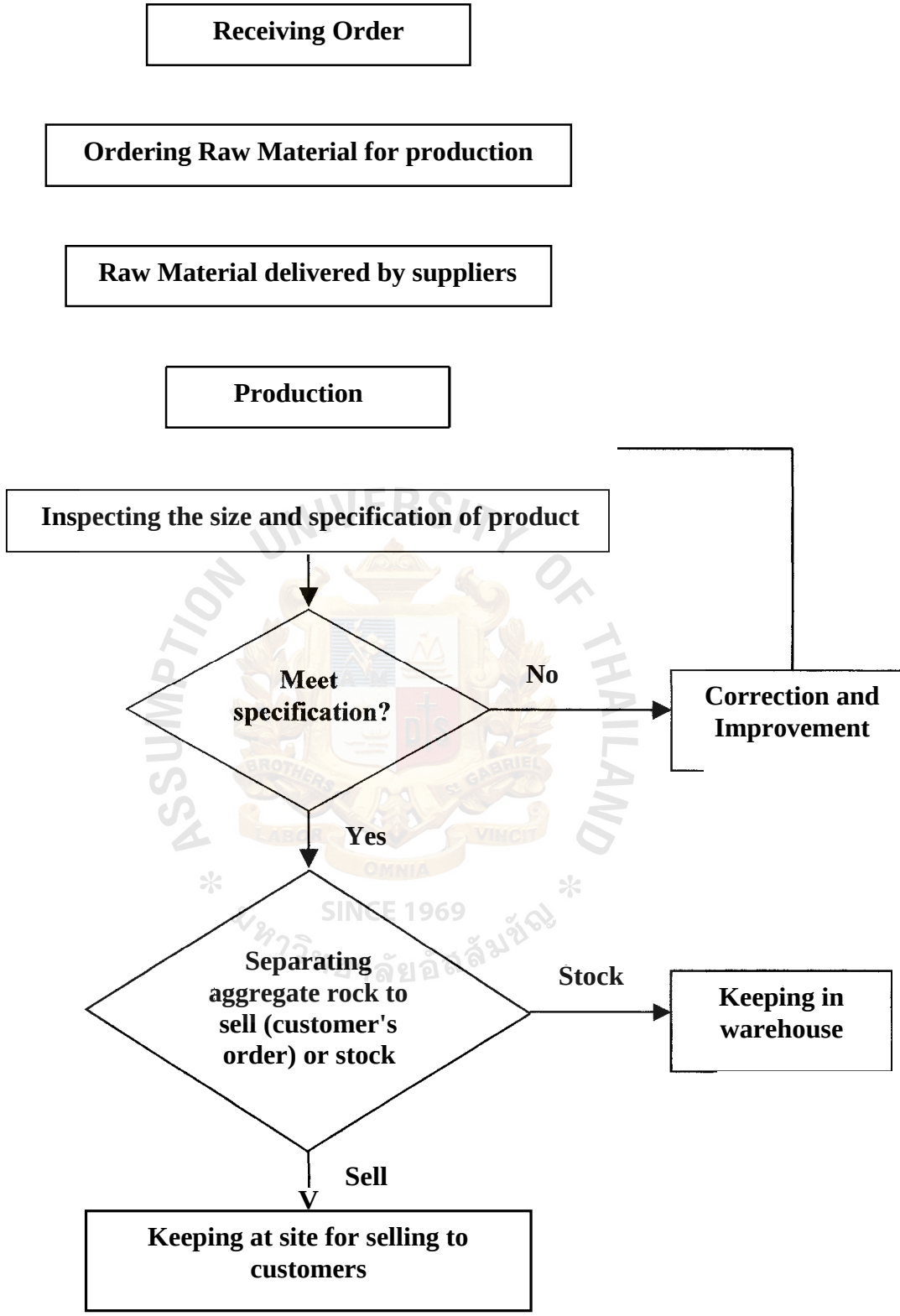


Figure 3.2. The Process of Operation of the Quarry.

3.4 Rock Production Process

Stone quarrying is the multistage process by which rock is extracted from the ground and crushed to produce aggregate, which is then screened into the sizes required for use or further processing, such as coating with bitumen to make bituminous macadam (bitmac) or asphalt.

The process begins with a detailed three dimensional survey of the quarry face. This allows the explosives engineer to design the blast and to plot where the shot holes should be drilled so that the blast can be carried out safely and efficiently. The survey will show if there are any bulges or hollows in the face. A bulge will need more explosive than normal to ensure that it is completely fragmented and not left in place in the face. Hollow areas require less explosive than normal. The placement of explosives is professionally planned to ensure that the required fragmentation of the rock is achieved with the minimum environmental impact.

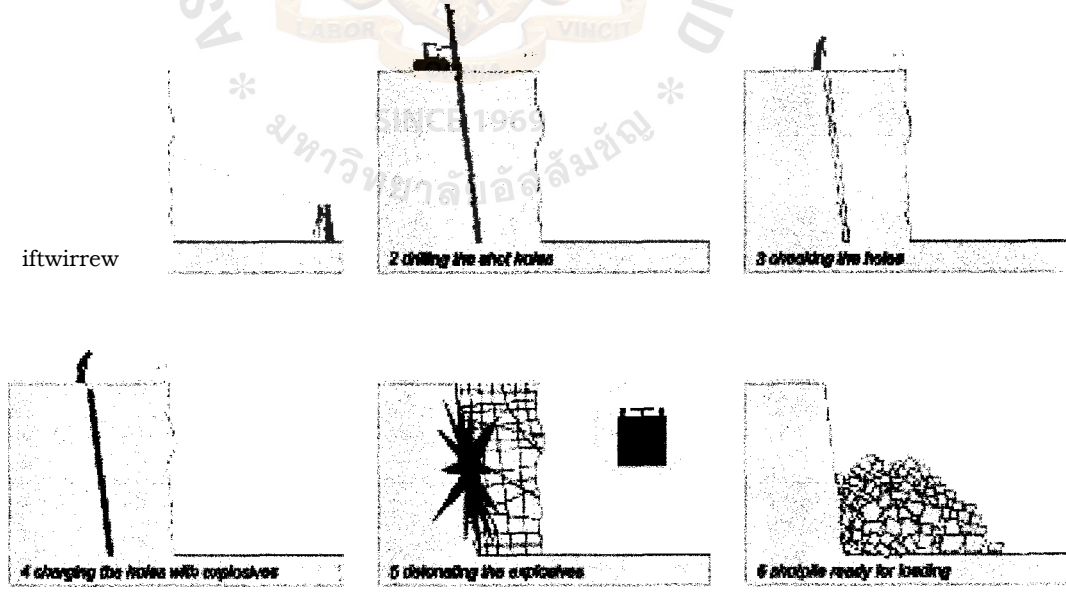


Figure 3.3. The production process.

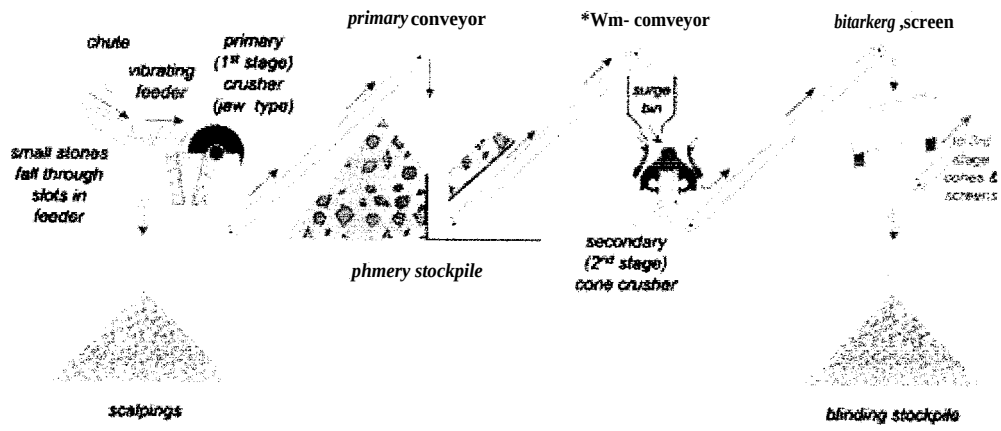
After the face profiling survey, the drilling contractor arrives. Using an air operated drilling rig, he drills the number of shot holes required at the marked spots corresponding to the hole positions on the blast design at the angles and depths required.

After the shot holes have been drilled, they are surveyed to check that they correspond to the blast design and the two surveys are combined to allow the blast engineer to work out how each shot hole is filled with explosives.

On the day of the blast, the explosives are delivered and taken to the site of the blast. The detonator cord is placed in each hole and the holes are then loaded with high explosives. The site is cleared. Sirens are sounded to make sure that everyone nearby is warned. The detonators are connected to the electric trigger wire and the circuit is checked. A final safety check is carried out and only then does the shotfirer set off the explosives. A single blast can fragment up to 20,000 tonnes of rock.

After the blast, the face and shotpile (sometimes called the muck-heap) are inspected to check that all the shot holes have fired correctly. The face shovel or loader then tidies up the shotpile and starts to load the dumper trucks that take the rocks to the crusher. Boulders which are too big to go through the crusher are set to one side for secondary breaking at a later date. Secondary breaking is typically done using a hydraulic digger fitted with a rock hammer, though crawler cranes with steel drop balls may be used in some quarries.

Crushing in most quarries is done in three stages, primary (first stage), secondary (second stage) and tertiary (third stage). Crushed rock, or product, is transported along the process line on conveyor belts or down chutes.



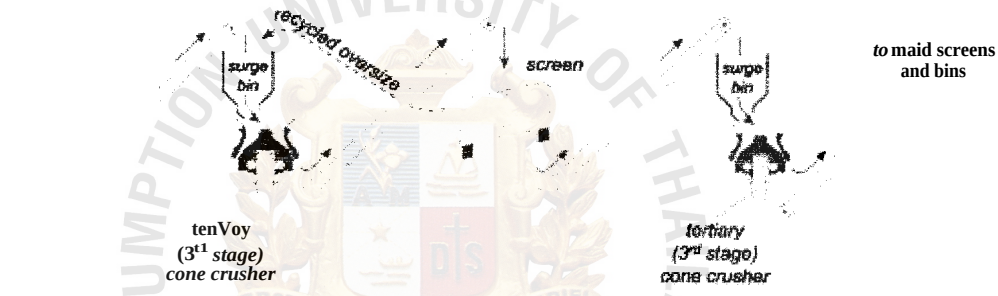


Figure 3.4. Crushing Process.

Primary crushing is usually by a jaw crusher consisting of a heavy metal plate which moves backwards and forwards against a fixed plate (the jaws). The moving plate is kept in motion and given its crushing energy by a large flywheel. The crusher is wider at the top than at the bottom. Rock from the quarry face is fed into the top of the crusher and crushed rock falls out of the bottom of the jaws. The size of the crushed stone which passes through the jaws is partly governed by the gap set at the bottom of the jaws, though larger size rocks can pass through if the rock being crushed is slabby or elongate in shape. Large scale gyratory crushers can also be used.

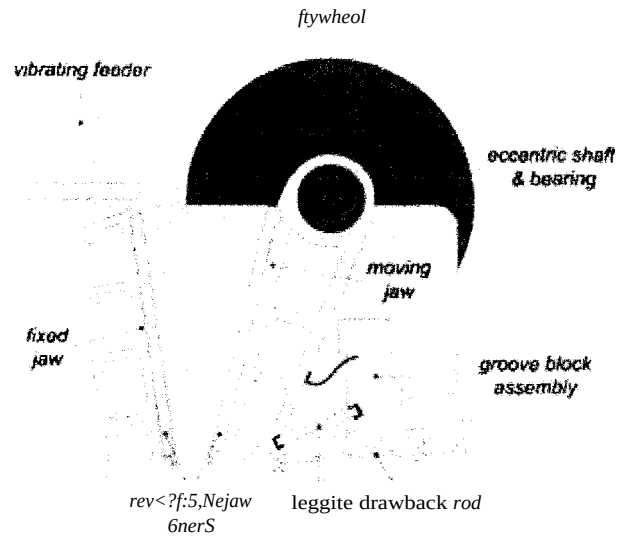
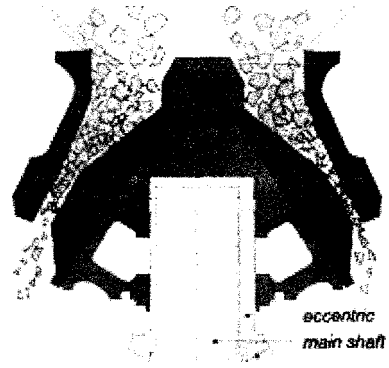


Figure 3.5. Jaw Crusher.

Secondary and tertiary crushers are generally gyratory, or cone, crushers. These operate on the principle of a steel cone mounted on an offset, vertical shaft. The cone rotates eccentrically within a static outer mantle. There is a gap between the mantle and the cone. The shape of the gap is tapered towards the base. As the cone rotates inside the mantle, the gap between the mantle and cone at any one point opens and closes on each rotation of the cone and this produces the required crushing action. Stone is fed in at the top and the crushed product falls out from the bottom of the cone. The cone can be raised or lowered within the mantle, allowing the gap and therefore the size of the crushed product to be varied to a limited degree. If the crusher is jammed by a stray bit of steel, e.g., a digger bucket tooth, the cone automatically moves down to clear the obstruction.

CONE CRUSHER

pain berme and other derails omMid *tor clerity)*



coonfershaft

v-bee drive wheel

Figure 3.6. Cone Crusher.

Each stage of crushing produces progressively smaller sized stones. In order to produce a usable end product, the crushed rock has to be screened into various size categories. The crushed and screened rock is called aggregate. Screening is done at various stages in the crushing process.

The primary crusher is fed via a chute and vibrating feeder. The base of the feeder is made of steel "grizzly" bars and it is here that the first screening operation is actually done. Fine material and dust produced by the blast, along with any remaining subsoil or weathered rock from the top of the quarry face, drops through the bars onto a separate conveyor belt and onto a stockpile. This screened material is called scalpings and is used as rock fill.

The output from the primary crusher is conveyed onto the primary stockpile from which the secondary crusher is fed. There is a screen house just after the secondary crusher which screens out small size crushed stone and dust onto blinding stockpiles. The larger sized stones pass through to the final tertiary crushing stage where they are

fed through a series of cone crushers and intermediate screens. The output from the tertiary cone crushers is finally conveyed to a screen house where large multiple deck screens sort the crushed stone into the required aggregate sizes.

Screened stone is known as screenings or aggregates. The term single size stone is also often used. Final screens are typically mounted in a screen house over large bins or hoppers into which the different sizes or grades of aggregate are fed. The hoppers are raised on legs so that trucks can drive under them to be loaded. Material is continually drawn from the storage bins for immediate use (e.g. in a coating plant) or for transfer, either by dump truck or conveyor, to storage stockpiles in the quarry.

3.5 **Statement of Problem in the Quarry**

From studying the quarry's actual status and working condition, operation of the quarry and rock production process, I use the information to list the situation in the quarry. The various problems are caused by improper management in method and process, and accessories which can be pointed out are as follows :

(1) For Mining Planning, there is no improvement in mining pattern that causes unable to increase the productivity.

(2) For Drilling and Blasting process, the operators still use the improper accessories and some workers are unskilled and misunderstand the process.

(3) For Hauling and Loading process, choosing draws only friable rock by each hauling machine and too small size of mouth of the crushers causing queues trucks waiting at mouth leads to poor productivity that adds to the overall cost.

(4) For Machinery Maintenance, there is high percentage of downtime (the time when the machines stops working) due to no Preventive Maintenance.

IV. STATEMENT OF PROBLEMS AND METHODOLOGY

During the Economic Crisis in 1997, the entrepreneurs in each business sectors were faced with the disaster that made them shut down or stop production temporarily. The construction industry is one of the business sectors that met this crisis.

After the last 6 years of severe economic recession; the quarry market is becoming more stable. This period of market rationalization will take up to 1-2 years to shake out due to the lack of economic direction and the government having very little reserve to continue with the country's much needed infrastructure projects.

The recovering market still has a high degree of volatility and although there is an increase in demand for aggregate to feed small infrastructure projects, the higher consumption is not being sustained in each region.

Before embarking on any improvement, an organization must analyze the existing process. It leads to point out the obstacles in production which effects the increase or decrease output. The winner will be the quarry that can capture the most market shares in anticipation of the expected increase in volume during the upturn.

4.1 Analysis of the Problematic Situation

To accomplish the quarry's objective of increasing the productivity and minimum cost, knowing the factors which effect these is the first thing to do. The structure of rock production cost consists of Drilling 17%, Blasting 13%, Hauling 15%, Loading 30% and Crushing 25%. When I analyzed the operation and process, I found that there are 4 main points that effect the productivity and cost. These are as follows :

(1) Mining Planning

The condition of rock in this region is lime stones which are mixed with soil and porosity. The rock production is quite big sized and back break. The owner who is the controller of the quarry site department sets the mining layout into two

layers, that is, upper and lower layer. Team A is responsible for the lower layer and Team B is responsible for the upper lower. Now the quarry opens the new lower layer for increasing output. The quarry layout is shown in Appendix A. Both Team A and B consist of 1 foreman and 5 workers.

Due to poor rock condition, cracks and cavities, and lack of a mining engineer who is the leader and planner for mining operation, it results in less productivity. Mining operation is the important procedure leading to increase in the productivity and the control the cost of operation. It is the starting point of quarry operation. If you have the good mining operation plan, you will receive a worthwhile return.

The owner uses continual improvement to improve the productivity but lack of knowledge of quarry management make him disinterested in mining management which the is the main point that helps in increasing the efficiency of machines and reducing the cost of production. Now drilling operators follow the same mining pattern with no improvement. The result can be seen from the rock production after blasting. There are many rocks piled on the bench which effects the next blasting. The result is decrease in output because the rocks lie and obstruct the blasting. This problem leads to the next problems which I will explain further.

(2) Drilling and Blasting process

Using the improper accessories is one of the causes of increasing production cost. The table below is the drilling consumption per month of the quarry.

Table 4.1. Drilling Consumption per month.

Drilling Accessories	**Quantity (pcs./month)**
Bit	3
Rod	8
Coupling	5
Shank	4

The ratios that are suitable for using the drilling accessories are the equal to the use of quantity between Bit and Shank, and Rod and Coupling. From the table, you will see that the quantities of using accessories are not in standard. The reasons are the poor rock condition and unskilled and lack of knowledge of workers. Choosing the accessories unsuitable for the rock condition causes breakage and damage in drilling accessories.

For the blasting process, I found that the problems in the process are consistent with the quantity of explosives. The blast's problems are; no steaming on holes with water causing fly rocks, energy escaping up from unstemmed holes, uneven distribution of energy in each holes due to bad loading of holes, and reasonable fragmentation but not enough throw causing blasted rocks to pile up high on the bench. These problems lead to difficulties in clearing and adds to the overall operating cost. The saved oversized rocks requiring secondary break adds to the overall cost, and also the backbreaks resulting from blasting before clearing the ground of rocks. The explosives consumption per month of the quarry is shown below :

Table 4.2. Explosive Consumption per month.

Type of Explosives	Unit	Quantities (per month)
PE	Kg.	792
IED	Pcs.	2,000
MSD	Pcs.	600
A/N	Kg.	40,775

After adjustment and improvement in the process, the use of the quantities of drilling accessories and explosives will decrease which I will show you in the next section.

(3) Hauling and Loading process

After the drilling and blasting process, it is the time of Hauling and Loading process. This process is one of the main factors of the cost of production. The quarry has 6 machines for Hauling ; 1 for CAT988, 2 for CAT966, 1 for Back Hoe, and 2 for Hydraulic Shovel; and 24 machines for Loading ; 2 for Terex 35T, 7 for 10 Wheels Trucks and 15 for 6 Wheel Trucks. Machines for Hauling will draw the rocks into the trucks for delivering to the crusher. For sufficient rock production, there are 2 Crushers in the quarry and outside the quarry. The sizes of the mouth of the crushers are 42*30 inch and 40*30 inch respectively.

From the tables below, I see the efficiency of Hauling and Loading from the collected data from the site.

Table 4.3. Efficiency in Hauling and Loading.

Machines for Hauling	Machines for Loading	Finishing Time		Wasting time for next loading
		Maximum	Minimum	
Back Hoe 320C	10 Wheels	3	2	1-16
Front end 988	10 Wheels	3	2	1-20
	Terex 35 T	3	3	1-20
Front end 966 (1)	6 Wheels	2	1	1-15
Front end 966 (2)	6 Wheels	3	1	1-20
Hydraulic Shovel	10 Wheels	3	2	1-20
	Terex 35 T	3	2	1-20

Table 4.4. Times for Hauling and Loading.

Front end 966 (1)			
Trucks	**Start**	**Finish**	**Total**
6 Wheels	13.24	13.26	2
6 Wheels	13.27	13.29	2
6 Wheels	13.30	13.31	1
6 Wheels	13.32	13.34	2
6 Wheels	13.35	13.37	2
6 Wheels	13.43	13.45	2
6 Wheels	13.49	13.50	1
6 Wheels	13.52	13.54	2
6 Wheels	13.55	13.56	1
6 Wheels	13.57	13.58	1
6 Wheels	13.59	14.00	1
6 Wheels	14.01	14.03	2
6 Wheels	14.13	14.15	2
6 Wheels	14.16	14.17	1
6 Wheels	14.20	14.21	1
6 Wheels	14.23	14.25	2
6 Wheels	14.26	14.27	1
6 Wheels	14.28	14.29	1
6 Wheels	14.30	14.31	1
6 Wheels	14.39	14.41	2
Front end 988			
10 Wheels	10.30	10.32	2
10 Wheels	10.32	10.35	3
10 Wheels	10.37	10.39	2
Terex 35T	10.41	10.44	3
10 Wheels	10.46	10.49	3
10 Wheels	10.49	10.51	2
Terex 35T	10.54	10.57	3
10 Wheels	10.57	10.59	2
10 Wheels	11.00	11.03	3
10 Wheels	11.09	11.12	3
10 Wheels	11.32	11.35	3
Terex 35T	11.37	11.40	3
10 Wheels	11.42	**11.44**	2
Terex 35T	11.44	11.47	3
10 Wheels	11.47	11.50	3
10 Wheels	11.50	11.52	2
10 Wheels	11.52	11.55	3

Front end 966 (2)			
Trucks	**Start**	**Finish**	**Total**
6 Wheels	13.36	13.37	1
6 Wheels	13.39	13.40	1
6 Wheels	13.41	13.42	1
6 Wheels	13.43	13.45	2
6 Wheels	14.04	14.06	2
6 Wheels	14.07	14.08	1
6 Wheels	14.09	14.11	2
6 'Wheels	14.11	14.13	2
6 Wheels	14.30	14.32	2
6 Wheels	14.34	14.35	1
6 Wheels	14.36	14.37	1
6 Wheels	14.40	14.41	
Hydraulic Shovel			
Terex 35T	13.31	13.34	3
10 Wheels	13.35	13.38	3
10 Wheels	14.19	14.21	2
10 Wheels	14.23	14.25	2
Terex 35T	14.31	14.33	2
10 Wheels	14.37	14.40	
Back Hoe			
10 Wheels	10.30	10.32	
10 Wheels	10.32	10.35	3
10 Wheels	10.37	10.39	2
10 Wheels	10.41	10.44	3
10 Wheels	10.46	10.49	3
10 Wheels	10.49	10.51	2
10 Wheels	10.54	10.57	3
10 Wheels	10.57	10.59	2
10 Wheels	11.00	11.03	3
10 Wheels	11.09	11.12	3
10 Wheels	11.32	11.35	3
10 Wheels	11.37	11.40	3
10 Wheels	11.42	11.44	2
10 Wheels	11.44	11.47	3
10 Wheels	11.47	11.50	3
10 Wheels	11.50	11.52	2
10 Wheels	11.52	11.55	3

I can conclude that the average time of hauling and loading process of each machine is 3 minutes and wasting time for the next loading is about 20 minutes. The reason why a long time is spent to operate is because of too small size of the mouth of the crushers causing trucks queues waiting at mouth leading to poor productivity that adds to the overall cost. And the other is choosing the draw of only friable rock by each hauling machine result in clearing and blasting process further.

(4) Machinery Maintenance

Due to the big quarry and saving cost, the quarry has its own machine maintenance department that is divided into 2 teams, that is, at site and workshop mechanical team. The mechanical engineer will control this department. Machines that have broken down and are unable to work will be sent back to the workshop for repairing. But the day to day repairs will be operated at site. There are service trucks for refilling the petroleum and sending the spare parts to the site. The drilling operator carries out daily checks and maintenance his own drilling machine such as draining water in the morning, cleaning the drilling machine after working, etc..

The problem in this department is high percentage of downtime due to no preventive maintenance machines. Downtime of machine shows the signal of decrease in productivity and waste of working time. The quarry's working days are 7 days per week so stopping the work of the machine may mean loss of profit. Therefore, I use the information about the drilling speed of each machine to consider which machine has the lowest productivity in each team. The information about the drilling speed of each machine is summarized in Table 4.5 and is shown in a form of histogram in Figure 4.1

Table 4.5. Drilling Speed of machinery.

Team	Drilling Rig	Speed (m/day)
A	HCR 9	180
	HCR 300 (1)	175
	HCR 300 (2)	182
B	HCR 180	186
	HCR 300 (3)	182
	HCR 300 (4)	168

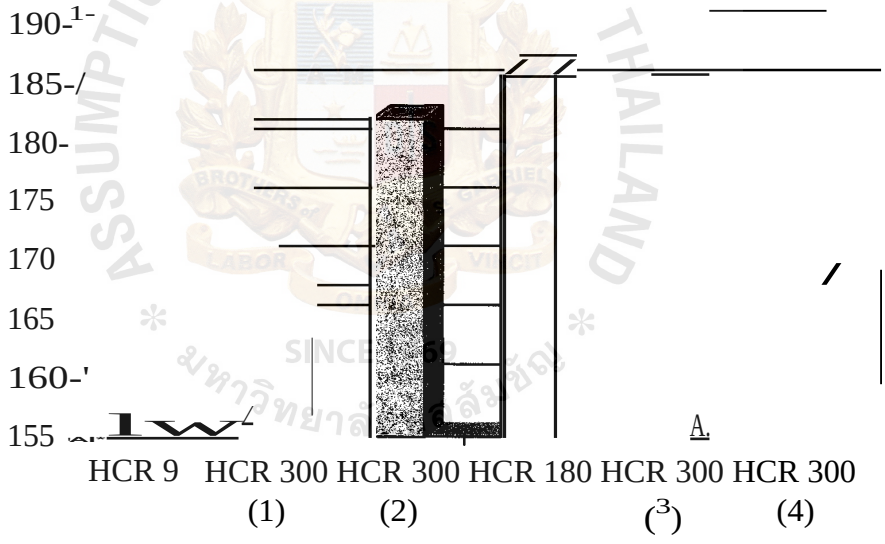


Figure 4.1. Drilling Speed of machines.

Considering the histogram, I obviously recognize that HCR 300(1) belongs to Team A and HCR 300(4) belongs to Team B and have the lowest productivity. Due to lack of Preventive Maintenance, the efficiency of machines decrease which result in output. Preventive Maintenance or PM is the important thing in

maintaining the lifetime of machines. This problem is one of main problems that should be corrected and improved to accomplish the quarry objective.

Later chapter will provide the analysis of possible root causes of problems and propose alternative solutions for solving the causes of problems.

V. SOLUTION FOR SOLVING THE PROBLEMS

In this chapter, I will provide the analysis of possible root causes of problems and propose alternative solution for solving the problems.

5.1 The Analysis of Causes of Problems

From the information in the last chapter, I found that 4 main problems obstruct to the accomplishment of the quarry's objective. The problems are no improvement of mining plan, lack of knowledge of drilling and blasting process, spending a lot of time in hauling and loading process, and no machinery maintenance. I use the ratio of cost of rock production that consists of drilling and blasting 30%, Hauling and loading 45% and Crushing 25% as shown in Figure 5.1 for the ranging level of importance of problems presented in Table 5.1.

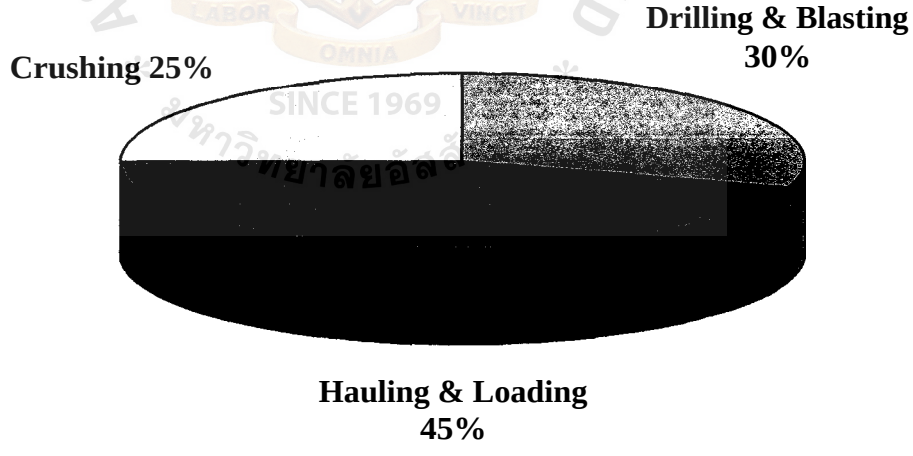


Figure 5.1. The ratio of cost of production.

Table 5.1. Problems effecting the cost of production (in percentage).

Process	Causes of Problems (Percentage)				Total
	(1) No improve in mining plan	(2) Lack of knowledge in drill and blast	(3) Spending a lot of time in haul and load	(4) No machine maintenance	
Drilling and Blasting	60	30	-	10	100
Hauling and Loading	40	20	35	5	100
Crushing	50	20	20	10	100
Total	**150**	**70**	**55**	**25**	**300**
Percentage	**50**	**24**	**18**	**8**	**100**

I use the information from Table 5.1 about problems that effect the cost of production in analysis by using the Pareto diagram that is presented in Figure 5.2.

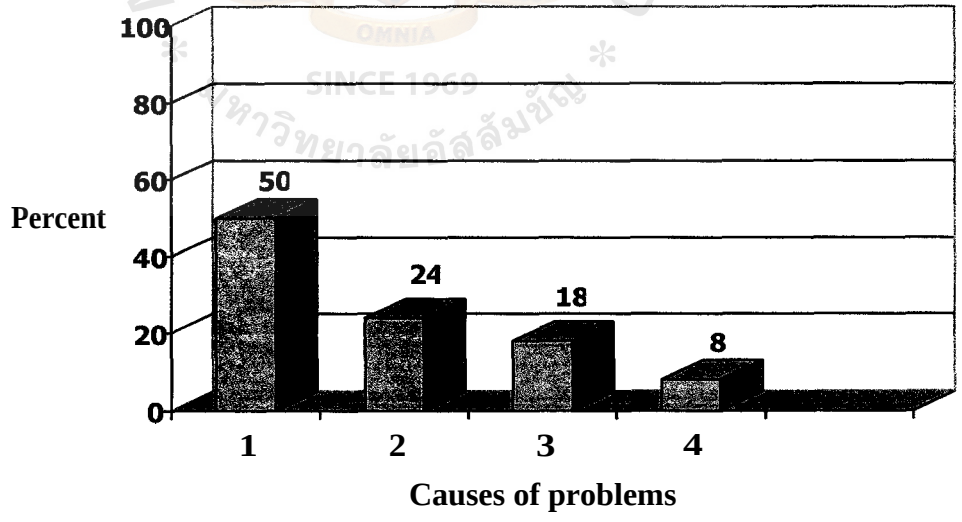


Figure 5.2. Pareto Diagram of causes of problems.

This Pareto diagram identifies the major causes of problems to be no improvement in mining plan. Correction or improvement the mining pattern is the most important because it leads to the solution of other problems. The cause and effect diagram is the tool that helps to identify the possible causes affecting a problem or project that is presented in Figure 5.3.

Studying the related information and the opinions from manager, engineers and high skilled and experienced workers, the major causes of the problems in rock production process shown in Figure 5.3 come from three main reasons which are :

(a) Poor planning method

(b) Lack of knowledge of workers

(c) No machinery maintenance

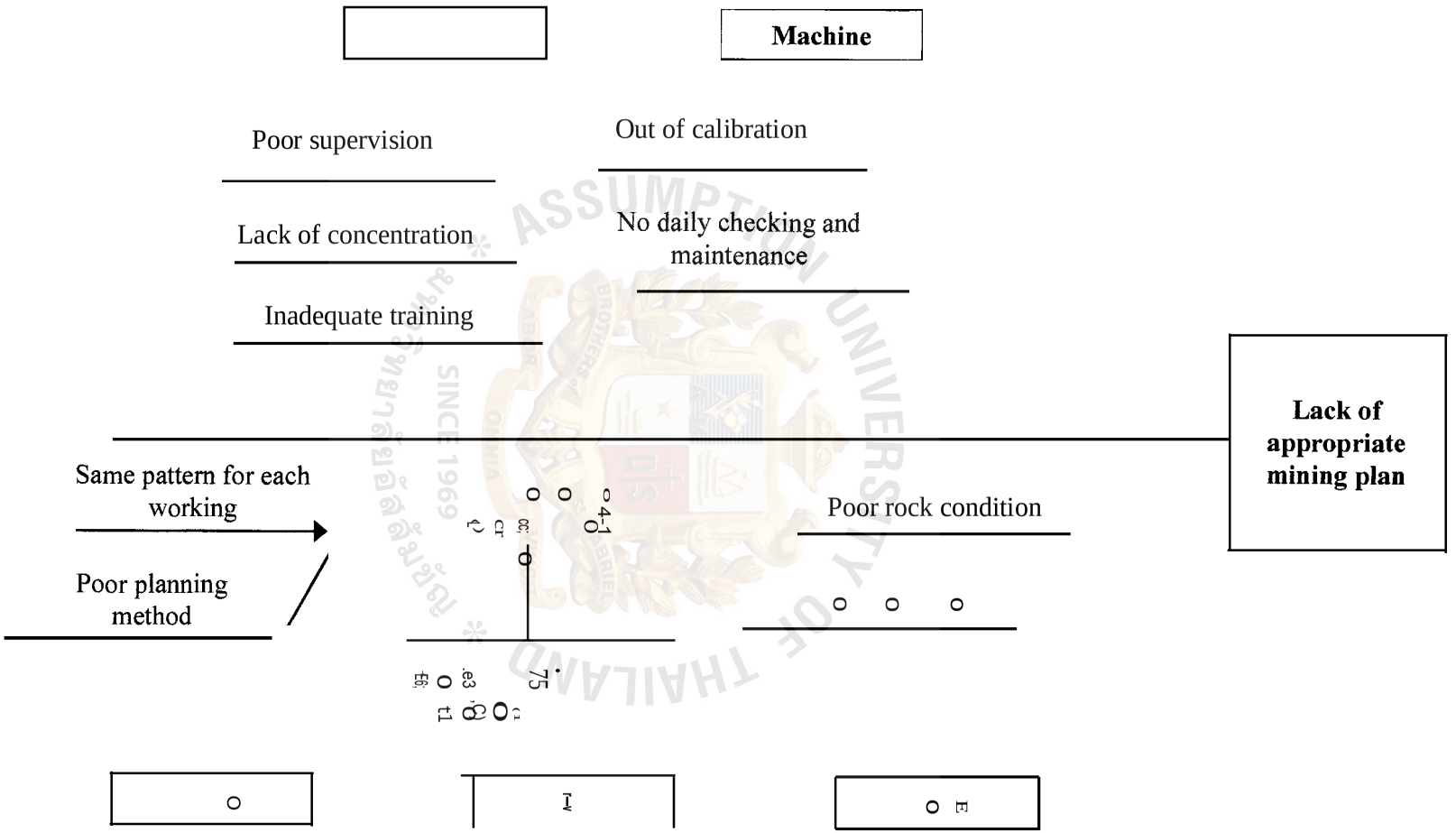
5.2 Solutions for solving problems

From the above reasons, I will make further analysis of the solution for the current problems.

5.2.1 Poor planning method

Due to poor rock production, the trouble is planning the mining operation. I know that the quarry uses only one pattern for each work with no improvement or adjustment in the plan. After each process, the operators do not record the result that is the factor that helps to analyze the causes of using the quantity of accessories and the cost and also lack of skilled personnel to analyze the information.

But now to accomplish the company objective, finding the root cause of the problem is the important thing. The unadjustment of mining planning is the main problem of this quarry that is related to the other problems.



bA M Cause and Effect Diagram of lack of appropriate mining plan.

Before I will improve the mining plan, the first thing that I must know is the factors that effect the mining pattern and cost of production. The first thing is surface of the quarry. In order to decrease obstacles and increase output, I must know the surface of the quarry such as density of the soil's layer or slope of surface. The next are the size of the quarry, suitability of the machines and accessories, environment, and timing for mining operation.

The following are the causes of high cost of production. I found that the causes of high cost of production of this quarry start from the inefficiency of drilling and blasting, waste time in adjustment, the big size of rock production that leads to difficulty in hauling and crushing. These problems are related to each other and leads to the next problem. The rock production is the indicator of the quality of planning and cost of production.

To understand easily, I will present the solving method by using quantities and expense to compare before and after the implementation. The first thing to do is hiring the mining engineer who controls and sets the mining plan. Correction and improvement processes, implementation, and evaluation are the following steps. Hiring the mining engineer is the responsibility of the quarry. For me, I will analyze and find the solving method in the next step. From the information, I know that the root of the problem is drilling and blasting process. Besides, the appropriate planning, knowledge and experience of the workers are the important things for these processes that I will analyze in the next section.

In the drilling process, it starts with plotting the holes and drilling by the drilling operators. Keeping no record of the drilling's result is one of the causes of the high cost of production. I suggest the solution by keeping the results of the drilling holes to

analyze the quantity of explosive used in the blasting process. The example of recording the condition of the drilling holes is shown in Table 5.2.

Table 5.2. Example of drilling result.

Hole/ row		**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Metre	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
1	4	4	4	4	4	4	4	4	4	4	4	4
2	4	4	4	4	4	4	4	J	4	4	4	4
3	x	J	4	4	4	J	4	4	4	4	4	4
4	x	4	4	4	4	4	4	J	4	4	4	-4
5	x	4	4	4	4	4	4	4	4	4	4	4
6	x	4	\/	-4	4	4	'J	4	4	J	J	4
7	Ai	4	4	4	4	4	4	4	4	4	4	4
8	"V	Ai	4	4	4	4	4	4	4	4	\/	J
9	J	4	4	4	J	4	J	J	J	4	4	4
10	\1	J	4	4	4	4	4	4	J	4	4	4
11	4	4	4	4	J	4	4	J	4	4	J	4
Deer) (m)	**5.0**	**10.7**	**10.5**	**11.0**	**10.8**	**10.6**	**10.8**	**10.8**	**10.7**	**10.8**	**10.8**	**10.6**

Hole/ row	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Metre	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**
1	-\/	-\/	J	-4	-4	x	x	x	4	4	4	4
2	§	4	4	4	4	4	©	4	4	-4	4	4
3	§	4	4	4	4	4	-4	4	§	©	§	4
4	§	4	4	4	4	4	4	4	4	4	4	4
5	-V	-V	Ai	-V	4	-4	4	4	4	©	§	4
6	4	4	4	4	4	4	4	4	§	-4	J	4
7	4	4	4	-\/	4	§	g	§	4	©	-\/	4
8	4	J	J	J	-4	J	J	J	4	4	4	J
9	4	4	4	4	4	-4	4	4	4	-4	-4	-4
10	4	4	4	4	4	4	4	-\/	4	4	4	4
11	4	4	4	4	4	4	4	4	4	4	4	4
Deep (m)	**10.6**	**10.8**	**10.8**	**11.0**	**10.8**	**10.6**	**3.0**	**10.9**	**10.4**	**8.0**	**10.6**	**11.0**

Signal for rock properties: J for strength x for crack for porosity g to be mixed soil

This information helps to know the reasons why the results of some drilling holes are not in standard. From interviewing the operators it was found that the condition of the rock is the factor that effects the depth of the drilling holes. From the example of the drilling data of 24 holes, there are 3 holes which are sub-standard. The 3 holes must re-drilled that means more cost of production.

The other reason is inappropriate use of drilling accessories the quantity of which is shown in Table 4.3. Correction of the drilling pattern suitable for the surface and using the drilling accessories appropriately are the solutions of this process. To reduce the quantity of drilling accessories, the operators should change the accessories at the same time to extend their life such as Rod and Coupling, and Bit and Shank, etc. The above adjustment helps to reduce about 20% of the quantity of accessories.

The good condition of drilling holes leads to the desired blasting result. Before adjustment, the blasting result is not specific and is unable to clear the bench in time for the next blasting. The rock will lay on the bench that will increase the quantity of rock and burden to the next blasting. The problems and results of inappropriate blasting are shown in the last chapter. The problems of this process are similar to the drilling process, that is, lack of knowledge and unskilled workers, no record the blasting result and inappropriate use of explosives.

From the analysis of the blasting problems of this quarry; the causes of the problems come from the result of inappropriate drilling process and lack of knowledge and unskilled workers. The first cause can be solved by adjusting the drilling pattern. Training is the method to solve the second problem. The theory of blasting efficiency and safety is more in detail so I will talk about it in the next topic. For this part, I will emphasize on the blasting process that is the dangerous process due to the concern

about using explosives that effect the safety of life and property. I recommend the method of recording data for improving the existing blasting process.

Sensible blast performance assessment can only be achieved if adequate information is collected before, during and after the blast. To understand the factors which produce different results, including unwanted side-effects, a certain amount of information must be recorded for later analysis. Simple report sheets can be used to record the essential information, to avoid any misunderstanding or reliance on fallible memories. The relevant information for each operation will depend to some extent on local conditions and requirements, but some factors are common to all blasting operations. A suggested format used in a quarry is included as Figure 5.4 to assist with the drafting of blast report sheets for specific quarry sites.

BLAST SUMMARY RECORD	
DATE ..... TIME ..... BLAST NO.	
BLAST GEOMETRY	**EXPLOSIVES**
No. Blastholes ..... No. Wet Blastholes ..... Blasthole Diameter (mm)	Explosive Types Dry ..... Wet .....
Bench Height (m) ..... Average Blasthole Depth (m) ..... Pattern (Bm x Sm) ..... Stemming Length (m)	Total Explosives Used (kg) Dry ..... Wet ..... Total .....
Blast Volume (m)	
POWDER FACTOR (KG/M^3)	
GROUND AND AIR VIBRATION Peak Particle Velocity (mm/s) ..... Air Overpressure (dBL) ..... Distance to Geophone (m)	
COMMENTS Fragmentation ..... Heave ..... Digability ..... General	
RECOMMENDATIONS FOR FUTURE BLASTING	
COMPILED BY	

Figure 5.4. Blast Summary Record.

Once a recording system is established, it is relatively simple to develop it into a comprehensive database, using a computer to store, manipulate and report relevant information. Such systems allow input of downstream activities such as digability and ideally would allow a bottom line cost to be developed also. After improving the

process and method, the quantity of using explosives will be reduced with less cost and more productivity. The result is shown in Table 5.3.

Table 5.3. The quantity of rock production and cost of explosive.

Month	Quantity of rock (Ton)	Type of Explosive		Cost per ton
		A/N (kg)	High Explosive (Kg)	Detonator (pc)	
October	191,437	40,775	750	2,600	3.27
November	178,211	40,550	750	2,400	3.42
December	**192,749**	**38,550**	**750**	**2,400**	**3.09**

From the table, you will see the result of more output, and reduction of explosives and cost per ton after improvement in December are the indicators of appropriate management.

After correction of drilling and blasting process, the problem of hauling and loading will disappear. Firstly, the problem of this process is spending a long time for operation due to the small mouth of the crushers and avoiding drawing in the poor rock condition of the hauling machines. Having 2 crushers is the reason why the quarry does not want to buy the new one as the cost is very high. So the choosen solving method is reducing size of rock production that helps to reduce the operation time and hauling disorders. From the adjustment of drilling and blasting process, the size of the rock becomes small which makes hauling easier and less time of loading is spent. Trucks do not have to wait for a long time at the mouth of the crushers. The result of improvement is presented in Table 5.4.

Table 5.4. The result of hauling and loading improvement.

Machines for Hauling	**Machines for Loading**	**Finishing Time**	
		Before	**After**
Back Hoe 320C	**10** Wheels	4	2
Front end 988	10 Wheels	3	2
	Terex 35 T	4	3
Front end 966 (1)	6 Wheels	3	2
Front end 966 (2)	6 Wheels	3	2
Hydraulic Shovel	**10** Wheels	3	2
	Terex 35 T	4	3

From the table, you will see that it can help to save time about 20%, reduce the working time of machines, and save cost of hauling and loading. The examples of cost of hauling and loading are lubricating oil, rattan basket, or maintenance.

After that trucks load the rocks to the crusher which is in and outside the quarry and the time of crushing is short due to the smaller size of the rocks that are easy to crush. The example of the result of reducing crushing time is shown in Table 5.5.

Table 5.5. The result of crushing improvement (for crusher is in quarry).

Loading Trucks	**Average Crushing Time (minute)**	
	Before	**After**
10 Wheels	4-5	3-4
Terex 35 ton	7-12	4-8

From the above data, you will see that the time of crushing is decreased by 30% which leads to reduced cost of crushing. The less damage of the crushing accessories is one of the advantages of appropriate management.

I can conclude that the drilling and blasting are the major processes that effect the cost of production and increase productivity. If you can manage in the appropriate way, the result is worthwhile and leads to the solution of other problems as I use to solve the problems in hauling and loading, and crushing process.

5.2.2 Lack of knowledge of workers

From the assumption, one of the many reasons that effect productivity may arise from lack of knowledge among the employees and unskilled employees. I surveyed the condition, procedure, steps and technique of working and also interviewed the employees about their work in order to prove our assumption. After that, I analyzed that this problem may occur in every process but I concentrated on the drilling and blasting processes that had more effect on productivity and cost of production. These processes rely on the experienced operators for controlling and solving the problem.

On the study of drilling and blasting processes, I find that the causes of problems result from lack of knowledge and unskilled workers, which the consequence is shown in the form of using quantities of accessories and productivity as presented in table 4.1 and table 4.2. From the organization chart in Figure 3.1, I see that no mining engineer controls the rock production process, the chief of each department is a foreman and the operator is a worker. This points out the level of education for they use the work experience more than the mining knowledge. The other reason why the quarry hires them is low wages.

From interviews with the operators, it was found that they will follow the original pattern that are planned by the chiefs or owners, for example, laying the drill pattern,

drilling and blasting method, and so on. I interviewed the owner about providing enough training to his employees to perform their jobs well and got the answer that the quarry does not provide any training or give any advice about the jobs. Most employees have to learn by themselves by asking among employees and prior employees. Giving training is the method for solving the problem. The employees should be trained so that they can understand the production process, technique, and choosing the accessories suitable for the job. The purpose of training is to increase and enhance the efficiency of each position and to change the old concept of production.

The objective of the training course is to train foremen and workers. I will divide the training group into 2 groups, for foremen and workers. The workers and foremen will learn about the standard work procedure with specific methods, tools and equipment to be used for each job. The foremen will also learn to analyze, solve and make corrections to the problems. The example of the training courses is shown in Appendix B (English Version) and Appendix C (Thai Version).

The key success of training needs cooperation among the employees, the supervisor, the manager and the management of the company to realize the importance of training. In the beginning the quarry should strictly follow the attendance of employees in the programs in order to build attention and interest of the participants. Moreover, the manager and the supervisor should closely follow the employees attending the training. Due to the limit of time, I cannot evaluate the result and impact of the training contribution to the production.

5.2.3 No machinery maintenance

Although this problem is not the major problem, that is, only 8% of 100%, it can help to reduce the cost of production. The heart of rock production is the efficient machine that leads to high output and low cost. This is the reason why this problem is

one of the problems to be solved. The quarry has many machines but I will emphasize on the drilling machine that is the estimator of the output. Breakdown of the drilling machine means stopping the production process and losing money. The working days of the quarry are 7 days per week; it means the machines must work all the time. Preventive Maintenance is one way to extend the lifetime of machines. The 6 drilling machines are used all the time but there is no maintenance. Mechanics repair the machines with only a little bit of damage at the site and if they are out of order, at workshop. After repairing, they do not keep the data in profile so they do not know the history of each machine. Now the status of machines is out of calibration with no daily checking and maintenance and no keeping of the record of machines.

From the analysis of the actual working situation, I found that every machine is running all day and there is no replacement. If the machines break down, it means that it takes a lot of time to repair. Having no preventive maintenance results in poor work. To solve this problem, the mechanical engineer should brainstorm with both at site mechanical team and workshop mechanical team to find the method to extend the life of the machine. Recording the history of each machine such as life of machine, efficiency in drilling, or length of repairing, and choosing the high efficient machines and then bringing the lowest efficient machines to preventive maintenance are examples of the methods to solve the problem. I recommend the maintenance planning to solve the problem that is shown in the form of a flowchart in Figure 5.5.

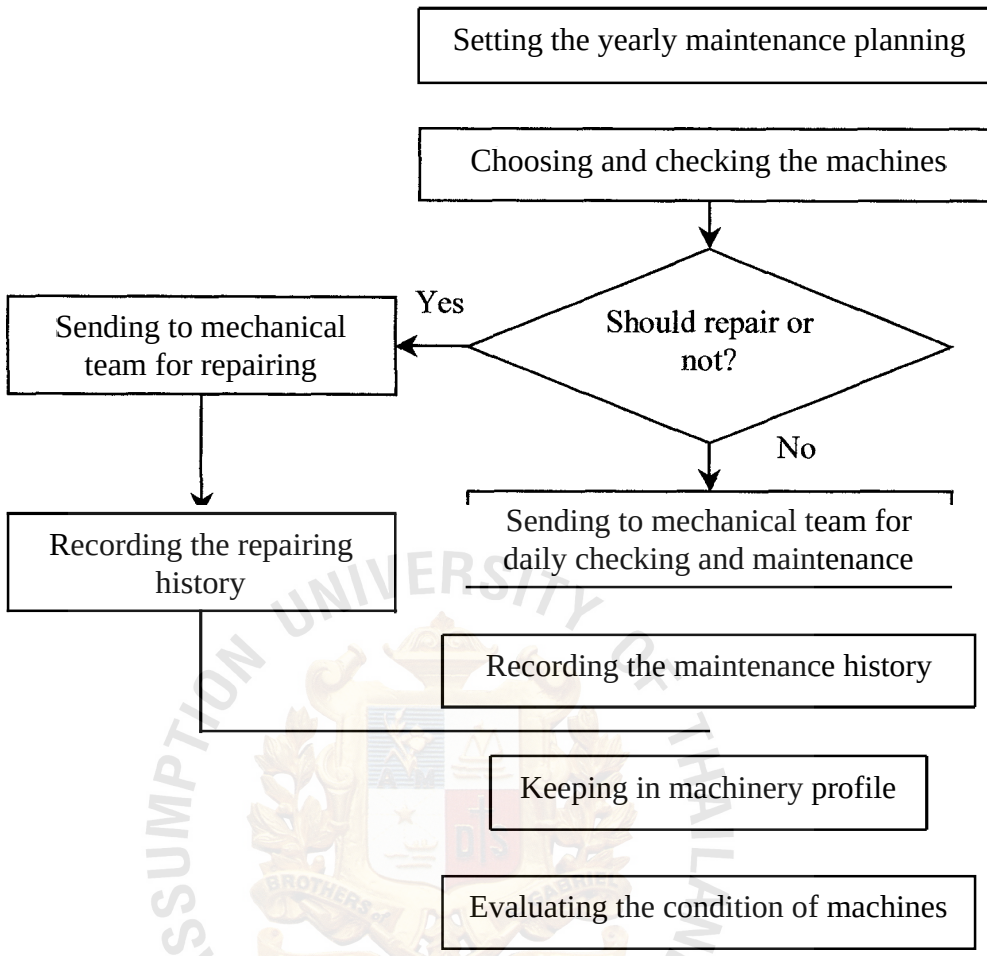


Figure 5.5. Flowchart of machinery maintenance.

From the above flowchart, you will see the procedure of machinery maintenance that can help to extend the life of machines and know the condition of each machine. It helps to evaluate the machines whether repairing or replacing. The result is enhancing efficiency of machines, increasing output and saving the cost of production.

VI. CONCLUSIONS AND RECOMMENDATIONS

This chapter presents conclusions and recommendations about the problems in rock production process by using the related information from the study of the quarry's actual status.

6.1 Conclusions

The aim of this project is studying the processes and problems of rock production, and then gathering the related information in the system for probably analyzing the data, determining solution, conclusions and recommendations to accomplish the quarry's objective. As a result, the improvement will contribute to the production efficiently by decreasing the time of operation and cost of production.

Tools for continual improvement are used to determine the major problem in the quarry and analyze the root causes. The major problem is lack of appropriate mining plan that affects the whole process and solving this problem can reduce the cost of production and increase output. Next, the analysis of the root causes by cause and effect diagram shows that the major causes are man, machine, material, method and environment. From the analysis, these major causes come from a poor planning method, lack of knowledge of workers and no machinery maintenance.

As discussed earlier, the operation of a quarry involves a wide range of activities including; design and planning, drilling and blasting, loading and hauling and crushing and screening. Drilling and blasting methods influence many different processes in a quarry and have a direct influence over productivity and the costs of all subsequent operations. From the above assumption, I studied the whole process and found that the problems came from the drilling and blasting process. So if I can solve these, it will lead to solve the other problems. From studying the quarry operation, there is no mining engineer who plans, controls, analyzes and solves the problem. So the

information comes from interviewing the owner, the manager, the engineer, the foremen and the workers and figure such as quantities of accessories comes from actual quantity per month.

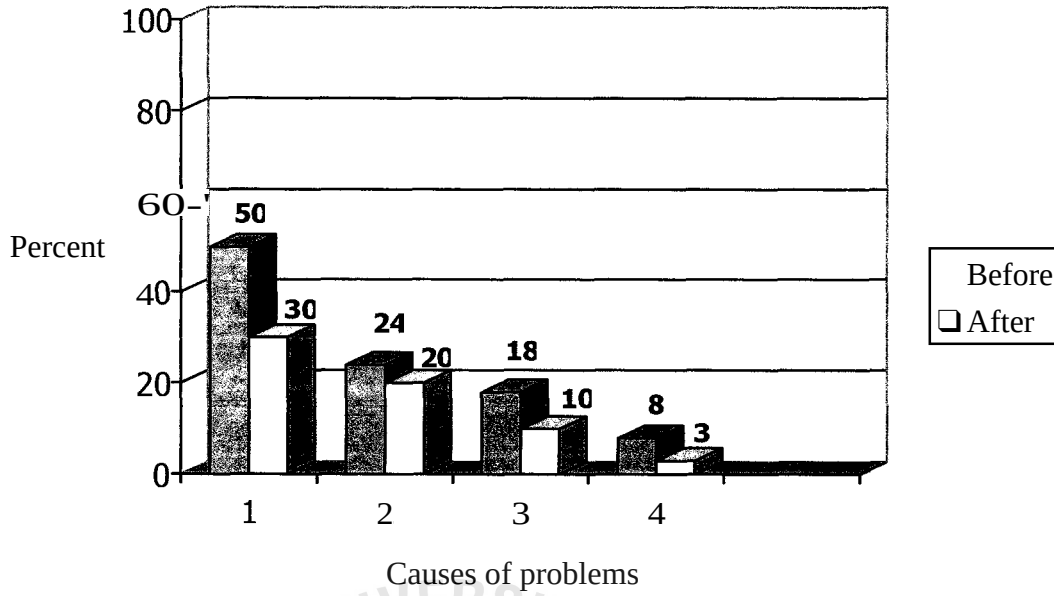
To accomplish the quarry's objective, that is, increase productivity by decreasing the usage of material, time of operation and cost of production, I studied the whole processes, organization chart, number of employees, production process, quantity of accessories and time for each process. After that I suggested the solutions and concluded the result which is related to the basic weight problem of the cause and effect diagram in figure 5.3. They are as follows :

In the drilling and blasting process, it is the start of the process so finding the problem is the first thing to do. The problem of this quarry is having no mining engineer. To solve the planning problem, I suggest hiring an engineer consultant to set the drilling and blasting plan suitable for the quarry's surface with crack and porosity condition. Training is the next step to enhance the knowledge of the foremen and the workers and recording and keeping the working data and quantity of accessories is the important method to analyze and determine the solutions. Machinery maintenance is one of the methods that I choose for increasing the productivity. Due to lack of maintenance, the lifetime of machines are short and lead to decreased output. The result of improving this process is a better mining plan leading to increase in productivity by increasing output and decreasing quantities of accessories and cost of production. After improving this process, it leads to solve the next problem, that is, the hauling and loading process.

In the hauling and loading process, the problem is spending a lot of time in operation due to the oversize of rocks which are difficult to dip and trucks have to wait for a long time for loading. The lubricant oil and rattan baskets are the examples of the

cost of this process. After decreasing the size of rock in the drilling and blasting process, the time of hauling and loading decreases. And the next problem is the crushing process.

In the crushing process, the problem is timing of crushing that depends on the size of rocks. The bigger sizes of rocks mean the more time of crushing. The result of solving this process is reducing time and having more output. After improvement, I interviewed the owner, the manager, the foremen and the workers to find whether the solution method can help to reduce causes of problems that effect the cost of production or not. The answer is YES but I cannot identify in total figure due to time restraint. So the result measurement is the satisfaction of the owner, the efficiency of working and the decreasing of the cost of production. I can analyze the decreasing of problems in percentage and conclude the result after improvement that is shown in a form of histogram in Figure 6.1.



1 = No improvement in mining plan 2 = Lack of knowledge in drilling and blasting

3 = Spending a lot of time in hauling and loading 4 = No machine maintenance

Figure 6.1. Pareto Diagram of causes of problems.

From the Figure above, there is change in every reason due to the improvement of the mining plan that effect the next problems but for reason no. 2, that is lack of knowledge in drilling and blasting, there is little percentage change due to lack of time for evaluating the result of training. As a result, the quarry will get the better quality product in case of size of rock production, save the time and cost of production. Moreover, it can produce more output to compete with competitors in the growing market.

6.2 Recommendations

From the study, I conclude and suggest recommendations for work performance in the future so that the quarry will improve and develop continuously.

(1) The quarry should hire its own mining engineer who can help to plan, analyze, find the problem and make solution.

(2) The quarry should set the working standard. In addition, it should prepare documents and instructions to guide the correct steps of working which include processing information and periodic update of the information.

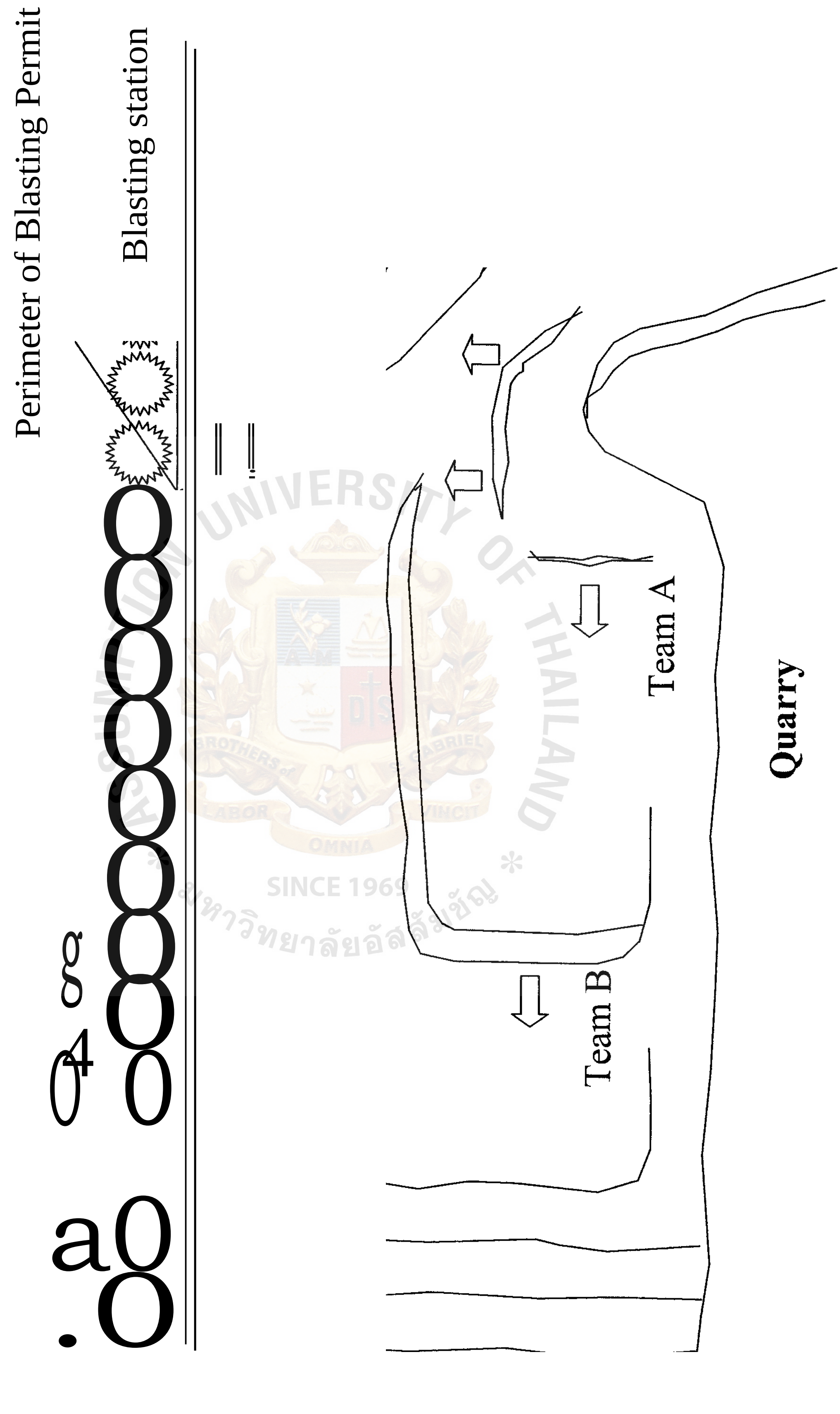
(3) The quarry should provide continuous training to employees for awareness of the importance of working, the right methods in working and prepare for the new machine or technology.

(4) The quarry should evaluate the result after training by using questionnaires or observation and follow up of work performance whether they have better understanding in their work or not.

(5) The quarry should give the opportunity to the employees to show their opinions about working especially in the production department to improve the present working conditions.

APPENDIX A

QUARRY LAYOUT



APPENDIX B

TRAINING COURSES (ENGLISH VERSION)

SEMINAR ON : DESIGN, ASSESSMENT & RECORD TRAINING COURSE

OBJECTIVE

The aim of this seminar is to introduce methods of recording information during and after blasting. To show the importance and necessity of using the recorded statistics to analyze and assess the result of your blast. Reliable information will assist in troubleshooting and improve planning for future blasting.

CONTENT

Drilling and Blasting Plan

(1) Planning procedure on design, drilling, blasting and checking the blasting result

(2) Record Data

Check and Evaluate

(1) Check and Evaluate the drilling result

(2) Check and Evaluate the charging explosive

(3) Check and Evaluate the blasting result

(4) Check and Evaluate the environmental effect on blasting

Recording

(1) Importance of data on drilling, charging and evaluating the blasting result

(2) Quality improvement on blasting

DESIGN FOR

Managers, Foremen and Operators in Drill & Blast Operation. Maximum 25 persons.

DURATION

2 days

SEMINAR ON : DESIGN, ASSESSMENT & RECORD TRAINING COURSE

TRAINING SCHEDULE

Day 1

(a) Objective and expectation of training

(b) Procedure on planning and design of blasting operation

(c) Check and record data for planning and designing of blasting operation

(d) Evaluation of the drilling report

(e) Evaluation of the charging report

(f) Questions and answers

Day 2

(a) Evaluation of the blasting result report

(b) Evaluation of the environmental effect on blasting

(c) Importance of data in drilling, charging and the blasting result report

(d) Quality improvement in blasting problems

(e) Questions & Answers and Summary

SEMINAR ON : BLASTING GEOMETRY

OBJECTIVE

The training course is aimed at introducing methods of planning and designing for a blast in order to achieve the optimum result. Identifying understanding all the factors that may cause errors and danger in your work and methods of controlling them.

CONTENT

Blasting Theory

(1) Factors that will effect the blasting energy

(2) Decking and distribution of energy

Pattern Design

(1) Definition of all variables in the pattern design

(2) Effect of all variables on drilling & blasting operation

Evaluation and Correction

(1) Evaluation of the blasting result based on each variable

(2) Correction of the variable to improve the blasting result

DESIGN FOR

Managers, Foremen and Operators in Drill & Blast Operation. Maximum 25 persons.

DURATION

2 days

SEMINAR ON : BLASTING GEOMETRY

TRAINING SCHEDULE

Day 1

(a) Objective and expectation of training

(b) Blasting Theory

(c) Energy distributions in blast holes

(d) Decking and energy distributions on blasting

(e) Pattern design and definition of all variables

(f) Effect of all variables on the blasting result

(g) Questions and answers

Day 2

(a) Effect of all variables on the blasting result

(b) Evaluation and correction of the blasting result

(c) Work shop

(d) Summary

SEMINAR ON : FIRING TIME

OBJECTIVE

The training course will introduce methods of achieving the desired firing time that is suitable for your work. Effect of the various factors on firing time which often cause errors and accidents in blasting. How to design firing time for the optimum blast.

CONTENT

Basics of Firing Time

(1) Identify factors that affect the "Ideal" sequence and delay timing for blast

(2) Difference between no delay time and delay time blasting

(3) Describe the effects of Inter-hole and Inter-row delays on blast performance

(4) Explain how delay timing can control the direction of movement of a blast

(5) Effect of delay time on blasting

Delay Time Design

(1) Nominate factors that affect the firing times of Pyrotechnic delay detonators

(2) How delay time effects muck pile and rock condition

(3) Design initiation sequences and delay timing for various blasting situations

(4) Evaluation and correction of delay time to suit the blasting condition

DESIGN FOR

Managers, Foremen and Operators in Drill & Blast Operation. Maximum 25 persons.

DURATION

2 days

SEMINAR ON : FIRING TIME

TRAINING SCHEDULE

Day 1

(1) Objective and expectation of training

(2) Difference between no delay and delay time on blasting

(3) Inter-hole and Inter-row delay time

(4) Effect of delay time on rock movement, muck pile and rock fragmentation

(5) Factors that effect delay time of Pyrotechnic delay detonators

(6) Questions and answers

Day 2

(a) Design initiation sequence and delay time for various blasting situations

(b) Evaluation and correction of delay time to suit the blasting condition

(c) Work shop

(d) Questions & Answers and Summary

SEMINAR ON : EXPLOSIVE PROPERTIES AND INITIATION SYSTEM

OBJECTIVE

The aim of the training course is to introduce the various types of explosives and initiation systems, their characteristics and properties. The improved result that can be achieved by using the products according to their design. Factory visit to gain understanding of how explosives and initiation system are manufactured.

Method of testing products, measuring and recording the result.

CONTENT

Explosive Properties and Initiation System

(1) Structure and properties of explosives and the initiation system

(2) Selection and application of explosives and the initiation system

(3) Process on manufacturing explosives and initiators

(4) Standard quality test for explosives and initiators

Priming and Charging

(1) Selection of primer

(2) Priming Theory

(3) Practical explosive charging

(4) Using different initiators of priming

DESIGN FOR

All personnel handling Explosives. Maximum 25 persons.

DURATION

2 days

SEMINAR ON : EXPLOSIVE PROPERTIES AND INITIATION SYSTEM

TRAINING SCHEDULE

Day 1

(a) Objective and expectation of training

(b) Structure and properties of explosives and the initiation system

(c) Selection and application of explosives and the initiation system

(d) Testing method on explosives and the initiation system

(e) Selection of primer

(f) Priming Theory

(g) Using different types of initiators for firing

(h) Work shop

(i) Questions and answers

Day 2

(a) Factory Visit (Look at manufacturing process of explosives and initiators)

(b) Field practices on the testing method for testing the quality of explosives and initiators

(c) Summary

SEMINAR ON : SAFE AND EFFICIENT BLASTING

OBJECTIVE

The seminar is aimed at raising safety awareness and the importance of safety when handling explosives. To ensure that all personnel handling explosives understand the safety procedures. How to avoid accidents by following the safety system and how to react when an accident occurs. How to introduce safety awareness in your department.

CONTENT

(1) Safety systems are designed to protect you

(2) Know how to handle explosives safely from storage until blasting

(3) Safety procedures in Drilling and Blasting operation

(4) Accident prevention and identifying hazards

(5) Dealing with misfires and Explosives destruction safely

(6) Basis of safety standard for ISO 18000

DESIGN FOR

All personnel operating with explosives. Maximum 20 persons.

DURATION

2 days

SEMINAR ON : SAFE AND EFFICIENT BLASTING

TRAINING SCHEDULE

Day 1

(a) Objective and expectation of training

(b) Safety procedure about operating with explosives and initiating system

(c) Identify accidents and hazards

(d) Case studies of accident occurrence in blasting operations

(e) Work shop 1

(1) Questions and answers

Day 2

(a) Safety procedure for Drilling and Blasting operation

(b) Safety procedure for misfired blast holes and explosives destruction

(c) Safety system for accident prevention

(d) Safety system for emergency incidents from materials and operations

(e) Work shop 2

(f) Questions and Answers

APPENDIX C

TRAINING COURSES (THAI VERSION)

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