REDESIGN OF STONE CRUSHING PLANT SYSTEM IN ATLANTIC SAND AND GRAVEL COMPANY

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ABSTRACT

The active aspect of stone crushing plant must be considered in order for process plants to achieve their goals and objectives in an efficient and cost effective manner. The key aspect of good crushing plant includes blasting and crushing process technology. In this study, the post-crushed quarrying plant processing and the expansion has been suggested.

In the concept of Lean Production, inventory is considered as the waste of the firm, so in this study the focus will be on fulfilling the market demand, eliminate the excess product as well as inventory and get more profit. Optimal crushing production is obtained by designing the tertiary crushing system as the expansion production line of the current plant. After all components has been identified, especially, the material handling within the plant. The essential part which is the project economic analysis will take place to verify that the proposed product has the profitability and viability to process.

Market demand analysis has been made, the tertiary crushing system and the 3D model has been designed, material and component usage has been selected, all cost and benefit have been identified. The result obtained has shown that the expansion is profitable to conduct. The break-even point was found to be in nine months of operation. The cost and benefit analysis has also been obtained while Net Present Value at 1,631 million kip (RM 652,400.00) of five years life cycle and Internal Rate of Return presents at 1.35. The overall crushing plant productivity improves to 0.99 percent and the manpower capacity improvement of 8.67 percent has been achieved.

ABSTRAK

Aspek aktif bagi suatu kilang memproses batu mestilah diambil kira bagi mempastikan kilang tersebut akan mencapai sasaran serta objektif dengan cara yang cekap serta berkesan. Aspek utama bagi suatu kilang pemecah batu merangkumi teknologi meletup dan proses menghancur. Didalam kajian ini pengembangan bagi proses pasca pemecahan di kuari telah dicadangkan.

Didalam konsep Produksi bersandaran, inventori adalah dianggapkan sebagai bahan buangan, dengan itu kajian ini akan menumpu kepada memenuhi keperluan pasaran, mengurangkan lambakan produk serta inventori dan menjana lebih keuntungan. Produksi pemecahan optimal diperolehi dengan cara merekabentuk sistem pemecahan ketiga sebagai garis pengembangan produksi bagi kilang. Selepas semua komponen-komponen terutamanya pengendalian bahan didalam kilang telah dikenal-pasti, bahagian yang teramat penting iaitu analisis ekonomi telah dibuat guna untuk produk yang dicadangkan berkeupayaan memberi keuntungan untuk dilakukan.

Analisis keperluan pasaran telah dibuat, sistem pemecah ketiga atau tertiary serta rekabentuk model 3D juga telah dibina, kegunaan komponen serta bahan beserta kosnya juga telah dikenalpasti. Keputusan kajian yang diperolehi menunjukkan pengembangan yang dicadangkan boleh mendatangkan keuntungan dan titik pulang modal menunjukkan secepat sembilan bulan beroperasi. Analisis kos dan faedah juga menunjukkan nilai semasa bersih adalah 1631 kip (RM 652,400) bagi kitan hayat lima tahun dan kadar Pulangan interal adalah 1.35 Kadar purata produktiviti keseluruhan kilang meningkat 0.99 peratus dan kapasiti tenaga manusia meningkat sebanyak 8.67 peratus.

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symbol	Description	Unit
2D	Two dimension	
3D	Three dimension	
A	area	m^2
BEP	Break-even point	ton
B_t	Monetary equivalent of benefit in *t* period time	kip
CAD	Computer aided design	
CBA	Cost benefit analysis	
C_L	Correction length factor of conveyor	
C_t	Monetary equivalent of cost in *t* period	Kip
F	Fix cost	Kip
F_H	Primary resistance of conveyor	N
F_N	Secondary resistance of conveyor	N
F_S	Special resistance of conveyor	N
F_{st}	Gradient resistance of conveyor	N
F_W	Motional resistance of conveyor	N
g	Accelerate due to gravity	m/s^2
H	High	m
IRR	Internal rate of return	%
L	Length	m
LCC	Life cycle costing	Kip
m_G	Belt weight per unit length	Kg/m
m_L	Load weight per unit length of conveyor	Kg/m

m_R	Idler weight per unit length	Kg/m
NPV	Net present value	Kip
P_{Merf}	Power requirement of motor	kW
Q	capacity	Ton/hr
R	Discount rate	%
S	Selling price	Kip
t	time	s
v	Velocity	m/s
V	Variable cost	Kip
Series 1	Material grain size at 20 to 40 mm	
Series 2	Material grain size at 12 to 19 mm	
Series 3	Material grain size at 5 to 12 mm	
Series 4	Material grain size at 0 to 5 mm	
α	Angle of surcharge	degree
δ	Incline angle of conveyor	degree
η	Overall efficiency	%
θ	Angle of repose	degree

Kip is Laos' currency, which convert ratio is RM 1 = 2,500 Kip

CHAPTER 1

INTRODUCTION

1.1 Background of study

Primary manufacturing is basically manufactured by a harvest or extract material from a natural resource and produces the raw material. Sand and gravel manufacturing is also considered as primary manufacturing, its production has been called a crusher-quarrying plant. The purpose of quarry industry is to produce product of specific size via the operation system of crushing and screening with variation as a function of the product requirement time(Engineering, 1998).

The crusher - quarrying plant is a various types and parameters which have to be considered. A common type is an open operation and an underground operation is either closed loop or opened loop, but all the type must contain main elements i.e. hopper, feeder, conveyor, screen and crusher (primary, secondary, tertiary). These five main elements dictate productivity, efficiency, energy consumption and so on.

Due to stone crushing plant is extracting the raw material from a natural, so that raw material can be considered as cheap, but the operating cost has to be considered carefully in order to earn an optimal profit. Basically, the plant design, element selection and the layout with the purpose to reduce energy consumption, maximize productivity and minimize a waste of system (Guimaraes, Valdes, Palomino, & Santamarina, 2007).

Lean manufacturing is considered as the best practice manufacturing system. Its purpose is to eliminate all the waste for instance: production of defective parts, overproduction, unnecessary processing steps, unnecessary transport and handling of materials, workers waiting, excessive inventories and unnecessary movement of the people. Due to most of crusher-quarrying plant is mass production and make to stock is a basic type of this business, so an inventory policy of finished goods should be able to take place carefully. Otherwise, these will affect the revenues of the company while the objects of those companies are making a profit. Flexible manufacturing would be adapted and should be applied in the advanced crusher-quarrying plant, it was designed to accommodate some of the adjustment or flexibility to match the variation market demand.

The research will be focused on one existent crusher-quarrying plant or stone crushing plant and will be investigated about its operating system, identify how is the plant can fulfil the market requirement in a varying demand during the year. Furthermore, this study will deal with current plant whether the plant meets the minimizing energy consumption or not, whether the plant can improve machine utilization and productivity. Emphasize on minimizing the finished goods inventory with the flexibility to satisfy the customers' variation requirement in the highest possible level as the best practice manufacturing plant should be performed (Flynn, Schroeder, Flynn, Sakakibara, & Bates, 2005).

1.2 Problem statement

Higher finished goods inventory means that the company has to invest a high capital of inventory and material handling, overproduction means that the company has produced excess product’s demand at such period time, and these products might be spending a long time in a warehouse and might as getting the result of being scrapped as obsolete (Demeter & Matyusz, 2011).

The reducing of a finished goods inventory has a significant effect on the firm’s financial due to the consequent of reducing the movement, handling, space, and so on with the result of a higher profit.

This research project focus on case study of stone crushing in a one company in Lao P.D.R, name Atlantic sand and gravel Co. Ltd which is running with a multiple of crushing plant; one of those is stone crushing plant. One of the stone crushing plane was located in the middle part of Laos, around 260 km far away from a capital city to the south part, (Phanalieng stone crushing plant) which has a technical capacity to crush stone 100 T/hr, generally this plant produces stone into 4 sides such as 0 – 5 mm, 5 – 12 mm, 12 – 19mm and 20 – 40 mm as in this research we represent it by the grain size in series 4, series 3, series 2 and series 1 respectively.

Basically this plant was established for the road constructions demand around nearby area, which the grain size of series 1 being used in the infrastructure of the road (base course) when the new road was constructed; this stone size would need a larger amount than the other side. For grain size series 2 and series 3 were used to cover the outer layer of a road respectively, the last is grain size series 4, this size was also used to mix in the base course in the road construction and it is also used instead of sand for making the concrete block, concrete brick, concrete pipe and pillars of small business and the village development.

Currently, the plant capacity is 352 m^3/day, counting from the feeding stone which has mass density is 1.5 - 1.6 T/m^3 and the production grain size are 32%, 27%, 24% and 17% percentage per mass will sort descending of the product size respectively. The main production system consists of a hopper, vibration feeder, primary crusher, secondary crusher and screens as shown in the diagram below.

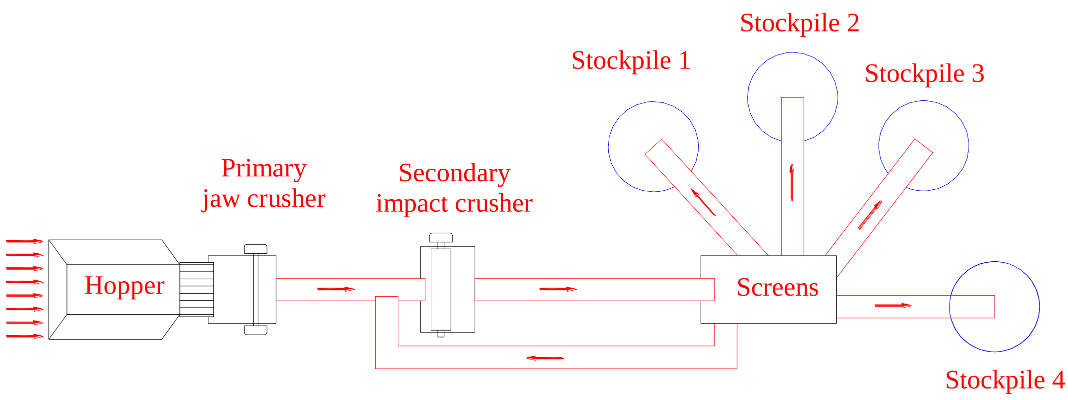

Figure 1.1 Plant frame work

Currently this crusher-quarrying plant encounter with variation of customers product demands in each time during the year, and the proportion of demand in all grain size also does not match with the proportion of the crushing productivity. These problems will lead to the requirement of huge stockpile space for the unsold product in such time whilst the empty stockpile and unable to complete the demand in some products grain size has befallen, it means that the company loses the chance to earn the revenue. In the aspect of management, large warehousing means that the lost will occur in an investment and will cause the waste in warehousing management (Hofer, Eroglu, & Rossiter Hofer, 2012). From the reason to satisfy and meet varying market demand in each time of the year and to minimize the stockpile warehousing of the unsold product, by the mean that to answer the question on what is an operating condition of plant to accomplish the market with maximum revenue.

The tertiary crushing machine has been proposed for this crusher-quarrying plant to solve these problems, the plant extension investigation will be conducted, the machine and component selection, layout and an operation system will be identified.

1.3 Objective

- To identify the operating condition to match the market demand with production capacity of each product grain size.
- To design the plant extension base on new operating condition with characteristic of continuous manufacturing system.
- TO conduct project economic analysis and productivity analysis.

1.4 Scope of research

The scope of this research is focusing on certain crusher quarrying plant (Pha Nalieng stone crushing plant) as the case study, the main component of this plant mostly manufacture form William Wong LTD., Part for instance vibrating feeder, jaw crusher, impact crusher. Bottom neck identification is considered only material handling system and supplying of raw material, due to main machine equipment is target of producing capacity of the plant. The product market demand of this plant is identified based on data collection in statistic of the plant, customer's contract of this plant and combine with mathematic analysis to determine operating condition.

The crusher quarrying plant extension of installing tertiary crusher machine which is linked to the main system, with the purpose of the tertiary crusher machine to crush the material grain size series 1 to grain size series 4 when the grain size series 4 in high demand whilst the low demand of grain size series 1.

The extension system should be operated either separately or simultaneously, as the target of the plant is high revenue and profit, so this extension must consume minimum capital cause in term of both of component cost and labor cost of installation, after the installation, the operation cost must be minimized and high efficiency. The new extension must not cause any problem to the current operating system.

Cost benefit analysis is conducting in the last stage of the research after the expansion plant design has been proposed. The analysis will take place on the principle expenses as: fuel and electricity consumption, maintenance and spare part cost, blasting and material extracting cost, and analysis with net revenue from the product's selling. For the minor expense and confidential cost of the company is unavailable to conduct in a cost-benefit analysis.

CHAPTER 2

LITERATURE REVIEW

The investigation of a work relates to insufficient of producing capacity and market demand of crushing rock industrial. The plant expansion associates to the machinery and bulk material handling design system of an existing rock crushing plant which has effects on excess of finished goods inventory in a variation market demand of period time. It has gained a reasonable attention due to its importance to firm's profit in an industrial competition. This chapter will discuss on three main stages, the effect of finished goods inventory, crushed plant extension with bulk material handling system design and cost benefit analysis as the firm suggestion.

2.1 Effect of inventory

The basic purpose of inventory in a classic for profit business, with the goal of those enterprises is commonly to earn profit by holding the inventory to protect the product, resource, and spare parts; there is a relationship between the volume of sales and the amount of inventory. So in the theoretical, we should know the sales volume and to understand the relationships (Lonnie, 2010)**.**

High inventory will lead to problems, e.g. hold the inventory costs a lot of money; we must handle it, it means that we require more machine and people. This in turn requires space and transportation, then we must keep the trace on it, which includes labor, computer programs, and reports, we must take care for this inventory to ensure that it does not get any damaged and eventually it has to be removed before it becomes obsolete.

All of these liabilities of inventory are obvious bottom-line opportunities, and the greatest advantage of inventory reducing. Due to the variety of systems which exists within the manufacturing process and that variation at some level is necessary, so it is important to comprehend that inventory has to be created largely. The reduction of inventory is not only let company to reduce cost but also contributes the companies to reduce production lead time and therefore it becomes more flexible and responsible.

One research (Hofer et al., 2012) has done a hypothesis about the effect of Lean Production on financial performance is mediated by inventory leanness. It takes place on the relationship between monetary performance and inventory. The result indicates that the better inventory leanness has much performance improving effect of external lean production and increasing the financial performance. Furthermore, they have found that the simultaneous implementation of internal and external lean's practices carries a better performance's benefit both in terms of inventory leanness and performance of financial.

2.2 Crushed quarrying plant

Stone crushing plant in quarry industrial is the primary manufacturing with duty to change form or reducing in terms of the size of the stone. Crushing is the process of transferring a force amplified by a mechanical advantage through a material that made from a strongly molecules bond, and a high resistance deformation than the stone, most of it uses metal surface. Generally crushing plant is designed to produce a certain throughout specific particle size while operating at a reasonable cost and minimizes the energy consumption (Asbjörnsson, Hulthén, & Evertsson, 2012). Crushing consists of a series of crusher machine in order to obtain the required products, namely primary, secondary, tertiary crush and so on. The arrangement is necessary due to each stage has limitations of reducing ratio between input and output material and different stage mostly use different type of machine, again because each type of the machine is working well with difference size and strength of material, for example: jaw crusher, gyratory crusher, cone crusher, horizontal impact crusher, vertical impact crusher, hammer crusher, etc. The material size is mainly distinguished by a screening machine which sorts and directs the product to further process.

In an operation, first raw material was fed with a boulder extracted from the rock quarry which will be exploited nearby the plant itself. Then the material will feed to the hopper by dump trucks, excavators. Vibration feeder will perform continuously and equilibrium feed to the jaw crusher, which performs as primary crusher.

The optimization of energy, labor and machine consumption of the plant is considered as the critical factor of profit to the firm, trough belt conveyor is the most suitable for bulk material handling system as the connection of each station in stone crushing plant with their advantage as less labor, continually transported, low energy consumption due to trough belt conveyor system consumes the electrical energy, which is considered as cheaper than the petroleum oil as most vehicle used.

The optimization of the crusher-quarrying plant in terms of the productivity, less inventory and warehousing are the critical task of the plant manager. Vary product grain sizes are produced inside the plant. Revenue’s improvement can be satisfied by answering the question of which operating condition of the particular machine and crushing system is capable to fulfill the quality and quantity requirement from several customers in all product grain sizes (Csöke, Pethö, Földesi, & Mészáros, 1996).

The quadrats differentiate has been proposed for the purpose to identify the market demand friction of all product grain sizes. The sums of the quadrats differentiate (*S*) should minimize as much as possible. The smaller *S* value demonstrates the higher plant revenue and less warehousing of the product.

$$S = \sum_{k=1}^{N}\left[\sum_{j=1}^{n} B_j F_{b,j}(x_k) - \sum_{i=1}^{m} A_i F_{p,i}(x_k)\right]^2 \qquad (2.1)$$

Let set *N* is the number of grain size under consideration.

Let $F_{b,j}(x_k)$ and $F_{p,i}(x_k)$ represent the mathematical function of the customers' requirement and the mathematical function of the finishing product of a certain crushing operation respectively.

Let B_j and A_i represent its quantity of customer requirement and finished product respectively.

By the propose of this paper (Csöke et al., 1996) is to determine the prediction of customers requirement and supplying with high sufficiency by creating mathematical model to illustrate the crushed function in each stage of the crushed quarrying plant.

2.2.1 Crushing plant layout design

Plant layout is considered as an optimum of the facilities' arrangement plan, which is including the operating station and equipment, personal, material handling system, space and storage until other supporting material along with the designate of the best structure to contain all these facilities. The objective is to optimize the profit by arrangement, which includes to minimize materials' handling and cost, high effective of all the equipment, space and human utilization, provide safety, comfort, easy to access and convenience to the employee. As the rock crushing plant is continuous manufacturing type, so product layout is the most suitable. The machines and equipment are arranged according to the processing sequence of the product. They can be arranged to reach an efficient flow of the material in lower cost per unit.

2.2.2 Material handling system

It has been well known that trough conveyor belt is the best solution of the bulk material handling system like crushed rock, coal, sand and other similar aggregate. Trough conveyor belt consists of two or more pulleys, and close loop of belt which rotates amount of itself in conveying the decide material. The power has been supplied in terms of electric or hydraulic motor on one or more pulleys, it depends on the distance and the load of conveying to move the material and the belt itself forwarding to the target location. Three main pulleys are set along the conveyor system. First is a driving pulley is powered pulley to operate the task. Trial pulley is the pulley which locates at opposite sides of a driving pulley. Idler pulleys are unpowered pulley but their duty is to support and maintain the shape of conveyor system.

There are two main conveyor belt types and it is classified into, first the unit material handling conveyor such as transport boxes along inside factory, baggage along inside the airport. The second type of conveyor system was designed to fulfil bulk material handling, namely bulk conveyors or trough belt conveyor are those used to transport agricultural and industrial material such as rice, grain, coal, sand, ores, cement and any unpackaged material. Inside main type of belt conveyor, it is also classified into various characteristics, which includes accumulating and non-accumulating, fix and portable conveyors (Fonseca, Uppal, & Greene, 2004). Fix conveyor is the inflexible system which it is not able to adjust transport location, transport capacity and material type. In contrast portable conveyor system was designed to able adjusted such of thing in order to perform flexible operation. Their adjustment must be taken in reasonable of time. Accumulating conveyors perform continuously and hence it contributes of the materials at a working site while non-accumulating conveyors is performed by stop moving whenever loading or unloading happened.

Figure 2.1Troughed conveyor belt

Generally, belt conveyor compound with multi layers of material, normally the outer layer is produced from the rubber to provide high friction coefficients between the material being handled and the belt, between the belt and the pulleys, the inside layer was made from steel or cotton and nylon fiber to reinforce belt linear strength.

Bulk material handling as main sand and gravel transportation inside the plant. In order to keep up the high performance, a significant technique in system design, numerical simulation and analysis are required to provide and to ensure their reliability and the availability of complex conveying applications (Alspaugh, 2004).

Material handling design and equipment selection is considered as complex due to have several manufacturing type to choose from but for all in all, certain standard also provides acceptable solution for conveying design. Besides that, the design conforms with involvement of machinery design at several principles, concepts and procedure to present all necessary characteristics (Paper, 1998). It is very significant to the firm, if the conveyor material handling system performs in an optimal technology and hence the selection of optimal way and orientation of the belt transformation is the critical factor for the life extension of conveyor belt operational capacity (Fedorko & Ivančo, 2012). In the worldwide, all models were originated from a well-known specification or standard such as DIN 22101 Germany, ISO 5048 and Conveyor Equipment Manufacturers Association (Zhang & Xia, 2010). And there are many design's constraints of an existing international standard, which have to be followed.

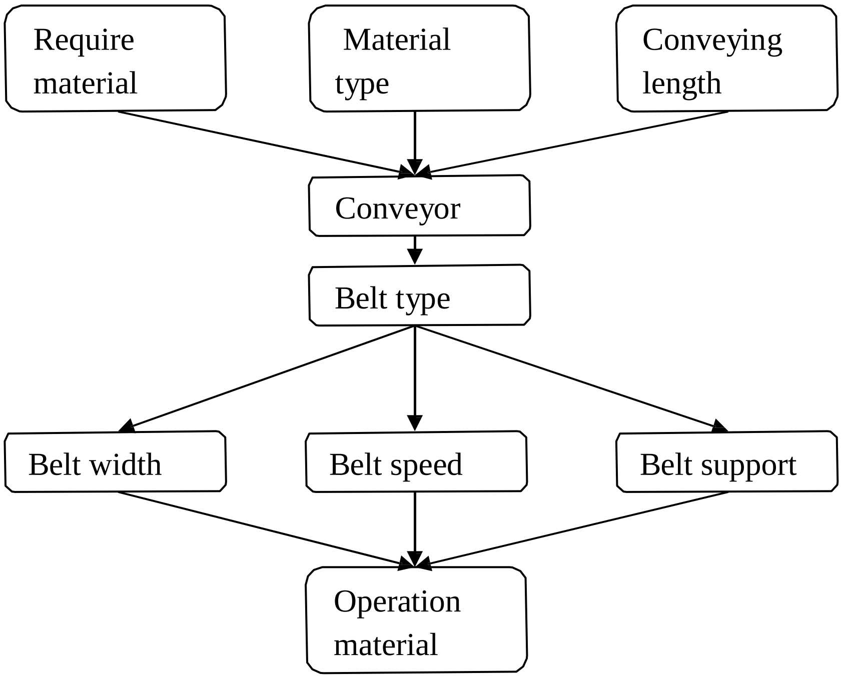

Figure 2.2 Belt conveyor design chat

Three parameters have been selected as the beginning of a design process for the material handling system by the engineers or managers which has the authority and the responsibilities to decide and selecting the type and/or equipment. This is because the material handling is the science and art which associated in offering the right materials to the right place for the exact condition, in the right quantities at the correct time and the right cost by using the right methods, once improper select may result in high cost and less efficient (Paper, 1998). Three parameters are followed below:

- Material type and its characteristic of both of physical and chemical
- Material requirement in handling
- The length that needs to transfer (conveying length)

The successful design of a trough belt conveyor system must start with the accurate valuation of the material characteristics to be transported and a material transported requirement combine together and being determined with belt type and belt widths (Equipment & Association, 2002). Few characteristics are concerned:

The critical angle of repose of the material is the steepest angle of the descent of normal slope surface at freely formed pile that makes with the horizontal plane.

The surcharge angle of a material is the angle to the horizontal which the surface of the material assumes while the material is at rest on a moving conveyor belt.

The lump size has influenced the belt specifications and the choice of carrying idlers as it is also empirically the relationships between the lump size and the belt width, belts must be wide enough to ensure any combination lumps and finder material does not carry and load too close or access to the conveyor belt’s edge.

Material transported requirement is come up with conveying capacity with is relationship the formula by the belt speed and belt width is following:

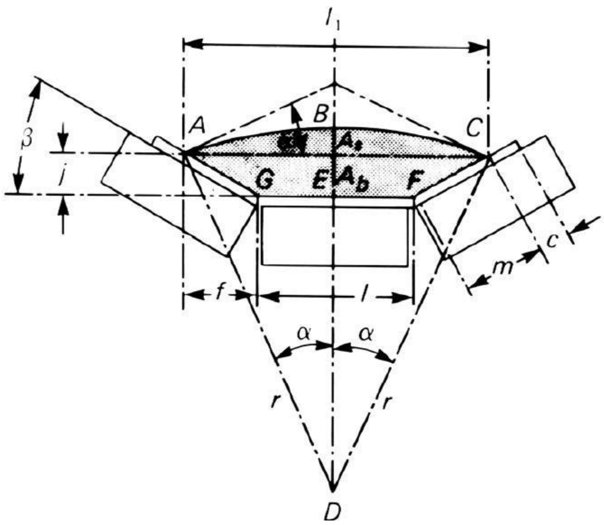

Figure 2.3 Cross section transport (Equipment & Association, 2002)

l length one edge of trapezoidal area, $l = 0.371b + 6.35$ (mm)

c edge distance of material to edge of belt $c = 0.055b + 22.86$ (mm)

The cross section area of transport material

$$A_t = A_b + A_s \tag{2.2}$$

Trapezoidal Area, A_b

$$(AECFG)A_b = \left(\frac{l + l_1}{2}\right)j \tag{2.3}$$

Circular segment area, A_s

$$(ABCE)A_s = \frac{\pi r^2 \alpha}{360} - \frac{r^2 \sin 2\alpha}{2} \tag{2.4}$$

For the belt speed, it depends on the type of material, the increasing of the belt speed may results in a permit decreasing of belt width and belt tension but deal with the possibility of increasing belt wear, a recommendation of a belt speed is attacked in Appendix B.

The power requirement to overcome the Motional resistances in a conveyor belt system is the critical determination due to the result is effected to the energy consumption of the system and it influences to the production cost. Mechanical requirement is determined as follows:

$$P_W = F_W v \tag{2.5}$$

And the power requirement for a driver motor may be higher due to the effect of drive efficiency of the gearbox or motor by itself.

$$P_{Merf} = \frac{P_w}{\eta} \tag{2.6}$$

With the belt movement in a steady operating state, motional resistances arise from the friction, weight and mass forces and this resistance is divided into 4 groups(Zhang & Xia, 2011), namely: primary resistance F_H , secondary resistance F_N, gradient resistance F_{st}, special resistance F_s,

Total motional resistance can be determined as follow

$$F_w = F_H + F_N + F_S + F_{st} \tag{2.7}$$

$$F_H = f.L.g\left[m_R + \left(2m_G + m_L\right)\cos\delta\right] \tag{2.8}$$

$$F_N = (C_L - 1)F_H \tag{2.9}$$

$$F_{st} = H.g.m_L \tag{2.10}$$

F_S generally occur only when special purpose design is required.

As the conveyor handling system in the bulk material performs continuously, the main operating cost is the energy consumption, and reducing energy consumption or energy cost of bulk material handling system is a great impact to the firm and has significance in increasing profitability. Most of the belt conveyor system's performance in practice did not meet the design condition and some of them has performed far away under the design aspect (Zhang & Xia, 2011). Once research has propose the way to reducing the production cost of the firm by using speed control of conveyor belt system, and it can be obtained without a substantial extra capital expenditure (Hiltermann et al., 2011).

2.3 Project economic analysis

Project economic analysis is the tool to analyze and to help designing and selecting the project, it helps in the decision of whether or not to proceed with this project. In particular, this tool of analysis can answer varying questions about the project's impact on the entity undertaking the project, and with various stakeholders, estimate the project's fiscal impact, determined whether the arrangements for cost recovery are efficient and equitable.

Cost-benefit analysis is one method of economic analysis used to evaluate and analyze from between benefits and costs perspective, CBA weight the gains and losses to different individuals and suggests carrying out changes that provide greater benefits than harm, in other word, CBA weights the costs against the benefits with target solutions to fulfil the requirement of the organization or business sector. It will also illustrate several of alternatives of investment, tactile and non-tactile benefits and results of the analysis. Generally, cost-benefit analysis mostly refers to the tools and the procedures needed to be established whether a proposed between alternatives or between the current operation with a proposed investment is worthwhile. Basically, cost -benefit analysis will list all cost and benefit factor then it will measure all of them, each will mark the importance with financial and balance conclusion (Gao & Li, 2009).

A procedure of analysis may be needed to capture the possible alternatives. The cost-benefit analysis shows the total cost and total benefit as well as the net cost and benefit for the choice across the lifespan of the project, and compares the tactile costs and tactile benefit of each alternative.

Cost benefit analysis consists of six stages as indicate in the chart below

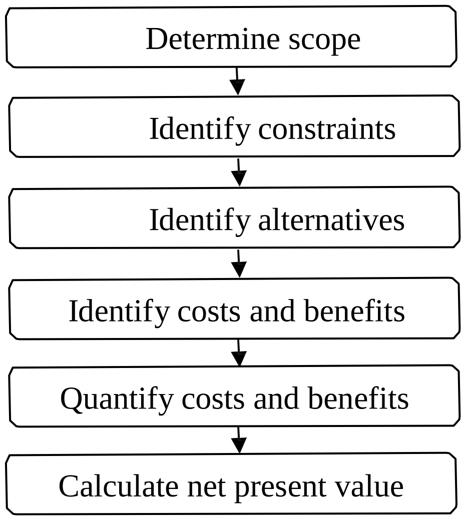

Figure 2.4 Cost benefit analysis procedure

The scope and objectives is a limited or the purpose behind the project which is the organization has been set, it is the first step in CBA of the project where it is defined clearly the objective that the project is trying to achieve. A clear definition of the objective is essential to reduce the number of alternatives considered and to select the tools to analyze and the performance indicators such as improving or decreasing something, for instance: to construct the highway and the bridge across the river to decrease or mitigate the traffic problem, damming to avoid the flooding problem and provide electricity. It would be answer to the question on what would happen if the project is undertaken and what would it look be if there is no project?

The constraints identifying of a project which includes the financial constraint of increasing the money for investment costs, and also including the additional impact, for instance: the dam construction in China takes a financial cost up to $US 10.7 billion, 145 square kilometre of cultivated land will be submerged, one or two millions of people have to resettle down (Kingston, 2001).

The alternatives in a cost-benefit analysis are to propose way or project which organization or firm will be considered. Sometime the alternative is given against the existed project. Otherwise, the alternatives will undertake a smaller or lager result against the other alternative project.

The next step is identifying the costs and benefit, costs tend to be clustered and up front, the costs which includes the capitalize investment, maintenance costs and operating costs. The benefits tend to be suffused out and could be earned next stage from the time of investment, some will be monetary ex: income from selling product and the other will be non-pecuniary ex: time saving to computers that are made possible by toll bridge.

Quantifying cost and benefit, is the procedure to estimate the cost and benefit in terms of a number or money, such as costs is expenditures on a project, equipment, structures and land. Benefits are usually more complicated to quantify, because sometime benefits relate to health, human feeling and so on. Some approach provides benefits that are by the consumer’s surplus technique. Environmental costs and environmental benefits tend to be complicated to measure. The simplify suggestion is to deal with tactile costs and tactile benefits as it begins with dividing the problem into easy platform.

The last procedure of cost-benefit analysis is to determine the net present value and evaluate the distinction of total costs and total benefits of the whole its lifespan, by putting into an account in the time value of money.

2.3.1 Essential decision rule

Most projects have complex patterns of costs and benefits over time, so the decisions rule is necessary to guide, many of the decisions rules have been proposed. Some work is good only in a particular situation; others are prone to error, only two rules are consistently accurate and reliable.

Decision rule one is for a single project unconstrained budget ‘go’ or ‘no go’ decision, do not undertake project whose *NPV* is less than zero, unless you are willing to lose money to achieve a non-economic objective or to say that it will be accepted by all of the projects with the net present value greater than zero and rejects the rest.

Decision rule two is for alternative the project, constrained budget is a ‘best set’ decision, multiple projects have its pros and cons; select the project with the highest *NPV*.

The basic tools of cost-benefit analysis is net present value (*NPV*), it has the difference between the present value of the future cash flows from an investment and the amount of investments. The common *NPV* formula illustrates below (Kingston, 2001).

$$NPV = \sum_{t=0}^{T} \frac{B_t - C_t}{(1 + R)^t} \tag{2.11}$$

The left-hand side of the equation indicates the value of net cost and will take into an account with the money at present time value. The *NPV* rule is more like excessing the profit than it is like profit.

$t(= 0,1,2,3...T)$ is the number of time interval from the present in when the benefit or cost is reacted, And T is the counting period until the project is scrapped.

B_t is the benefit in teams of pecuniary equivalent which is received from the project in t period.

C_t is the cost in teams of pecuniary equivalent which is expensed from the project in t period.

2.3.2 Break even analysis

Break even analysis is one technique, which use production and operation management, it was applied to analyze and determine the point that all revenues equal to total costs. Break even analysis is concerned about the relationship between the fixed cost of the firm, variable cost per unit output and the selling price of the product. It has also provided the answers to the manager in which is how much the minimum selling price of the product to maintain the balancing revenue and cost, it is called ‘Break-even Point’.

The Break Even Point (BEP) in units can be identifying by the formula below:

$$BEP = \frac{F}{S - V} \tag{2.12}$$

2.3.3 Related research on project economic analysis

(Pellegrini, Soave, Gamba, & Langè, 2011) Propose project economic analysis of an integrated energy generation plant, the research takes place on the conventional of methanol production plant by modifying the plant configuration for the integrated electric energy and methanol production. Consequently, the plant is able self-sufficient for the electrical energy usage, which is exactly produced on site. It is a large scale combined production by an economic point of view of natural gas in evaluated and simulated. Both operation and investment costs are considered as in the plant has unreacted gases are burned, it is the energy production unit has to be added to an existing methanol plant without affecting the main production and the result will demonstrate that the modification of the methanol plant is profitable though investment cost are higher for the combined production the result obtained break even time is less than five years, which is more reasonable to conduct.

The paper (Papaemmanouil, Member, & Andersson, 2009) focuses on the policy power production plant transmission and its coordination planning, which will play more essential role in the further life, the proposed methodology is based on a cost-benefit analysis for the supporting eventually decision. Power plant investments and installations are implemented and the results for *IRR* and *NPV* have been made at various levels of demand growth. It is very sensitive to identify the demand growth input in determination as it is a key in leading to negative or positive values of *NPV*. Negative *NPV* means that the project can not acceptable and it does not matter what the value of *IRR* is. The proposed cost-benefit analysis process can provide evidence about the profitability of plant coordinated projects.

One paper present (Jun, Xu, Xue, Xiaolin, & Yuxi, 2011) the implementation of the project economic analysis by cost-benefit method in the project life cycle time. It is the carbon emission reduction project in the current global carbon trade situation in the power section. The analytical model has been conducted in power generation projects. Through the algorithm analysis, the result of obtain the alternative option which has a high economic efficiency. The sensitivity analysis assessments are conducted on the net present value of gas power generation projects. This model also provides a preferable decision for inventors to rational investment in a clean energy market.

2.4 Conclusion

This literature reviews on theoretical and some of empirical research; the review is focused on principle and related problems, plant design and plant expansion of sand and gravel crushing system. It is highly emphasizing on material handling system, and the analysis of business point of view, many empirical researchers are related and mentioned throughout the chapter for good understanding of problems and can be able to illustrate the problem's solution.

CHAPTER 3

METHODOLOGY

This chapter explains the methods used in carrying out the study, giving special emphasis to the analysis data. It should be noted from the outset that the methodology to a certain extent was an evolving one which took definite shape as the study progressed as quantitative perspectives. This chapter is organized by a logical order which arrange the content in terms of the relationships among the concepts. The order that is followed by research context and participants, data collection and instrument used, the procedure used and data analysis, and chapter summary.

3.1 Research context

This study took place in the stone crushed quarrying plant name Atlantic sand and gravel company (Laos). It is located in the middle part of Laos, in the connection of Xayabori and Khammoune Province, Laos P.D.R. The location is very suitable for crushed rock industrial due to it is attached with 200 m far from national main road number 13 South, and the extracting of the law material by quarrying is inside the plant site itself and within 1.5 km of distance. Consequently, this plant can exceed to electricity grid, it is easier to access to the villager, and faster respond of maintenance or accidental.

From this location, within 50 km to south and 50 km to the north, there are no crushing rocks industrial. All of these advantages could be guaranteed that any construction of the road, house, damp etc. in this area would be taken by the rock form this plane, as well as it guarantees in an unfaltering of stone crushing business of the plant.

Figure 3.1 Sand and gravel crushed plant

For the purpose of developing the country from the government policy, fast and comfortable transportation is the aim. By these reasons, this plant has been settled down and product sand and gravel to support only the road construction and road's maintenance in this rural area, firstly this plant was managed by a military section due to the security aspect of heavy plant and quarrying bomb material. Now the plant is owned by the private company and running a business in widely purposes in order to earn the highest revenue with fulfil customer demand as much as they can.

3.1.1 Sand and gravel manufacturing process.

Sand and gravel manufacturing at this plant is simple and similar with many common rock crushing plants in several places. Natural granite mountain as the open field without any soil cover on it, so the surface cleaning process is not required as the result is no investment in this task. The quarrying process begins with a detailed survey which allows the explosives engineers to design the blast and to plot where the shot holes should be drilled for the purpose of safely and efficiently blast. After a survey, the drilling process is conducted, mobile drilling machine with air operated drilling rig by using electrical energy supply, driller drills the number of shot holes required at the marked sport corresponding to the holes positions on the blast design. On the day of the blast, the explosives are delivered and taken to the site of the blast, detonator cord is placed in each hole and the holes are then loaded with high explosives to within a few meters from the top. The site is cleared, sirens are sounded to make sure that everyone nearby is warned then the circuit set off the explosives. After the blast, the inspector comes to check that all the shot holes have been fired correctly, and then they will start to load the dumper trucks by the excavator and take to the crusher.

Figure 3.2 Quarrying site

Currently this sand and gravel crushed plant was done in two crushed stages; it consists of a primary crushed, and secondary crushed. The dumper trucks place the rock from the blast to the hopper or a chute, and then it is transferred to the primary crusher by the vibrating feeder. the vibrating grizzly feeder is consist of metal bar to allow the dust fall down before supplying it to the crusher, the metal bars is placed in a horizontal with the ground, two vibrated motors has been use, the model is WVF-416.

Figure 3.3 Primary crushed stage

Primary crushing in this plant using jaw crusher model WL-4230, it is consisting of heavy metal plate which moves backwards and forwards against a fixed plate. The moving plate is kept in motion and given its crushing energy by a large flywheel. Rock from the quarry site is fed into the top of the crusher and crushed rock falls out of the bottom of the jaws.

The output from the primary crusher is placed in primary conveyed and conveying to the secondary crusher (second crushed stage) this system use horizontal impact crusher model WIM-51with the operate on the principle of horizontal shaft rotate at high speed with hard metal head, this head is attacked with fed rock and crush it by impact force. The crushed rock is falling down to the bottom of the machine and it is carried to the screen in the next step.

Figure 3.4 Secondary crusher

Each stage of the crushing progressively produces and reduces the stone size. In order to manufacture the usable product, the crushed rock has to be screened into a various size categories according to its requirement. The screen in this crushed plant uses a WV-616 which consist of basic box frames into which sheets of screen meshes, this screen is multi deck, the whole screen is coupled to its support frame by the springs. The screen is made in order to be vibrated by an unbalanced rotating transverse shaft when it is driven by an electric motor combined with the mounting angle screen decks so that the aggregate moves down from the top screen deck and drop down through a mesh, the aggregate is then sorted according to the mesh sizes fitted. These screen planes sort the material into 4 sizes, which is from series 1 to series 4 as mentioned in chapter 1. The stone size which is larger than the requirement will return to secondary crusher by returning conveyor.

Figure 3.5 Aggregate screen

Sorted end-product is transported to primary stockpile by belt conveyor which is 18 m length from the screening in a different angle. As the conveyor belt is the most efficient and reliable of bulk material handling, no vehicle will involve during this process. The product is sold and transported by the customers' dumper trucks, as the wheel loader will load the aggregate to the dumper according the requirement product size. Then the financial calculate the product price which has been sold-out by the weight of the product by an electrical truck weighting scale.

Figure 3.6 Aggregate loading and sold-out weighting

The study takes place in the beginning of the year 2013 when this crushed plant encountered unbalancing of the product requirement and the production capacity when this plant sells their products in a various purposes including the road construction and maintenance, concrete block, brick, pipe and pillars as it is useful in village construction. By a various demand, some product series is being run out of stock at somehow some of the product would be obsolete, that lead to the result of losing revenues of that part, at the same time the firm will also expense in the obsolete part, keep it or clear it from the stockpile.

3.2 Data collection and instrument used

Data collection has been conducted in a multiple categories involving interview, company documentation, future contract and actual measurement in a production plant as demonstrate in figure 3.7.

The first step was conducted by interviewing with manager, production manager and technicians and all operators whom has been participated in the firm for well-known of a depth understanding of specific work process. This stage interviews in the problem of the production and the critical issue of stage and machinery as well as the requirement of the firm and the feasibility issues which can be developed and implemented under the company's objective. Data collection is aware of the skills and the proficiency of technicians and mechanical engineer as well as the maintenance team combined with the instrument and equipment on hand with an ability to adopt, adjust and modify even when installing the machine and the process line.

The parallel data collection is the firm's documentation; these data provide the exact numerical statistic data of the production in each month during the year which is available in a production report. In addition, the statistic data of selling product and firm's revenues is also available in the financial report at a year 2012 as well as operating costs, including the expense of employee's salary, maintenance cost of machinery and heavy vehicle along the plant, energy consumption and energy expenditure in both electric and fuel which has got the high influence in an operating cost and has a significance to profit of the company. Beside that the quantity requirement contract with some construction companies is the meaningful data to analyze the end-product requirement of the plant in the future. However some information data are confidential and no permission to exhibit in publish as it concerns about the company negotiation, reliability and safety issue especially the data of explosive and detonator usage and the expense regarding to this issue.

Table 3.1 The crushed quarrying plant in crushed quarrying plant

Rock crushed product capacity of 2012					
	Product series 1	Product series 2	Product series 3	Product series 4	Total in mass (Ton)
Jan	4420	3730	3316	2350	13816
Feb	4298	3626	3224	2284	13432
Mar	4195	3540	3147	2230	13112
Apr	4234	3570	3176	2250	13230
May	4083	3454	3063	2170	12770
June	3849	3247	2887	2045	12028
July	3920	3300	2940	2083	12243
Aug	3847	3245	2886	2040	12018
Sep	4130	3485	3098	2194	12907
Oct	4586	3869	3440	2437	14332
Nov	4478	3778	3360	2373	13989
Dec	4638	3913	3480	2464	14495
Total in series	50678	42757	38017	26920	158372
average	4223	3563	3168	2243	13197

By these numerical data, it provides the feasibility to the analysis and evaluate the differentiation of the plant’s productivity and the product’s proposition with a market requirement of the end-product which will be demonstrated in a data analysis, as well as the estimation of losing the chance of earning profits and how much it cause to handle and eliminate the obsolete product.

Observations of solidity and a data measurement have been conducted during the 25 days of a data collection. Obtrusive observation allows us to well understanding about the aggregate manufacturing procedures, the characteristics and the phenomenon of all production stages, the movement of machinery and vehicles, as well as the technical data of the machines and a power motor usages which have a significance to plant's performance and energy consumption. Furthermore, this observation is also demonstrating operation controlled behaviour and the duty that the operator has to respond, since the raw material feeds into a hopper until the end-product has been sorted out and sent to a stockpile as it was handled by one operator. However, the significant dimension measurement is conducted in detail, the length, width, high, level of infrastructure, orientation of all machines, equipment and material handling system have been measured and the value has been noted. This purpose is to emphasize on crushed plant layout, and the result comes up with a layout modelling, which is beginning step of the manufacturing plant extension design (layout modification with installing new machine and a link to this system). The measurement equipment which involved is the measuring tape, bubble level measure equipment, total station and stopwatch.

Sufficient data have been collected until finished; all these data are very important as it is the initial information about this study, as the result might differ if the initial data is varied. Based on data on hand, the data will conclude and analysis in the consequence procedure of the study.

3.3 The procedure used and data analysis

In carrying out this study, several procedures were used, as the main purpose of this study is to identify how the plant will be improved the profit by adding the value into the unsold product before it is scrapped obsolete. The aim is fulfilling market demand, reducing the inventory and operating cost. For well understanding, the procedure of this study is explained by a description and sequence chart as follow below.

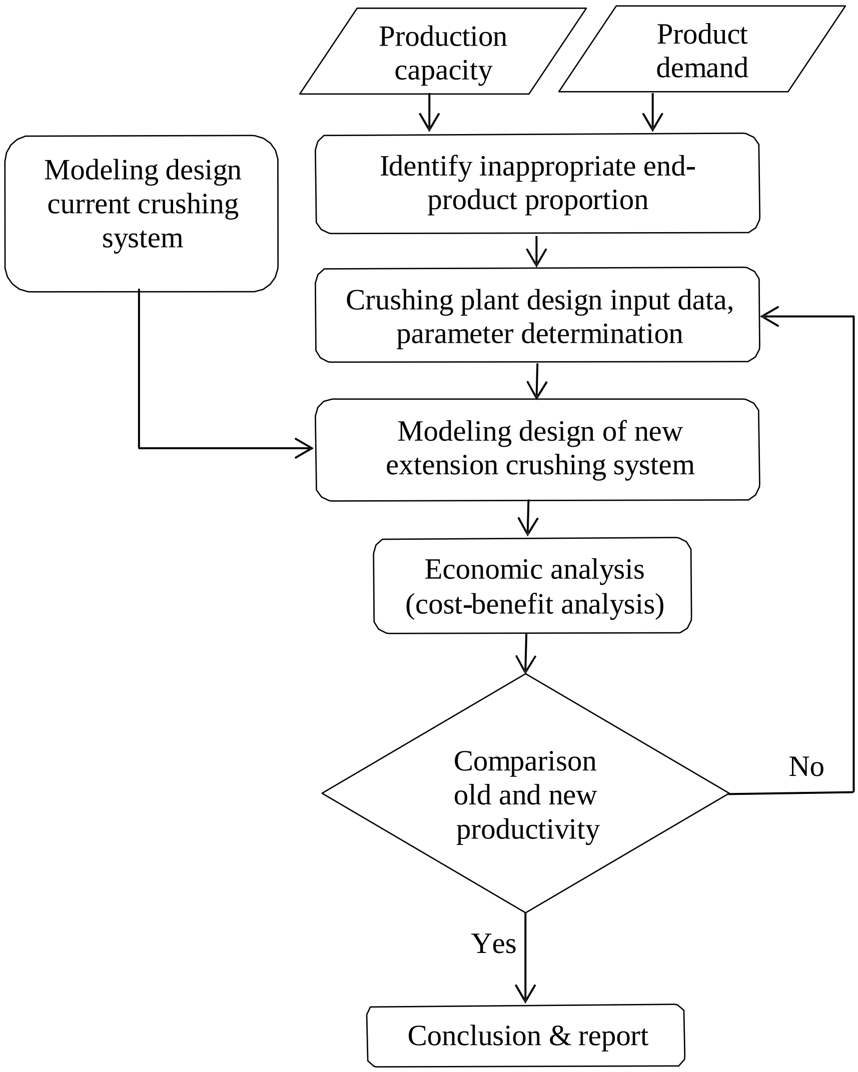

Figure 3.7 Method procedure

Dimension measurement has been summed up, and used it in a current crushing system drawing and modelling. All the parts model of the design are created using the IronCAD, then the parts will be assembled to perform the full design. Some of these parts are constructed through a single feature but most of them are constructed through several features. IronCAD is a mechanical engineering and design CAD tool is capable of creating a complex 3D model, assembles, and 2D measured drawings. It consists of solid model data for tooling and rapid prototyping, CNC manufacturing and a bill of material can be modelled accurately with a fully associated engineering drawing and a control information.

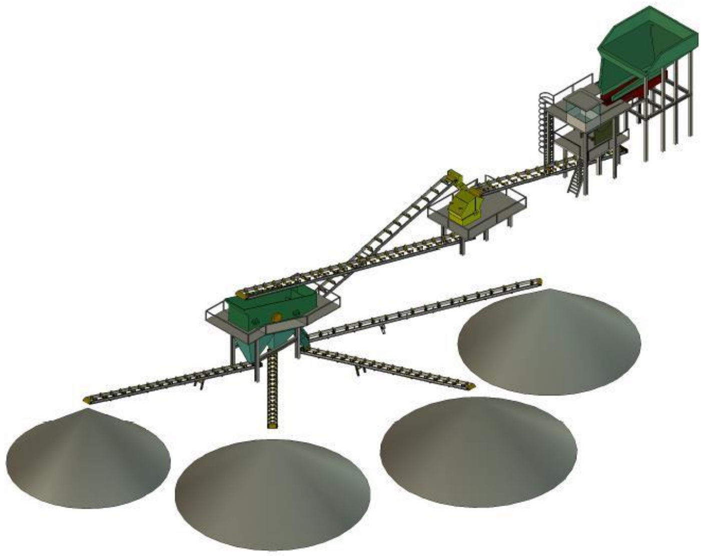

Figure 3.8 Current crushing plant

3.3.1 Identify appropriate end-product proportion

Current plant product capability, market demand data is the initial information that is used to analyze the proper end-product proportion in all of the 4 series, as the result of this analysis, it demonstrates the inappropriateness of a current product capacity’s proportion, so the plant modifying should be taken to increase the profit of the firm. The quadrats differentiate formula which has been proposed in a literature review which has been conducted to identify the market demand friction of all product grain size. This formula has been modified from the original configuration, the main purpose of this formula is to determine the requirement product proportion in a various grain size before settling the manufacturing system, with the same formula, this study use it to identify the differentiate of a current product capability and market demand as it has been demonstrated at equation (2.1).

Mathematical function has been used according to uncertain customers' requirement during the year due to the customers are varied from many businesses by the biggest purchaser is the construction companies although it is the few companies however they have been required a huge quantity of all gain size but their requirement are distinct in each period. Another purchaser is small enterprises of several concrete manufacturers although the requirement of each manufacturer is less but there are more than 30 enterprises surrounded that area, unfortunately, their requirement has set in some specific product grain size as series 3 and series 4 is the most common. While the production capacity doesn't vary, as the formula present mathematical function of the production capacity and market demand respectively.

$$\sum_{j=1}^{n} B_j F_{b,j}(x_k) \tag{3.1}$$

$$\sum_{i=1}^{m} A_i F_{p,i}(x_k) \tag{3.2}$$

Each product grain size has been analyzed according to the function above and before a combination; it has been done separately in order to determine the unbalances of product capacity and market demand of each production grain size. The determination's sequence of this analysis will attach in an appendix and the result will be presented in chapter four.

3.3.2 Crushing plant expansion design

Since the improper production series grain size proportion has been determine, the crushing system should be adopted, modify, redesign and lead to add more machine if it is considering suitable and improve profits of the firm as well as the productivity in terms of monetary. By these reasons, adding a machine to the plant is considered as a choice for this study and it leads to the crushing plant expansion design. The plant expansion is divided into several steps, including a machine selection, station layout, connection system as well as the material handling system.

Machine selection procedure follows the requirement of this crushing plant, the purpose for this installation is to crush the rock of series 1 which is having higher production capacity than a market demand, this installation will prevent the excess product of series 1 from being obsolete, at more values to that product, decreasing storage and an inventory cost. The end-product of the new machine can be flexible, it will crush the series 1 which has the lowest price and the output is the product series 4 which has got the highest price. Hammer crusher machine has been selected for this case study which has capacity ten to twelve tons per hour as shown in figure below.

Figure 3.9 Horizontal hammer crushing machine

3.3.3 Station layout design

Station layout or plant layout design refers to the physical arrangement of work station. According to this manufacturing which the volume of production is high and the production volume must be sufficient to achieve satisfactory utilization of the equipment, product layout is used as the flow line production. The new machine station has been selected and settled down; this layout selection must achieve high equipment efficiency, minimum of initial capital and operation cost, safety, convenience and easy to access in the maintenance time as the crushing expansion plant layout design illustrates in the figure below, the initial investment and operating cost has been determine for using to analyze in the next procedure.

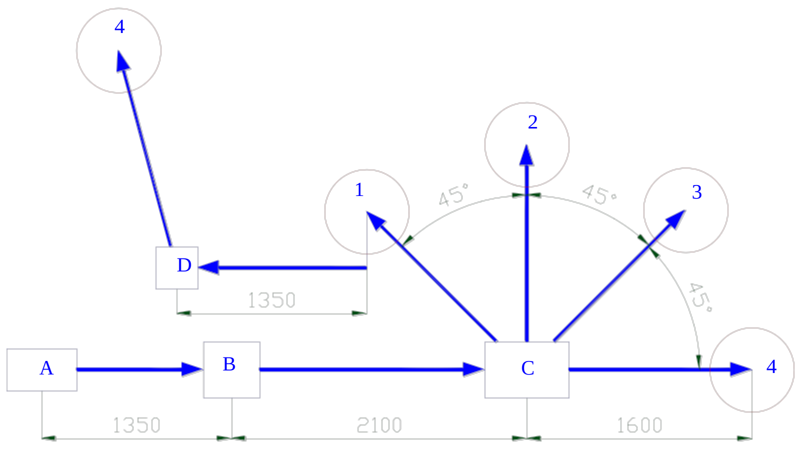

Figure 3.10 Layout dimension

The production layout of the figure 3.10 has been proposed for the plant which is number 1, 2, 3, 4 on the figure are referred to a series production gain size, whilst the letter A, B, C and D refers to a machinery station of the plant respectively. The length unit is represented at centimetre.

3.3.4 Material handling system design

Since the layout has been selected, material handling is identified to connect the work flow from the main system to the new machine. As it is continuously manufactured, so the flow is fairly constant between the two fixed station positions which is unable to change, so the fixed equipment of the material handling is preferable, sand and gravel is the bulk material, troughed belt conveyor is the most suitable. The troughed belt conveyor has been designed according to the length, the capacity that needs to be handled, the material characteristic, the design will determine into the detail, including the type and size of the belt conveyor, power usage, idler type and space until the cost determination of material handling system.

3.3.5 Economic analysis

Economic analysis is the important step in the project evaluation to make the decision of the firm, either eliminating the project or continuing the project. The result of this analysis might guarantee the profitability in term of the business point of view. It is the consideration throughout the project cycle. This economic aspect will be conducted by cost-benefit analysis method, all cost and benefit of the project will be estimated, and the total cost is determined by using a Life Cycle Costing formula (Jun et al., 2011).

$$LCC = (C + M + R - S) \quad (3.3)$$

This formula sums up all the cost of project construction since the beginning until the project is ready to operate, maintenance cost during the life cycle time, as well as the repaired cost of the project, the salvage cost of the end life cycle also might not be ignored.

The project construction cost base on a machinery cost, quantity and the type of component including motor type, conveyor belt, bearing and as well as the material usage such as steel beam, steel farm of all stationary parts, infrastructure and so on. All this cost is taken into an account base on the market price, as the labour to install this project is performed by the mechanical engineer and technician of the plant, so employing outside is not required. Operation cost of this project includes the expenditure of an operator, electrical energy and fuel consumption, and all the addition to use in the plant every day.

Table 3.2 Operation cost in crushed quarrying plant year 2012

Operation cost of year 2012		
blasting cost	108,537,875	Kip/year
electricity cost	553963,000	Kip/year
feul cost	655,455,000	Kip/year
employee expanse	624,088,840	Kip/year
official and confidential expanse	95,551,000	Kip/year
Total operation cost	2,037,594,000	Kip/year

Whereas the maintenance and the repaired cost is complicated to be identified, some of the repaired cost might count of the component life usage and replacement, for the rest is based on a statistic data of the plant in the previous year by the ratio percentage of production output and maintenance cost. The last one is the salvage cost which the plant is expected to earn back when selling the fix asset at the end of the life cycle, the life cycle of this project is taking place in five years.

Table 3.3 Maintenance and repair cost of plant in a year 2012

Maintenance and repair cost of 2012		
machinery replacement part	969,212,000	Kip/year
heavy vehicle replacement part	136,303,000	Kip/year
component delivery and transportation	37,408,000	Kip/year
lubricant and dairy maintenance	954,417,000	Kip/year
Total	2,097,339,000	Ton/year

All the benefits are simplified and determined by the revenues of the new amount of production selling, based on the various products' price and quantity. Consequently all cost and benefit will take into analysis by break event method, internal rate of return and the net present value and decision's conclusion.

This project proposes the plant expansion against the current plant, there is no other alternative option will be considered in this project. All the costs and benefits is compared between current plant and the propose plant, based on those results, this project able to make the conclusion and give clearly the benefit and the scope in the future.

3.3.6 Productivity analysis.

Productivity analysis will be conducted at the last step, as the productivity is the quantitative and qualitative results of the input of all resources. The productivity is the tool to measure the effectiveness of the company; the higher productivity shows better firm's efficiency and performance. Two methods of productivity will be used, firstly is multifactor productivity which is determined in terms of monetary. And secondly is labour productivity (manpower capacity) which is determined the output per labour input and it also show the effectiveness of labour.

3.4 Summary

This chapter has explained the methods used in this quantitative study of one crushing plant, provided the scope and well understanding of the plant situation, all the procedure in this method has been conducted especially layout and material handling design, the final analyse by a cost-benefit analysis method as the sequence of the project. The following chapter will present the results obtained with these methods.

CHAPTER 4

RESULT AND DISCUSSION

As stated in chapter one, this chapter will report all the results which cover the objectives purpose of this study by using methods from the previous chapter. This chapter has been organized in terms of the objective order as well as the sequence of the work which has been done, including the identification of a suitable operating condition to match with a market demand, crushed quarrying expansion plant design and the component selection in designing process, presenting the result of the economic analysis from all cost which need to be invested and new benefit that proposed to the plant.

4.1 Identification of market demand

Stone crushing plant encounter an inappropriate product proportion in all of the series of grain size, this result was gained from mathematical determination method. All the information and data of this procedure are based on the plant production report in the year 2012 and the company supply contracts and interviews. This identification has been done in each product series separately and it has been demonstrated in the differential of plant capacity with customers' requirement, the following chart demonstrates the detail of the comparison of plant product capacity and a market demand in each series and the following table presents the difference S all of the production grain sizes. For well understanding and the detail of mathematical determination was explained in appendix A.

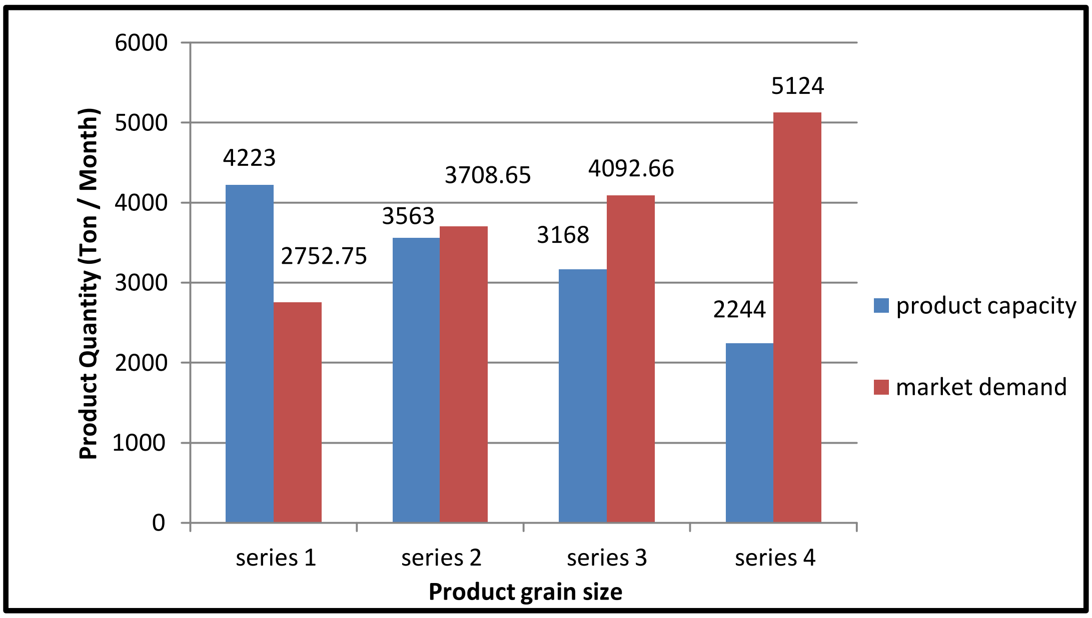

Figure 4.1 Comparison of plant capacity and market demand chart

Figure 4.1 presents the product series 4 has the production capacity higher than the customer's requirement in the market place. It indicates that if this plant operates in full capacity, the material grain size series 1 will excess more than 53 percent of the market demand and will lead to inventory cost and problems, e.g. the plant has to eliminate or do something with that excess product before it becomes obsolete, in contrast the product grain size series 2 to series 4 have the production capacity less than the customer requirement. As for the product series 2 the difference between the plant capacity and a market demand is small, the difference is only 4 percent. Similarity, the product grain size series 3 which has the difference around 22 percentages of market demand that is unable to be fulfilled. In contrast the production grain size series 4 which has a huge amount of differences, this plant production capacity is able to fulfil with only 44 percentages, another 56 percentages of the market's requirement that the plant is unable to supply.

Table 4.1Difference (S) of plant capacity and demand and percentage

Plant capacity VS market demand				
	plant capacity (T/month)	customer requirement (Ton/month)	Percentage (%)	*S* (Ton/month)
series 1	4223	2752.75	153.41	1470.25
series 2	3563	3708.65	96.07	-145.65
series 3	3168	4092.66	77.41	-924.66
series 4	2244	5124	43.79	-2880
Note: Percentage in table represents plant capacity of fulfilling the demand and negative value of (*S*) represents unfulfilled demand quantity.				

The difference (*S*) of product series 1 and 4 indicate the plant problem, and it has significant influences to the plant profit. This difference will lead to new plant conception, this concept is to improve a market fulfilling as well as the profitability of the plant. The concept is "modify the excess or obsolete production of series 1, crush it and become the product of series 4", if this concept successes, the excess and obsolete product of the plant will be eliminated, while the market fulfilling of series 4 will be improved from 43.79% to 72.49 % and the difference (*S*) will decrease from (-2880) to (-1409.75) Ton/month, as the smaller number of (*S*), illustrates the better production plant. Consequently, the differential of end-products and market demand brings to the stone crushed quarrying plant modification.

There are two ways to process this strategy. Firstly, bring all excess product from series 1 return to secondary crushing again, but this way will decrease the overall production rate. Secondly, the plant modification as the plant extension project, this way will not affect the overall productivity rate and the result is plant expansion has been designed for the existing plant as explained in following.

4.2 Plant expansion design

New plant expansion could be more flexible and versatile; it can operate separately when the main crushed line in a down time. Tertiary machine and the material handling system can be settled as the following figures demonstrate the current plant and the plant's expansion.

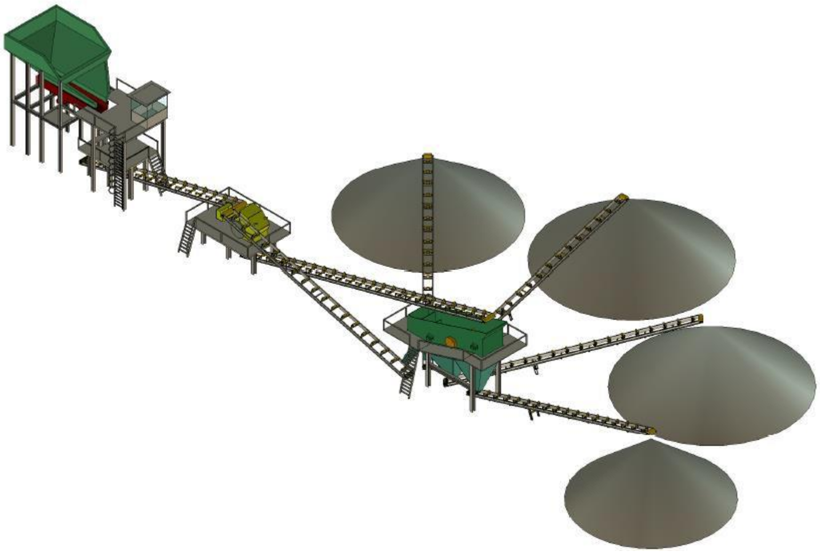

Figure 4.2 Stone crushing (current plant)

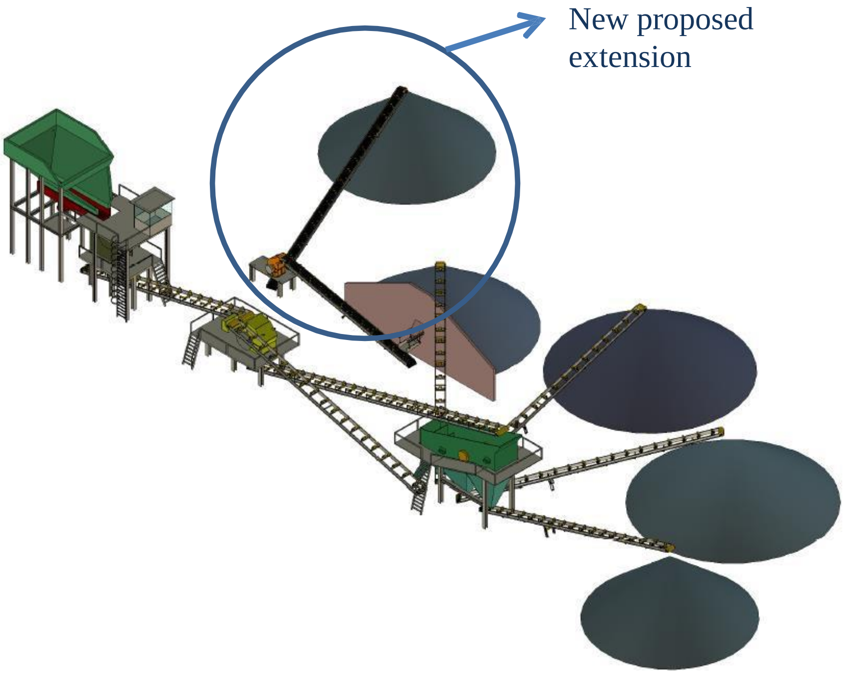

Figure 4.3 Stone crushing (plant expansion)

Plant expansion design has been separated into several procedures, including stockpile preparing design, mathematical determination of tertiary crusher machine, the mathematics of the material handling system and the 3D model of all systems.

4.2.1 Stockpile preparing and design

The expansion crushing system takes product from the stockpile series 1 as the raw material, so this stockpile has to be prepared for this purpose. Normally the series 1 stockpile is a natural gravity bulk material stockpile with conical shape and has angle of repose equal to 37 degrees. The maximum capacity contain of this stockpile is 230.52 m^3 as the high is 5 m.

One concrete wall has been designed and it cuts stockpile of series 1 to prepare the material flow way for the tertiary crushing as it is demonstrated in figure below.

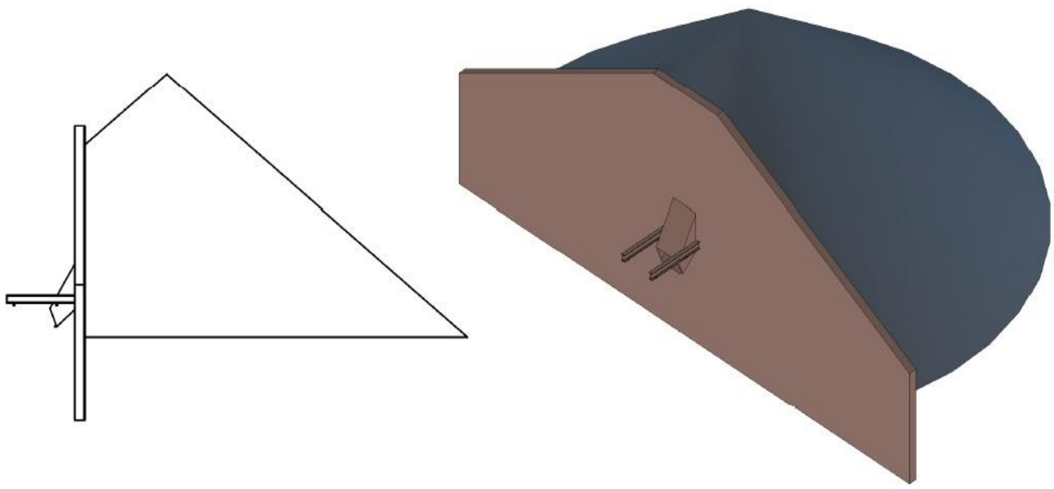

Figure 4.4 New series 1 stockpile

This concrete wall consists of the 20 centimeter concrete thickness with the maximum length is 14 meters and the maximum high is 5.6 meters, this concrete wall is deep into the ground with 1.6 meters for fixing the wall and its durability. The hold and a flow way of aggregate with the starting hold with dimension of 1 meter in high and 0.6 meters in width as well as the end of the flow way is 35 centimeters in high and 60 centimeters in width. The opposite of the stockpile consists of 2 steel beam on the top of the material flow way, those steel beam has a length of 1.5 meters with the purpose to hang down the vibratory feeder. For the detail of stockpile preparing is demonstrated in an appendix B.

4.2.2 Vibratory feeder design

Feeder in this designing process has been selected Mogensen Vibratory feeder which is suitable for the secondary and tertiary crushed step, due to the design of this feeder style is simple so the maintenance is simple, where the starts and stops are easily controlled, the receiving and a feeding volume are instantly adjustable and the capability of the remote control can be easily adopted, the feeder is being hung down by the steel chain or spring as shown in the figure 4.5 below.

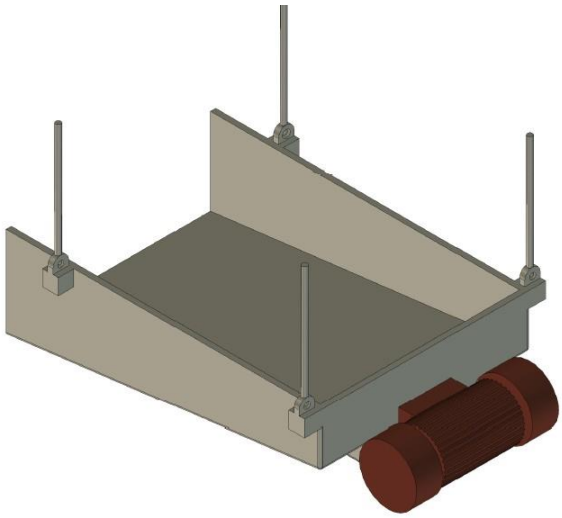

Figure 4.5 Mogensen Vibratory Feeder

This vibratory feeder has been designed to feed bulk material at steady state approximate around 10 cubic meters per hour with a supply energy by a complete set of unbalanced rotating drive shaft, 500 Watt of electric motor has been selected, three phase supply with 50 – 60 Hz which is available in the market. Material construction of this feeder uses 6 mm thickness mild steel plate as well as 6 mm thickness mild steel bottom liner with an abrasive resistant manganese or stainless steel are coated and the reinforcement of the strength by steel bones. The installation of this feeder and the material flowing way is designed based on the gravity flow and preventing material over receiving from the stockpile. For the detail dimension is attacked in appendix B.

4.2.3 Tertiary crushed machine design and selection

The product type and the product capacity are the high factor of the crushing machine and it has high significant to energy consumption of the plant, due to different type of machines are suitable with a different type of material characteristics. As this purposed condition where is the production capacity is around 10 ton/hr, end product size is 0 to 5 mm (series 4) and material input is 20 mm to 40 mm (series 1), normal abrasive material of granite stones. By these characteristics, a horizontal drive shaft hummer crusher machine was selected, and due to the product output is one size, so the changeable material screening is installed inside the machine itself. One crushing machine has been selected with China's technology; the machine has been shown in Figure 3.9, one electric motor of 65 kW, 1400 rpm of three phases has been used. The machine will be installed on the top of the supporting machine house which is higher from ground with 1.2 meters.

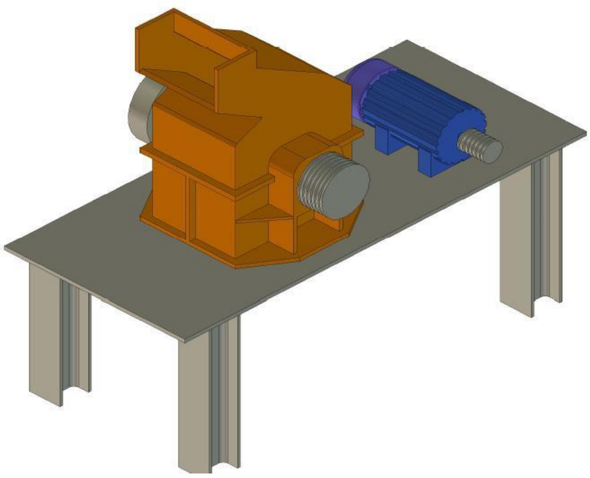

Figure 4.6 Tertiary crushing machine

The material is supplied at the top of the machine with a dimension of 30×60 cm and the product comes out at the bottom of the machine, both material input and output are supplying and sending by trough conveyor belt as the main of bulk material handling system.

4.2.4 Material handling system design.

From the common usage as well as this design proposes, the material handling system or material transporting system of this stone crushing system use trough conveyor belt. Two trough conveyor belt components have been designed and selected, one is the input conveyor and second is for the output conveyor for a tertiary crushed machine, although both conveyors have the same conveying capacity but they have differences of the material's size, difference of length and the angle of conveying, these bring the result of the design that has a differences on some of parameter. The result of conveyor is illustrated in Table 4.2.

These results are based on a mathematic determination according to the standard of DIN 22101 as well as ISO 5038 formulas; the detail of the determination is attached in appendix C, the belt conveyor type has been selected according to the market availability, with EP 400/3 450 means polyester 400 total tensile strength with three plied and 450 mm in width, the conveyors are simple, easy on access and maintenance, construct in a straight line, non-curvature, one motor drive at the end point, the conveyor modelling is demonstrated in the figure 4.7.

Figure 4.7 Troughed conveyor belt design.

Table 4.2 Determinant result and component selected of conveyor belt.

	input conveyor	output conveyor	unit
conveyer type	EP400/3 450 DIN	EP400/3 450 DIN	
toughing idle type	series 25 type 60 frame D127	series 25 type 60 frame D127	
driving pulley type	25x60 cm welded steel pulley	35x60 cm welded steel pulley	
tail pulley type	20x60 mm Lagged wing pulley	30x60 mm Lagged wing pulley	
bearing	UCP 211	UCP 213	
convey capacity	10	10	T/hr
conveyor velocity	0.1777	0.1777	m/s
incline angle	15	17	degree
toughing angle	35	35	degree
contact pulley angle	180	180	degree
length centre to centre	12	18	m
vertical conveying high	2.5	5.26	m
Idler spacing	1	1	m
transformation length	0.7	0.75	m
Primary Resistance	753	1121	N
secondary Resistance	2259	2915	N
Gradient Resistance	383	807	N
Total Motional Resistance	3395	4843	N
Total Power Required	0.927	1.32	kW
motor selection	1	1.5	kW

4.2.5 Extension stone crushed system

The decision to extension the plant as provide at previously, the procedure design which has been done, each stage, each component that has been designed are connected together and come up with the completion of tertiary crushing system as the model shown below.

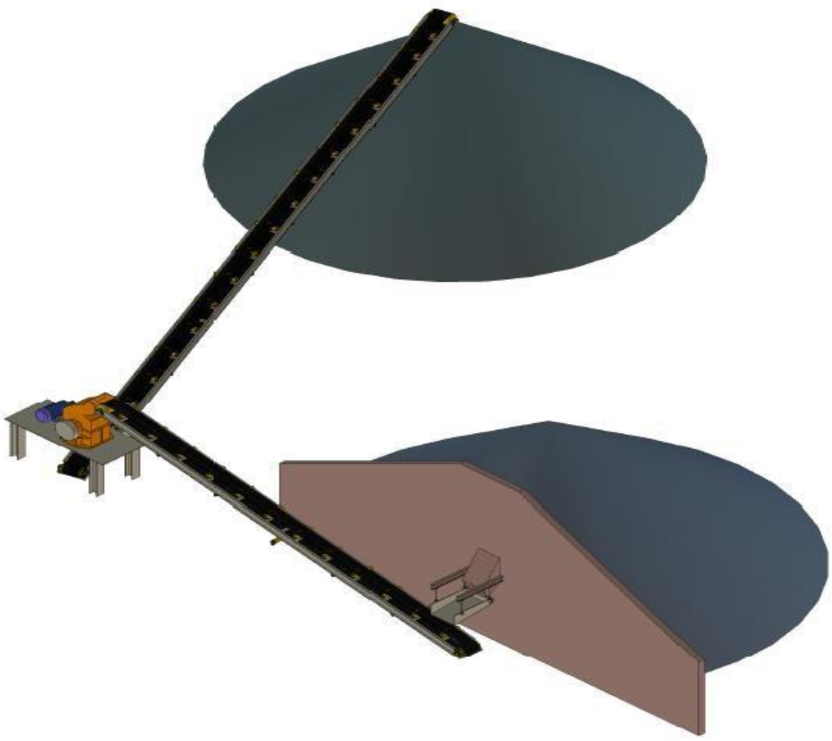

Figure 4.8 Tertiary crushing system

The production of this system is followed by the material from the stockpile of series 4 flow through the wall by the free flowing way. It goes to a vibrating feeder which is installed below the flow way with suitable orientation in order to prevent the overflow of materials. The feeder is vibrated by a motor at the back and feeds the material to the input conveyor at nearly constant quantity. The input conveyor length 12 m and bring the material up to 2.5 m, and drop the material to the top of a hummer crusher machine with a capacity of 10 T/hr. The product drop down to the output conveyor with grain size 0 to 5 mm, the output conveyor, which has length up to 18 meters, will bring the product up to the top of gravity's conical shape with the height of more than 5 meters. The control system of tertiary crushing system is joining together in an operation control room as the main crushing system; however the control panel and electric supply are run separately from the main system, as the result the expansion system can be operated during the down time of the main crushing system. The expansion system might consume the electrical energy only 68.5 kW. The complete system is shown in the figure below with the expected of better product variation as well as the productivity of the plant.

All consumption conditions have been determined and the results are shown in table 4.3 below. As nature, when a new machine or new system has been added into an existing system, the total cost mush increase as well as the increasing of revenues, in this study the fuel consumption has significantly decreased due to the eliminating of product transport of series 1 into another inventory.

Table 4.3 Summation of plant operation cost and revenues

	current plant	plant after expansion	Unit per month
electric consumption	62,300	74,813	kWh
fuel consumption	5,749	5,551	litter
employee	22	22	person
total cost	363,680,250	389,847,667	kip
total revenues	804,630,000	914,978,750	kip

Once the expansion of the crushed quarrying plant has been designed, construct and operate, consequently, the plant will get better answer to the market by a new product proportion, the plant’s production quantity is presented in the figure below. This result has a significant in reducing of difference (*S*), mean that the overall plant production has been improved.

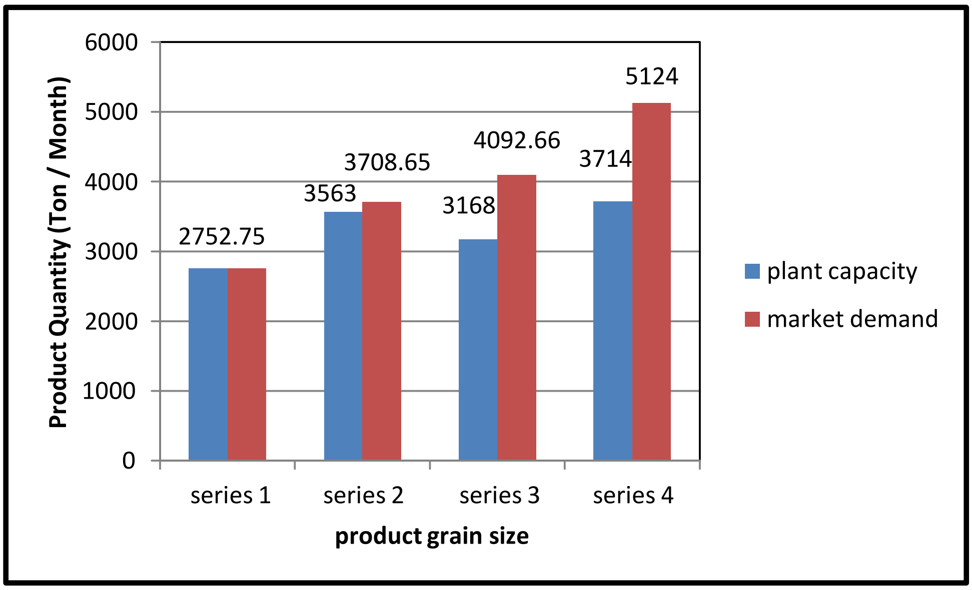

Figure 4.9 Fulfilling market demand

4.3 Economic analysis

4.3.1 Identifying cost and benefit

(a) Identifying cost and benefit of current plant

Initial step is the overall costs and benefits of concurrent plant must be identified, as the base to identify of plant expansion. As usual, this identification uses raw data from statistics financial report in year 2012 and the detail of these identifying are attached in appendix D. The result has present in following table.

Table 4.4 Current plant cost identifying.

category	cost (kip/year)	average cost (kip/month)
maintenance cost	2,097,339,000	174,778,250
operation cost	2,037,594,000	169,799,500
Depreciation of plant	229,230,000	19,102,500
Total cost	4,364,163,000	363,680,250

The maintenance cost of this plant including machinery, heavy vehicle replacement part and a spare part cost, part component delivery and a transportation, lubricant and the daily maintenance. As well as the operation cost of the plant consists of blasting cost, electricity and fuel energy cost, employee expense or salary, official and confidential expanse. The last cost is the depreciation of the plant, with the total production is 158372 Ton/year.

The same as the cost identifying, the benefit is based on the product selling of all products on the production report in the year 2012 as it has been illustrated below.

Table 4.5 Current plant revenue identifying

product	Product selling (Ton/month)	price (Kip/ton)	firm revenues (Kip/month)
series 1	2,753	60,000	165,165,000
series 2	3,563	70,000	249,410,000
series 3	3,169	70,000	221,830,000
series 4	2,243	75,000	168,225,000
Total	11,728		804,630,000

Both costs and benefits identifying of the current plant indicate that the current plant has benefits more than costs, we can say that the plant's revenues is more that 190% of the plant expanse, but this result is not the optimization of the plant, the plant benefit can be improved by the plant expansion which is the costs and benefits identifying will be conduct in following section. Consequently, the current cost identifying of current plant that allows us to identify the maintenance cost per unit output is 13,243 Kip/Ton, this maintenance cost is approximated as the maintenance cost in the tertiary crushing system.

(b) Identifying cost and benefit of plant expansion

Cost identifying of a tertiary system is conducted by overall Life Cycle Costing method, as the design purpose of life cycle of five years, and the salvage cost approximate to zero at the end of life. The detail determination is shown in appendix C and the result is demonstrated in the table below, as the maximum capacity of the machine is excess requirement of (series 1) totally 1,471 Ton per month.

Table 4.6 Cost identifying of tertiary system

category	cost	unit
construction	393,631,000	Kip
operation cost	9,009,000	Kip/month
maintenance cost	19,480,626	Kip/month
material cost	40,535,472	Kip/month

As normal the benefit of tertiary come from selling product which the series 4 product grain size and the quantity is 1471 tons per month, it is equivalent to 110.03 million Kip per month. Since the cost and the benefit have been identified, the analysis will be conducted in following section.

4.3.2 Break even analysis

As the simple analysis method to determine the point, that the total revenues are equal to the total costs, over this point, the firm will start earning a profit, as the result obtains in the analysis, the breakeven point at 13,872 Tons of product, with the duration of operation on normal condition around 9 months (operate 1,471 ton/month), graph result is indicated on the chart below.

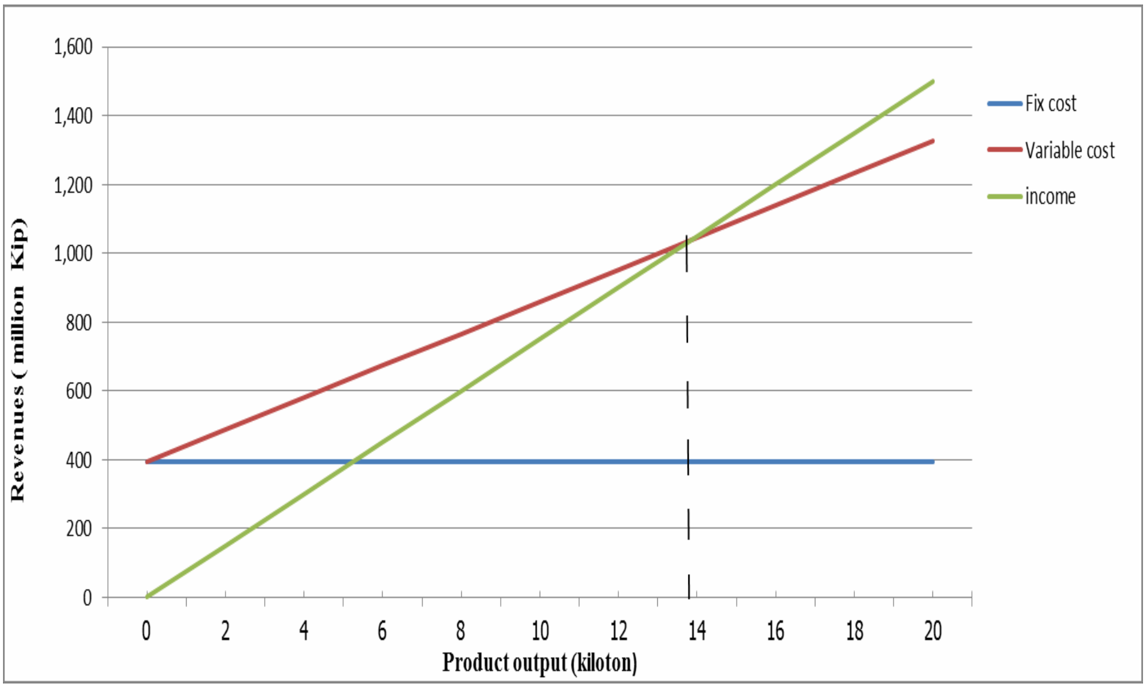

Figure 4.10 Break Even Analysis chart

As it has been indicated in the chart above, this is the breakeven analysis of the tertiary crushing system only. The fixed cost in the chart refers to the construction cost of the machine and system, for the variable cost refers to material principle cost, operating cost and maintenance cost, which is 27,556 kip/ton 3,554 kip/ton; and 13.243 kip/ton respectively. As it stated earlier, after nine months of operation, the firm will earn the profit until the end of lifecycle (five years). Furthermore, this chart illustrates that the construction cost has less influence to benefit, based on the capacity of the tertiary system can make the income to the firm equals to the construction cost within three point six months, but in contrast, variable cost has high influence to the firm profit, both of them has high amounts that significantly increases when the amount of the product increased.

4.3.3 Cost benefit analysis

Cost benefit analysis is conducted after the costs and benefits identification step, the two main tools as net present value (*NPV*) and internal rate of return (*IRR*) have been used to make a decision. Costs and benefits chart under the expansion plan of the tertiary crushing system is illustrated below.

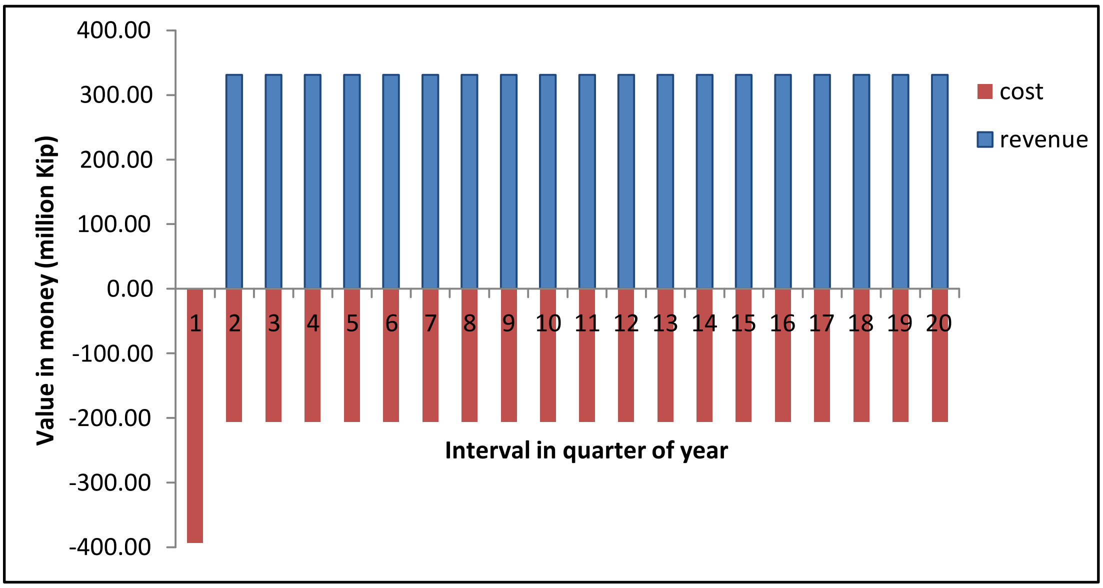

Figure 4.11 Cost and benefit chart of expansion system

The result obtains that net present value of expansion system *NPV*= 1,631 million Kip with all its life cycle time. It is not only at the positive side, but it also comes up with the high amount, this determination is based on the interest rate at 20 percentages per annum (*i*=0. 2) the determination as well as the chart at above was divided into quarters until the end of the life cycle, totally twenty intervals. This result will place into the decision rule one which is stated in chapter two. The rule has mentioned that all projects that have *NPV* excess zero are reasonable to process and undertaken the project. The *IRR* of this project also presented at value 1.35, most of the project accepts at *IRR* 0.2 and above, it means that, this *IRR* gives a high supporting to the value of *NPV* and decision can make easily.

4.4 Productivity analysis

As the most manufacturing field concern, the productivity and the manpower capacity analysis have been conducted between the current plant and the plant after expansion, the productivity of the plant presents in the table below and the detail of determination is attached in appendix E.

Table 4.7 Comparison of manpower and productivity in production plant

	manpower capacity (Kip/labour.hr)	MFP (output/input)
current plant	138,571	2.32
plant after expansion	150,585	2.35

As the results obtained and illustrated in the table above, the crushed quarrying expansion plant's operation will improve the manpower capacity from 138,571 to 150585 kip per labour and hour, it increases 8.67 percentages. The increased of the manpower capacity is due to the improving of the production price without adding the operator, it means that even though the expansion crushed system has been added and connected to the main crushing system, but the number of the operator, maintenance team and every officer unit still remained the same number, all the operation functions of the expansion system are linked to the main operation room. Another factor is the productivity of plant and due to various goods is concerned, so the multifactor productivity *MFP* is used, and it is determined in the terms of money value, as it is the measurement of effectiveness of all output against all input, and it has been improved from 2.32 become 2.35, increasing 0.99 percent.

4.5 Result discussion

Based on the result which achieves in all procedures analysis, the current plant production has the problem in the market satisfaction of vary customers' requirement of all the product grain side during the year. It is has been proven by the market demand identification analysis, it acts as the confirmation to modify the crushing plant, make it better in fulfilling the market demand, and it will lead to the feasibility study to the plant expansion.

The plant expansion has been designed and mathematic analyse of suitable and compulsory component in the expansion system, make it flexible, available to operate with or without the main system. The result of the design demonstrates the components selected and 3D model of production plant, the electrical usage increases from 356 kW becomes 427.5 kW. The result has been used in the next analysis, new-producing capacity, maintenance and operating costs has been taking place in the economic analysis, better product capacity proportion as well as market demand is shown in section 4.3. The excess production in series one is reducing from 1471ton per month to be equivalent to market demand. In contrast, the unfulfilling of the production series 4 is improving form -2888 ton per month to -1410 ton per month. Consequence analysis let we know that this project has high significance to bring a profit to the plant as the plant revenues increases from 804 million to 914 million per month. It is proved by *NPV* of 1,631 million Kip until the end of life and the *IRR* present at 1.35, break even analysis also proves that the time of the total revenues equivalent to the total costs in mine months of full operation, the benefit will earn totally at four years and three months. This plant expansion also improves productivity and manpower efficiency as there is no any additional number of new workers.

CHAPTER 5

CONCLUSION

5.1 Conclusion

The objectives of this study are to design the expansion of the stone crushed plant in order to satisfy the market demand and at the same time to increase the profit. In order to achieve the purpose, a study of stone crushing plant was conducted in Laos namely Atlantic Sand and Gravel Company. The case study was emphasized into two phases with three objectives, the first phase is machinery system designed and modelling and secondly is the economic and productivity analysis. Most of the real data comes from data collection with duration of twenty five days and various statistical company's reports of the year 2012.

The aim of the first objective is to determine the suitability of crush operating condition to meet the market demand. The analyses give the answer of the difference of existing production capacity against the customer requirements. The study shows that the crushing plant operation is far away from an optimum condition to serve the market. Furthermore, it presents the feasibility to modify or adapt the crushing plant with a reasonable improvement.

The new machinery system was designed to tackle with an inappropriate product proportion and hence to get better proportion of product served to the market demand with higher profit. The market demand is the key of all enterprises. This procedure is called the expansion system, it is including hammer crushing machine, vibration feeder and conveyor material handling system was linked and available to operate simultaneously or separately with the main system. The obvious advantage of expansion system is to help the company to produce an optimal product proportion by eliminating the excess production of certain stone size and also reduce the inventory cost.

The final objective is looking at the economic section by using the cost-benefit analysis method. All the costs and benefits have been identified and analysed, various tools has been used, including Break Even analysis, *NPV* and *IRR*. Break even analysis tells the duration of the time that the total income is equivalent to all costs within nine months. *NPV* presents 1,631 million Kip within five years duration of cycle life and lastly *IRR* which presents the value of 1.35. All of these three values indicate this project is viable to be processed. In this study, the three values considered as the prove or a confirmation tool to validate that the proposed project will bring more the profit to the company.

According to the manufacturing concern, the manpower capacity and the plant productivity is the tool to prove or measure the efficiency of the plant. Productivity always played as a key role in the economics of all enterprises. After the plant expansion starts its operation, the productivity will increase by 0.99 percent and the manpower in teams of efficiency increases by 8.67 percent. Both values are really useful to validate the improvements of the production plant.

The solution in this study could also be suitable to be applied in another stone crushing plant and various categories of enterprises. Project design and the economic analysis are a useful method to estimate the result of the project as the purpose is to obtain a better feedback to market's requirement and to possibly increase the revenues when the excess product has been eliminated and the shortage of product has been eliminated.

5.2 Limitation and Recommendation

Although this study has conducted properly, but it also has limitations on showing the actual evidence to verify the analysis result, due to most of the research on the project economic analysis as well as this study are analysed by the mathematic model, or some computer’s simulation. The main barrier appeared in two ways, the first is impossible to get a permission of the company to change according to the research result, and second barrier is the duration of the study is not long enough to wait until the end of a life cycle project. For the further research on the project design and the economic analysis should be combined with the continuing research when the end of the project life cycle.

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Appendix A

MEETING MARKET DEMAND

The optimization of the crusher-quarrying plant in term of productivity, less inventory and warehousing are the critical task of the plant manager. Vary product grain size are produced inside the plant, revenue improvement can be satisfy by answering the question of which operating condition of particular machine and crushing system is capable to fulfill the quality and quantity requirement form several customer in all product grain size.(Csöke et al., 1996)

The quadrats differentiate has been propose with the purpose to identify the market demand friction of all product grain size. The sum of quadrats differentiate (*S*) should be minimize as much as possible, the smaller *S* value demonstrate the higher plant revenue and less warehousing of the product.

$$S = \sum_{k=1}^{N} \left[\sum_{j=1}^{n} B_j F_{b,j}(x_k) - \sum_{i=1}^{m} A_i F_{p,i}(x_k) \right]^2 \quad (1)$$

Let set *N* is the number of grain size under consideration.

Let $F_{b,j}(x_k)$ and $F_{p,i}(x_k)$ represent mathematic function of the customer requirement and the mathematic function of finisher product of certain crushing operation respectively.

Let B_j and A_i represent its quantity of customer requirement and finished product respectively.

The finish product in Pha nalieng plant site of Atlantic sand and gravel company is mainly serving in road construction and road maintenance, raw material supported to small business manufacturing of concrete block, paver block, concrete pipe, cement pillars and concrete board in house construction within area of 50 Km radius.

Road construction and road maintenance which consume highest demand of crushed rock product of the plant, layer flexible pavements are design and consisting of multilayer such as compacted subgrade, subbase course, base course, binder course and surface course or wearing course(Saltan & Selcan Fındık, 2008).

Wearing course or surface course is the top layer of road which has the thickness average 3 cm and it requires fully series 3 of rock product grain size, blending with asphalt of ratio 95:5 by mass (Bocci, Grilli, Cardone, & Virgili, 2012).

Bender course is intermediate of the road between wearing course and base course with thickness not less than 6 cm, it is consisted of coarse grain size aggregate bounded with bituminous, it the reason if this course require crushed rock with grain size series 2 as the main material with blending ratio with bituminous 95:5 by mass (Bandyopadhyaya, Das, & Basu, 2008).

Base course is high compressive course under binder course with thickness 20 cm, aggregate of this course consist of a combination of both fine and coarse fragments of hard crushed stone, crushed gravel mixed with soil and sand or other similar approved material, base course construction require all of product grain size with difference ratio for instance: product grain size of series 1, series 2, series 3 and series 4 are required 40%, 15%, 8% and 10% respectively blend with soil 33% by mass (Frempong & Tsidzi, 1999).

In conclude of road construction base on three layer require the crushed rock from the plant represent in product ratio rock series 1, series 2, series 3 and series 4 is represent in 34.49%, 36.66%, 20.21%, 8.62% in mass.

Crushed rock in this plant also serve as the main aggregate of more than 30 small business manufacturer of concrete block which has mixing ratio of coarse aggregate (series 4) with cement 10:1 in mass (Poon & Lam, 2008) and concrete pipe, brick and cement pillars which has mixing ratio of aggregate (series 4), (series 3) and cement of 2:3:1 in mass (Mohd. Zain, Nazrul Islam, & Hassan Basri, 2005). All those manufacturing during 7 month peak production require the crushed rock in ratio of series 3 and series 4 represent in 90 Ton/month and 160 Ton/month of 15 concrete block manufacturers.

Otherwise the plant also sells the crushed rock to nonspecific propose and uncertain requirement with small amount per month.

Road base course requirement

Note that: this requirement for road construction of 1 km length, 6 m width and base course thickness 20 cm, it requires 1200 m^3 equivalent to 2760 T		
Grain size	Percentage by mass	Requirement (Ton)
Series 1	40	1104
Series 2	15	414
Series 3	8	220
Series 4	10	276
soil	33	910.8

Road requirement

Grain size	Mass requirement / km road length	Percentage by mass
Series 1	1104	34.49
Series 2	1173.6	36.66
Series 3	647	20.21
Series 4	276	8.62
The peak time of the road is constructed from Oct to April (7 month) and the requirement of crusher-quarrying plant to supply is 4 km per month		

This table below represents the requirement of 15 concrete block manufacturers per day, within 50 km radius from the plant, this requirement represent on all concrete block, brick, concrete pipe and cement pillars.

Concrete block manufacturer

Grain size	Product Requirement T/day	Percentage
Series 3	90	36%
Series 4	160	64%

Current plant productivity as it was collected of year 2012 was illustrate below

Rock crushed productivity of 2012					
	Product series 1	Product series 2	Product series 3	Product series 4	Total in mass (Ton)
Jan	4420	3730	3316	2350	13816
Feb	4298	3626	3224	2284	13432
Mar	4195	3540	3147	2230	13112
Apr	4234	3570	3176	2250	13230
May	4083	3454	3063	2170	12770
June	3849	3247	2887	2045	12028
July	3920	3300	2940	2083	12243
Aug	3847	3245	2886	2040	12018
Sep	4130	3485	3098	2194	12907
Oct	4586	3869	3440	2437	14332
Nov	4478	3778	3360	2373	13989
Dec	4638	3913	3480	2464	14495
Total in series	50678	42757	38017	26920	158372
average	4223	3563	3168	2243	13197

According to the optimization equation above, the value of sum quadrats differentiate can be identified.

For grain size series 1

$$\sum_{j=1}^{n} B_j F_{b,j}(x_k) = 168.96 \times 25$$

$$\sum_{i=1}^{m} A_i F_{p,i}(x_k) = \left(\frac{7}{12}\right)\left[(1101 \times 4) + \frac{-2305}{12}\right] + \left(\frac{5}{12}\right)\left(\frac{2305}{12}\right)$$

So:

$$\sum_{k=1}^{1}\left[\sum_{j=1}^{n} B_j F_{b,j}(x_k) - \sum_{i=1}^{m} A_i F_{p,i}(x_k)\right]^2 =$$

$$\sum_{k=1}^{1}\left[168.96 \times 25 - \left(\left(\frac{-7}{12}\right)\left[(1101 \times 4) + \frac{-2205}{12}\right] + \left(\frac{5}{12}\right)\left(\frac{2205}{12}\right)\right)\right]^2 = (1471)^2$$

For product grain size series 2

$$\sum_{j=1}^{n} B_j F_{b,j}(x_k) = 142.5 \times 25$$

$$\sum_{i=1}^{m} A_i F_{p,i}(x_k) = \left(\frac{-7}{12}\right)\left[(1173.6 \times 4) + \frac{-11643}{12}\right] + \left(\frac{5}{12}\right)\left(\frac{11643}{12}\right)$$

So

$$\sum_{k=2}^{2}\left[\sum_{j=1}^{n} B_j F_{b,j}(x_k) - \sum_{i=1}^{m} A_i F_{p,i}(x_k)\right]^2 =$$

$$\sum_{k=2}^{2}\left[142.5\times 25-\left((\frac{7}{12})\left[(1173.6\times 4)+\frac{11643}{12}\right]+(\frac{5}{12})(\frac{11643}{12})\right)\right]^2=(-146.15)^2$$

For product grain size series 3

$$\sum_{j=1}^{n} B_j F_{b,j}(x_k)=126.72\times 25$$

$$\sum_{i=1}^{m} A_i F_{p,i}(x_k)=(\frac{7}{12})[(674\times 4)+90\times 28]+(\frac{5}{12})(90\times 28)$$

$$\sum_{k=3}^{3}\left[\sum_{j=1}^{n} B_j F_{b,j}(x_k)-\sum_{i=1}^{m} A_i F_{p,i}(x_k)\right]^2=$$

$$\sum_{k=3}^{3}\left[126.72\times 25-\left((\frac{7}{12})[(674\times 4)+90\times 28]+(\frac{5}{12})(90\times 28)\right)\right]^2=(-924.6)^2$$

For product grain size series 4

$$\sum_{j=1}^{n} B_j F_{b,j}(x_k)=89.72\times 25$$

$$\sum_{i=1}^{m} A_i F_{p,i}(x_k)=(\frac{7}{12})[(276\times 4)+160\times 28]+(\frac{5}{12})(160\times 28)$$

$$\sum_{k=4}^{4}\left[\sum_{j=1}^{n} B_j F_{b,j}(x_k)-\sum_{i=1}^{m} A_i F_{p,i}(x_k)\right]^2=$$

$$\sum_{k=4}^{4}\left[89.72\times 25-\left((\frac{7}{12})[(276\times 4)+160\times 28]+(\frac{5}{12})(160\times 28)\right)\right]^2=(-2881)^2$$

Identifying sum squire differential

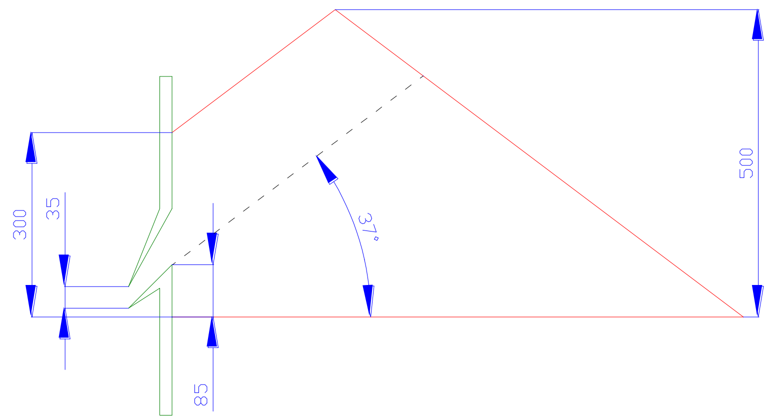
$$S=(1471)^2+(-146.15)^2+(-861.6)^2+(-2881)^2=11332245$$

Appendix B

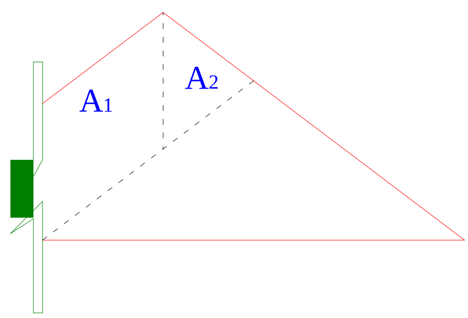
STOCKPILE AND FEEDER SELECTION

Stockpile preparing

The principle product stockpile of series 1with conical shape and has angle of repose equal to 37 degree. The maximum capacity contain of this stockpile is 230.52 m^3 as the high is 5 m. one part of them has been divide for installing the vibratory feeder and loading point of conveyor one. Concrete wall has been constructed for dividing purpose, after preparing the stockpile for plant expansion, the capacity storage reduce to 213 m^3, the dimension of stockpile preparing is show in figure below.



Wall determination



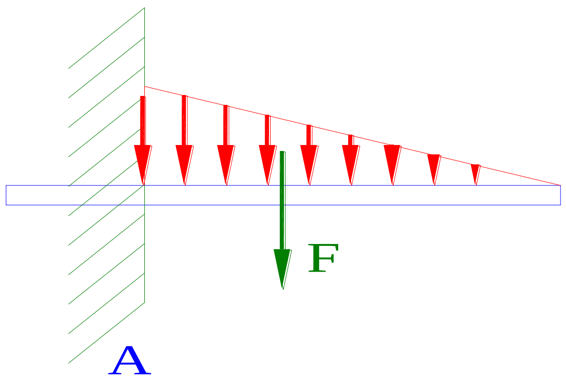
On this determination we consider the at 1m width of wall and material, as the figure above, all the force act to the wall can be determined below

$$F = V\rho g \sin 37°$$

$$V = (A_1 + A_2) \times 1$$

$$F = 13.95 \times 1.5 \times 9.81 \times \sin(37) = 123.53kN$$

Force diagram is illustrate below



The reaction force at point a is

$$R_A = F = 123.53kN$$

Moment reaction at point a is

$$M_A = F.\frac{l}{3} = 123.53\frac{3}{3} = 123.53kN.m$$

Determine the compressive and tensile stress which the same due to symmetry cross section

$$\sigma = \frac{M_{\max}}{I_X} y$$

$$\sigma = \frac{F \quad h}{\frac{bh^3}{12} \quad 2}$$

In the beginning we assume that the wall thickness is 20 cm so

$$\sigma = \frac{123.53 \quad 0.2}{\frac{1 \times 0.2^3}{12} \quad 2} = 18526 kN/m^2 = 18.52 MPa$$

According to the compressive and tensile strength of steel reinforcement concrete, both value are higher 40 *MPa*, it confirms that the wall is safe enough from breaking.

Free flow way calculation

$$\theta = 37°$$

$$\Rightarrow \mu_s = \tan(37°) = 0.75$$

Material flow requirement is 10 T/hr

$Q = Av\rho = 10T/hr$ as $A = 0.6 \times 0.35 = 0.21$

$$v = \frac{Q}{A\rho} = \frac{10 \times 1000}{0.21 \times 1500 \times 3600} = 8.6 \times 10^{-3} m/s$$

As second law of Newton

$$\sum F = ma$$

And the mass we require is 2.77 kg/s with velocity at 8.6x10^{-3} m/s

$$a = \frac{v_t - v_0}{t} = \frac{8.6 \times 10^{-3} - 0}{1} = 8.6 \times 10^{-3} m/s^2$$

$$\sum F = ma = 2.77 \times 8.6 \times 10^{-3} = 0.0232N$$

Determine the force to overcome friction in order to move the material 2.77 kg

$$F_S = N \times \mu_s = p \times \mu_s \times \cos\theta$$

$$F_S = 2.77 \times 9.81 \times 0.75 \cos(37°) = 16.27N$$

Check the force to push the material from the gravity force of material at the top of flow way.

$$F_a = P_a \sin\theta$$

Base on the shape of stockpile we can determine the mass at the top of flow way is 6750 kg

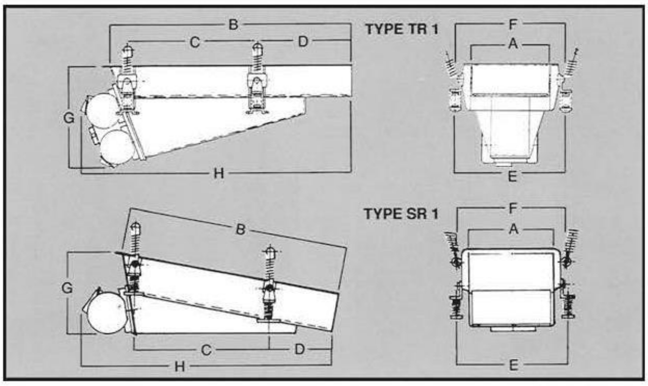
$$F_a = 6750 \times 9.81 \sin(35°) = 37980N$$

$$\sum F = F_a - F_S = 37980 - 16.27 = 37963.73N$$

As the result obtain that the $\sum F > 0.0232N$ so we can pursue that material will flow to the feeder corresponding to the requirement.

Vibratory feeder

The vibratory feeder selection is based on catalogue table below with the condition feeding is 10 ton per hour with abrasive material and no dust contain. In this study we selected feeder type SR1which is the interval feed capacity adjusted by chance incline angle of the feeder.



TYPE TR1 VIBRATORY FEEDERS										
A	B	WATT	MZSTPH	C	D	E	F	G	H	Wt/Kg
630	/1000-244	1000	125	640	245	815	795	610	1120	220
	/1000-254	1000	210	640	245	815	795	610	1120	220
	/1250-254	1000	180	768	365	815	795	660	1340	250
	/1500-254	1000	155	788	560	815	795	715	1560	280
	/1750-254	1000	135	938	660	815	795	775	1775	310
800	/1250-254	1000	190	768	365	985	965	660	1340	280
	/1500-254	1000	165	768	560	985	965	715	1560	315
	/1750-254	1000	140	938	660	985	965	775	1775	350
1000	/1500-254	1000	165	768	560	1185	1165	715	1560	360
	/1750-254	1000	140	938	660	1185	1165	775	1775	400
	/1750-304	1920	275	938	660	1185	1165	840	1860	460

TYPE SR1 VIBRATORY FEEDERS										
A	B	WATT	MZSTPH	C	D	E	F	G	H	Wt/Kg
• 315	/800-204	250	35	542	145	470	450	350	925	75
	/1000-244	500	55	640	245	470	450	400	1175	130
	/1250-254	500	75	768	365	470	450	445	1415	150
	/1500-254	500	65	788	560	470	450	490	1655	160
• 400	/800-204	250	35	542	145	555	535	350	925	85
	/1000-244	500	55	640	245	555	535	400	1175	135
	/1000-254	500	100	640	245	555	535	400	1175	140
	/1250-254	500	85	768	365	555	535	445	1415	165
	/1500-254	500	70	788	560	555	535	490	1655	185
500	/1000-244	500	55	640	245	685	665	400	1180	155
	/1000-254	500	105	640	245	685	665	400	1180	160
	/1250-254	500	85	768	365	685	665	445	1415	185
630	/1000-254	500	110	640	245	815	795	400	1180	180
	/1250-254	500	85	768	365	815	795	445	1415	210
	/1500-304	960	150	788	560	815	795	520	1690	270
800	/1000-254	500	110	640	245	985	965	400	1180	205
	/1250-254	500	80	768	365	985	965	445	1415	240
	/1250-304	960	190	768	365	985	965	475	1460	270
	/1500-304	960	160	788	560	985	965	520	1690	305
1000	/1500-304	960	160	788	560	1185	1165	520	1690	345

Appendix C

CONVEYOR DESIGN

Material handling conveyor design start with motional resistances determination, the determination below base on the procedure standard of DIN 22101 and ISO 5048

Before design the troughed conveyor, condition and material characteristic must be well known, and it will list down below.

Capacity 10 T/hr

Incline high 2.5 m for conveyor 1

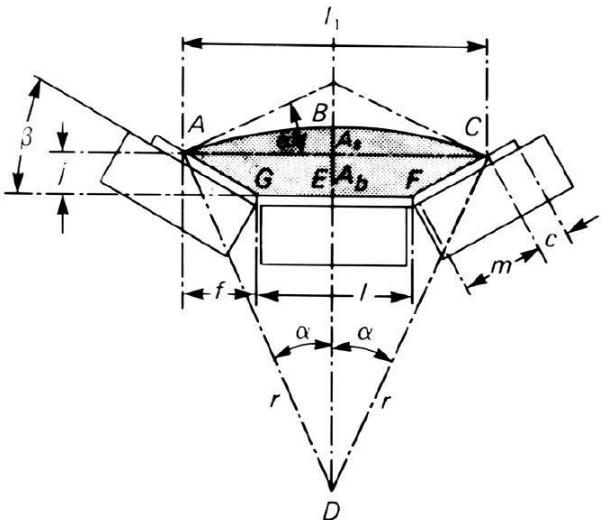
Material size is 20 to 40 mm diameter

Angle of repose 35°

Angle of surcharge 25°

Material abrasive and contain explosive dust.

Cross section area of conveying



$$A_t = A_b + A_s$$

Trapezoidal Area, A_b

$$(AECFG)A_b = \left(\frac{l + l_1}{2}\right)j$$

And

$$l = 0.317b + 6.35 = 0.317 \times 450 + 6.65$$

$$l = 173.3mm$$

$$l_1 = l + 2f = l + 2m\cos\beta = l + 2(0.2596b - 25.625)\cos\beta$$

$$l_1 = 173.3 + 2(0.2595 \times 450 - 25.625)\cos(35)$$

$$l_1 = 324.43mm$$

$$j = m\sin\beta = (0.2595 \times 450 - 25.625)\sin(35)$$

$$j = 52.28mm$$

$$A_b = \left(\frac{173.3 - 324.43}{2}\right)(52.28)$$

$$A_b = 13010.66mm^2$$

Circular segment (surcharge) area A_s

$$A_s = A_{ABCD} - A_{AECD}$$

$$A_{(ABCD)} = \frac{2r^2\alpha\pi}{360}$$

$$A_{(AECD)} = \frac{r^2 \sin 2\alpha}{2}$$

$$A_s = \frac{2r^2\alpha\pi}{360} - \frac{r^2 \sin 2\alpha}{2} = r^2(\frac{\pi\alpha}{180} - \frac{\sin 2\alpha}{2})$$

$$A_s = 383.83(\frac{25\pi}{180} - \frac{\sin(50)}{2})$$

$$A_s = 7874.07mm^2$$

$$A_t = A_b + A_s = 13010.66 + 7854.07 = 20864mm^2$$

With the conveyor width 450 mm has highest capacity cross section at 20864 mm^2 but our requirement, and 450 mm is the smallest of the common belt conveyor usage.

Due to preventing overload of conveyor belt when loading, the cross section was selected at 50% of maximum cross section. And the velocity of conveying is determined below.

$$v = \frac{Q}{A}$$

$$v = \frac{10(T/hr)}{1.5(T/m^3) \times 0.5 \times 20.86 \times 10^{-3} \times 3600}$$

$$v = 0.17755m/s$$

As the result obtain is below 2 m/s, so it is suitable to use with material that contain dust.

So the belt selected which is available in market is EP 400/3 450 DIN with the thickness 9 mm and weight 10 kg/m^2

Movement resistance

$$F_W = F_H + F_N + F_{st} + F_S$$

$$F_H = fgl\left[m_R + (2m_G + m_L)\cos\delta\right]$$

$$F_N = F_{bA} + F_f + F_w + F_t$$

Or $F_N = (C_L - 1)F_H$

$$F_{st} = Hgm_L$$

F_S is special resistance with special purpose design of belt conveyor

Total primary resistance

$$F_H = fgl\left[m_R + (2m_G + m_L)\cos\delta\right]$$

f is friction factor respectively in top/return run as 0.18 of favorable, 0.2 is normal and 0.28 unfavorable.

g acceleration due to gravity 9.81 m/s^2

$$m_G = 4.5kg/m$$

$$m_L = \frac{Q}{v} = \frac{10(T/h)}{0.17766(m/s)\times 3600(s/h)} = 15.645kg/m$$

According to the convenient of conveyor beam construction, the length center to center selected at 12 m, and incline at 14°

$$\delta = 14°$$

$$F_H = 0.2 \times 9.81 \times 12 \times [4 + (2 \times 4.5 + 15.645)\cos(14)]$$

$$F_H = 755.05N$$

Total secondary resistance

$$F_N = F_{bA} + F_f + F_w + F_t$$

In order to simplify the secondary resistance

$$F_N = (C_L - 1)F_H$$

C_L is correction length factor as the shorter belt need more power to overcome friction resistances than longer belt conveyor as following table below.

Belt length (m)	3	4	5	6	8	10	13	18	20	25	32	40	50	63	80
C_L	9	7.6	6.6	5.9	5.1	4.5	4	3.6	3.2	2.9	2.6	2.4	2.2	2	1.8

$$F_N = (4 - 1) \times 755.05$$

$$F_N = 2265.15N$$

Gradient resistance

$$F_{st} = Hgm_L$$

$$F_{st} = 2.5 \times 9.81 \times 15.465$$

$$F_{st} = 383.69N$$

$$\Rightarrow \quad F_W = 755.05 + 2265.15 + 383.69 = 3403.9N$$

Power requirement

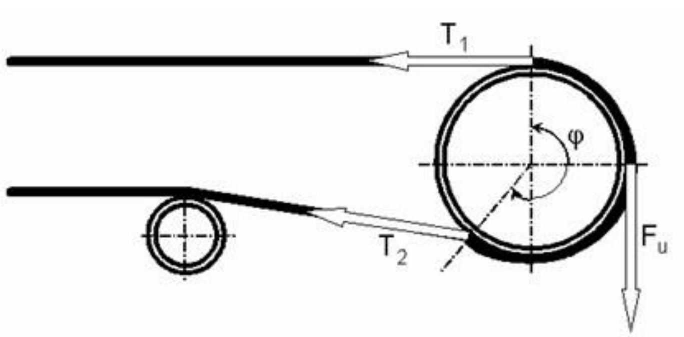
$$P_W = F_W V$$

$$P_{Merf} = \frac{P_w}{\eta} = \frac{3403.9 \times 0.1776}{0.65}$$

$$P_{Merf} = 929.79W = 9.3kW$$

As the result of motor requirement is not commercial use, so this design has selected motor with power 1 kW

Detemine the belt tension at the pulley



$$\frac{T_1}{T_2} = e^{\varphi\mu}$$

As for inclination of conveying, it noted that if power is transmitted from the pullet to the belt, the approaching portion of the belt will have the larger tension T_1 and the departing portion will have the smaller tension, T_2 . If power is transmitted from the belt to the pulley, as with a regenerative declined conveyor, the reverse is true. Warp is used here to refer to the angle or arc of contact the belt makes with the pulley's circumference.

$$T_1 = T_2 + F_W$$

$$\frac{T_1 + T_2}{T_2} = \frac{F_W}{T_2} = e^{\mu\varphi} - 1$$

$$T_2 = \frac{1}{\left(e^{\mu\varphi} - 1\right)} F_W$$

μ Coefficient of friction between pulley surface and belt surface 0.25 for rubber cover belt surface driving bare steel or cast iron pulley, 0.35 rubber surface belt driving rubber lagged pulley surface.

The angle of contact or angle of pulley warp, in this design is normal condition of conveying with less quantity, so the warp angle is 180° without snub.

$$T_2 = \frac{1}{\left(e^{0.25\pi} - 1\right)} \times 3403.9$$

$$T_2 = 2852.56N$$

$$T_1 = T_2 + F_W = 2852.56 + 3403.9$$

$$T_1 = 6256.4N$$

Pulley determination

$$D_{\min} = \frac{360 F_W}{g p B \mu \pi}$$

$$D_{\min} = \frac{360 \times 3403.9}{1800 \times 9.81 \times 0.45 \times 180\pi}$$

$$D_{\min} = 0.24m$$

According to the standard of driving pulley, the design has chosen D = 0.25 m and due to the width of conveyor belt is 450 mm, as for safely operation the width of pulley must be longer than belt conveyor width. Pulley width is 600 mm of lagged welded steel pulley.

The tail pulley generally is smaller than driving pulley since the friction and force transition is not concern on the tail and tensioning pulley as follow in the formula below.

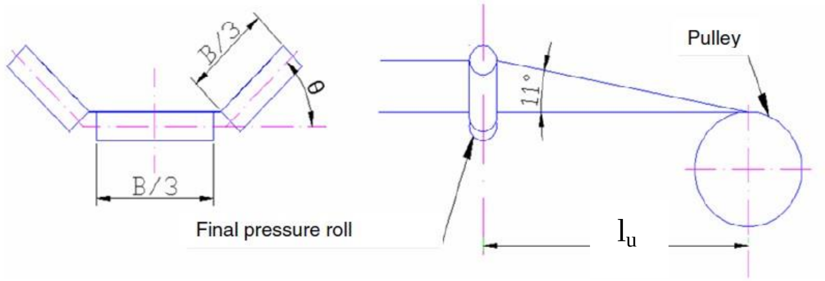
$$D_{tail} = D_{tensioning} \cong 0.8D$$

$$D_{tail} = D_{tensioning} \cong 0.8 \times 0.25$$

$$D_{tail} = D_{tensioning} \cong 0.19m$$

As the result, the standard pulley for the tail and the tensioning has chosen of 0.2 m diameter with 600 mm width as the driving pulley and use lagged wing pulley as the tail pulley as it has been design for cleaning the belt when it return and use the typical welded steel pulley and tensioning pulley.

Transformation length



$$l_u = \frac{100b}{3}\sqrt{\frac{2(1-\cos\theta)}{\varepsilon^2 + 200\varepsilon}}$$

ε is maximum acceptable deviation is equal 0.2 for steel ropes and 0.8 for textile belts, according to belt selected is textile belts

$$l_u = \frac{100\times 450}{3}\sqrt{\frac{2(1-\cos 35)}{(0.8)^2 + 200\times 0.8}}$$

$$l_u = 711.76mm$$

Transformation length is use to minimize the stress concentration.

- **BEARING SELECTION**

Bearing selection for conveyor one as the command component in the plant, the chain pulley has diameter 45 cm. the necessary data is list below.

$D_{pulley} = 250mm$ $T_1 = 6256.4N$

$D_{Chain} = 450mm$ $T_2 = 2852.56N$

- **Determine torque of pulley**

$$T = F_w \times \frac{D_{pulley}}{2}$$

$$T = 3403.9 \times \frac{0.25}{2} = 424.37 N.m$$

❖ **Determine tensile force of chain to drive pulley**

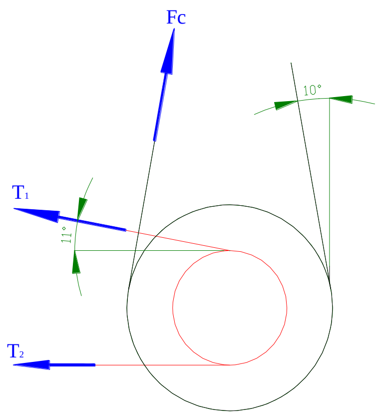
$$F_C = \frac{T}{R_{chain}}$$

$$F_C = \frac{424.37\ N.m}{0.225m} = 1891.06N$$

❖ **Determine all force in X and Y plant direction according to figure below. T$_1$**

Green colour is chain drive and red colour is

Belt conveyor



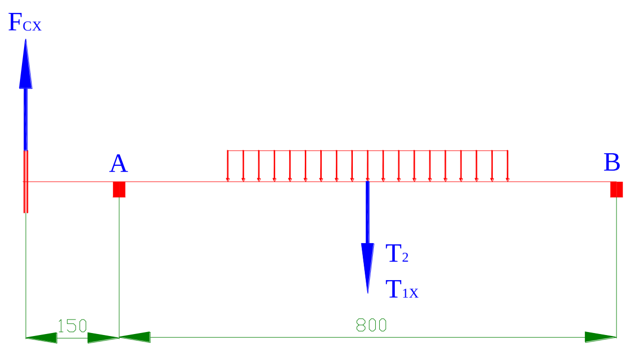
$$T_{1x} = T_1 \times \cos 11° = 6141.51N$$

$$T_{1y} = T_1 \sin 11° = 1192.74N$$

$$F_{CX} = F_C \sin 10° = 328.38N$$

$$F_{CY} = F_C \cos 10° = 1862.33N$$

❖ **Plant ZX**



Determine reaction force at point A and point B

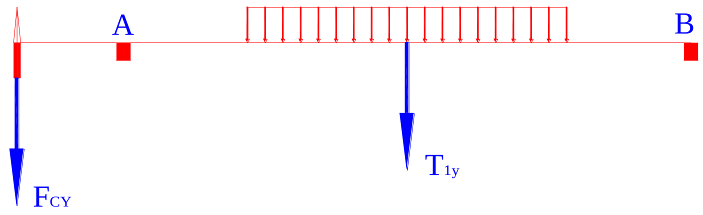
$$\sum M_A = 0; 800R_B - 150 \times F_{CX} - 400(T_2 + T_{1x}) = 0$$

$$\Rightarrow R_B = \frac{(150 \times 328.38 + 400(6141.51 + 2852.56))}{800} = 4558.61N$$

$$\sum M_A = 0; -800R_{\mathbf{A}} - 950 \times F_{CX} + 400(T_2 + T_{1x}) = 0$$

$$\Rightarrow R_A = \frac{(400(6141.51 + 2852.56) - 950 \times 328.38)}{800} = 4107.09N$$

❖ **Plant ZY**



Determine reaction force at point A and point B

$$\sum M_A = 0; 150F_{CY} - 400T_{1Y} + 800R_B = 0$$

$$\Rightarrow R_B = \frac{1193.79 \times 400 - 150 \times 1862.33}{800} = 247.71N$$

$$\sum M_A = 0; -800R_{\mathbf{A}} - 950F_{CY} + 400T_{1Y} = 0$$

$$\Rightarrow R_A = \frac{(400 \times 1193.79 - 950 \times 1862.33)}{800} = 2808.41N$$

Determine total reaction force

$$R = \sqrt{R_x^2 + R_Y^2}$$

$$\Rightarrow R_A = \sqrt{4107.09^2 + 2808.41^2} = 4975.47N$$

$$\Rightarrow R_B = \sqrt{4558.61^2 + 2808.41^2} = 4565.33N$$

Maximum reaction force occur at point A so $F_r = R_A = 4975.45N$

As the design we select bearing life cycle time is $l_{10} = 10000$ hour operation.

$N_{rev} = \frac{v}{2\pi R}$ is the revolution of bearing

$$N_{rev} = \frac{0.1776m/s \times 60}{2\pi(0.25/2)} = 13.56rpm$$

$$l_d = l_{10} \times N_{rev} \times 60$$

Determine dynamic load rating

$$C = F_r\left(\frac{l_d}{10^6}\right) = 4975.45\left(\frac{10000 \times 13.56 \times 60}{10^6}\right)$$

$$C = 40491.97N$$

According to the dynamic load rating at the calculation process, we selected bearing for drive and tail pulley is UCP 211 which maximum dynamic load is 43 kN and bearing for transition pulley is UCT 211 as well. The bearing table is attach at the end of appendix.

Similarity for bearing determination and selection of the second conveyor and the obtain value is list down below.

Reaction force

$R_A = 7780.15N$

$R_B = 6595.09N$

$F_C = R_A$

Dynamic load rating is

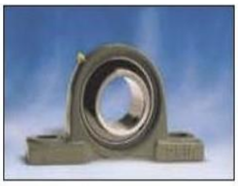
$C = 45226.66N$

According to obtain value above, the drive and tail pulley for this conveyor, we select bearing UCP 212 and for the transition pulley is UCT 212.

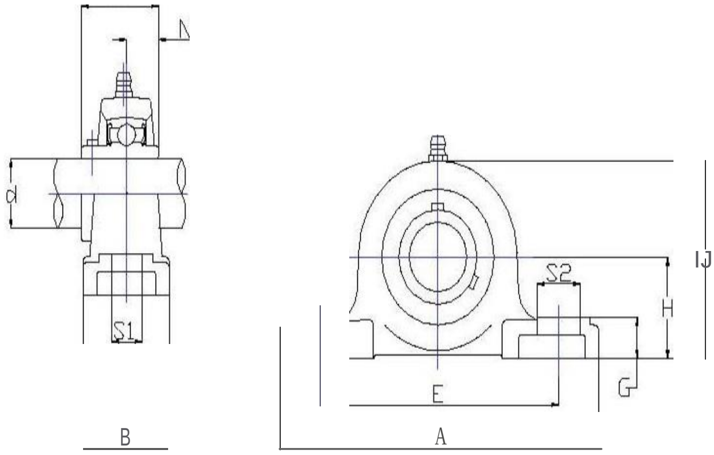
Recommendation maximum belt speed (Equipment & Association, 2002)

Material Being Conveyed	Belt Speeds (fpm)	Belt Width (inches)
Grain or other free-flowing, nonabrasive material	500 700 800 1000	18 24-30 36-42 48-96
Coal, damp clay, soft ores, overburden and earth, fine-crushed stone	400 600 800 1000	18 24-36 42-60 72-95
Heavy, hard, sharp-edged ore, coarse-crushed stone	350 500 600	18 24-36 Over 36
Foundry sand, prepared or damp; shake-out sand with small cores, with or without small castings (not hot enough to harm belting)	350	Any width
Prepared foundry sand and similar damp (or dry abrasive) materials discharged from belt by rubber-edged plows	200	Any width
Nonabrasive materials discharged from belt by means of plows	200, except for wood pulp, where 300 to 400 is preferable	Any width
Feeder belts, flat or troughed, for feeding fine, nonabrasive, or mildly abrasive materials from hoppers and bins	50 to 100	Any width

GBR
Bering unit



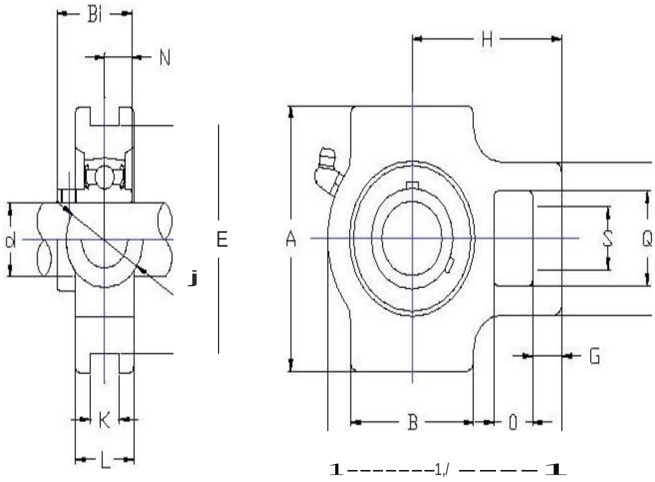
Supporto ritto a piedini
Fusione in ghisa
Cuscinetto in acciaio
Codice: **UCP200**



	Dimensioni (mm)													
CODICE	d	H	A	E	8	S2	S1	G	W	Bi	N	M	C. dinamico	C. statico	peso
	mm												N	N	Kg
UCP204	20	33,3	127	96	38	19	13	15	65	31	12,7	10	12800	7500	0,76
UCP 205	25	36,5	140	105	38	19	13	16	71	34,1	14,3	10	14000	7900	0,9
UCP 206	30	42,9	161	121	48	21	17	17	84	38,1	15,9	14	19500	11300	1,3
UCP 207	35	47,6	167	127	48	21	17	18	93	42,9	17,5	14	25700	15400	1,6
UCP 208	40	49,2	178	136	52	21	17	19	98	49,2	19	14	29100	17900	2
UCP 209	45	54	190	146	54	21	17	20	106	49,2	19	14	32700	20400	2,2
UCP 210	50	57,2	206	159	60	22	20	21	113	51,6	19	16	35100	23200	2,8
UCP 211	55	63,5	219	171	60	22	20	22	125	55,6	22,2	16	43300	29400	3,6
UCP 212	60	69,8	241	184	70	25	20	23	138	65,1	25,4	16	52400	36100	5
UCP 213	65	76	263	205	69	27	25	27	150	65	25,4	20	57200	40100	6
UCP 214	70	78	267	210	72	27	24	32	156	75	25,4	20	62200	44100	6,8
UCP 215	75	83	276	210	75	27	25	28	166	78	30,2	20	67400	48280	7,3
UCP 216	80	88,9	292	232	78	27	35	32	174	82,6	33,3	20	72700	52950	9
UCP 217	85	95,2	310	247	83	27	40	32	185	85,7	34,1	20	84000	61950	10,8
UCP 218	90	101,6	327	262	88	27	45	34	198	96	39,7	22	96100	71490	14

Supporto ritto a T
Fusione **in** ghisa
Cuscinetto in acciaio
Codice: **UCT 200**

GBR
Bering unit



p

	Dimensioni(mm)																	
CODICE	d	O	G	Q	p	S	8	K	E	A	W	J	L	H	BiN		C.dinamico	C. statico	peso
	mm																N	N	Kg
UCT204	20	16	10	32	51	19	51	12	76	89	94	32	21	61	31	12,7	12800	7500	0,79
UCT205	25	16	10	32	51	19	51	12	76	89	97	32	24	62	34,1	14,3	14000	7900	0,84
UCT206	30	16	10	37	56	22	57	12	89	102	113	37	28	70	38,1	15,9	19500	11300	1,30
UCT207	35	16	13	37	64	22	64	12	89	102	129	37	30	78	42,9	17,5	25700	15400	1,70
UCT208	40	19	16	49	83	29	83	16	102	114	144	49	33	88	49,2	19	29100	17900	2,42
UCT209	45	19	16	49	83	29	83	16	102	117	144	49	35	87	49,2	19	32700	20400	2,52
UCT210	50	19	16	49	83	29	86	16	102	117	149	49	37	90	51,6	19	35100	23200	2,70
UCT211	55	25	19	64	102	35	95	22	130	146	171	64	38	106	55,6	22,2	43300	29400	4,10
UCT212	60	25	19	64	102	35	95	22	130	146	171	64	38	106	55,6	22,2	52400	36100	5,20
UCT213	65	33	21	70	112	41	120,5	26	150	168	224	70	44	137	65	23,4	57200	40100	6,90
UCT214	70	33	21	70	112	41	121	26	150	168	224	70	46	137	74	30,2	62200	44100	7,00
UCT215	75	33	21	70	112	41	120,5	26	150	168	232	70	48	139	77	33,3	67400	48280	7,20

Second conveyor

Second conveyor design is similarity as the first conveyor design, the differently is as the second conveyor is conveying to stock pile with the high 5.5 m with the length the same as the other stockpile conveyor is 18 m centre to centre and the result is show below.

	input conveyor	output conveyor	unit
conveyer type	EP400/3 450 DIN	EP400/3 450 DIN	
toughing idle type	series 25 type 60 frame D127	series 25 type 60 frame D127	
driving pulley type	25x60 cm welded steel pulley	35x60 cm welded steel pulley	
tail pulley type	20x60 mm Lagged wing pulley	30x60 mm Lagged wing pulley	
convey capacity	10	10	T/hr
conveyor velocity	0.1777	0.1777	m/s
incline angle	15	17	degree
toughing angle	35	35	degree
contact pulley angle	180	180	degree
length centre to centre	12	18	m
vertical conveying high	2.5	5.26	m
Idler spacing	1	1	m
transformation length	0.7	0.75	m
Primary Resistance	753	1121	N
secondary Resistance	2259	2915	N
Gradient Resistance	383	807	N
Total Motional Resistance	3395	4843	N
Total Power Required	0.927	1.32	kW
motor selection	1	1.5	kW

Appendix D

ECONOMIC ANALYSIS

Cost and benefit identifying of current plant

Most of cost identifying of current plant is based on financial report of company at year 2012 which including maintenance cost, operation cost and Depreciation cost with the total amount is 4,364,163,000 kip per year and all the data is list down below.

maintenance and repair cost of 2012		
machinery replacement part	969,211,000	Kip/year
heavy vehicle replacement part	136,303,000	Kip/year
component delivery and transportation	37,408,000	Kip/year
lubricant and dairy maintenance	954,417,000	Kip/year
Total	**2,097,339,000**	Kip/year
maintenance	**13,243.12**	Kip/ton

operation cost of year 2012		
blasting cost	108,537,000	Kip/year
electricity cost	553,963,000	Kip/year
fuel cost	655,455,000	Kip/year
official and confidential expanse	95,551,000	Kip/year
employee expanse	624,088,000	Kip/year
Total operation cost	**2,037,594,000**	Kip/year

depreciation		
building depreciation	23,960,000	Kip/year
machine & component depreciation	39,070,000	Kip/year
vehicle depreciation	163,980,000	Kip/year
office depreciation	2,220,000	Kip/year
Total depreciation	**229,230,000**	Kip/year

The benefit or the revenue of the plant is also based the statistic financial report of the company which is corresponding to the product sold out of the plant.

product	Product selling (Ton/month)	price (Kip/ton)	firm revenues (Kip/month)
series 1	2,753	60,000	165,165,000
series 2	3,563	70,000	249,410,000
series 3	3,169	70,000	221,830,000
series 4	2,243	75,000	168,225,000
Total	11,728		804,630,000

Cost and benefit identifying of expansion system

The first consideration of the expansion system is construction and installation of tertiary system which is will determine by following section, another cost is operation cost, maintenance cost and material cost.

Operation cost

$$C_{OP} = P \times T \times r$$

P is power usage of the system (68 kW)

T is operation time of the month (7x25=175 hour per month)

r electricity price rate (720 kip per kWh)

$$C_{OP} = 68 \times 175 \times 720 = 8568000 kip/month$$

Material cost

Material cost refer to the principle cost to product the product series 1 at the main system and it equals to

$$M_C = \frac{4364163000}{158372} \times 1471 = 40535472 kip/month$$

Maintenance cost

Maintenance cost is determined by ratio of total maintenance cost per product output. With unit kip per ton

$$M_t = \frac{2097339000}{158372} \times 1471 = 19480626 kip/month$$

Investment cost.

The investment cost consists of all the part or comportment usage and the labour cost during installation period, as it list down below.

Conveyor one

Conveyor one is length 12 meter so it use 5 of C steel channel with length 6 m and section 25 x 6 cm as the beam and connection with 2 of L steel with section 5x5 cm and 5 mm thickness, 4 pipe steel with diameter 10 cm and 3 mm thickness were use as supported beam. Conveyor belt length 29 m was use and this conveyor use 17 idlers with drive and tail pulley, the total bearing has been use 5 pair. One 1 kW motor was use as power generation and 3 v belt type C-100.

Conveyor two

Conveyor two is 18 meter in length so it use 7 of C steel channel, 3 of L and 4 pipe steels with the section as usual in the conveyor one, due to the conveyor more longer, so 23 idlers was use with the belt length 41 meter, and the bearing and the V belt is required as conveyor one, 1.5 kW electric motor is required.

Tertiary station

In tertiary machinery station consist of complete set of hummer crushing machine, motor, bearing and driving pulley and belt. 25x25 cm H steel bean is used as the pillars and rectangular horizontal beam, so 3 H steel beam, 2 C steel channels and 1 steel plate is required.

Stockpile preparing and vibratory feeder

Concrete wall has been constructed with 2 H steel beam are require for hanging the vibratory feeder and supported the wall, one steel plate is required for make material flow way. Inside the concrete wall require 5 tones reinforce steel. For the vibratory feeder require 6 mm thickness of steel plate and 3 L steel for bone reinforcement of the feeder structure, and unbalance drive shaft motor with 0.5 kW. Overall component usage in investment period is list down in table below.

construction cost			
name	price (kip)	quantity	cost (Kip)
hummer crushed machine	88,000,000	1	88,000,000
belt conveyor per m	186,500	70	13,055,000
motor 1, 1.5 kW	795,000	2	1,590,000
motor 500 W	500,000	1	500,000
bearing UCP 212	185,000	20	3,700,000
driving pulley	1,200,000	2	2,400,000
tial pulley	700,000	2	1,400,000
supporting pulley	275,000	40	11,000,000
V belt type C-100	100,000	6	600,000
chain NO: 120	200,000	2	400,000
H steel beam 25x25	4,146,000	5	20,730,000
C steel beam 25	1,935,000	14	27,090,000
O steel beam 10	371,000	8	2,968,000
L steel beam 5x5	212,000	12	2,544,000
concrete steel 1ton	6,950,000	5	34,750,000
cement 1 ton	800,000	5	4,000,000
steel plate 6 mm thickness 120x240	1,120,000	3	3,360,000
sand	75,000	9	675,000
stone	65,000	18	1,170,000
electrical wide and controller	5,000,000	1	5,000,000
material cost			224,932,000
labour and accessory cost			168,699,000
construction cost			393,631,000

- **Break even analysis.**

$$BEP = \frac{F}{S - V}$$

F is fix cost refer to machine, component and construction cost

V is variation cost refer to maintenance, operation and material cost

S is sale product price, 75,000 kip per ton

$$BEP = \frac{393613000}{75000 - 46624.13} = 13872.03 ton$$

Determine time period

$$T_{period} = \frac{13872.03(ton)}{1471(ton / month)} = 9.43 month$$

❖ **Cost benefit analysis**

Two main tools that use to determine in cost benefit analysis, fist is net present value and second is internal rate of return, and the cost benefit table is show below.

year	quarter	cost (Kip)	revenues (Kip)
	first quarter	-393,631,000	0
	second quarter	-205,752,000	330,975,000
	third quarter	-205,752,000	330,975,000
first	fourth quarter	-205,752,000	330,975,000

As the cost and revenues of expansion system is maintain constant from second quarter of first year to fourth quarter of fifth year (end of life).

NPV

In order to determine *NPV*, the interest has been select at high values as 0.2 or 20 percentage per year.

$$NPV = \sum_{t=0}^{T} \frac{B_t - C_t}{(1 + R)^t}$$

$$NPV = \sum_{t=0}^{19} \left[\frac{0 - 393631}{1} + \frac{330975 - 393631}{(1+\frac{0.2}{4})^1} + \frac{330975 - 393631}{(1+\frac{0.2}{4})^2} + ... + \frac{330975 - 393631}{(1+\frac{0.2}{4})^{19}} \right] \times 1000$$

$NPV = 1{,}631$ million kip

IRR

Internal rate of return, by the ideal of *IRR* is the internal rate when the *NPV* equal zero. In addition computer software determination is useful to find *IRR* or using trial and error method and finally we get the result of *IRR* = 1.35.

Appendix E

PRODUCTIVITY

Plant productivity determination of this study is conducted with comparison of current crushing plant and plant after expansion. Due to 4 type of product has been produce with the same material, labour and production line, so the productivity is considered in multifactor productivity method, mean that all the output and input value are determine in term of currency value. Labour productivity or manpower capacity also illustrate for the alternative comparison. All tables below will list down the capital cost of current plant

operation cost of year 2012		
blasting cost	108,537,000	Kip/year
electricity cost	553,963,000	Kip/year
fuel cost	655,455,000	Kip/year
official and confidential expanse	95,551,000	Kip/year
employee expanse	624,088,000	Kip/year
Total operation cost	2,037,594,000	Kip/year

Depreciation of year 2012		
building depreciation	23,960,000	Kip/year
machine & component depreciation	39,070,000	Kip/year
vehicle depreciation	163,980,000	Kip/year
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Total depreciation	229,230,000	Kip/year

maintenance and repair cost of 2012		
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component delivery and transportation	37,408,000	Kip/year
lubricant and dairy maintenance	954,417,000	Kip/year
Total	2,097,339,000	Kip/year
maintenance	13,243.12	Kip/ton

average cost		
category	cost (kip/year)	average cost (kip/month)
maintenance cost	2,097,339,000	174,778,250
operation cost	2,037,594,000	169,799,500
Depreciation of plant	229,230,000	19,102,500
Total cost	4,364,163,000	363,680,250

From the table above we can determine that the principle cost of product output is 27,556 Kip per ton.

- **Current plant productivity**

$$MFP = \frac{Output}{Labour + capital + enery}$$

$Capital$ = refer to depreciation, maintenance and blasting cost

$Energy$ refer to cost of electricity and fuel

$Output$ = refer to the product sold-out and unsold product in inventory

$$MFP = \frac{(804{,}630{,}000 + 1471 * 27556)(Kip)}{(52008000 + 100784000 + 210888000)(Kip)} = 2.32$$

- **Manpower capacity**

Manpower capacity in this study is refer to the income capacity that one labour can done within one hour

$$ManpowerCapacity = \frac{Output - input}{Labour} = \frac{(845172000 - 311672000)(Kip)}{(22labour)(25day/month)(8hour/day)}$$

$$ManpowerCapacity = 138{,}517 kip/hour$$

- **Plant after expansion productivity**

After the plant expansion, the excess product is eliminated as well as the elimination of transportation from stockpile to inventory. So the fuel consumption will decrease 196 litres per month. Dump truck and wheel loader is use to move the excess product to inventory.

Inventory cost		
quantity in move	1,471	T/month
dump truck in capacity	15	T
round drum number	98	round
fuel consume 1.2 L/round	116	Litre
wheel loader 3 min/round	8	hour
fuel consume 1.2 L/round	80	litre
Total fuel consumption	198	litre

The cost of the plant after expansion is determine by current plant cost after minus the fuel for inventory then plus with operation and maintenance cost of terribly system

energy cost of tertiary system		
	power	unit
hammer	11,375	kWh/month
feeder	87.5	kWh/month
new1 conveyor	175	kWh/month
new2 conveyor	263	kWh/month
total	11,900	kWh/month
cost	8,568,000	Kip/month

maintenance cost of tertiary system		
production	1,471	ton/month
Maintenance	13,342	Kip/ton
Total maintenance cost	19,480,626	Kip/month

The table below indicate the cost of the main system after plant expansion

average expansion plan		
category	cost (kip/year)	average cost (kip/month)
maintenance cost	2,097,339,000	174,778,250
operation cost	2,015,019,500	167,918,292
Depreciation of plant	229,230,000	19,102,500
Total cost	4,341,588,500	361,799,042

$$MFP = \frac{914978000(Kip)}{(361799042 + 19480626 + 8568000)(Kip)}$$

$$MFP = 2.35$$

- **Manpower capacity**

Manpower capacity in this study is refer to the income capacity that one labour can done within one hour

$$ManpowerCapacity = \frac{Output - input}{Labour} = \frac{(914978000)(Kip)}{(22labour)(25day/month)(8hour/day)}$$

$$ManpowerCapacity = 150585kip/hour$$

	manpower efficiency (kip/hr)	MF productivity
current plant	138,571.28	2.32
plant after expansion	150,585.02	2.35