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COAL BLENDING OPERATION MODEL

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งานวิจัยนี้มีจุดประสงค์หลักเพื่อพัฒนาแบบจำลองการผสมถ่านหินเพื่อปรับปรุงคุณภาพให้มีมูลค่าเพิ่มขึ้นโดยการผสมถ่านหินต่างชนิดจากแหล่งต่าง ๆ ของบริษัทที่ทำการศึกษาเพื่อให้ได้คุณภาพและปริมาณตามที่ลูกค้าต้องการ

การศึกษาได้แบ่งขั้นตอนออกเป็นสองขั้นตอนคือ ขั้นตอนการวางแผนและขั้นตอนการออกแบบการใช้งาน ในขั้นตอนการวางแผนนั้นจะใช้กำหนดการเชิงเส้นในการคำนวณหาแผนการผสมถ่านหินเพื่อให้ได้ผลกำไรเพิ่มขึ้นโดยขึ้นอยู่กับข้อจำกัดเชิงเส้นของการปฏิบัติงานของบริษัทที่ทำการศึกษา ผลลัพธ์ที่ได้ในขั้นตอนนี้คือแผนการผสมถ่านหินจากแหล่งต่าง ๆ เพื่อให้ได้ผลกำไรเพิ่มขึ้นให้กับบริษัทและแผนการผสมถ่านหินนี้จะถูกนำไปใช้ในการตกลงการซื้อขายถ่านหินกับลูกค้า

ขั้นตอนที่สองคือ ขั้นตอนการออกแบบการใช้งาน ในขั้นตอนนี้จะทำการรวบรวมข้อมูลเพิ่มเติมจากการปฏิบัติงานและพัฒนาแผนการปฏิบัติงานการผสมถ่านหินเพื่อใช้ในการปฏิบัติการ กำหนดการเชิงเส้นจะถูกใช้ในการคำนวณหาแผนการผสมถ่านเพื่อให้ได้ผลกำไรเพิ่มขึ้นโดยขึ้นอยู่กับข้อมูลเพิ่มเติมที่ได้จากการปฏิบัติงาน ผลลัพธ์ที่ได้จากขั้นตอนนี้คือระเบียบการปฏิบัติงานเพื่อการผสมถ่านหินและแผนการผสมถ่านหินที่แก้ไขใหม่เพื่อใช้ประกอบการตัดสินใจในการจัดส่งถ่านหินให้ลูกค้า

ผลลัพธ์จาการศึกษาที่ได้ในขั้นตอนการวางแผนปรากฏว่า บริษัทมีกำไร 488 ล้านเหรียญสหรัฐ ซึ่งมากกว่าแผนปัจจุบันที่มีกำไร 451 ล้านเหรียญสหรัฐ หรือคิดเป็นกำไรที่เพิ่มขึ้น 8.20 เปอร์เซนต์จาการผสมถ่านหินโดยใช้กำหนดการเชิงเส้นในการคำนวณ และผลลัพธ์จากการศึกษาที่ได้ในขั้นตอนการออกแบบการใช้งานปรากฏว่า แผนขั้นตอนการปฏิบัติงานเพื่อการผสมถ่านหินสามารถช่วยในการตัดสินใจในการส่งถ่านหินให้กับลูกค้ามีระบบยิ่งขึ้น แต่ยังคงต้องมีการพัฒนาเพิ่มเติมในส่วนของข้อกำหนดเชิงเส้นที่ต้องปรับเปลี่ยนให้ใกล้เคียงกับการปฏิบัติงานให้มากที่สุดเพื่อให้ได้ผลลัพธ์ที่ดีที่สุดและเหมาะกับการนำไปใช้งานจริง

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The purpose of this research is to study coal blending operation model. The objective of this research is to develop coal blending operation model in order to get additional benefit from blending coals from various sources to satisfy customer demand.

To develop coal blending operation model, there are 2 stages of study. First is planning stage. In this stage, the linear programming will be used to calculate the blending scenarios to get addition profit base on coal price forecast and other constraints. The output from this stage is the optimal blending plan which return higher profit to company. The optimal blending plan will be committed to customer and use for implement in next stage. Second stage is the implementation stage, this stage will develop work procedure for blending coal base on update key information such production and sales volume. The linear programming will be used to calculate revise blending plan to improve value of profit. The outputs from this stage are the work procedure for revise blending plan and information for support decision making

The results of the study in planning stage show that the EBIT from optimal blending program is 488 million USD. which higher compared with original plan which is 451 million USD. The company can get additional benefit from blending program about 8.20 % compared with original plan. The result of study in implementation stage show that the coal blending procedure which was implemented in studied company can help management to make decision and adjust production plan that more systematic and base on value management. But there are some constraints in linear programming need to adjust according to real operation of this studied company for get suitable solution for blending coal.

The Regional Centre for Manufacturing Systems Engineering Student's Signature..Jamon.......

Field of Study :Engineering Management Advisor's Signature................

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Contents

Page

Abstract (Thai) iv

Abstract (English) v

Acknowledgements vi

Contents.. vii

List of Tables.. x

List of Figures xii

Chapter I

1.1 Background of the Research 1

1.2 Objective 4

1.3 Research Scope and Assumptions 4

1.4 Research Procedure 7

1.5 Expected Benefits 7

Chapter II

2.1 Company Overview 8

2.1.1 Coal Indonesia Opearion.. 10

2.1.2 Coal China Opearion 10

2.2 Current Coal Indonesia Operation 11

2.3 Problem and Limitation if Current Coal Flow Operation 17

Chapter III

3.1 Literature Survey 21

3.2 Theory of Management Science 24

3.3 Theory of Linear Programming.. 27

Page

3.3.1 Characteristics of Linear Programming Problems 27
3.3.2 Formulating Linear Programming Method 28
3.3.3 Linear Programming Model Problem-Solveing Methods 29
3.4 Collaborative, Planning, Forecasting and Replenishment.............................. 30
3.4.1 Stage of Collaboration 31
3.4.2 CPFR Process Model.. 33
3.4.3 CPFR Success Factors.. 33
3.4.4 Factor Influencing Adoption 34
Chapter IV
4.1 Study of Current System... 35
4.1.1 Procedure of Annual Production Plans and Existing Operations........ 35
4.1.2 Annula Production Plan 42
4.1.3 Operating Cost 48
4.1.4 Coal Price Assumptions... 56
4.1.5 Coal Loading to Vessel Facilities... 60
4.1.6 Coal Transportation 62
4.1.7 Finincial Evaluation 62
4.2 Modeling Concept.. 64
4.2.1 Coal Blending Problem.. 65
4.2.1.1 Assumptions and Notation.. 66
4.2.1.2 Objective Function.. 67
4.2.1.3 Decision Variable.. 68
4.2.1.4 Represent Constraints 69

Page

4.2.2 Dynamic Cola Blending Plan Procedure 71

4.3 Coal Blending Operation Model 74

4.3.1 Coal Blending Optimization Plan 74

4.3.1.1 Understanding the Problem 74

4.3.1.2 Identifying the Decision Variables 74

4.3.1.3 Choosing a Numerical Measurement of Objective Function . 76

4.3.1.4 Representing a Linear Expression of Effectiveness 76

4.3.1.5 Identifying and Representing Constraints and Parameters... 76

4.3.1.6 The Linear Model of Coal Blending 77

4.3.1.7 Result of the Linear Programming for Coal Blending 81

4.3.1.8 Comparison of Linear Programming plans and Previous...... 81

4.3.2 Dynamic Coal Blending Procedure 82

4.3.3 Implement Dynamic Coal Blending Procedure 87

Chapter V

5.1 Conclusion 93

5.2 Recommendations 94

5.2.1 Implementaion of Coal Blending Operation 94

5.2.2 Extension of the Coal Blending Operation 95

References.. 97

Appendix 99

Biography 104

List of Tables

Page

Table 2-1 Coal specification of Indonesia operation 10
Table 2-2 Coal specification of China operation 11
Table 4-1 IMM annual production plan 44
Table 4-2 TCM annual production plan 45
Table 4-3 JBG annual production plan 46
Table 4-4 EMB annual production plan 47
Table 4-5 Operating costs for IMM West Area 51
Table 4-6 Operating costs for IMM East Area 52
Table 4-7 Operating costs for TCM 53
Table 4-8 Operating costs for JBG 54
Table 4-9 Operating costs for EMB 55
Table 4-10 Coal proce estimatation 59
Table 4-11 Coal loading capacity 60
Table 4-12 EBIT of existing operation 64
Table 4-13 Summary of EBIT of each product and coal loading area 78
Table 4-14 Coal blending portion for maximum EBIT 79
Table 4-15 Remaining product for direct sale 80
Table 4-16 EBIT from optimization at each location 81
Table 4-17 IMM mine updated production plan on July until September 2010 87
Table 4-18 TCM mine updated production plan on July until September 2010 87
Table 4-19 JBG mine updated production plan on July until September 2010 88
Table 4-20 EMB mine updated production plan on July until September 2010 88
Table 4-21 Updated commit sale plan on July until September 2010 88
Table 4-22 Result from linear programming calculation for blendd product 89
Table 4-23 Result from linear programming calculation for direct sale product 90

Page

Table 4-24 Result from linear programming for blended product to meet commit volume 91
Table 4-25 Result from linear programming for direct sale product to meet commit volume 92

List of Figures

Page

Figure 1-1 Forecast coal price vs. calorific value 2
Figure 1-2 Flow process of coal blending operation model.......... 5
Figure 2-1 Coal delivery from mine to customer 9
Figure 2-2 Coal fired power generation project 9
Figure 2-3 Layout Indonesia mine operation 12
Figure 2-4 Jorong coal delivery to customer 13
Figure 2-5 Indominco coal delivery to customer.......... 13
Figure 2-6 Trubaindo coal delivery to customer 14
Figure 2-7 Embalutcoal delivery to customer 15
Figure 2-8 Alternaitves to transport coal from mines to customer.......... 16
Figure 2-9 Current process for establish production plan 17
Figure 2-10 Blending optimization in production plan process 19
Figure 3-1 Manangement science process 25
Figure 3-2 Classification of management science techniques 26
Figure 3-3 The component of CPFR model.......... 31
Figure 3-4 Collaboration activities 32
Figure 4-1 Annual production planning procedure.......... 36
Figure 4-2 Meeting schedule between operations and marketing department 40
Figure 4-3 Basic concept of mine market software 41
Figure 4-4 Thermal coal pricing history 57
Figure 4-5 Coal loading to vessel facilities 61
Figure 4-6 Work procedure for the formation of a dynamic coal blending plan 73
Figure 4-7 Dynamic coal blending procedure 83
Figure 4-8 The format of update production plan information 84
Figure 4-9 The format of sale plan information update 85

CHAPTER I

INTRODUCTION

1.1 Background of The Research

To be more competitive in recent world coal mining business, firms are thriving to be cost competitive through flexible management leading to higher marginal profit. This business practice is one of the crucial development organization are sustainably required to put an effort into study and implementation.

In coal mining business, coal market-price is the important external factor which is struggled to forecast and control. Basically, the coal price is based on Coalin Q index and Barlow Jonker Index, these indexes indicates the global market-price standards in coal mining business. However, the coal price can be fluctuated by other surrounding variables or factors such as the oil price, GDP and global economic situation. Despite the global economic crisis during the past two years, oil price and coal price have been fluctuating continuously. As a result, the revenue of the studied company has also been fluctuated from coal price instability as the coal price is the key factor affecting directly on the revenue.

Since coal price is difficult to predictable; the company can implement business practices to maximize profit. One of the prosperous practices is to understand trends of coal market as well as customer demands in order that the company can produce the expected coal as customer specification and on-time delivery can be achieved to satisfy the customer requirements.

According to coal price forecast of studied company, it is indicated that the best average range of calorific value to maximize the benefit is 6,300 kcal/kg. This is due to the fact that the incremental marginal profit per calorific value in this range is higher than other range. Figure 1-1 illustrates the forecast of coal price in relation to calorific value.

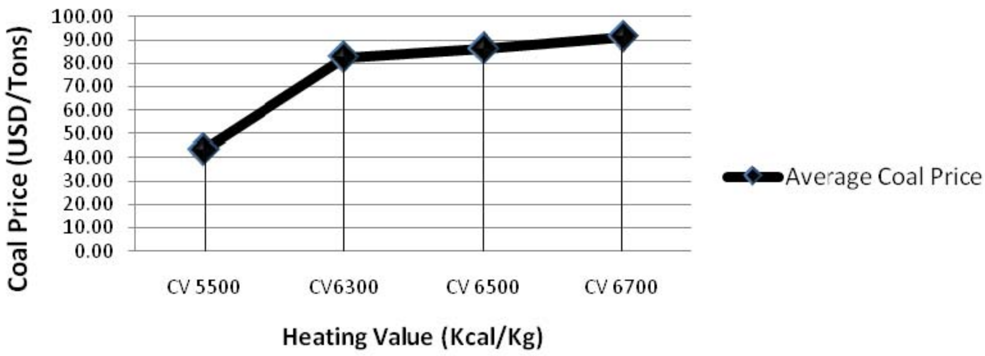


Figure 1-1: Forecast Coal Price vs. Calorific Value

Source: BANPU Public Company, M&L Department

Since the studied company provides wide ranges of coal quality, for example, the blending coal at optimized level can increase company's benefits to improve the coal production process to get additional profits for the company, there is the technical improvement to blend coal with high calorific value exceeding 6,500 kcal/kg to coals with calorific value lower than 6,300 kcal/kg to gain the expected range of calorific value of 6,300 kcal/kg.

In the coal operation of studied company, there are two types of coal delivery processes; (1) coal getting from mine pit delivers to barge loading and (2) coal barging delivers to customers. The delivery process from coal barging to customer strongly requires the efficient coal barging plan and blending plan. The efficient blending plan should be able to propose the blending coal to meet market demand and committed sale volume which returns highest benefit to company as well as to obtain the customer satisfactory. In general of coal blending process, planners have to figure out on what types of coal the operation team should target from mine and what types of coal can be sold to get the maximum profit to company. To figure out these things are not easy. Planners require a lot of necessary information to help support the decision making as well as the efficient tools to help analyze and compute. The coal blending plan process starts from collecting coal production forecast from mine operation and marketing department prepare coal price forecast and committed coal sale tonnage for planner. After receiving information from marketing department, the coal planners have to finalize the product type for sell. The coal planners have to calculate blending plan base on raw coal production and time constraints to meet sale volume and get maximum profit to company.

In a real world business, the coal prices, production rates and other related factors are dynamic. There are gradual changes in coal prices, production rate and coal quality along the production process. Additionally, the inventory spaces at coal loading ports and terminals are limited. To efficiently control and manage the overall production process from mining, coal transportation, quality control, blending and on-time delivery with committed specification leading to the maximum benefit, the company requires having tool to proactively handle with these changes and issues.

As mentioned above, the problem of developing coal blending operation model can separate into two parts which are:

- How to blend the coal to get maximum profit
- How to implement coal blending procedure base on changing of many factors

In summary, the company required having appropriate tool which assists the company to plan, control and manage uncertainties from operations such as the changing of coal quality and the quantity of production. This study proposes to develop coal blending operation model to solve problem as mentioned above. Within blending operation model, optimization techniques will be applied for blending coal from various sources or sites including procedure to monitor the coal quality (from calorific value) to exploit benefits out of operation. The coal blending operation model will show the result in amount of coal blended from each source and identify which type of coal quality and quantity company should produce to get additional benefit to company.

1.2 Objective

The objective of this research is to develop coal blending operation model in order to get additional benefit from blending operation of coals from various sources to satisfy customer demand.

1.3 Research Scope and Assumptions

In this research, the coal blending operation model, is designed and developed to help coal planners plan the coal blending and deliver to customer base on updated information. The developed coal blending operation model is one function of the operation support system which mainly consists of operation function, marketing function, production forecasting and coal price forecasting. In coal blending operation model is classified into two main parts according to the characteristics of coal business that are planning and implementing part. The planning part, this part is to gather information and assumptions from production and sale plan to create optimize blending plan which get maximum benefit to company. Next is implementing part, this part is to update actual condition from operation and sale to revise blending plan as actual condition and keep maximum benefit to company base on updated condition.

The planning stage is to input received data from the operation function. The data of annual production plan and operating cost in each mine site will be divided into monthly basis. The linear programming is applied to develop the decision model by adding constraints and objective function complying with the organization goal (to maximize profit) into the decision model. The output from this stage is the optimize sale plan which return additional profit to company. The optimize sale plan will be committed to customer and used for implementation in next stage

During implementation stage, the optimize sale plan from previous calculation will be used for commit product delivery to the customer. Dispute the production from mine may change from production plan due to many factors as mentioned above. The coal production forecast both quantity and quality will be updated monthly from mine operation and marketing function. Base on this updated information, the linear programming will be used for calculate and revise blending plan in order to maintain coal product deliver to customer as optimize sale plan. The result from calculation will be used as decision support to manage coal delivery to customer. Figure 1-2 illustrates flow process of coal blending operation model.

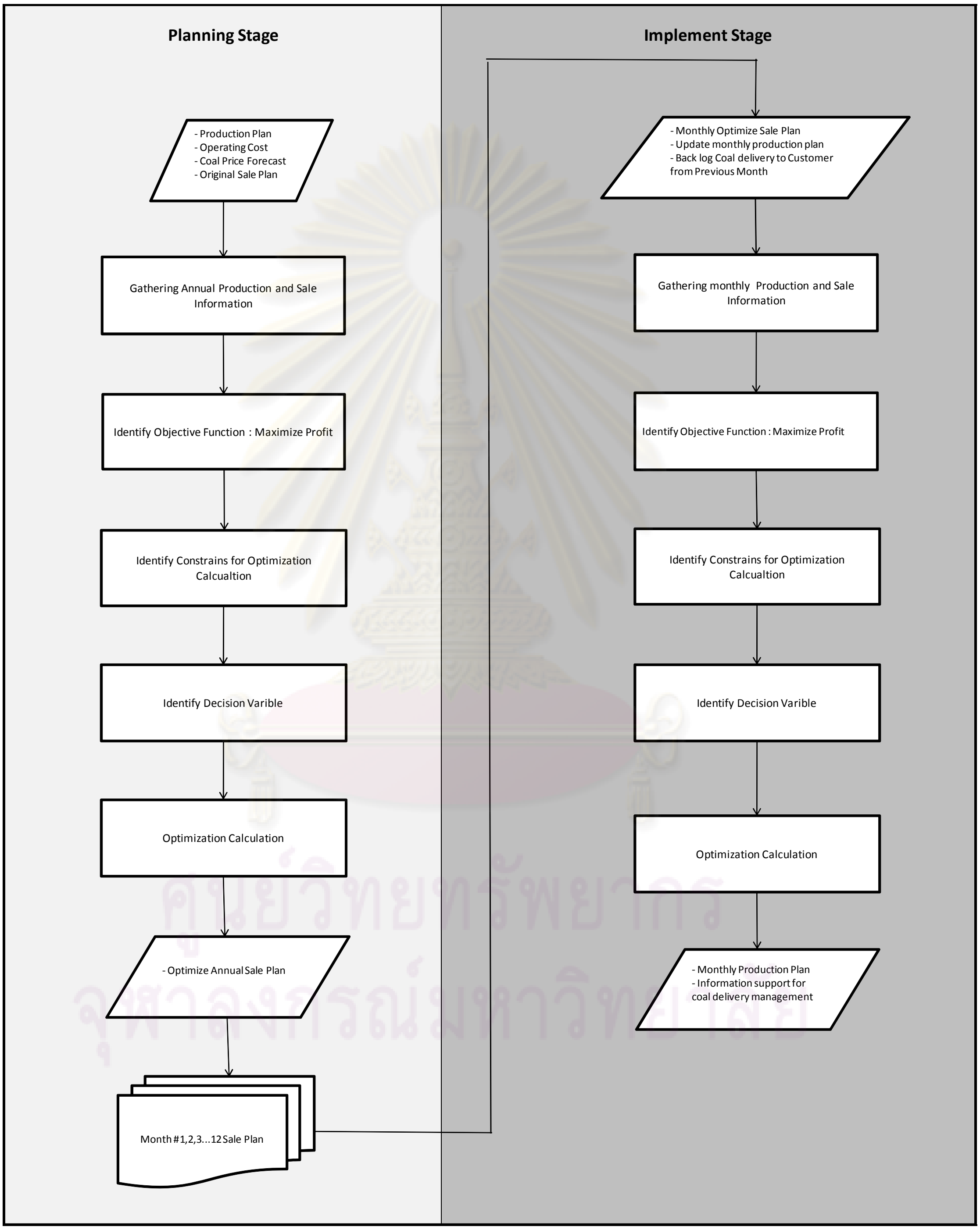


Figure 1-2: Flow process of coal blending operation model

As figure 1-2, there are 2 stages of coal blending operation model. First is planning stage. Second stage is the implement stage; the implement stage will update key information for production base on real situation. The update production information will be updated by 1 until 3 months rolling. The linear programming will use these update information and constraints to calculate monthly blending plan to maximize value of profit. The outputs from this stage are the revise monthly blending plan and information for decision support to manage coal deliver to customer.

In this study, there are many limitations and assumptions applied to develop the coal blending operation model. The research will use the existing information of annual production, sale plan, operating costs of each mine site including coal price forecast to evaluate profit of the company. After that, the linear programming will be applied in order to calculate optimize sale plan based on product mixed between mine to get the higher profit for the company. The quality of product can be calculated as product mixed or weighted average by given maximum or minimum of coal specification. The assumptions of this study can list as below;

1. The production capacity, the coal loading capacity on each location, and all unit costs are assumed to be known.
2. The operating cost is per unit per time and is assumed to be known.
3. The varying price and the availability of raw materials are assumed to be known.
4. The material and product characteristics are assumed to be known.
5. The quality specifications are assumed to be known.
6. Blended quality can calculate as weighted average.
7. Coal inventory not considered in this model.
8. Reworks, defects or repairs are not considered in this model.
9. There are single blended product can be produced in a period.
10. A workstation for coal blending can operate only one product.

Next topic will discuss about the research procedure for this thesis study and the expected benefit from study.

1.4 Research Procedure

The procedure of this case study starts from collecting all data relating to the existing coal operation flow, coal price and operating costs followed by developing the coal blending operation model which is suitable for the existing operation including the determination of blending plan through optimization program. Next, this study will evaluate the result by comparing profits of operations between the original plan and the developed optimize plan with coal bending operation model. Finally, implement coal blending operation model to company and analyze result. Accurate details can be described as bellows;

1 Study literature review for material blending optimization

2 Collect coal market-price statistics and coal price forecast.

3 Collect, analyze and summarize the existing coal flow operation, operating costs and relevant constraints to determine value of this operation.

4 Develop coal blending operation model

5 Determine the optimum blending plan by using optimization program.

6 Calculation and summarize the optimum coal blended operation cost and determine value of coal blending operation model.

7 Comparison profits between existing coal flow operation and optimum coal blending operation.

8 Implement coal blending procedure and evaluate result

1.5 Expected Benefits

This research is expected to deliver coal blending operation model in order to create value added in coal blending process leading to higher marginal profits to the company as well as the guideline to other similar processes to optimally improve their operations within the same industry or others.

CHAPTER II

PROBLEM ANALYSIS

Here, in this chapter, primary details are provided for a better understanding of the problem found in the existing coal operation of this studied company. This chapter consists of three parts. The first section is a general profile of BANPU public company. The second part is background of coal Indonesia operation and the last is problem from existing operation. Moreover, this chapter also describes in detail of the blending operation problem in order to be solved by solving method conducted in this thesis.

2.1 Company Overview

The company which would be used for this thesis study is the biggest coal mining company in Thailand. This company was established in 1983 as a small coal business company in the north of Thailand. As the dynamic growth in energy business, the company nowadays is not only the foremost energy company in Thailand but also the leading energy company in South East Asia region. The company has operations in Indonesia and China and Laos. This company is holding two core business groups which are coal mining and coal-fired power generation.

- **Coal Mining Business**

This company has shown the core competency and competitive advantages in the cost-efficient development and operation of coal mine which are in both domestic and overseas. The company currently manages production capacity of approximately 25.5 million tons per annum from its mine in Indonesia and China. Next page, figure 2-1 illustrated coal delivery to customer.

Figure 2-1: Coal delivery from mine to customer

Source: BANPU Public Company

- **Power Business**

This company has been successful in power generation development both in Thailand and China. The company is now applying this expertise to develop coal-fired power project in other Asian countries. Recently, Lao People's Democratic Republic has appointed the company to do a feasibility study for development and investment in a 1,800 MW min-mouth power plant project in Hongsa, Xayabury, and Lao PDR. Figure 2-2 illustrated coal-fired power generation project

Figure 2-2: Coal –fired power generation project

Source: BANPU Public Company

This thesis study will focus on coal business in terms of establishing coal blending operation model to get additional value from blending operation. This company has two major coal mine operations in Indonesia and Republic of China. The major coal production and specification of this company can be categorized by locations as following;

2.1.1 Coal Indonesia Operation

Mining operation in Indonesia, this company was ranking as the fourth largest Indonesian coal producer with full production capacity around 20 million tons per annum from four operations. This company produces several types of sub-bituminous and bituminous coals to supply domestic utility plants as well as commercial customers from Japan, Taiwan, Korea, Hong Kong, Philippines and other countries in Asia and Europe. The specification of coal type in this operation shows as table 2-1

Table 2-1: Coal specification of Indonesia operation

Company		Jorong Mine	Indominco Mine	Embalut Mine	Trubaindo Mine	
Brand Name		**Jorong J-1**	**MCV**	**HCV**	**MCV**	**PCI**
Coal Quality	**Unit**					
Total Moistudr (AR)	**%**	30	15.5	15-20	13.5	10
Inherent Moisture (AD)	**%**	17	11	7.4	9	6
Ash (AD)	**%**	4	5.5	2.8	5.5	4
Volatile Matter (AD)	**%**	42.5	40	42.6	39.7	41
Fixed Carbon (AD)	**%**	38.5	43.5	47.2	45.8	49
Calorific Value (AD)	**kcal/kg**	5,300	6,050 - 6,500	5,750	6,550	7,200
Sulphur (AD)	**%**	0.3	0.8	1.4	0.8	0.6

The coal specification of Indonesia mines have calorific value (Ad) range from 5,300 kcal/kg until 7,000 kcal/kg, the percent sulfur content in coal is approximately range from 0.3% - 1.4% while percent ash content in coal varies from 2.8% - 5.5%

2.1.2 Coal China Operation

The production in China has its own capacity around 5.5 million tons per annum; the typical of coal in this location is bituminous coals, which is used as a base load fuel for domestic utility generators. The specification of coal type for China operation shows as table 2-2 below.

Table 2-2: Coal specification of China operation

Company		Daning Mine	Hebi Mine
Coal Quality	Unit		
Total Moistudr (AR)	%	5	10
Inherent Moisture (AD)	%	1	3 – 8.5
Ash (AD)	%	12	10 – 26.5
Volatile Matter (AD)	%	6 – 18	12 – 15
Fixed Carbon (AD)	%	79 - 81	50 – 70
Calorific Value (AD)	kcal/kg	6,800 – 7,300	5,300 – 6,800
Sulphur (AD)	%	0.5	0.35

The coal specification of China mines have calorific value (Ad) range from 5,400 kcal/kg to 7,300 kcal/kg, the percent sulfur content in coal approximate range about 0.35% - 0.5% while percent ash content in coal varies from 10.0% - 26.5%

Due to the Indonesia operation is a major production of this company and also has high range of calorific value, percent ash content and percent sulfur content, which are also the key factors of coal pricing, therefore this thesis study will focus on Indonesia operation in order to establish coal blending operation model to get additional benefit from blending to the company.

2.2 Current Coal Indonesia Operation

The coal Indonesia operation is one of BANPU's key functions. This company has own four coal mine concessions. Three of them are located in East Kalimantan province and the last one is located in South Kalimantan province. Moreover, there is another coal terminal which use for loads coal to customer called "Bontang Coal Terminal" which located at Indominco mine. The layout of mines location and coal terminal illustrated in figure 2-3

Figure 2-3: Layout Indonesia mine operation

Source: BANPU Public Company

From figure 2-3 above, there are three coal mines which called Indominco, Trubaindo and Embalut mine are located at East Kalimantan province, While Jorong mine are located at South Kalimantan province. In order to operate coal transportation to customers, there are two models of transportation equipment involved. They are barging and trucking for transport coal. Each mode is utilized according to a geographical suitability of each destination. The detail of coal transportation in each mine describe as follow.

Jorong mine, the coal was hauled 15 km. long by trucks from mine pits to port stockyard. Then, the coal was delivered and loaded to the barge by using conveyor system. After that, the coal was barged to customers at proposed destinations. In this current operation, the coal was delivered to customer by two destinations which are Bontang Coal Terminal and Jorong Anchorage area. Figure 2-4 below illustrated diagram of coal delivery from plant to customers.

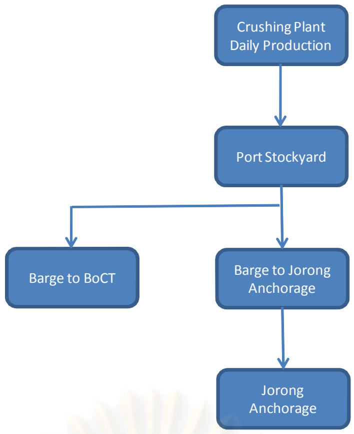


Figure 2-4: Jorong coal delivery to customer

Indominco mine, the coal from crushing plant was delivered to Bontang Coal Terminal by trucks along hauling road 40 km. As the result of complex facility of Bontang Coal Terminal for blending coal, it is possibly that coals from other mines were delivered to blend together with coal from Indominco mine. For the existing operation, there are alternatives that the coal from Jorong and Trubaindo mine were delivered to this coal terminal. Figure 2-5 below illustrated Indominco coal delivery from plant to customer.

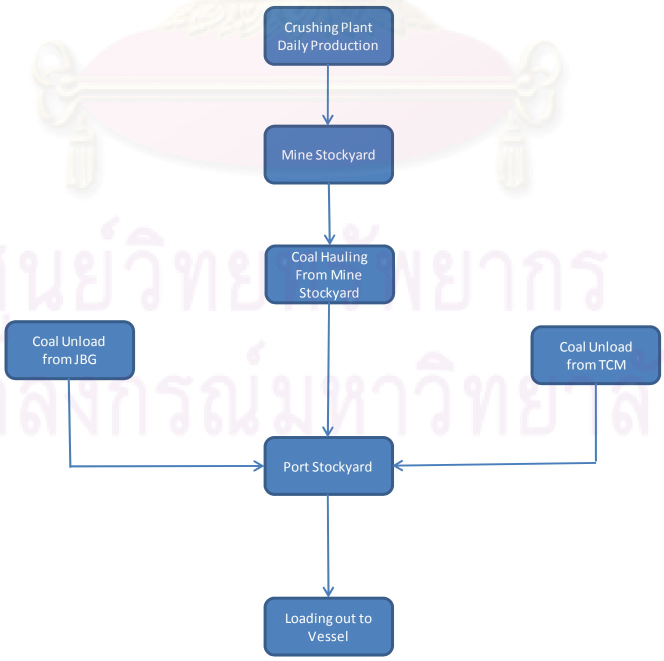


Figure 2-5: Indominco coal delivery to customer

Next, the coal delivery from crushing plant of Trubaindo mine to customer, the coals were hauled by trucks from mine stockyard to port stockyard. The coals at port stockyard were delivered to barge by using conveyor system to barge. The figure 2-6 illustrated Trubaindo coal delivery from plant to customer. There are several alternatives to barge coal to customer from this mine. The existing destinations which this coal mine delivers coal to customer are;

- Muara Jawa
- Samarinda
- Muara Berua
- Balikpapan Coal Terminal
- Jorong
- Bontang Coal Terminal

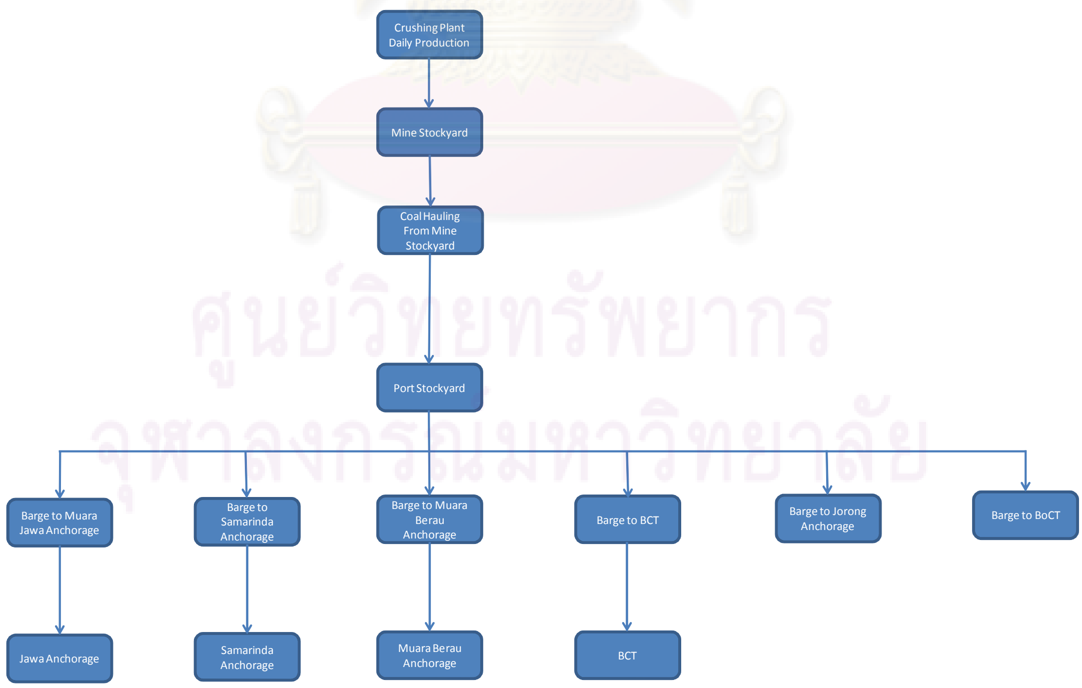


Figure 2-6: Trubaindo coal delivery to customer

Embalut mine, coal from Embalut mine was delivered from mine to coal loading port by trucks and then barging coal to customer in several locations. Figure 2-7 below illustrated coal deliver from Embalut Mine to customer.

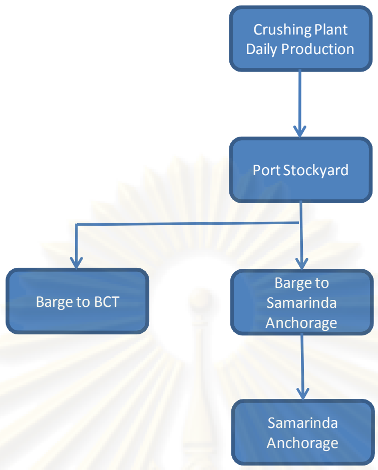


Figure 2- 7: Embalut coal delivery to customer

In addition, there are other possible alternatives to transport coal from mines to customer as figure 2-8. In order to increase additional benefit to company, there are opportunities to blend coal between mines to meet customer requirement. This thesis study requires to understanding and identifying constraints for coal blending from existing coal flow operation. Then prepare the coal blending operation model and utilize optimization tool to define blending plan in order to get add value and benefit to the company. The details will be described in the next part.

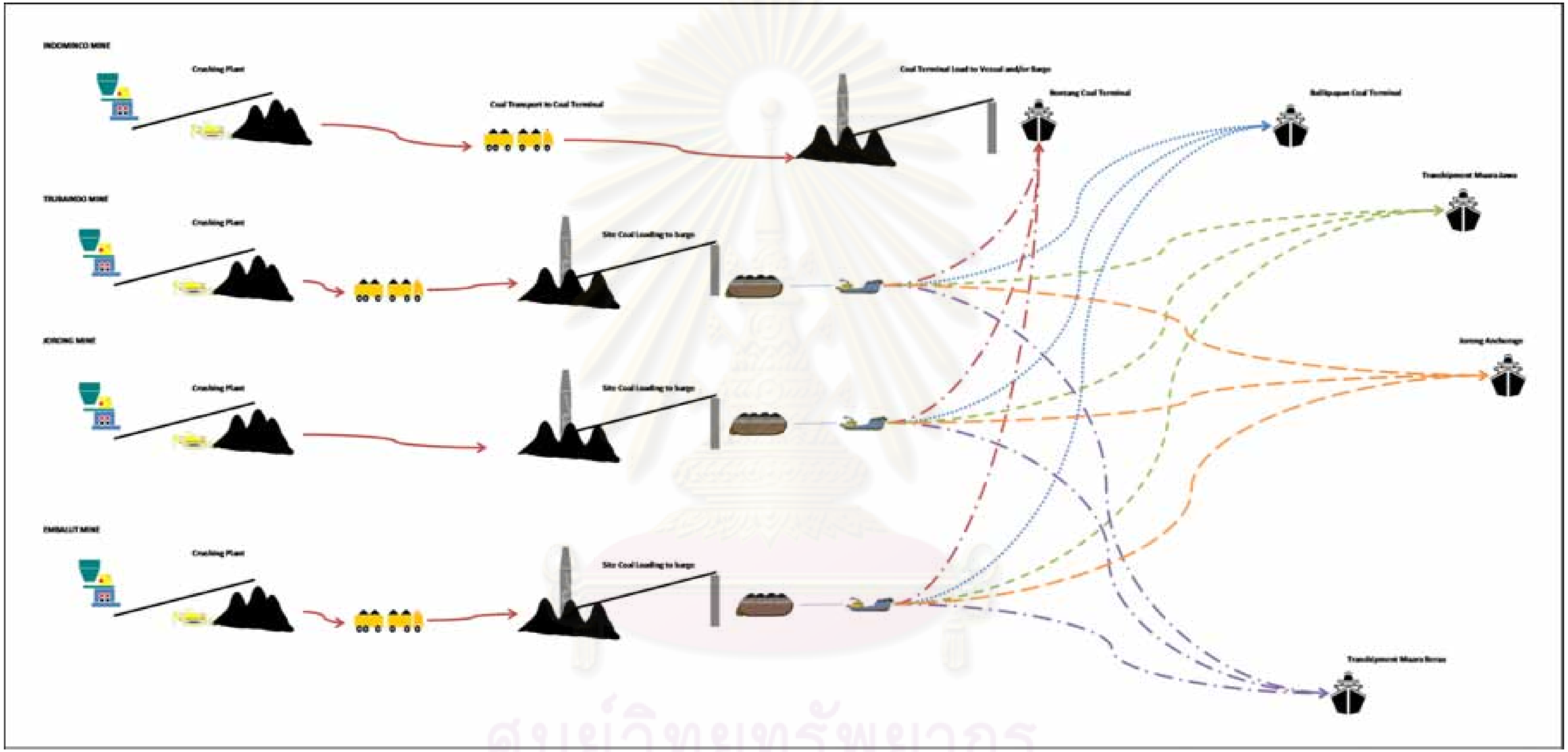


Figure 2-8: Alternatives to transport coal from mines to customer

2.3 Problems and Limitation of Current Coal Flow Operation

In the existing system, the coal delivery is scheduled by the experience of coal scheduler only. There is no scientific method to help judging whether or not the existing system is appropriate or it is done in the logical way. This may result a low rate of resource utilization or not optimize of coal blending to get maximum benefit to the company.

Moreover, the coal supply to customer from mine site during operation has fluctuated. There are many factors that affect the production performance as mentioned in chapter 1. These problems cause the coal scheduler to adjust schedule plan to meet customer specification both quantity and quality base on their experience. The experience of coal scheduler is the only one thing that indicates the suitability of the existing system at the present. There is no systematic methodology to be used as a guideline to help setting the coal schedule.

After studying the current coal flow operation, there are opportunities for creating the additional value from blending process for these mines both in planning stage and implementation stage. The current process for establishing the production plan of this company illustrated as figure 2-9 below.

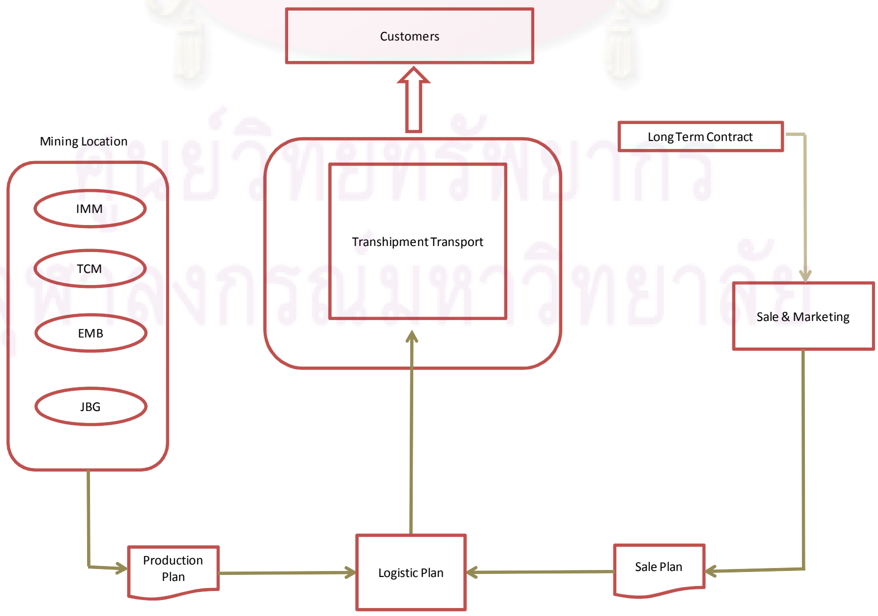


Figure 2-9: Current process for establish production plan

The production plan was created by each mine site preparing production plan which depends on mining sequence and other constraints at site location. While the sale & marketing department will forecast the demand which based on long term contract and new customer demand. The sale & marketing department also forecast the coal price from each mine to estimate the revenue to the company. There are adjusting production and sale plans to match between demand and supply side. Based on current practice, the planning staff has regulation to maintain inventory same level in each period. The sales plan consider to sales coal from production plan in each month only. They not consider to using coal from inventory to create sale plan. After getting the matching production and sale plan, then the logistic department will prepare logistic plan to deliver coal production to customer.

The company has a plan to sale coal production from each mine directly to customer. The coal products in each mine has different specification and the coal price depends on the specification of coal-product such as calorific value, percentage of sulfur and percentage of ash content in coal products. To sell direct products from mines to customers directly may cause company not to get maximum benefit.

For example, the fix specification of coal from each mine may not have a high demand in some periods which leads to lower the price of coal products. The company needs to improve coal products to meet customer requirement so that the company will get higher coal product price. There are several methods to improve coal specification. This thesis will propose to use coal blending from mines to improve coal specification to meet customer requirement.

In addition, the calorific value and percentage of sulfur are indicators in coal quality specification, which also are applied as the blending constraints for optimization calculation. The calculation of blended coal specification was calculated by weight proportional. The group of blended coal specification is calculated by the following procedure:

$$1 \le i \le n \qquad M = \sum_{1}^{n} m_i \qquad P = \frac{\sum_{1}^{n} (m_i * p_i)}{M}$$

mi = Quantity of coal for blending i

pi = Quality of coal specification i

M = Quantity of total coal blended

P = Quality of blended coal specification

Where,

i = Number of coal for blend

n = Total number of coal for blend

As mentioned in chapter 1, there is an opportunity to blend coal from four mines to optimum benefit for the company. The coal from each mine is planned to blend together to get the blended product that meets customer requirement and gets additional revenue. The blending optimization will be used for defining the blending program to increase revenue to the company. Figure 2-10 illustrated the blending optimization in production plan process.

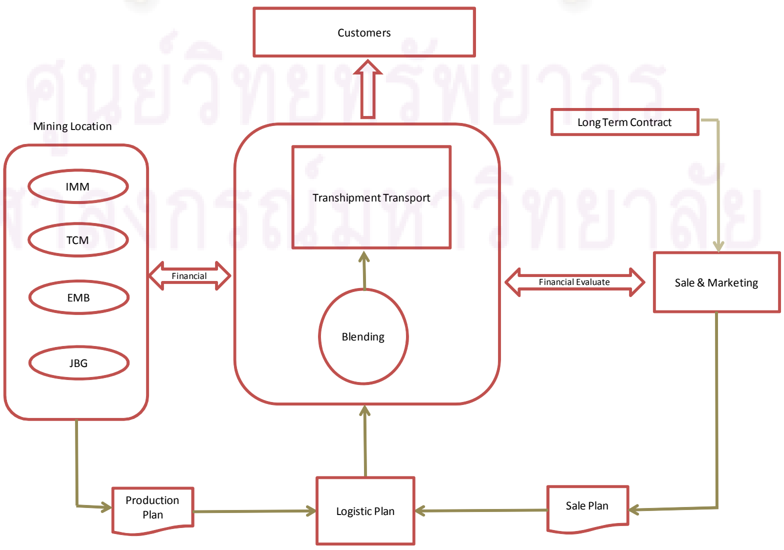


Figure 2-10: Blending optimization in production plan process

The blending optimization will use information such as coal price from sale & marketing, production specification, operating and logistic cost from operation function to define the blending program and blended product to deliver to customer in order to have additional benefit to the company.

Next, the implementation period, there are risks/problems which may occur during the production period and cause production mismatch from plan. When the company can't deliver coal production to customer as commitment and company will get penalty from customer. The company requires having information sharing system for operation and marketing function updated information between them and uses this information for support decision making. As mentioned above, the revised coal schedule plan is based on experience of coal scheduler. There is no systematic methodology to be used as a guideline. Therefore this thesis will propose procedure to use the blending optimization to define revise blending plan in order to meet commit volume with customers.

In summary, as mentioned in Chapter I, the problems and opportunities may be listed below;

1. Values add of coal blending from lower calorific value with higher calorific value to meet optimum calorific value which is required from customer.

2. Existing use manual calculation to blend coal to meet customer target.

3. There are some mismatches between production and marketing side during operation

4. Shortage of requested coal specification to deliver to customers

The above problems are the reasons, which have an effect on the profitable and cost control of the company. Hence, this research will focus on how to develop coal blending operation model for this company.

CHAPTER III

RELATED LITERATURE REVIEW

This chapter consists of four parts. The first section is a literature survey. The second part addresses management science theories. The third covers theories on linear programming. The fourth section comprises collaborative planning, forecasting and replenishment (CPFR). All of the reviewed items are needs in making decision for establish coal blending operation model.

3.1 Literature Survey

According to Supakanya Chinprateep and Rien Boondiskulchok (2010) *"Operations Research with optimization technique is more vital than ever. Now, it can successfully be applied to resolve a number of important problems arising in the planning and management of an operation. Its applications are not only having benefits for modeling and analysis of supply chain management strategies and practices, but also for studying critical trade-off and alternatives in practical decision-making."* There are a number of researches concerning the optimization of material blending and transportation by using linear programming as follows:

Jhih Shyang Shih and H. Christopher Frey (1993) studied coal blending optimization under uncertainty. This study focused on coal blending alternatives for reducing sulfur emissions from coal-fired power plants. The uncertainty and variability of coal specification were the main problems for this study which developed a multi-objective chance-constrained optimization model for solving the coal blending problem by using a linear programming algorithm. The objectives of this study were to minimize operation costs and sulfur emissions of coal-fired power plants.

G. T. Lineberry and E. L. Gillenwater (1987) studied improvements in raw coal blending by using linear programming. This study used a linear programming algorithm to define optimized coal blending scenarios for power plants. The objective of this study was to match coal feed rate and plant target for improving plant economics.

Gwo-Hshiung Tzeng et al. (1995) developed a logistic plan for transporting coal from mine to power plant. The main objectives of this study were as follows:

- To define the annual loading amount stipulated in the contract to be allocated each month to satisfy the monthly demands of power plants.

- To define the average dispatch of the dedicated coal-carriers for monthly voyages from each unloading port.

This study proposed a coal allocation model and a dynamic fleet assignment model, developing an algorithm to transpose the optimal allocation of the number of monthly voyages from each unloading port and establishing a coal logistics decision support system for dealing with the uncertainty problem.

Yasumasa Fujii et al. (2002) studied analysis of the optimal configuration of energy transportation infrastructure in Asia with a linear programming. This study investigated the possible future configuration of energy and CO_2 related infrastructures in Asia and Eurasia by using a large-scale energy system model for minimizing cost.

Moslehi et al. (1991) studied optimal scheduling of long-term fuel purchasing, distribution storage and consumption. The objective of this study was to minimize the total fuel purchase and storage costs with generation and fuel constraints. The modeling and solution of the long-term fuel scheduling of this study has been implemented for large electrical utilities.

A number of researches were found concerning the optimization of material blending and optimization of transportation by other algorithm programming with related problem solving for optimization.

Chungen Yin et. al. (2000) studied non-linear programming coal blending technology for power plants. This study used non-linear programming rather than a linear programming algorithm to solve blending problem. The use of nonlinear programming proposed in this study has now been successfully applied at the Hangzhou Coal Blending Center.

A. Ravindran and Derwood L. Hanline (1980) studied definitions of optimal locations for coal blending plants by Mixed Integer Programming. In this paper, the establishment of centralized blending plants capable of taking coals of varying sulfur content and producing a coal product that would meet the coal consumers needs based upon effluent standards is the main problem requiring a solution. A mixed integer programming model was developed to study this problem, the model results on the number of blending plants to be selected, their site locations, optimal blending ratios, transportation configuration and cost savings.

Chiun-Ming Liu and Hanif D. Sherali (2000) studied coal shipping and blending for an electric utility company. In this paper, a mixed-integer programming model was presented for finding optimal shipping and blending decisions on coal fuel from each overseas contract to each power plant.

The collaboration of planning, forecasting and replenishment is also related to this study and several studies related to these topics were found.

Mohsen Attaran and Sharmin Attaran (2007) studied collaborative supply chain management, which aims to provide an overview of contemporary supply-chain management systems. The collaborative planning, forecasting and replenishment (CPFR) was applied to improve supply chain effectiveness with demand planning, synchronized production scheduling, logistic planning and new product designs.

Pierre Hadaya and Luc Cassivi (2007) studied joint collaboration planning actions in a demand driven supply chain. The objective of this study was to measure the influence of joint collaboration planning actions on the strength of relationships, inter-organizational information systems and firm flexibility. The study demonstrated that joint collaboration planning actions positively and significantly impact the strength of relationships.

Linea Kjellsdotte Ivert and Patrik Jonsson (2010) studied potential benefits of advanced planning and scheduling systems in sales and operations planning. The purpose of this paper was to explore what potential benefits may be achieved by using advanced planning and scheduling systems in the sales and operations planning process.

3.2 Theory of Management Science

Bernard W. Taylor (1999) described the theory of management science which may be of benefit in conducting research. This general idea can be applied to helping solve problems.

General Ideas about Management Science

According to Benard W. Taylor (1999) *"Management science is the application of a scientific approach to solving management problems in order to help management make better decisions."* Numerous management techniques have been presented to improve the efficiency of process or business. Management science techniques can be applied to solving problems in difference types of businesses. The approach of management can be divided into the following 5 stages which:

- Observation
- Problem definition
- Model construction
- Solution
- Implementation

The management science approach is illustrated in figure 3-1 Management Science Process.

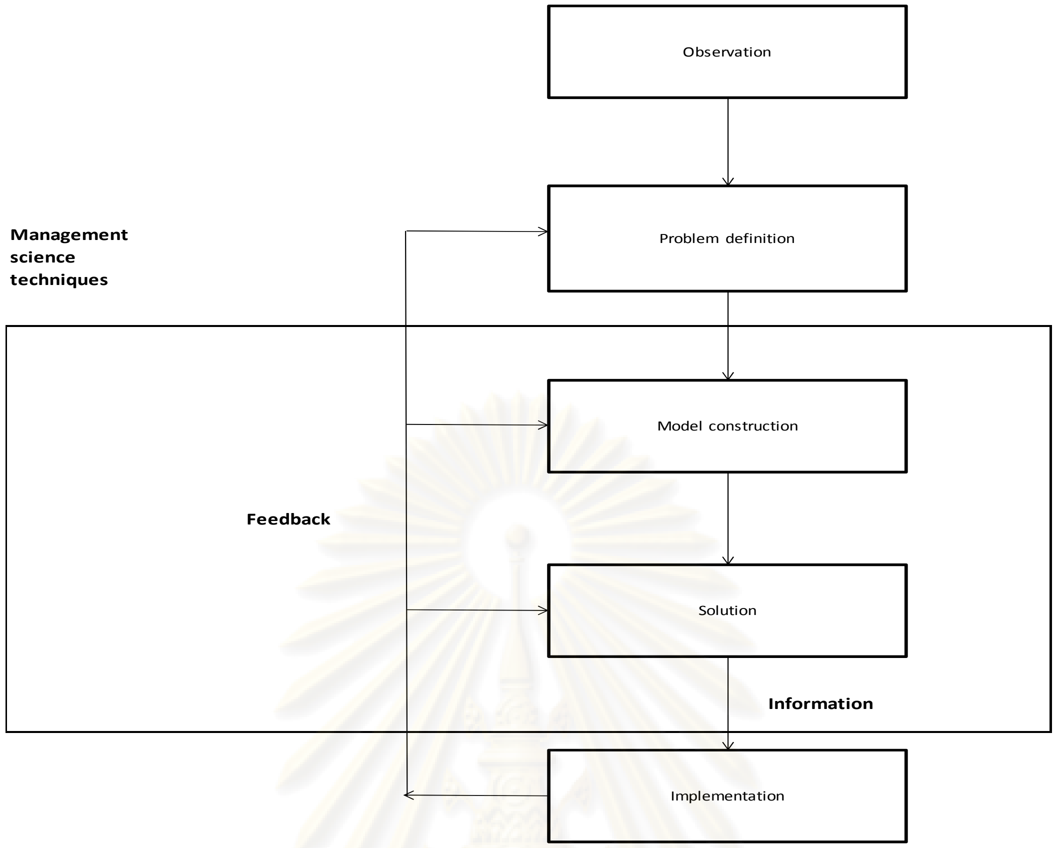


Figure 3-1: Management Science Process

Source: Benard W. T., 1999

From Figure 3-1, the description in each stage following;

Observation

This is the first step in the management science process where observation is the identification of a problem occurring in a system or process. Close monitoring and observation of the system or process is required at this stage to define the real problem.

Definition

This is the second stage. Once a problem has been identified, we need to define the problem. The limits of the problem and the degree to which it pervades other units of the company must be included in the problem definition.

Model Construction

As asserted by Benard W. Taylor (1999), *"A management science model is an abstract representation of an existing problem situation. It can be in the form of a graph or chart, but most frequently a management science model consists of a set of mathematical relationships. These mathematical relationships are made up of numbers and symbols."*

Model Solution

Once a model has been constructed in management science, problems are solved using the management science techniques as shown in Figure 3-2. The management science solution technique usually applies to a specific type of model.

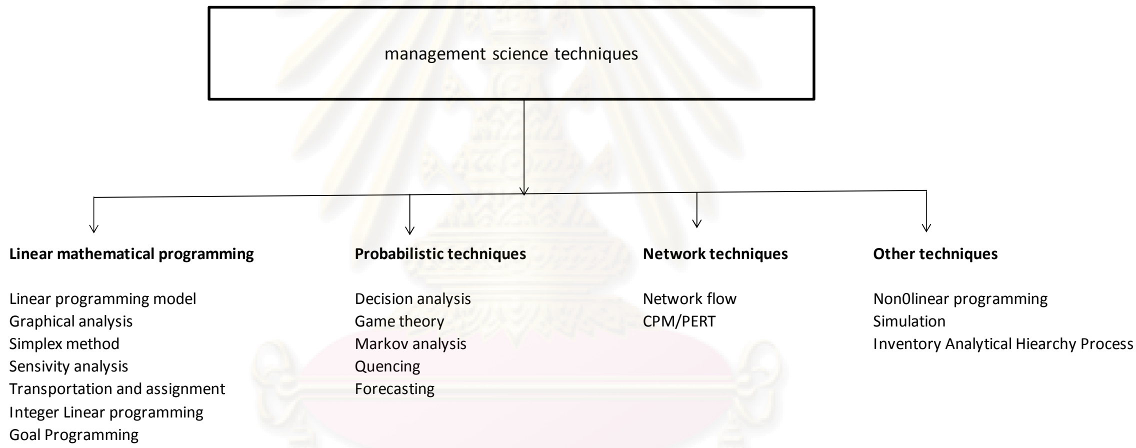


Figure 3-2: Classification of Management Science Techniques

Source: Benard W. T., 1999

The implementation is the actual use of the model once it has been developed, or the solution to the problem the model was developed to solve.

Nowadays, computers play an integral part in enabling modern practitioners to employ practical advances to obtaining solutions for a number of issues. A decision-making process appears in two basic forms, namely qualitative and quantitative approaches. A quantitative analysis is essential to arriving at a decision and tends to concentrate on quantitative data related to the problem. Hence, mathematical expressions can be developed to illustrate the objectives, limitations and other relationships with the issue at hand. However, the integration of quantitative solutions and qualitative consideration is the best decision making. Linear programming is a management science technique or problem solving approach developed to help with managerial decision-making. It involves with maximizing or minimizing some quantity i.e cost, revenue, time etc. Next topic will discuss more detail about the theory of linear programming.

3.3 Theory of Linear Programming

According to Hossein Arsham (2008), *"linear programming is a mathematical procedure for determining optimal allocation of scarce resources."* Moreover Hossein also mentioned that *"linear programming deals with a class of programming problems where both the objective function to be optimized is linear and all relations among the variables corresponding to resources are linear. This problem was first formulated and solved in the late 1940's. Rarely has a new mathematical technique found such a wide range of practical business, commerce and industrial applications, and simultaneously received so thorough a theoretical development, in such a short period of time."*

This section will describe the characteristics of linear programming, linear programming models for formulating linear programming and problem-solving methods for linear programming.

3.3.1 Characteristics of Linear Programming Problems

Mokhtar S. Bazaraa et. al (1990) asserts that linear programming problems require a choice between different options. In the model, decisions are illustrated by decision variables. The initial steps in the formulation process are determining a chosen task and defining the decision variables. Next, the objective function the person making the decision seeks to achieve must be defined. The objective must yield favorable outcomes in terms of maximized or minimized value. Another characteristic of linear programming problems are the constraints encountered which prevent unlimited achievement of the objective function. Linear mathematical functional relationships are required for defining these constraints. The value of the model parameter is the last characteristic of linear programming. Generally speaking, we assume the model parameters to be invariable and definitely known. In conclusion, the linear programming model shows signs of sharing the following characteristics in common:

- Objective function to be maximized or minimized
- A set of constraints
- Decision variables for measuring the level of activity
- Linearity among all constraint relationships and objective function

3.3.2 Formulating Linear Programming Model

According to Thomas M. Cook et al. (1993), the constructing linear programming should follow the steps below:

- Understand the problem
- Identify decision variables
- Choose a numerical measure of effectiveness for the objective function
- Represent the measure of effectiveness as a linear expression involving the decision variables
- Identify and represent all constraints as linear expressions involving decision variables
- Collect data or make appropriate estimations for all parameters of the model. All parameters of the model must be defined as numerical constants.

Once the model has been completely constructed, the next step is to determine the optimum answer by solving the model mathematically. The next section will discuss problem-solving methods for the linear programming model.

3.3.3 Linear Programming Model Problem-Solving Methods

"Theoretically, a linear programming model can be solved by manually applying various types of mathematical methods, such as the direct elimination method, mathematical deduction method, graphical method, general algebraic method, simplex method, two phase method and so on. However, in real working environments, the linear programming model involves a large number of variables and constants. Solving it by hand seems both impossible and unheard of." Rajsuda Rungsiyakull (2000)

Rajsuda Rungsiyakull (2000) also suggested the following three main areas of focus for a computer-based solution:

- Model Formulation: Model builders should spend as much time as possible in studying the details concerning linear programming software packages to be used, so they can build the model properly in line with that particular software package format.

- Preparing Input: This is the phase where model builders need to know exactly how to access and run the right program whereby inputs concerned with maximizing or minimizing conditions, a number of real variables and a number of constants are usually specified.

- Interpreting Output: Once output has been generated from the linear programming software, particular focus should be placed on optimal values in the following areas:

    - Objective function
    - Individual variables
    - Supplemental variables

Emphasizing these areas facilitates interpretation while enhancing effectiveness. Moreover, there is a chance that output will have nonstandard characteristics e.g. no feasible solution, unbounded solution space, redundant constraint, alternative optima, etc., which should be noticed. These nonstandard characteristics are best observed and noted in the interpreter's mind so an accurate interpretation of the output can be provided.

3.4 Collaborative Planning, Forecasting and Replenishment

Let's start with the history of collaborative planning, forecasting and replenishment (CPFR). According to Hagg et al. (2006), the first initiative of CPFR began in 1995 by the co-lading of Wal-Mart, Cambridge, Massachusetts software and strategy firm and Benchmarking Partners which released the initiative originally called "collaborate, forecasting and replenishment (CFAR)" The concept of CFAR was to collaborate on the management of inventories, forecasting and replenishment of products in a supply chain.

Then in July of 1996, the Wal-Mart's executives as along with other retailers and the Uniform Code Council, Benchmarking Partners, presented CFAR to the Board of Directors of the Voluntary Inter-industry Commerce Standards Committee (VICS) which aims to promote CFAR as an international industry standard and rename CFAR to be CPFR. So this is starting point of CPFR.

Most researchers have focused their attention on the study of Collaborative Planning, Forecasting and Replenishment (CPFR) for integrating supply chains by means of cooperative management of inventories with joint visibility, replenishment and information sharing. The aim of CPFR is to share information between the supply and demand sides to improve supply chain efficiency. According to Mohsen and Sharmin Attaran (2007), the CPFR is proposes facilitating restructuring replenishment between trading partners. One key advantage of CPFR is that forecasting accuracy can improved through customer-supplier participation in the forecast. As collaborators, buyers and sellers work together to satisfy the demands of end customers. Figure 3-3 shows the components of the CPFR model.

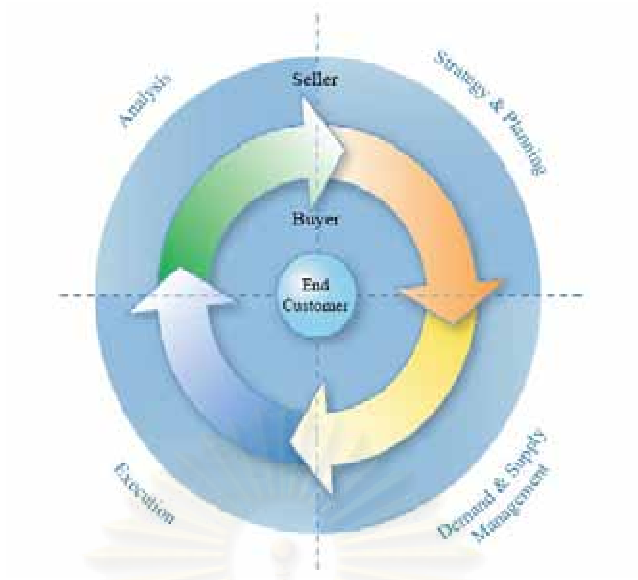


Figure 3-3: The component of CPFR model

Source: Mohsen and Sharmin, 2007

As in the above figure, trading partners meet and make decisions about replenishing quantity to solve the issue at hand. Collaboration of this kind holds stands an excellent chance of drastically improving supply chain performance by means of collaborative demand planning, synchronized production scheduling, logistics planning and new product development. The collaboration phases for CPFR comprise the following four main stages:

- Strategy & Planning
- Forecasting Demand and Supply
- Execution
- Analysis

3.4.1 Stages of collaboration

According to the VICS Association, VICS (2004) the template of CPFR for supply chain collaboration involves four phases as individually detailed below:

Planning Stage: this is the first stage, during this stage the buyers and sellers will plan the production and sell plan together then update together until can make front-end agreement and join business plan.

Forecasting Demand and Supply Phase: This is the stage where sales/order forecasts are formed, while exceptions or inconsistencies are both identified and resolved. The CPFR process improves the accuracy of forecasts by stipulating that both customers and suppliers have a part in forecasts for sales/orders. Hence, buyers and sellers are brought together to ensure compatible goals.

Execution Phase: This is the stage where orders originate as goods are received and displayed on retail shelves, shipments are made ready and sent, sales transactions are recorded and payments are made.

Analysis Phase: This stage is marked by monitor planning and execution activities especially for extraordinary circumstances. If there is an inconsistency, both trading partners can meet together, so they can share ideas, modify plans and resolve inconsistencies. The abovementioned stages are presented in logical order below as shown in Figure 3-4. It should be noted, however, that most companies can easily be simultaneously involved in all of these phases at any given time.

Figure 3-4 Collaboration Activities

Source : Mohsen and Sharmin, (2007)

3.4.2 CPFR Process Model

The CPFR process model integrates long-term collaboration with manufactures or suppliers/vendors on the demand side. A number of processes are required in order to complete the CPFR model to correspond with the supply chain. According to VICS VICS (2004), CPFR is a nine-step process model consisting of the following:

- Developing Collaboration Agreements
- Creating Joint Business Plans
- Creating Sales Forecasts
- Identifying Exceptions For Sales Forecasts
- Resolving/Collaborating on Exception Items
- Creating Order Forecasts
- Identifying Exceptions for Order Forecasts
- Resolving/Collaborating on Exception Items
- Generating Orders

After we understand about the process of creating CPFR, we should understand the supporting factors and effects of CPFR implementation. The next topic will address the successes and influencing adoption factors for implementing CPFR

3.4.3 CPFR Success Factors

The CPFR model has yielded advantages for hundreds of manufacturers and retailers over the past ten years. Some of the key achievements potentially influencing CPFR adoption on a larger scale are presented below:

- Top Management Involvement

- Trust Between Collaborating Partners
- Continuous Measurement of Performance
- Innovative IT Strategy
- Up-to-Date Cost Accounting Methods
- Emphasis On Customer Satisfaction
- Flexible Organizational Structure
- Proper Staff Training

3.4.4 Factors Influencing Adoption

The implementation of CPFR processes has benefited a number of companies and supply chain costs including production, inventory, marketing, distribution and selling costs have frequently been referred to as key issues affecting CPFR. CPFR partners can gain the following significant business advantages by adopting CPFR, VICS (2002):

- Enhanced Relationships Between Partners
- Increased Sales Revenue
- Improved Product Offering
- Reliable and Accurate Order Forecasts
- Reduced Inventories
- Improved Technological Return on Investment

CHAPTER IV

COAL BLENDING OPERATION MODELING

The topics discussed in Chapters 1-3 represent the researcher's effort to provide details concerning the research problem in addition to related theoretical issues. Once the problem is understood, problem-solving methods can be categorized into two phases: (1) Application of linear programming in order to determine a solution for coal blending from mines with an aim toward obtaining additional benefits from blending and (2) creating operational procedures to form a dynamic coal blending plan aimed at supporting decision-making based upon updated information.

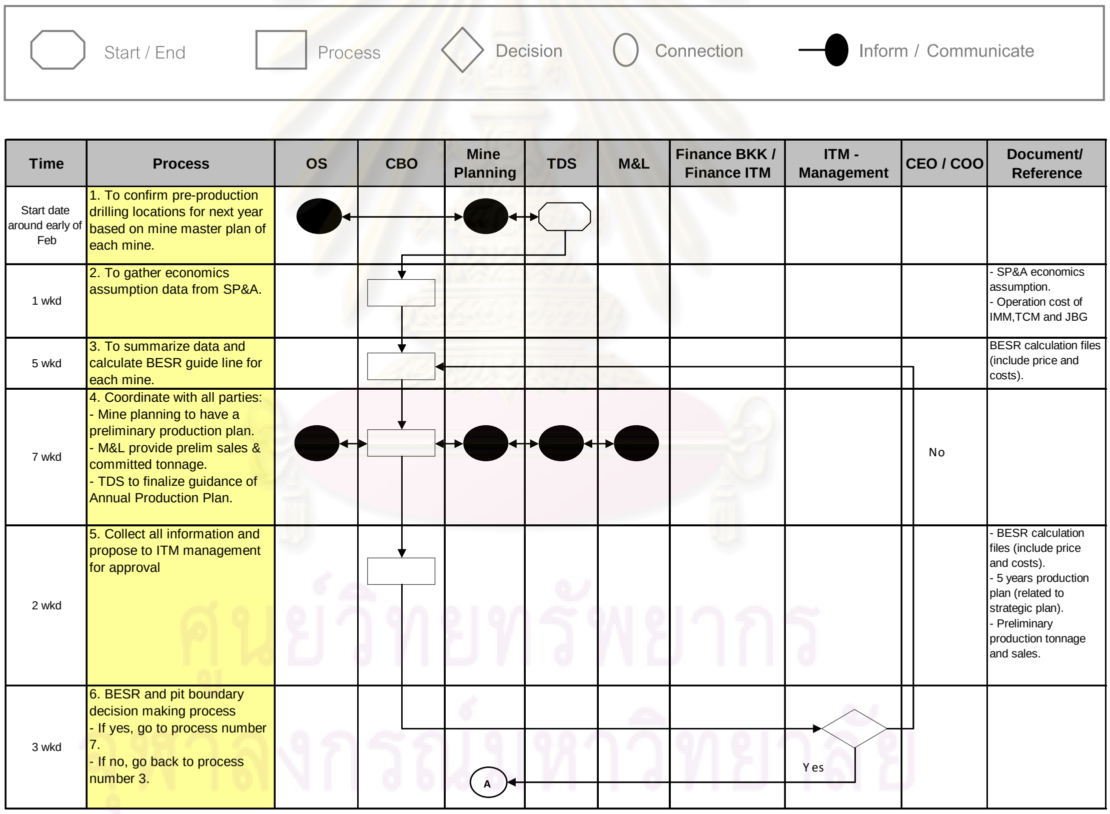
This chapter applies the linear programming theory covered in Chapter 3 with currently existing coal flow operations. Next, the solution derived from the linear programming model is interpreted with the goal of obtaining an initial concept of optimal conditions for blending operations at each terminal. Linear program calculating is then calculated in line with the limitations of production, transportation, coal loading capability and coal specification, so blending scenarios can be identified for maximal benefit.

4.1 Study of Current System

In order to develop a blending operation model, the requirements of current system production planning, coal price forecasting, transportation systems, operating costs and financial evaluations have to be considered in order to obtain suitable results for the company.

4.1.1 Procedure of Annual Production Plans and Existing Operations

The current procedures for creating annual plans are related to all functions on either the operation side or supply side and the marketing side or demand side. The annual creation of production plans starts with each mine producing its own production planning based on supported information such as strategic planning, long term master plans, updated economic assumptions and available areas for assessing the mines. The annual production planning for each mine is divided into quarterly and monthly production plans. The sales plans are formed by the Marketing Department according to the long-term master plan as a guideline for long-term coal contract with customers. The sale plans contain both long term contracts for demand and spot demand. The spot demand is considered to depend on the annual production plans created by mine sites. The Marketing Department then uses the annual production plan from operation to create sales plans on a quarterly and monthly basis. After obtaining both production and sales plans, management considers the EBIT of the company and makes a decision to approve the annual plan. The detailed procedures involved in the formation of annual plans for this company has a flowchart as shown in Figure 4-1 below.



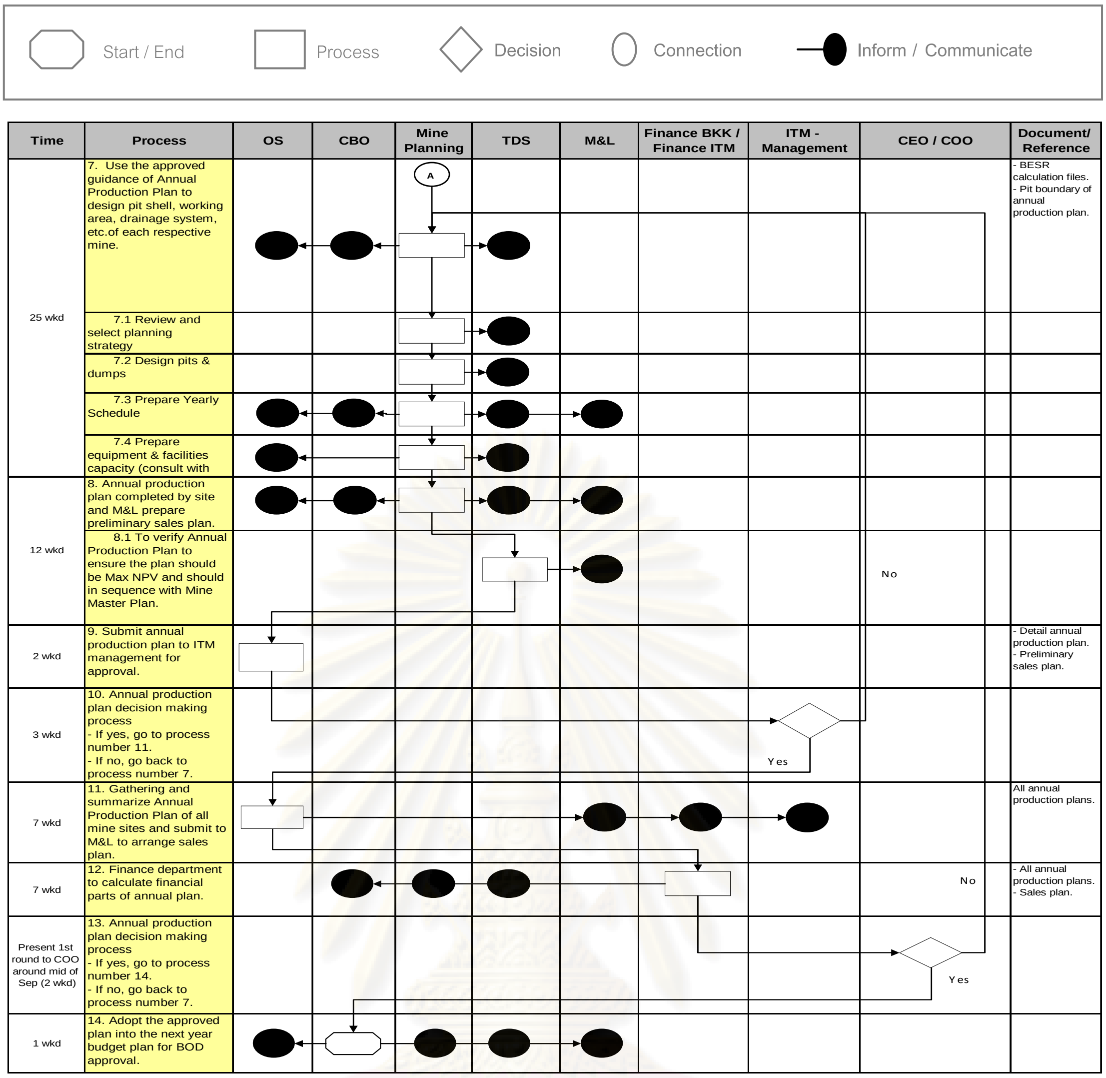


Figure 4-1: Annual Production Planning Procedures

Source: BANPU Public Company

Definitions:

TDS: Technical Development and Services Department

OS: Operation Support Department

CBO: Coal Business Office Department

M&L: Marketing and Logistics Department

BESR: Break-even Stripping Ratio

Procedure Details

As mentioned above, the procedures of forming annual plans comprise 14 stages related to many functions. The details of each stage of these procedures can be explained as follows:

- Step 1: TDS confirms pre-production drilling locations for next year based on the mine's master plan.
- Step 2 : CBO gathers economic assumption data from strategic planning meetings.
- Step 3: CBO summarizes data and calculates BESR guidelines for each mine site.
- Step 4: CBO coordinates with all concerned parties.
- Step 5: CBO collects all information and proposes to ITM management for approval.
- Step 6: Management considers the proposed BESR and pit boundary
- If yes, BESR and pit boundary are approved and the team moves on to Step 7.
- If no, the BESR calculation and pit boundary are returned to CBO for rectification.
- Step 7: Mine planning team of each site uses the approved guidance of annual production plans to design pit shells, working areas, drainage system, etc. All of these processes must be closely communicated to TDS.
- Step 8: Mine planning completes annual production plans and M&L prepares preliminary sales plans.

- Step 9: Operation Support submits an annual production plan to management for approval.

- Step 10: Management considers the annual production plan.

- If yes, the plan is approved and the team proceeds to Step 11.

- If no, the entire plan is returned to annual production to mine planning team for further clarification and rectification

- Stage 11: Operation Support gathers and summarizes the annual production plans of all mine sites and submits to M&L to arrange sales planning.

- Stage 12: Finance Department calculates financial parts of the annual plan then, proposes to CEO/COO for the approval process.

- Stage 13: CEO/ COO considers the annual production plan

- If yes, the plan is approved and the team proceeds to Step 14.

- If no, the annual production plan is returned to Mine Planning with comments for correction and revision.

- Stage 14: CBO adopts the approved plan for next year's budget plans for BOD approval.

During the annual product planning process, the coal blending between mines remains unconsidered in terms of improving the company's revenue. The procedures for creating annual production plans considers only individual mine production. Scenarios were mentioned in Chapter 1 to show that the coal blending process can improve the company's revenue.

During the operational period, the annual production and sales plans are divided into quarterly and monthly plans as the approval of the production plan created is accepted by all departments concerned with producing coal for customers.

Unfortunately, the implementation may deviate from the plan for a number of reasons as mentioned above. The company holds regular meetings to update information among all related departments so production schedules can be revised. These meetings are scheduled on monthly basis. The monthly meetings between the mine operations and marketing will discuss the outlook of the production yielded from mine, the quantities and quality of coal products from the mine and the extent of demand from the customers in that month from each mine. Figure 4-2 below illustrates the meeting schedule between the Operations and Marketing Departments.

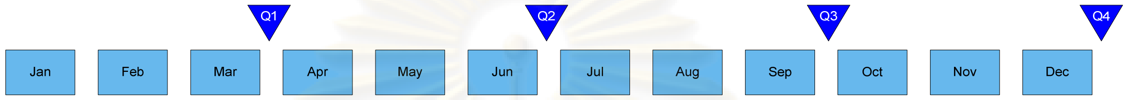


Figure 4-2: Meeting Schedule between Operations and Marketing Department

Source: BANPU Public Company

The meeting includes discussions about how to achieve quarterly plans, problems affecting production and how marketing can modify coal delivered to customers in line with the output yielded by the operations. At this stage, marketing is required to adjust their plans in order to coincide with the operation output. This corrective action is normally used in attempts to blend coal from other sources in order to meet customer demands. Under normal circumstances, the coal blending at this stage employs a manual calculation which continues to lack consideration of addition costs potentially occurring during coal blending to meet customer targets.

To obtain good information support for the monthly meeting, the company needs to have a reliable system for recording the production output from mines. This company studied has software to help the management obtain information from the mine pit until coal is delivered to customers. This company uses software called “Mine Market” for recording the actual production from mine production until coal is delivered to customers. The software is also used for recording the production status from mine pits to production at the crushing plant, coal loading port and delivery to customers. The software consists of the following 3 modules:

- Aramis – Sales & Marketing
- MineTrak – Production & Logistics
- CCLAS – Quality Management

The basic concept of this software is to synchronize supply chain flow from mine pits to customer. The "Aramis" module correlates with the Sales and Marketing Department to record customer demands and shipment schedules in accordance with the sales plans approved by the management in line with the annual production plan. The sales plans are recorded in this system which is used for controlling and monitoring the actual sale products. The "MineTrak" module is used for mine operations to record the production output from the mine pit to compare with the production plan for monitoring and controlling. The last module is CCLAS, which is used for controlling coal quality from mine pits until delivery to customers. Figure 4-3 shows the basic concepts of Mine Market software.

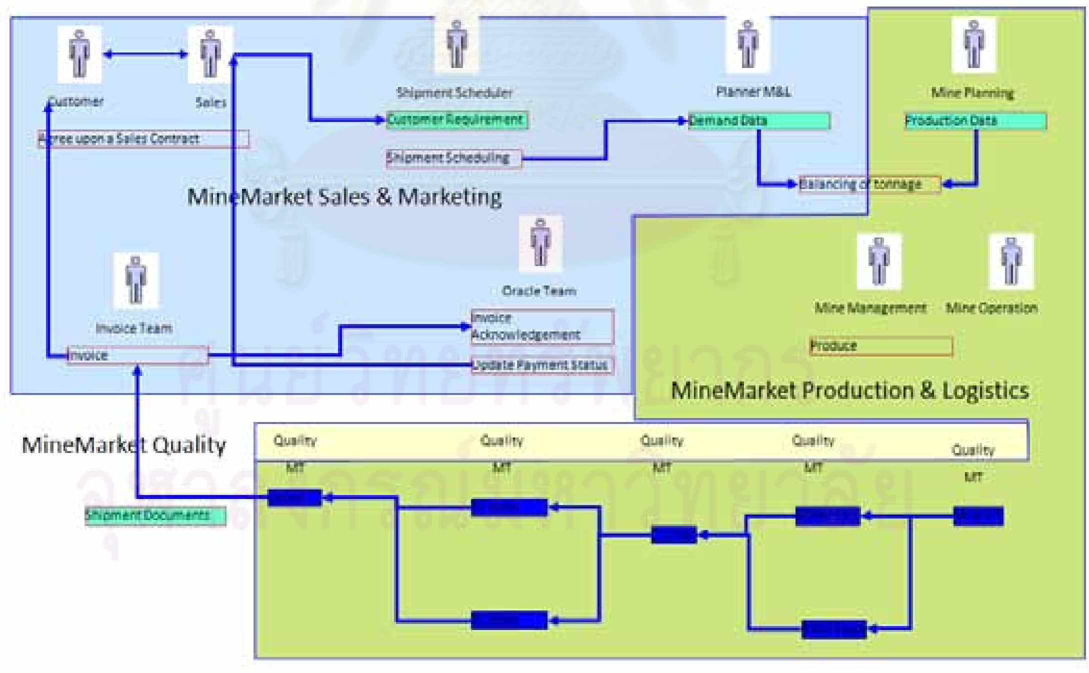


Figure 4-3: Basic Concept of Mine Market Software

Source: BANPU Public Company

Based on these software operations, the three modules have been proposed for reporting to the management on actual production, actual sales and quality control. To solve the problems possibly missed by production in the plan, this software still requires decision-making from the planner or the management based on existing information. Therefore, optimization coal blending tools will facilitate the planner or the management in making a decision to revise the plan based on updated information.

In summary, the company has sound procedures for creating production and sales plans. Nevertheless, this company still has no procedure for blending coal between each mine to meet customer targets or yield additional benefits from blending. During the operational period, the updated information about production plans and marketing sales plans are required. The improvements on information transfer flow needs to be considered in order to update information for all functions, while the optimization tool will help the planner to adjust plans with sufficient response time based on valued analysis.

4.1.2 Annual Production Plan

The annual production plan which will be used for this study is the annual production plan of 2010 which was approved by the management. The annual production plan of IMM mine consists of 3 coal types i.e. West PAMA, West Ketadin and East Area while TCM mine has an annual production plan consisting of 3 coal types i.e. LCV, HCV and HCV-HS areas. The annual production plan of EMB mine consist of 2 raw coal sources i.e. North and South areas. The JBG mine has only one raw coal source which is called the LCV area.

The coal production in each area has different production rates depending upon the equipment and machines used for mining coal. Furthermore, the coal quality specifications have different types at each location. The coal quality specifications employed in this study have two categories i.e. heating value and percent of total sulfur.

The range of coal quality specification in each mine show as list below;

- IMM-West PAMA has heating value in range 6,200 – 6,300 Kcal/kg. and Sulfur content 0.7 – 0.9 %
- IMM-West Ketadin has heating value in range 6,400 – 6,500 Kcal/kg. and Sulfur content 0.6 – 1.70 %
- IMM-East Area has heating value in range 5,900 – 6,000 Kcal/kg. and Sulfur content 1.7 – 1.9 %
- TCM-LCV has heating value in range 6,200 – 6,300 Kcal/kg. and Sulfur content 0.7 – 0.8 %
- TCM-HCV has heating value in range 6,700 – 6,800 Kcal/kg. and Sulfur content 0.7 – 0.8 %
- TCM-HCV HS has heating value in range 7,000 – 7,100 Kcal/kg. and Sulfur content 1.7 – 1.9 %
- EMB-North has heating value in range 6,200 – 6,300 Kcal/kg. and Sulfur content 0.7 – 0.8 %
- EMB-South has heating value in range 5,700 – 5,800 Kcal/kg. and Sulfur content 0.1 – 0.2 %
- JBG LCV has heating value in range 5,200 – 5,300 Kcal/kg. and Sulfur content 0.3 – 0.6 %

Table 4-1 – 4-4 shows the summary of the annual production plans for 2010 at each mine.

Table 4-1: IMM Annual Production Plan

IMM Mine	Unit	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
WEST PAMA AREA														
Over burden revoval	1000 bcm	8,020	7,407	8,183	8,209	8,618	8,100	8,594	8,597	7,814	8,334	7,967	7,563	**97,406**
Coal Mine	1000 tons	559	506	558	557	569	542	565	565	513	547	541	534	**6,552**
CV	Kcal/kg	6,222	6,281	6,265	6,269	6,290	6,286	6,280	6,261	6,261	6,217	6,256	6,268	**6,263**
TS	%	0.85	0.79	0.86	0.87	0.82	0.87	0.86	0.85	0.85	0.88	0.81	0.78	**0.84**
Ash	%	5.52	5.27	5.19	5.27	5.05	5.20	5.20	5.20	5.23	5.65	5.46	5.43	**5.31**
WEST KETADIN AREA														
Over burden revoval	1000 bcm	3,673	3,622	4,018	3,847	4,629	4,341	3,106	3,584	3,313	3,841	2,427	0	**40,400**
Coal Mine	1000 tons	208	203	218	200	223	206	203	222	180	210	194	184	**2,450**
CV	Kcal/kg	6,553	6,488	6,411	6,412	6,350	6,376	6,471	6,432	6,480	6,650	6,732	6,779	**6,506**
TS	%	0.78	0.70	0.81	0.82	0.69	0.60	0.68	0.57	0.73	1.22	1.55	1.70	**0.89**
Ash	%	7.19	7.53	8.85	8.86	7.68	7.50	5.78	6.69	6.65	5.03	4.09	3.46	**6.66**
EAST AREA														
Over burden revoval	1000 bcm	2,531	2,372	2,813	3,324	3,455	3,598	3,903	4,421	4,451	4,659	4,579	4,111	**44,218**
Coal Mine	1000 tons	230	284	306	352	351	373	432	504	508	536	554	460	**4,889**
CV	Kcal/kg	5,942	5,957	5,955	5,931	5,926	5,923	5,924	5,961	5,961	5,955	5,991	6,037	**5,958**
TS	%	1.88	1.81	1.83	1.81	1.84	1.86	1.87	1.87	1.79	1.72	1.80	1.74	**1.81**
Ash	%	4.35	4.44	4.29	4.56	4.64	4.56	4.54	4.12	4.21	4.32	4.67	4.13	**4.39**
TOTAL IMM														
Over burden revoval	1000 bcm	**14,224**	**13,401**	**15,014**	**15,381**	**16,701**	**16,039**	**15,602**	**16,602**	**15,578**	**16,834**	**14,972**	**11,675**	**182,024**
Coal Mine	1000 tons	**997**	**993**	**1,081**	**1,108**	**1,143**	**1,120**	**1,199**	**1,290**	**1,200**	**1,293**	**1,288**	**1,177**	**13,891**
CV	Kcal/kg	**6,227**	**6,231**	**6,207**	**6,187**	**6,190**	**6,182**	**6,184**	**6,173**	**6,167**	**6,178**	**6,214**	**6,257**	**6,199**
TS	%	**1.07**	**1.06**	**1.12**	**1.16**	**1.11**	**1.15**	**1.20**	**1.20**	**1.23**	**1.29**	**1.35**	**1.30**	**1.19**
Ash	%	**5.60**	**5.49**	**5.67**	**5.69**	**5.44**	**5.41**	**5.06**	**5.03**	**5.01**	**5.00**	**4.92**	**4.61**	**5.22**

44

Table 4-2: TCM Annual Production Plan

TCM Mine	Unit	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
LCV AREA														
Over burden revoval	1000 bcm	1,651	1,731	1,824	1,933	2,097	2,068	2,133	2,208	1,987	1,761	1,553	1,544	**22,491**
Coal Mine	1000 tons	167	86	82	170	200	200	190	180	180	174	185	185	**2,000**
CV	Kcal/kg	6,250	6,250	6,250	6,263	6,274	6,282	6,254	6,292	6,272	6,273	6,250	6,253	**6,265**
TS	%	0.80	0.80	0.80	0.80	0.80	0.80	0.79	0.79	0.79	0.79	0.80	0.80	**0.80**
Ash	%	5.50	5.50	5.50	4.90	4.97	4.94	5.29	5.19	5.20	5.22	4.99	5.00	**5.15**
HCV AREA														
Over burden revoval	1000 bcm	1,651	1,731	1,824	1,933	2,097	2,068	2,133	2,208	1,987	1,761	1,553	1,544	**22,491**
Coal Mine	1000 tons	124	146	173	170	170	170	170	165	165	165	165	165	**1,948**
CV	Kcal/kg	6,750	6,750	6,750	6,792	6,771	6,792	6,767	6,768	6,767	6,760	6,753	6,754	**6,765**
TS	%	0.80	0.80	0.80	0.80	0.80	0.78	0.80	0.80	0.79	0.77	0.77	0.78	**0.79**
Ash	%	5.50	5.50	5.50	4.55	4.45	4.48	4.54	4.37	4.34	4.33	4.17	4.20	**4.64**
HCV HS AREA														
Over burden revoval	1000 bcm	1,651	1,731	1,824	1,933	2,097	2,068	2,133	2,208	1,987	1,761	1,553	1,544	**22,491**
Coal Mine	1000 tons	221	285	314	156	128	166	175	174	179	177	170	172	**2,317**
CV	Kcal/kg	7,000	7,000	7,000	7,065	7,055	7,060	7,058	7,053	7,037	7,052	7,011	7,050	**7,031**
TS	%	1.80	1.80	1.80	1.78	1.79	1.77	1.75	1.75	1.74	1.70	1.70	1.80	**1.77**
Ash	%	5.50	5.50	5.50	4.50	4.48	4.50	4.52	4.52	4.52	4.58	4.72	4.96	**4.91**
TOTAL TCM														
Over burden revoval	1000 bcm	**4,954**	**5,194**	**5,472**	**5,798**	**6,291**	**6,205**	**6,400**	**6,624**	**5,961**	**5,283**	**4,660**	**4,632**	**67,473**
Coal Mine	1000 tons	**512**	**518**	**570**	**496**	**498**	**536**	**535**	**519**	**524**	**516**	**520**	**522**	**6,265**
CV	Kcal/kg	**6,694**	**6,805**	**6,815**	**6,697**	**6,644**	**6,685**	**6,680**	**6,698**	**6,689**	**6,696**	**6,658**	**6,674**	**6,704**
TS	%	**1.23**	**1.35**	**1.35**	**1.11**	**1.05**	**1.09**	**1.11**	**1.11**	**1.12**	**1.10**	**1.09**	**1.12**	**1.15**
Ash	%	**5.50**	**5.50**	**5.50**	**4.65**	**4.67**	**4.66**	**4.80**	**4.70**	**4.70**	**4.72**	**4.64**	**4.73**	**4.90**

45

Table 4-3: JBG Annual Production Plan

JBG Mine	Unit	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
LCV AREA														
Over burden revoval	1000 bcm	656	611	806	739	761	671	766	941	1,016	1,336	1,276	1,271	**10,850**
Coal Mine	1000 tons	185	189	246	219	219	203	91	109	126	140	141	134	**2,000**
CV	Kcal/kg	5,340	5,323	5,312	5,319	5,272	5,309	5,283	5,273	5,320	5,308	5,392	5,367	**5,318**
TS	%	0.64	0.59	0.54	0.59	0.62	0.52	0.46	0.45	0.32	0.34	0.39	0.47	**0.52**
Ash	%	4.73	4.75	4.67	4.64	4.70	4.61	4.82	5.05	4.94	5.02	4.35	4.56	**4.72**
TOTAL JBG														
Over burden revoval	1000 bcm	**656**	**611**	**806**	**739**	**761**	**671**	**766**	**941**	**1,016**	**1,336**	**1,276**	**1,271**	**10,850**
Coal Mine	1000 tons	**185**	**189**	**246**	**219**	**219**	**203**	**91**	**109**	**126**	**140**	**141**	**134**	**2,000**
CV	Kcal/kg	**5,340**	**5,323**	**5,312**	**5,319**	**5,272**	**5,309**	**5,283**	**5,273**	**5,320**	**5,308**	**5,392**	**5,367**	**5,318**
TS	%	**0.64**	**0.59**	**0.54**	**0.59**	**0.62**	**0.52**	**0.46**	**0.45**	**0.32**	**0.34**	**0.39**	**0.47**	**0.52**
Ash	%	**4.73**	**4.75**	**4.67**	**4.64**	**4.70**	**4.61**	**4.82**	**5.05**	**4.94**	**5.02**	**4.35**	**4.56**	**4.72**

46

Table 4-4: EMB Annual Production Plan

EMB Mine	Unit	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
NORTH AREA														
Over burden revoval	1000 bcm	704	705	704	736	730	719	746	748	751	749	744	799	**8,837**
Coal Mine	1000 tons	81	81	81	85	85	84	88	88	88	88	87	93	**1,028**
CV	Kcal/kg	5,747	5,804	5,834	5,887	5,944	5,960	5,926	5,836	5,880	5,925	5,865	5,763	**5,864**
TS	%	0.19	0.20	0.19	0.16	0.15	0.15	0.15	0.15	0.15	0.16	0.16	0.15	**0.16**
Ash	%	5.80	5.28	5.19	5.70	5.10	4.89	5.41	6.70	6.48	5.91	6.67	8.00	**5.95**
SOUTH AREA														
Over burden revoval	1000 bcm	423	425	460	425	558	541	527	529	525	427	428	387	**5,656**
Coal Mine	1000 tons	48	49	49	51	51	51	53	53	53	53	52	56	**617**
CV	Kcal/kg	5,764	5,801	5,827	5,859	5,896	5,912	5,866	5,883	5,912	5,938	5,885	5,812	**5,864**
TS	%	0.18	0.19	0.18	0.17	0.16	0.15	0.16	0.16	0.16	0.17	0.16	0.16	**0.17**
Ash	%	5.96	5.54	5.12	5.48	5.05	4.80	5.32	5.39	5.23	4.98	5.29	6.29	**5.37**
TOTAL EMB														
Over burden revoval	1000 bcm	**1,128**	**1,130**	**1,165**	**1,160**	**1,288**	**1,260**	**1,273**	**1,277**	**1,277**	**1,176**	**1,172**	**1,186**	**14,492**
Coal Mine	1000 tons	**129**	**130**	**129**	**136**	**135**	**135**	**140**	**141**	**141**	**140**	**139**	**149**	**1,644**
CV	Kcal/kg	**5,754**	**5,803**	**5,831**	**5,876**	**5,926**	**5,942**	**5,904**	**5,853**	**5,892**	**5,930**	**5,873**	**5,781**	**5,864**
TS	%	**0.19**	**0.20**	**0.19**	**0.16**	**0.15**	**0.15**	**0.16**	**0.16**	**0.15**	**0.16**	**0.16**	**0.15**	**0.16**
Ash	%	**5.86**	**5.38**	**5.16**	**5.61**	**5.08**	**4.86**	**5.38**	**6.21**	**6.01**	**5.56**	**6.15**	**7.36**	**5.74**

47

The annual production plan of 2010 will be employed in this study in order to apply blending optimization to improve blending plans between mines and also to obtain additional benefits from the blending process. In order to compare additional value from blending, this study is required to examine the operating costs and coal prices for each product type and mine. The next section will address further details concerned with operating costs and coal prices.

4.1.3 Operating Costs

This topic covers the operating costs and how these costs can be estimated. The majority of the operating costs are generated by using annual budgets approved by the management. These budgets are estimated based on analysis and compared with experiences from existing mines. The costs used in the study are based on the reference operating budget for 2010. The operating costs are grouped into the following five major costs:

- Production Costs
- Overburden Removal Costs
- Selling Costs
- Other Costs
- Transportation Costs

The major activities conducted by contractors are drilling and blasting, coal mining, hauling and barging can be explained as follows:

Drilling and Blasting: The overburden material will require drilling and blasting to break the rock. Drilling and blasting will be completed by using drilling machines to drill holes and load blasting agents into drilling holes then blasting.

Overburden Removal: Loading and hauling will be completed by the hydraulic loading dump trucks of mining contractors. Most of the materials will initially be hauled to an outside dump, but some burden will be dumped into the mined-out pits.

Coal Mining: Coal loading and hauling will be completed by the excavator-equipped dump trucks of mining contractor. The coal will be hauled from the pit to a coal stockpile area where it will be dumped and then re-loaded into the coal crusher.

Coal Hauling: The coal hauling contractor will load coal into trucks from the crushing plant to the destination. The coal hauling contractor is also responsible for maintenance of the access/haul road.

Barging: The barging contractors will barge the coal from the coal loading at the mine sites to a vessel or coal terminal.

As mentioned above, the majority of the work carried out by the contractors involves mining, hauling and barging work. The company will supply staff to direct and monitor the mining, coal transport and coal barging contracts and to operate the coal handling facilities. The major operating costs incurred by company operations associated with in-house staff consists of the following:

- Coal crushing, stacking, reclaiming and barge loading operations
- Fuel usage for equipment and machines
- Overhead costs i.e. manning costs at mine sites in Jakarta consisting of manning, marketing and other costs

Coal Crushing and Handling: Coal crushing, conveying and barge loading facilities are operated by in-house staff. Operating costs have been developed for operating labor, maintenance and repair costs (including maintenance and repair labor), and repair parts. The cost estimate for this part will use part of the records from last year's operations as a guideline for the cost estimate.

Fuel Usage for Equipment and Machines: Fuel usage is another major operating cost paid by the company. Fuel usage represents fuel for the generator, all facilities and all machines in this company.

Mine Administration: General and administrative costs include an estimate of all indirect or non-mining operation costs and are composed of the following major items:

- Salaries for administrative personnel
- Flight costs for essential personnel and families
- Costs for office and engineering supplies
- Costs for general automotive expenses, such as pickups, vans and 4x4's
- Bus costs for contractors and owner employees
- Miscellaneous operating expenses
- Health and safety compliance costs
- Consultant fees

Table 4-5 – 4-9 show the operating costs for each mine; the operating costs of four mine sites are shown in the table below.

Table 4-5: Operating Costs for IMM West Area

IMM Mine West Area	Unit	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Production cost	**USD/t FC.sales**	**11.97**	**11.97**	**11.97**	**11.97**	**11.97**	**11.97**	**11.97**	**11.97**	**11.97**	**11.97**	**11.97**	**11.97**
Coal mining cost	USD/t FC.sales	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10
Depreciation and Amortization	USD/t FC.sales	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36
Manning cost	USD/t FC.sales	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
Overhead cost	USD/t FC.sales	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72
Fuel Oil - Operating cost	USD/t FC.sales	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
ROM. Rehandling cost	USD/t FC.sales	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Transportation & Hualing	USD/t FC.sales	3.59	3.59	3.59	3.59	3.59	3.59	3.59	3.59	3.59	3.59	3.59	3.59
Other Variable Cost	USD/t FC.sales	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46
Selling cost	**USD/t FC.sales**	**12.27**	**12.27**	**12.27**	**12.27**	**12.27**	**12.27**	**12.27**	**12.27**	**12.27**	**12.27**	**12.27**	**12.27**
Selling Expenses	USD/t FC.sales	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Load to Vessel	USD/t FC.sales	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Commission	USD/t FC.sales	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62
Demurrage / Dispatch	USD/t FC.sales	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Export Fee	USD/t FC.sales	-	-	-	-	-	-	-	-	-	-	-	-
Agency Fee	USD/t FC.sales	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Royalty	USD/t FC.sales	10.17	10.17	10.17	10.17	10.17	10.17	10.17	10.17	10.17	10.17	10.17	10.17
Other cost	**USD/t FC.sales**	**0.46**	**0.46**	**0.46**	**0.46**	**0.46**	**0.46**	**0.46**	**0.46**	**0.46**	**0.46**	**0.46**	**0.46**
Reclamation Cost	USD/t FC.sales	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Admin Cost	USD/t FC.sales	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36
OB removal cost	**USD/t FC.sales**	**32.96**	**33.62**	**34.01**	**34.45**	**36.16**	**35.99**	**32.97**	**33.48**	**34.73**	**34.81**	**30.61**	**22.79**
OB removal cost	USD/bcm	1.92	1.92	1.92	1.92	1.92	1.92	1.92	1.92	1.92	1.92	1.92	1.92
Blasting and Explosive cost	USD/bcm	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
Net OB removal Cost	USD/bcm	2.16	2.16	2.16	2.16	2.16	2.16	2.16	2.16	2.16	2.16	2.16	2.16
Total production cost	**USD/t FC.sales**	**57.66**	**58.32**	**58.71**	**59.15**	**60.86**	**60.69**	**57.67**	**58.18**	**59.43**	**59.51**	**55.31**	**47.49**

Table 4-6: Operating Costs for IMM East Area

IMM Mine East Area	Unit	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Production cost	**USD/t FC.sales**	**10.22**	**10.22**	**10.22**	**10.22**	**10.22**	**10.22**	**10.22**	**10.22**	**10.22**	**10.22**	**10.22**	**10.22**
Coal mining cost	USD/t FC.sales	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.22
Depreciation and Amortization	USD/t FC.sales	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36
Manning cost	USD/t FC.sales	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
Overhead cost	USD/t FC.sales	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72
Fuel Oil - Operating cost	USD/t FC.sales	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
ROM. Rehandling cost	USD/t FC.sales	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Transportation & Hualing	USD/t FC.sales	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72
Other Variable Cost	USD/t FC.sales	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46
Selling cost	**USD/t FC.sales**	**10.46**	**10.46**	**10.46**	**10.46**	**10.46**	**10.46**	**10.46**	**10.46**	**10.46**	**10.46**	**10.46**	**10.46**
Selling Expenses	USD/t FC.sales	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Load to Vessel	USD/t FC.sales	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Commission	USD/t FC.sales	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62
Demurrage / Dispatch	USD/t FC.sales	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Export Fee	USD/t FC.sales	-	-	-	-	-	-	-	-	-	-	-	-
Agency Fee	USD/t FC.sales	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Royalty	USD/t FC.sales	8.36	8.36	8.36	8.36	8.36	8.36	8.36	8.36	8.36	8.36	8.36	8.36
Other cost	**USD/t FC.sales**	**0.46**	**0.46**	**0.46**	**0.46**	**0.46**	**0.46**	**0.46**	**0.46**	**0.46**	**0.46**	**0.46**	**0.46**
Reclamation Cost	USD/t FC.sales	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Admin Cost	USD/t FC.sales	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36
OB removal cost	**USD/t FC.sales**	**22.54**	**17.09**	**18.83**	**19.34**	**20.11**	**19.72**	**18.47**	**17.95**	**17.94**	**17.76**	**16.90**	**18.30**
OB removal cost	USD/bcm	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97
Blasting and Explosive cost	USD/bcm	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Net OB removal Cost	USD/bcm	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05
Total production cost	**USD/t FC.sales**	**43.69**	**38.23**	**39.97**	**40.48**	**41.25**	**40.86**	**39.61**	**39.09**	**39.08**	**38.91**	**38.04**	**39.44**

52

Table 4-7: Operating Costs for TCM

TCM Mine	Unit	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Production cost	**USD/t FC.sales**	**13.86**	**13.86**	**13.86**	**13.86**	**13.86**	**13.86**	**13.86**	**13.86**	**13.86**	**13.86**	**13.86**	**13.86**
Coal mining cost	USD/t FC.sales	3.03	3.03	3.03	3.03	3.03	3.03	3.03	3.03	3.03	3.03	3.03	3.03
Depreciation and Amortization	USD/t FC.sales	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56
Manning cost	USD/t FC.sales	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36
Overhead cost	USD/t FC.sales	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99
Fuel Oil - Operating cost	USD/t FC.sales	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46
ROM. Rehandling cost	USD/t FC.sales	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49
Transportation & Hualing	USD/t FC.sales	3.23	3.23	3.23	3.23	3.23	3.23	3.23	3.23	3.23	3.23	3.23	3.23
Other Variable Cost	USD/t FC.sales	1.74	1.74	1.74	1.74	1.74	1.74	1.74	1.74	1.74	1.74	1.74	1.74
Selling cost	**USD/t FC.sales**	**22.44**	**22.56**	**22.59**	**22.48**	**22.45**	**22.45**	**22.46**	**22.47**	**22.47**	**22.48**	**22.46**	**22.46**
Barge to vessel	USD/t FC.sales	7.11	7.11	7.11	7.11	7.11	7.11	7.11	7.11	7.11	7.11	7.11	7.11
Port charge	USD/t FC.sales	5.30	5.30	5.30	5.30	5.30	5.30	5.30	5.30	5.30	5.30	5.30	5.30
Other selling cost	USD/t FC.sales	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
Commission	USD/t FC.sales	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26
Demurrage / Dispatch	USD/t FC.sales	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Agency Fee	USD/t FC.sales	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42
Royalty	USD/t FC.sales	9.16	9.28	9.31	9.20	9.16	9.17	9.18	9.18	9.19	9.19	9.18	9.18
Other cost	**USD/t FC.sales**	**0.46**	**0.46**	**0.46**	**0.46**	**0.46**	**0.46**	**0.46**	**0.46**	**0.46**	**0.46**	**0.46**	**0.46**
Reclamation Cost	USD/t FC.sales	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Admin Cost	USD/t FC.sales	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36
OB removal cost	**USD/t FC.sales**	**19.81**	**20.53**	**19.65**	**23.91**	**25.84**	**23.68**	**24.47**	**26.10**	**23.27**	**20.94**	**18.33**	**18.15**
OB removal cost	USD/bcm	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97
Blasting and Explosive cost	USD/bcm	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Net OB removal Cost	USD/bcm	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05
Total production cost	**USD/t FC.sales**	**56.57**	**57.42**	**56.57**	**60.72**	**62.61**	**60.46**	**61.26**	**62.90**	**60.06**	**57.74**	**55.12**	**54.94**

53

Table 4-8: Operating Costs for JBG

JBG Mine	Unit	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Production cost	**USD/t FC.sales**	**14.75**	**14.75**	**14.75**	**14.75**	**14.75**	**14.75**	**14.75**	**14.75**	**14.75**	**14.75**	**14.75**	**14.75**
Coal mining cost	USD/t FC.sales	3.02	3.02	3.02	3.02	3.02	3.02	3.02	3.02	3.02	3.02	3.02	3.02
Depreciation	USD/t FC.sales	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17
Manning cost	USD/t FC.sales	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97
Overhead cost	USD/t FC.sales	3.29	3.29	3.29	3.29	3.29	3.29	3.29	3.29	3.29	3.29	3.29	3.29
Fuel Oil - Operating cost	USD/t FC.sales	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39
ROM. Rehandling cost	USD/t FC.sales	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Contingency	USD/t FC.sales	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Other Variable Cost	USD/t FC.sales	4.34	4.34	4.34	4.34	4.34	4.34	4.34	4.34	4.34	4.34	4.34	4.34
Selling cost	**USD/t FC.sales**	**9.76**	**9.76**	**9.76**	**9.76**	**9.76**	**9.76**	**9.76**	**9.76**	**9.76**	**9.76**	**9.76**	**9.76**
Barging cost	USD/t FC.sales	3.71	3.71	3.71	3.71	3.71	3.71	3.71	3.71	3.71	3.71	3.71	3.71
Selling Expense	USD/t FC.sales	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Commission	USD/t FC.sales	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
Demurrage / Dispatch	USD/t FC.sales	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Stevedore	USD/t FC.sales	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66
Tug berthing	USD/t FC.sales	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Export Fee	USD/t FC.sales	-	-	-	-	-	-	-	-	-	-	-	-
Agency Fee	USD/t FC.sales	-	-	-	-	-	-	-	-	-	-	-	-
Royalty	USD/t FC.sales	4.87	4.87	4.87	4.87	4.87	4.87	4.87	4.87	4.87	4.87	4.87	4.87
Other cost	**USD/t FC.sales**	**1.17**	**1.17**	**1.17**	**1.17**	**1.17**	**1.17**	**1.17**	**1.17**	**1.17**	**1.17**	**1.17**	**1.17**
Reclamation Cost	USD/t FC.sales	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Admin Cost	USD/t FC.sales	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
OB removal cost	**USD/t FC.sales**	**5.96**	**5.43**	**5.52**	**5.68**	**5.85**	**5.57**	**14.14**	**14.50**	**13.55**	**16.03**	**15.20**	**15.93**
OB removal cost	USD/bcm	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68
Blasting and Explosive cost	USD/bcm	-	-	-	-	-	-	-	-	-	-	-	-
Net OB removal Cost	USD/bcm	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68
Total production cost	**USD/t FC.sales**	**31.63**	**31.10**	**31.19**	**31.36**	**31.52**	**31.24**	**39.82**	**40.18**	**39.22**	**41.71**	**40.88**	**41.61**

54

Table 4-9: Operating Costs for EMB

EMB Mine	Unit	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Production cost	**USD/t FC.sales**	**9.04**	**9.04**	**9.04**	**9.04**	**9.04**	**9.04**	**9.04**	**9.04**	**9.04**	**9.04**	**9.04**	**9.04**
Coal mining cost	USD/t FC.sales	1.84	1.84	1.84	1.84	1.84	1.84	1.84	1.84	1.84	1.84	1.84	1.84
Depreciation	USD/t FC.sales	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29
Manning cost	USD/t FC.sales	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54
Overhead cost	USD/t FC.sales	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
Fuel Oil - Operating cost	USD/t FC.sales	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56
ROM. Rehandling cost	USD/t FC.sales	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Transportation & Hualing	USD/t FC.sales	-	-	-	-	-	-	-	-	-	-	-	-
Other Variable Cost	USD/t FC.sales	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32
Selling cost	**USD/t FC.sales**	**14.96**	**14.96**	**14.96**	**14.96**	**14.96**	**14.96**	**14.96**	**14.96**	**14.96**	**14.96**	**14.96**	**14.96**
Barging cost	USD/t FC.sales	6.55	6.55	6.55	6.55	6.55	6.55	6.55	6.55	6.55	6.55	6.55	6.55
Selling Expense	USD/t FC.sales	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31
Commission	USD/t FC.sales	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Demurrage / Dispatch	USD/t FC.sales	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Royalty	USD/t FC.sales	7.25	7.25	7.25	7.25	7.25	7.25	7.25	7.25	7.25	7.25	7.25	7.25
Other cost	**USD/t FC.sales**	**1.73**	**1.73**	**1.73**	**1.73**	**1.73**	**1.73**	**1.73**	**1.73**	**1.73**	**1.73**	**1.73**	**1.73**
Reclamation Cost	USD/t FC.sales	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Admin Cost	USD/t FC.sales	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43
OB removal cost	**USD/t FC.sales**	**21.19**	**21.19**	**21.86**	**20.79**	**23.14**	**22.71**	**22.05**	**22.05**	**22.05**	**20.32**	**20.44**	**19.32**
OB removal cost	USD/bcm	2.43	2.43	2.43	2.43	2.43	2.43	2.43	2.43	2.43	2.43	2.43	2.43
Blasting and Explosive cost	USD/bcm	-	-	-	-	-	-	-	-	-	-	-	-
Net OB removal Cost	USD/bcm	2.43	2.43	2.43	2.43	2.43	2.43	2.43	2.43	2.43	2.43	2.43	2.43
Total production cost	**USD/t FC.sales**	**46.92**	**46.92**	**47.59**	**46.52**	**48.87**	**48.45**	**47.79**	**47.79**	**47.79**	**46.06**	**46.17**	**45.06**

55

In summary, the operating costs are based on the budget approval for 2010. These operating costs will be used for calculating the company's financial statement both before the additional blending program and after the additional blending program for comparison. Once the operating costs of the mines are understood, the next section will discuss the coal prices to be used for calculating the company's revenue in order to calculate the company's financial statement.

4.1.4 Coal Price Assumptions.

A large amount of coal being traded is sea-borne trade. The sea-borne market is the market this company is planning to supply with its product. The market is segmented into industries which utilize the coal and the regions in which the plants are located. General categorizations of the industries consuming this coal are as follows:

- Power Generation Industry
- Steel Making Industry
- General Industries, such as cement plants, chemical plants, etc.

Each of the above industries demands specific types of coal, depending upon the technology utilized in the plant. In general, the specifications of this coal for each of the industries, falls within a certain range of heating value, percent of sulfur content and percent of ash content.

The market is also segmented into two main regions, namely the Pacific and Atlantic Regions. Countries within the Pacific Region, such as China, Japan, Korea, South East Asia, Indonesia, and Australia, are on the fringe of the Pacific Ocean. The Atlantic Region includes countries on the fringe of the Atlantic Ocean, such as Europe, including the Mediterranean, East Africa and Eastern America. These regions have been based on the natural locations of these countries with respect to both of the Oceans.

The Marketing and Logistics team which is responsible for selling coal products has considerable experience in these diverse markets. The group has a network of relationships with its customers and traders since the group has been selling its existing products from its operating mines, such as Indominco, Trubaindo, Embalut and Jorong products, since 1997 and beyond. It has gathered information and responded to potential clients, especially potential customers from power generation in the Pacific Region.

As a result of globalization trends, coal price history is continually evolving. Figure 4-5 shows the history pricing of thermal coals base on international standards.

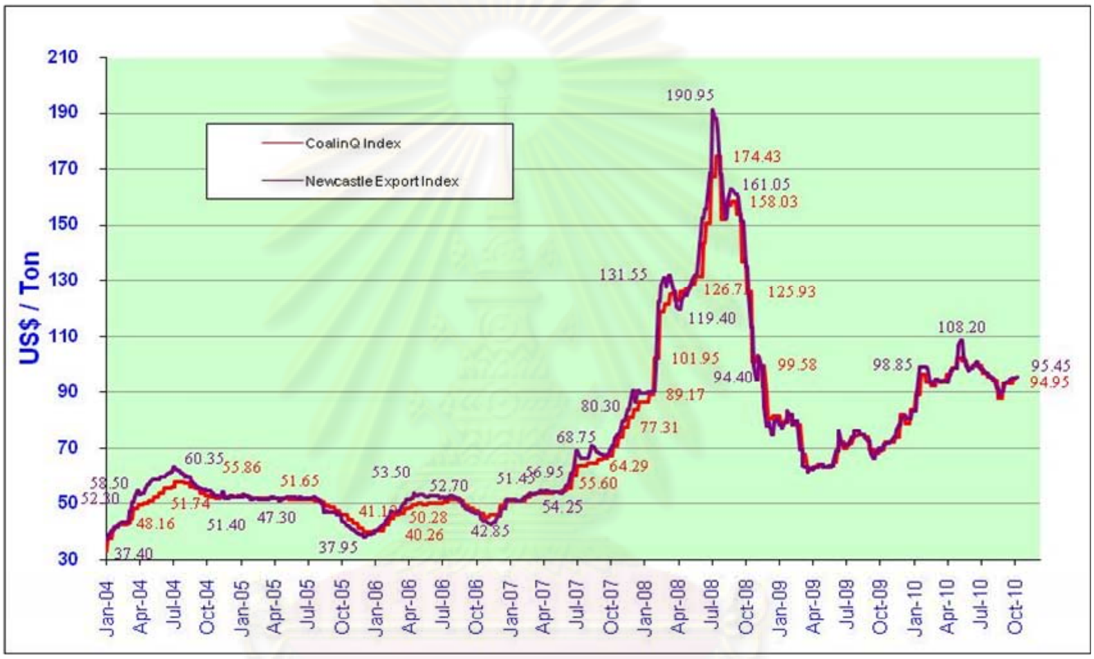


Figure 4-4: Thermal Coal Pricing History

Source: BANPU Public Company

Figure 4-4 above also shows pricing for different types of contracts in relation to a benchmark or a reference price as shown in Figure. 4-5 the contract types are

- Coalin Q Spot Price, FOBT Newcastle
- Newcastle Export Index, FOBT Newcastle to Japan

Coal pricing for this coal company has been estimated based on international benchmark and past experience of selling coal from existing mines. The coal price that was forecasted to be selling for this company can separate into 7 types which have difference coal specification. The coal price and specification in each product type can explain as list below;

- JPU product has minimum heating value 6,700 kcal/kg. and maximum heating value 6,800 kcal/kg while minimum sulfur content is 0.7 % and maximum sulfur content is 0.9%. This product was forecasted to sell at price 85.0 USD per tons

- CV 6300 product has minimum heating value 6,250 kcal/kg. and maximum heating value 6,350 kcal/kg while minimum sulfur content is 0.7 % and maximum sulfur content is 0.9%. This product was forecasted to sell at price 76.3 USD per tons

- HCV HS product has minimum heating value 6,950 kcal/kg. and maximum heating value 7,050 kcal/kg while minimum sulfur content is 1.7 % and maximum sulfur content is 1.9%. This product was forecasted to sell at price 81.0 USD per tons

- MCV product has minimum heating value 6,450 kcal/kg. and maximum heating value 6,550 kcal/kg while minimum sulfur content is 0.7 % and maximum sulfur content is 0.9%. This product was forecasted to sell at price 80.0 USD per tons

- IMM East Block product has minimum heating value 5,950 kcal/kg. and maximum heating value 6,050 kcal/kg while minimum sulfur content is 1.7 % and maximum sulfur content is 1.9%. This product was forecasted to sell at price 62.9 USD per tons

- JBG product has minimum heating value 5,250 kcal/kg. and maximum heating value 5,350 kcal/kg while minimum sulfur content is 0.45 % and maximum sulfur content is 0.65 %. This product was forecasted to sell at price 39.9 USD per tons

- EMB product has minimum heating value 5,750 kcal/kg. and maximum heating value 5,850 kcal/kg while minimum sulfur content is 0.2 % and maximum sulfur content is 0.4 %. This product was forecasted to sell at price 61.3 USD per tons

Table 4-10 illustrates coal price estimation for this company product.

		Unit	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
JPU														
	Price	USD	**85.00**	**85.00**	**85.00**	**85.00**	**85.00**	**85.00**	**85.00**	**85.00**	**85.00**	**85.00**	**85.00**	**85.00**
	CV	Kcal/kg	6,800	6,800	6,800	6,800	6,800	6,800	6,800	6,800	6,800	6,800	6,800	6,800
Maximum	TS	%	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
	Ash	%	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50
	CV	Kcal/kg	6,750	6,750	6,750	6,750	6,750	6,750	6,750	6,750	6,750	6,750	6,750	6,750
Spec	TS	%	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
	Ash	%	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50
	CV	Kcal/kg	6,700	6,700	6,700	6,700	6,700	6,700	6,700	6,700	6,700	6,700	6,700	6,700
Minimum	TS	%	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
	Ash	%	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50
CV6300														
	Price	USD	**76.30**	**76.30**	**76.30**	**76.30**	**76.30**	**76.30**	**76.30**	**76.30**	**76.30**	**76.30**	**76.30**	**76.30**
	CV	Kcal/kg	6,350	6,350	6,350	6,350	6,350	6,350	6,350	6,350	6,350	6,350	6,350	6,350
Maximum	TS	%	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
	Ash	%	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50
	CV	Kcal/kg	6,300	6,300	6,300	6,300	6,300	6,300	6,300	6,300	6,300	6,300	6,300	6,300
Spec	TS	%	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
	Ash	%	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50
	CV	Kcal/kg	6,250	6,250	6,250	6,250	6,250	6,250	6,250	6,250	6,250	6,250	6,250	6,250
Minimum	TS	%	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
	Ash	%	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50
HCV.HS														
	Price	USD	**81.00**	**81.00**	**81.00**	**81.00**	**81.00**	**81.00**	**81.00**	**81.00**	**81.00**	**81.00**	**81.00**	**81.00**
	CV	Kcal/kg	7,050	7,050	7,050	7,050	7,050	7,050	7,050	7,050	7,050	7,050	7,050	7,050
Maximum	TS	%	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90
	Ash	%	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50
	CV	Kcal/kg	7,000	7,000	7,000	7,000	7,000	7,000	7,000	7,000	7,000	7,000	7,000	7,000
Spec	TS	%	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80
	Ash	%	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50
	CV	Kcal/kg	6,950	6,950	6,950	6,950	6,950	6,950	6,950	6,950	6,950	6,950	6,950	6,950
Minimum	TS	%	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70
	Ash	%	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50
MCV														
	Price	USD	**80.00**	**80.00**	**80.00**	**80.00**	**80.00**	**80.00**	**80.00**	**80.00**	**80.00**	**80.00**	**80.00**	**80.00**
	CV	Kcal/kg	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550	6,550
Maximum	TS	%	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
	Ash	%	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50
	CV	Kcal/kg	6,500	6,500	6,500	6,500	6,500	6,500	6,500	6,500	6,500	6,500	6,500	6,500
Spec	TS	%	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
	Ash	%	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50
	CV	Kcal/kg	6,450	6,450	6,450	6,450	6,450	6,450	6,450	6,450	6,450	6,450	6,450	6,450
Minimum	TS	%	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
	Ash	%	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50
IMM East Block														
	Price	USD	**62.90**	**62.90**	**62.90**	**62.90**	**62.90**	**62.90**	**62.90**	**62.90**	**62.90**	**62.90**	**62.90**	**62.90**
	CV	Kcal/kg	6,050	6,050	6,050	6,050	6,050	6,050	6,050	6,050	6,050	6,050	6,050	6,050
Maximum	TS	%	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90
	Ash	%	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50
	CV	Kcal/kg	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000
Spec	TS	%	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80
	Ash	%	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50
	CV	Kcal/kg	5,950	5,950	5,950	5,950	5,950	5,950	5,950	5,950	5,950	5,950	5,950	5,950
Minimum	TS	%	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70
	Ash	%	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50
JBG														
	Price	USD	**39.90**	**39.90**	**39.90**	**39.90**	**39.90**	**39.90**	**39.90**	**39.90**	**39.90**	**39.90**	**39.90**	**39.90**
	CV	Kcal/kg	5,350	5,350	5,350	5,350	5,350	5,350	5,350	5,350	5,350	5,350	5,350	5,350
Maximum	TS	%	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65
	Ash	%	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50
	CV	Kcal/kg	5,300	5,300	5,300	5,300	5,300	5,300	5,300	5,300	5,300	5,300	5,300	5,300
Spec	TS	%	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
	Ash	%	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50
	CV	Kcal/kg	5,250	5,250	5,250	5,250	5,250	5,250	5,250	5,250	5,250	5,250	5,250	5,250
Minimum	TS	%	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
	Ash	%	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50
EMB														
	Price	USD	**61.30**	**61.30**	**61.30**	**61.30**	**61.30**	**61.30**	**61.30**	**61.30**	**61.30**	**61.30**	**61.30**	**61.30**
	CV	Kcal/kg	5,850	5,850	5,850	5,850	5,850	5,850	5,850	5,850	5,850	5,850	5,850	5,850
Maximum	TS	%	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
	Ash	%	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50
	CV	Kcal/kg	5,800	5,800	5,800	5,800	5,800	5,800	5,800	5,800	5,800	5,800	5,800	5,800
Spec	TS	%	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
	Ash	%	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50
	CV	Kcal/kg	5,750	5,750	5,750	5,750	5,750	5,750	5,750	5,750	5,750	5,750	5,750	5,750
Minimum	TS	%	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
	Ash	%	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50

According to table 4-10, the coal price forecast of this company is divided into several products. Each product has different coal specifications. The coal pricing for this study will use estimated coal price information from the marketing team in order to calculate revenue for the company. Coal pricing will use the international benchmark as a guideline. The most important coal specifications aimed at increased or decreased pricing is the heating value. The marketing team will use past experience to evaluate coal prices from existing products by comparing heating value with the international benchmark.

4.1.5 Coal Loading to Vessel Facilities

This topic outlines the facilities capacity for loading coal into vessels. This section of the coal chain is critical to meeting the quantity and quality of the coal being shipped to customers. The coals from mine are delivered to coal loading facilities by barging and trucking. The coal was planned to transport from four mines to coal loading facilities. There are 5 locations for loading coal to vessels for this study. Figure 4-6 show the coal loading to vessel facilities. The coal loading to vessel facilities namely Muara Jawa, Muara Berau, Jorong, Bct and Boct location

Each coal loading facility has a different coal loading rate. The coal loading capacities vary from 500 tons/hr to 3300 tons/ hr. depending upon the capacity of the facility. The coal loading capacity for each location is shown in Table 4-11 below.

Table 4-11 Coal Loading Capacity

Coal Loading to vessel	Unit	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Muara Jawa	K.ton	250	250	250	250	250	250	250	250	250	250	250	250
Muara Berau	K.ton	250	250	250	250	250	250	250	250	250	250	250	250
Jorong	K.ton	250	250	250	250	250	250	250	250	250	250	250	250
Bct	K.ton	500	500	500	500	500	500	500	500	500	500	500	500
Boct	K.ton	1700	1700	1700	1700	1700	1700	1700	1700	1700	1700	1700	1700

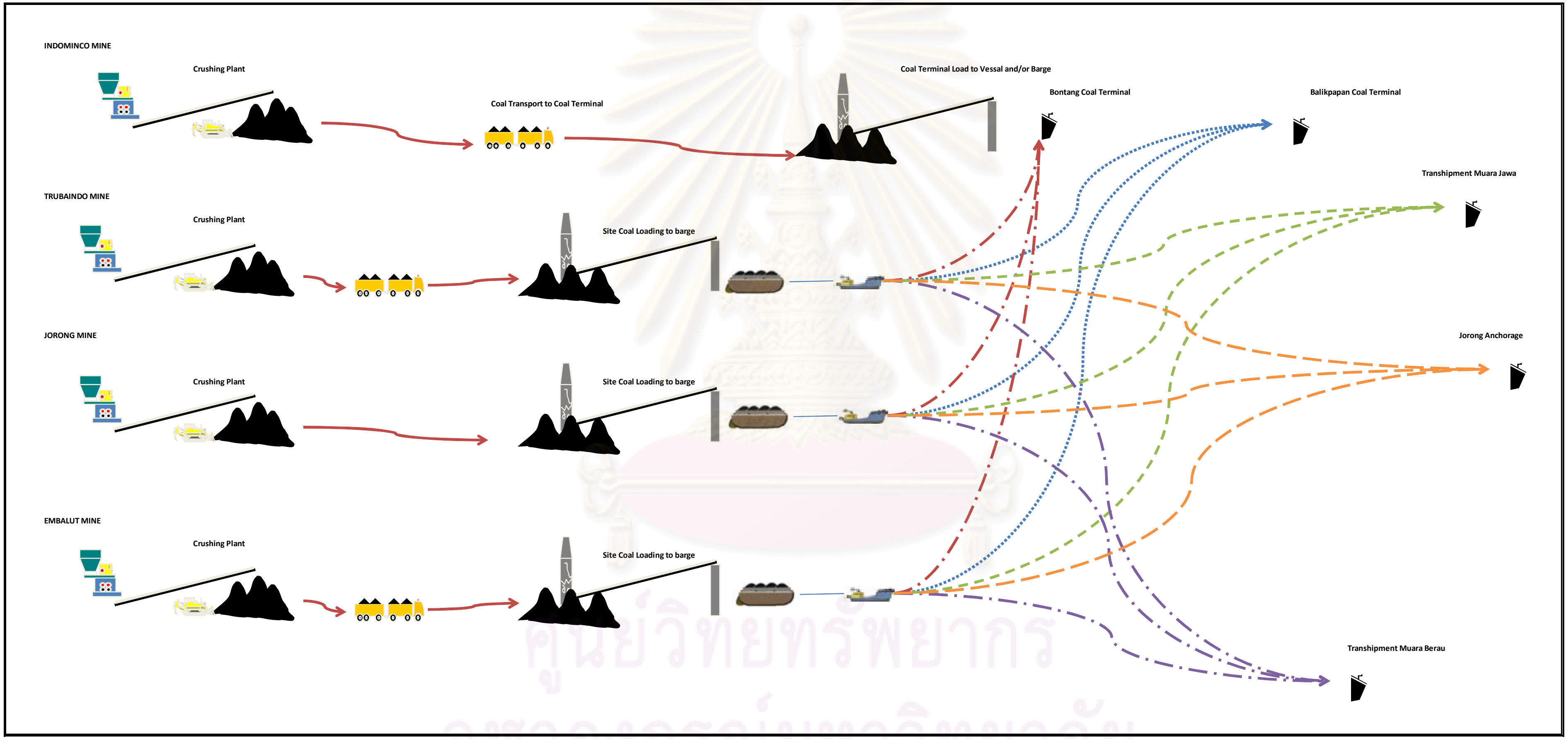


Figure 4-5: Coal Loading to Vessel Facilities

In summary, each coal loading facility has a different loading capacity. These are constraints which this study must consider in order to manage the coal blending program. This study will employ given information on loading capacity from this company for calculating optimization blending scenarios.

4.1.6 Coal Transportation

The coal transportation in this study will be related to the transportation of coal from mine to coal loading to vessel facility. Coal transportation from the mine to vessel loading by barges is a major concern for this study. There are cost estimate for transport coal from mine to each coal loading to vessel facility which will be used for calculate transportation cost. . Each mine has different coal transport cost structures. The detail of transportation cost for each mine to each coal loading to vessel show in **Appendix.** This study will employ given information on transportation costs for this company to calculate optimization blending scenarios.

4.1.7 Financial Evaluation

The financial analysis attempts to show financial indicators of this study. For the present study, EBIT will be used as the main indicator. Some major assumptions have been made during the analysis. These assumptions are generally outlined by BANPU's Corporate, or general rules in Indonesia. Costs parameters are also outlined.

Assumptions of the Analysis

The financial analysis has adopted some major assumptions as follows:

- Base year to be Year 2010
- Coal price is based on the coal price forecast as shown in the coal price assumption chapter
- The cost of capital will use depreciation in order to calculate financial analysis
- Royalty payment is 13.5% of the price of coal at port (ie. Selling Price – barging and trans-shipment costs)

All of the above parameters will be used in the financial analysis

Cash-flow Methodology

The cash-flow is defined in the following steps,

Total Revenue *= Tonnage x sale price/ton*

Revenue FOB *= Total Revenue - Barging and Trans-shipment Costs*

Revenue after Royalty *= Total Revenue – Revenue FOB x 13.5%*

Income before Tax (EBIT) *= Revenue after Royalty – Operating costs.*

Cash-flow Schedule

The cash-flow in Table 4-12 shows the outcomes of the financial analysis. The major results of the analysis are the EBIT for each mine and the total EBIT based on existing operations for the company studied is 451 million USD.

Table 4-12: EBIT of Existing Operations

IMM Mine West Area	Unit	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Total
Revenue	1000 USD.	58,518	54,120	59,181	57,726	60,425	57,014	58,531	60,007	52,846	57,692	56,010	54,744	686,814
Production cost	1000 USD.	9,180	8,490	9,284	9,055	9,479	8,944	9,182	9,413	8,290	9,050	8,786	8,588	107,739
Selling cost	1000 USD.	9,408	8,701	9,514	9,280	9,715	9,166	9,410	9,647	8,496	9,275	9,005	8,801	110,418
Other cost	1000 USD.	356	329	360	351	367	347	356	365	321	351	341	333	4,177
OB removal cost	1000 USD.	25,280	23,845	26,377	26,066	28,638	26,897	25,293	26,334	24,056	26,321	22,470	16,351	297,926
EBIT	1000 USD.	14,295	12,756	13,646	12,973	12,227	11,661	14,290	14,248	11,683	12,695	15,409	20,671	166,556

IMM Mine East Area	Unit	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Total
Revenue	1000 USD.	14,444	17,854	19,219	22,113	22,100	23,476	27,190	31,694	31,928	33,743	34,853	28,908	307,521
Production cost	1000 USD.	2,347	2,901	3,123	3,593	3,591	3,814	4,418	5,150	5,188	5,483	5,663	4,697	49,965
Selling cost	1000 USD.	2,401	2,968	3,195	3,677	3,674	3,903	4,520	5,269	5,308	5,610	5,795	4,806	51,128
Other cost	1000 USD.	107	132	142	163	163	173	201	234	236	249	257	213	2,268
OB removal cost	1000 USD.	5,177	4,851	5,753	6,800	7,067	7,359	7,983	9,043	9,104	9,529	9,365	8,409	90,441
EBIT	1000 USD.	4,412	7,002	7,006	7,881	7,605	8,226	10,068	11,998	12,092	12,872	13,773	10,782	113,718

TCM Mine	Unit	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Total
Revenue	1000 USD.	41,143	42,102	46,437	40,057	40,078	43,156	43,122	41,853	42,258	41,638	41,911	42,073	505,828
Production cost	1000 USD.	7,091	7,174	7,895	6,875	6,903	7,430	7,416	7,194	7,264	7,153	7,208	7,236	86,838
Selling cost	1000 USD.	11,479	11,678	12,865	11,152	11,178	12,034	12,018	11,661	11,774	11,597	11,681	11,726	140,843
Other cost	1000 USD.	237	240	264	230	231	249	248	241	243	239	241	242	2,907
OB removal cost	1000 USD.	10,132	10,623	11,192	11,858	12,867	12,691	13,090	13,548	12,192	10,806	9,531	9,474	138,006
EBIT	1000 USD.	12,203	12,387	14,221	9,941	8,898	10,752	10,350	9,208	10,785	11,843	13,249	13,395	137,234

JBG Mine	Unit	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Total
Revenue	1000 USD.	7,382	7,541	9,795	8,718	8,718	8,080	3,631	4,349	5,027	5,586	5,626	5,347	79,800
Production cost	1000 USD.	2,728	2,787	3,621	3,222	3,222	2,986	1,342	1,608	1,858	2,065	2,079	1,976	29,496
Selling cost	1000 USD.	1,805	1,844	2,396	2,132	2,132	1,976	888	1,064	1,230	1,366	1,376	1,308	19,516
Other cost	1000 USD.	216	221	287	255	255	236	106	127	147	163	165	156	2,336
OB removal cost	1000 USD.	1,102	1,026	1,354	1,242	1,278	1,127	1,287	1,581	1,707	2,244	2,144	2,135	18,228
EBIT	1000 USD.	1,530	1,662	2,138	1,867	1,830	1,754	8	(30)	86	(253)	(138)	(229)	10,225

EMB Mine	Unit	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Total
Revenue	1000 USD.	7,924	7,943	7,934	8,312	8,290	8,262	8,593	8,619	8,619	8,612	8,541	9,139	100,788
Production cost	1000 USD.	1,169	1,172	1,170	1,226	1,223	1,219	1,268	1,271	1,271	1,270	1,260	1,348	14,867
Selling cost	1000 USD.	1,934	1,938	1,936	2,029	2,023	2,016	2,097	2,103	2,103	2,102	2,084	2,230	24,596
Other cost	1000 USD.	224	225	224	235	234	234	243	244	244	243	241	258	2,849
OB removal cost	1000 USD.	2,739	2,746	2,829	2,818	3,129	3,061	3,092	3,101	3,101	2,855	2,847	2,880	35,198
EBIT	1000 USD.	1,858	1,863	1,774	2,004	1,681	1,732	1,894	1,900	1,900	2,141	2,108	2,422	23,277
Total EBIT	1000 USD.	34,299	35,670	38,785	34,666	32,241	34,125	36,609	37,324	36,546	39,299	44,401	47,041	451,009

In summary, the company studied expects to yield EBIT amounting to approximately 451 million USD from the production plan for 2010. This EBIT will be used to compare with the additional blending operations suggested by this study to increase the value from the blending program. The next section discusses coal blending modeling and results from the optimization calculation for blending.

4.2 Modeling Concept

As mentioned in Chapter 3, numerous optimization algorithms are available, but some methods are limited to only certain types of problems. Generally speaking, the mathematical characteristics of the objective function, limitations and controllable decision variables are used to classify optimization problems. The next section of this study explains the coal blending model concept along with its objective function,decision variables and limitations as well as the dynamic coal blending procedures.

4.2.1 Coal Blending Problem

Blending problem occur in various industries such as in the petroleum, chemical, food industry and etc. For coal blending problem, the wide range of studies has been done as mentioned in Chapter 3. However, in this thesis study focus on production and transportation part. With different prices of products, the objective of the problem is to decide how to blend two or more resources to produce one more products which satisfy product specifications and product demands at maximize profit.

In the system considered here, various raw coal materials will be blended to be final products and the remaining of raw coal will sell in direct sale product. Every product will have specification both in term of quality and quantity. As it is assumed that continuous production process for delivering, there is no lead-time considering and no limited capacity for transportation mode. There are nine items of raw coal, five blending ports and seven type of coal product for blend. The capacity of blending port is limited by availability of its maximum capacity.

In summary, the blending model for this studied company has several limitations and constraints for coal blending from various sources. Starting from the blending source, there is a limitation on the amount of coal production from the production side. The coal loading capacity can also be a constraint requiring consideration for creating a blending plan. There are limitations to the coal loading rate at each type of coal loading area. Moreover the requirements of coal quality specifications from customers represent another constraint for blending operations. The coal quality specifications have many items to control. In company studied, the main coal quality items used for controlling the coal blending quality specifications are calorific value and percent sulfur content. The blending operations need to blend coal to meet the requirements of customers in order to obtain maximum benefit from the blending program. This case study addresses the objective function, decision variables and limitations illustrated below.

4.2.1.1 Assumptions and Notation

As mentioned in chapter 1, the research will use the existing information of annual production, sale plan, operating costs of each mine site including coal price forecast to evaluate profit of the company. After that, the linear programming will be applied in order to calculate optimize sale plan based on product mixed between mine to get the higher profit for the company. The quality of product can be calculated as product mixed or weighted average by given maximum or minimum of coal specification. The assumptions of this study can list as below;

1. The production capacity, the coal loading capacity on each location, and all unit costs are assumed to be known.
2. The operating cost is per unit per time and is assumed to be known.
3. The varying price and the availability of raw materials are assumed to be known.
4. The material and product characteristics are assumed to be known.
5. The quality specifications are assumed to be known.
6. Blended quality can calculate as weighted average.
7. Coal inventory not considered in this model.
8. Reworks, defects or repairs are not considered in this model.
9. There are single blended product can be produced in a period.
10. A workstation for coal blending can operate only one product.

There are the notations which use in this study as follow;

p represents the coal blend product, whereby $p = \{1,...,7\}$

m represents the coal from mining area, whereby $m = \{1,...,9\}$

$port$ represents the coal loading area, whereby $port = \{1,...,5\}$

t represents the period for blend coal, whereby $t = \{1,...,12\}$

$Price_{p,m,t}$ = Coal Price of product ‘p’ from mine ‘m’ in period ‘t’

$X^{B}_{p,m,port,t}$ = Coal tonnage for blended product ‘p’ from mine ‘m’ at coal loading area ‘port’ and mine in period ‘t’

$X^{S}_{p,m,port,t}$ = Coal tonnage for direct sale product ‘p’ from mine ‘m’ at coal loading area ‘port’ and mine in period ‘t’

$TotalCost^{B}_{p,m,port,t}$ = Total cost of coal for blend product ‘p’ from mine ‘m’ at coal loading area ‘port’ and mine in period ‘t’

$TotalCost^{S}_{p,m,port,t}$ = Total cost of coal for direct sale product ‘p’ from mine ‘m’ at coal loading area ‘port’ and mine in period ‘t’

$Production_{m,t}$ = Coal production from mine ‘m’ in period ‘t’

$Coalloading_{port,t}$ = Coal loading capacity at port ‘port’ in period ‘t’

$CV_{p,m,port,t}$ = Heating value of blend product ‘p’ from mine ‘m’ at coal loading area ‘port’ and mine in period ‘t’

$Sul_{p,m,port,t}$ = Percent sulfur content of blend product ‘p’ from mine ‘m’ at coal loading area ‘port’ and mine in period ‘t’

$MaxCVProduct_{p,t}$ = Maximum CV for blended product for product ‘p’ in period ‘t’

$MinCVProduct_{p,t}$ = Minimum CV for blended product for product ‘p’ in period ‘t’

$MaxSulProduct_{p,t}$ = Maximum Sul for blended product for product ‘p’ in period ‘t’

$MinSulProduct_{p,t}$ = Minimum Sul for blended product for product ‘p’ in period ‘t’

4.2.1.2 Objective function

Profit maximization them becomes an objective function of this linear programming model. The linear programming model stipulates that the blending plan should be operated to achieve maximal profit while all other limitations involved remain fully covered.

$$Max\,Profit = \sum_{p,m,port,t} (Price_{p,m,t} - TotalCost^{B}_{p,m,port,t}) * X^{B}_{p,m,port,t} + \sum_{p,m,port,t} (Price_{p,m,t} - TotalCost^{S}_{p,m,port,t}) * X^{S}_{p,m,port,t}$$

Where,

$Price_{p,m,t}$ = Coal Price of product 'p' from mine 'm' in period 't'

$X^{B}_{p,m,port,t}$ = Coal tonnage for blended product 'p' from mine 'm' at coal loading area 'port' and mine in period 't'

$X^{S}_{p,m,port,t}$ = Coal tonnage for direct sale product 'p' from mine 'm' at coal loading area 'port' and mine in period 't'

$TotalCost^{B}_{p,m,port,t}$ = Total cost of coal for blend product 'p' from mine 'm' at coal loading area 'port' and mine in period 't'

$TotalCost^{S}_{p,m,port,t}$ = Total cost of coal for direct sale product 'p' from mine 'm' at coal loading area 'port' and mine in period 't'

4.2.1.3 Decision Variable

Decision variables have been varied in order to determine an optimal solution. In this case, the model requiring a solution is the coal tonnage (IMM, TCM, JBG and EMB) from each mine to each coal loading point in order to blend each type of blending product on a monthly schedule. The destinations of coal loading in this case are Maura Java, Maura Berau, Jorong, Boct and Bct.

Where,

$X^{B}_{p,m,port,t}$ = Coal tonnage for blended product 'p' from mine 'm' at coal loading area 'port' and mine in period 't'

$X^{S}_{p,m,port,t}$ = Coal tonnage for direct sale product 'p' from mine 'm' at coal loading area 'port' and mine in period 't'

4.2.1.4 Represent Constraints

In this case, the limitations have been categorized into 4 main groups, namely, tonnage of coal production from the mine must follow the production plan; coal loading capability is not exceeded; specifications for the blending product must range from the product type specification and the non-negative limitations of the variable. All the constraints can be described in terms of linear expression as follows:

Balance Constraints

In balance constraints, the amount of coal tonnage for coal blending must be less than or equal to the production plan from operations at each mine on a monthly basis.

$$\sum_{p,port} (X^{B}_{p,m,port,t} + X^{S}_{p,m,port,t}) = \mathrm{Pr}oduction_{m,t} \forall m,t$$

Where,

$X^{B}_{p,m,port,t}$ = Coal tonnage for blended product ‘p’ from mine ‘m’ at coal loading area ‘port’ and mine in period ‘t’

$X^{S}_{p,m,port,t}$ = Coal tonnage for direct sale product ‘p’ from mine ‘m’ at coal loading area ‘port’ and mine in period ‘t’

$Production_{m,t}$ = Coal production from mine ‘m’ in period ‘t’

Loading Capacity Constraints

The coal loading capacity constraint is given to the constraint of the maximum amount coal loading capacity provided per month.

$$\sum_{p,m} (X^{B}_{p,m,port,t} + X^{S}_{p,m,port,t}) \le Coalloading_{port,t}; \forall port,t$$

Where,

$Coalloading_{port,t}$ = Coal loading capacity at port ‘port’ in period ‘t’

$X^{B}_{p,m,port,t}$ = Coal tonnage for blended product ‘p’ from mine ‘m’ at coal loading area ‘port’ and mine in period ‘t’

$X^{S}_{p,m,port,t}$ = Coal tonnage for direct sale product ‘p’ from mine ‘m’ at coal loading area ‘port’ and mine in period ‘t’

Coal Specification Constraints

The coal specification constraints for this coal blending model employ two types of quality specifications for consideration. The heating value and the percent sulfur content are constraints for optimization calculation whereby the coal specifications of the blended coal must be greater than the minimum specifications and less than the maximum specifications for each product type.

$$\sum_{m}(CV_{p,m,port,t} * X^{B}_{p,m,port,t}) \leq MaxCV\,\mathrm{Pr}oduct_{p,t} * \sum_{m} X^{B}_{p,m,port,t}; \forall p, port, t$$

$$\sum_{m}(CV_{p,m,port,t} * X^{B}_{p,m,port,t}) \geq MinCV\,\mathrm{Pr}oduct_{p,t} * \sum_{m} X^{B}_{p,m,port,t}; \forall p, port, t$$

$$\sum_{m}(Sul_{p,m,port,t} * X^{B}_{p,m,port,t}) \leq MaxSul\,\mathrm{Pr}oduct_{p,t} * \sum_{m} X^{B}_{p,m,port,t}; \forall p, port, t$$

$$\sum_{m}(Sul_{p,m,port,t} * X^{B}_{p,m,port,t}) \geq MinSul\,\mathrm{Pr}oduct_{p,t} * \sum_{m} X^{B}_{p,m,port,t}; \forall p, port, t$$

Where,

$X^{B}_{p,m,port,t}$ = Coal tonnage for blended product ‘p’ from mine ‘m’ at coal loading area ‘port’ and mine in period ‘t’

$CV_{p,m,port,t}$ = Heating value of blend product ‘p’ from mine ‘m’ at coal loading area ‘port’ and mine in period ‘t’

$Sul_{p,m,port,t}$ = Percent sulfur content of blended product ‘p’ from mine ‘m’ at coal loading area ‘port’ and mine in period ‘t’

$MaxCVProduct_{p,t}$ = Maximum CV for blended product for product ‘p’ in period ‘t’

$MinCVProduct_{p,t}$ = Minimum CV for blended product for product ‘p’ in period ‘t’

$MaxSulProduct_{p,t}$ = Maximum Sul for blended product for product ‘p’ in period ‘t’

$MinSulProduct_{p,t}$ = Minimum Sul for blended product for product ‘p’ in period ‘t’

Non-negative Constraint

The coal tonnage for blending product and coal tonnage for direct sale products must be greater than zero

$$X^{B}_{p,m,port,t} \geq 0; \forall p, m, port, t$$
$$X^{S}_{p,m,port,t} \geq 0; \forall p, m, port, t$$

Where,

$X^{B}_{p,m,port,t}$ = Coal tonnage for blended product ‘p’ from mine ‘m’ at coal loading area ‘port’ and mine in period ‘t’

$X^{S}_{p,m,port,t}$ = Coal tonnage for direct sale product ‘p’ from mine ‘m’ at coal loading area ‘port’ and mine in period ‘t’

The results of the linear programming model are generated by the application of a tool called Solver of Microsoft Excel. The results of the linear programming model will be used as a blending plan which can generate additional benefits for the company studied.

4.2.2 Dynamic Coal Blending Plan Procedure

The implementation period is marked by a high degree of uncertainty with potential for upsetting previously optimized plans and schedules with variations derived from two main parts, i.e. mine operating function and marketing function, during implementation. Details concerning the variation between mine operations and marketing function are discussed as follows;

With regard to operation function, mismatched production may stem from various sources such as production equipment breakdown, rain and slippery conditions in mining areas, mining contractor performance, etc. As previously mentioned, these factors cause the production to yield less than planned. The mismatch of coal quality produced by the mine may deviate from the plan due to the accuracy of information of coal quality during exploration, contamination during the mining process, etc. These are common problems which lead to coal quality specifications in production that differs from the plan. It is well-known that the mining business contains many risks in operation to meet production targets. Some of these risks include obtaining information on underground coal from drilling information and the fact that operation capacity is closely related to weather conditions as mine equipment cannot operate during rain. The equipment breaks down from heavy duty operations, which also causes the production to be less than targets. All of the factors mentioned above cause the production to miss scheduled goals.

As for marketing function, the mismatched production with schedule may stem from new opportunities to increase revenue by changing coal prices or higher demands by coal users. The spot coal sale will normally brings a higher price for the company due to urgent requirements from customers, which represent a good opportunity for the company to increase revenue.

On the other hand, the marketing team requires confirmation of shipment schedules to customers as planned. If there is any delay in coal delivery to customers, the company may be subject to penalties from customers and demurrage fees from charter owners. These penalty and demurrage charges are costly for the company, so the company requires a reliable coal delivery schedule from mine operation until delivery of the coal to customers.

To reduce the impact of mismatched production, this study formulates a dynamic coal blending plan procedure aimed at maximal benefits for the company based on updated information. The main concept of the dynamic coal blending plan procedure is illustrated in Figure 4-6 below and the procedures are as follows:

- Step 1: Update information on operation production and marketing plans.
- Step 2 : Linear programming for creating a blending plan.

- Step 3 : Compare results of linear programming with blending plan. If a match is obtained, continue to Step 5 for a summary and confirm the blending plan. If not, continue to Step 4.

- Step 4 : Revise marketing plans and continue to Steps 2 and 3 repeatedly so as to determine the matching between linear programming blending and revise marketing plan.

- Step 5 : Summarize and confirm the blending plan.

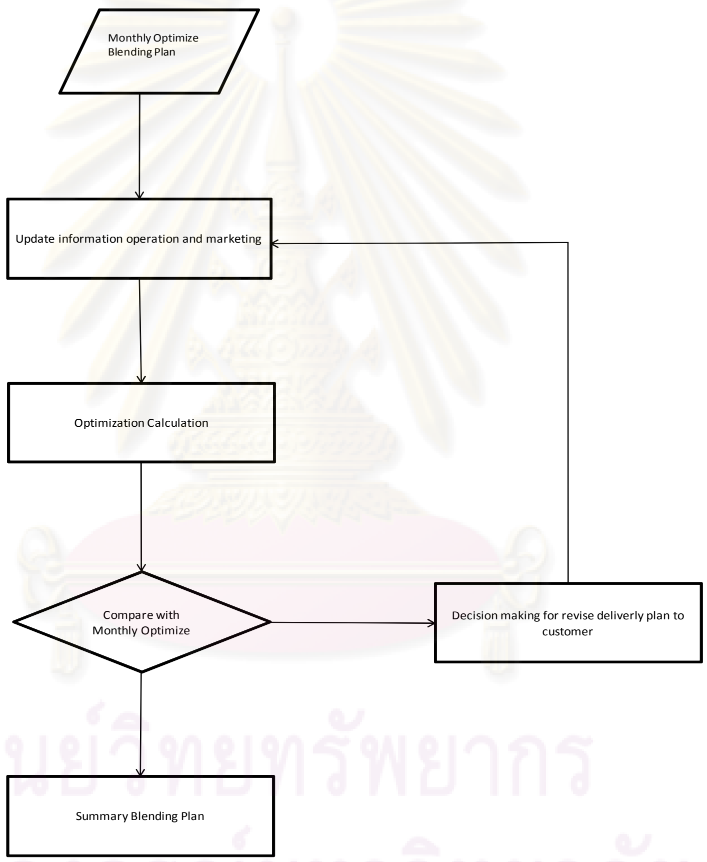


Figure 4-6: Work Procedures for the Formation of a Dynamic Coal Blending Plan

The next topic will explain the details of the current system employed by this company beginning with the establishment of an annual production plan, monthly meetings for controlling operations and daily performance records.

4.3 Coal Blending Operation Model

After analyzing the current system and collecting data, a model of coal blending optimization was developed. As mentioned in “Modeling Concept” in 4.1, linear programming is suitable for this problem in order to obtain maximum benefit from the blending program. When considering the data, coal prices, operating costs and transportation costs, additional value can be calculated from the blended product tonnage and the blended coal price. The model can be divided into two sections i.e. coal blending optimization plan and dynamic coal blending plan.

4.3.1 Coal Blending Optimization Plan

The linear programming algorithm will be used to create blending optimization for this blending operation. This algorithm will be used to calculate blending scenarios to obtain additional benefits or adjust the blending plan to meet customer requirements from updated information. This optimization blending plan will identify the coal transported from a certain source to a certain coal terminal or area and how much coal will be used for blending for a certain product. The optimized coal blending will be done according to the formulating steps of linear programming discussed in 4.1 as follows:

4.3.1.1 Understanding the Problem

The problem is that there was no mathematical method applied to the coal blending plan for company studied. All of the details concerning the existing problem and the general profile of coal operation systems have already been clearly explained in Chapters 1 and 2, respectively.

4.3.1.2 Identifying the Decision Variables

As previously discussed, the supply sources for coal blending involve in this case are coal tonnage from each mine to each coal loading point for blending each type of blending product on a monthly basis. The coal tonnages from each mine involve the following nine types:

- IMM West PAMA

- IMM West Ketadin
- IMM East Area
- TCM LCV
- TCM HCV
- TCM HCV-HS
- EMB North Area
- EMB South Area
- JBG LCV

In this case, the coal loading port locations cover the following five areas:

- Maura Java
- Maura Berau
- Jorong
- Bct
- Boct.

The coal products in this case involve the following 7 coal product types:

- JBU
- CV 6300
- HCV HS
- MCV

- IMM East
- JBG
- EMB

4.3.1.3 Choosing a Numerical Measure of Effectiveness for Objective Function

As mentioned in 4.1, maximizing the profit is then an objective function of this linear programming model.

4.3.1.4 Representing a Linear Expression of a Measure of Effectiveness

The EBIT of the company is the summation of EBIT for each coal product from each coal loading terminal minus the total cost of each coal product. The EBIT can be calculated from Tonnage x (Coal price – Total Cost) of each product.

4.3.1.5 Identifying and Representing Constraints and Parameters

As previously discussed, the constraints involved in this case are categorized into 4 main groups i.e. tonnage of raw materials from the mines must follow the production plan; coal loading capability must not be exceeded; specifications for the blending product must be within the range of product type specifications and non-negative constraints of the variable.

Balance Constraints

The source of coal for blending will use annual production plans from each mine. The limitations of the sources for coal blending are determined by production plans for each month.

Coal Loading Capacity Constraints

There are limitations in the coal loading capacity of each facility. As described in 4.3.5, “Coal loading capacity”, the constraints can be presented in terms of limited tonnage for coal loading on a monthly basis as follows: Maura Java, Maura Berau, Jorong, Bct and Boct.

Total Coal Loading at Maura Java ≤ 250 K.Tons per month

Total Coal Loading at Maura Berau ≤ 250 K.Tons per month

Total Coal Loading at Jorong ≤ 250 K.Tons per month

Total Coal Loading at BCT ≤ 500 K.Tons per month

Total Coal Loading at Boct ≤ 1700 K.Tons per month

Coal Specification Constraints

The limitations of coal specifications for each product depend upon heating value and percent of sulfur content. As described in 4.3.4, "Coal Price Assumption", the constraints can be presented in terms of limited coal blending specifications within a range of acceptable products for each blended product on a monthly basis.

Non-negative Constraints

The coal tonnage transportation for blending and direct sales must be a positive value.

4.3.1.6 The Linear Model of Coal Blending

According to all of the steps carried out, the final LP model is as follows:

Objective Function

$$Max\,Profit = \sum_{p,m,port,t} (Price_{p,m,t} - TotalCost^{B}_{p,m,port,t}) * X^{B}_{p,m,port,t} + \sum_{p,m,port,t} (Price_{p,m,t} - TotalCost^{S}_{p,m,port,t}) * X^{S}_{p,m,port,t}$$

Balance Constraints

$$\sum_{p,port} (X^{B}_{p,m,port,t} + X^{S}_{p,m,port,t}) \le Production_{m,t} \forall m,t$$

Loading Capacity Constraints

$$\sum_{p,m} (X^{B}_{p,m,port,t} + X^{S}_{p,m,port,t}) \le Coalloading_{port,t}; \forall port,t$$

Quality Constraints

$$\sum_{m}(CV_{p,m,port,t} * X^{B}_{p,m,port,t}) \le MaxCV\,\Pr oduct_{p,t} * X^{B}_{p,m,port,t}; \forall p, port, t$$

$$\sum_{m}(CV_{p,m,port,t} * X^{B}_{p,m,port,t}) \ge MinCV\,\Pr oduct_{p,t} * X^{B}_{p,m,port,t}; \forall p, port, t$$

$$\sum_{m}(Sul_{p,m,port,t} * X^{B}_{p,m,port,t}) \le MaxSul\,\Pr oduct_{p,t} * X^{B}_{p,m,port,t}; \forall p, port, t$$

$$\sum_{m}(Sul_{p,m,port,t} * X^{B}_{p,m,port,t}) \ge MinSul\,\Pr oduct_{p,t} * X^{B}_{p,m,port,t}; \forall p, port, t$$

Non-negative Constraints

$$X^{B}_{p,m,port,t} \ge 0; \forall p, m, port, t$$
$$X^{S}_{p,m,port,t} \ge 0; \forall p, m, port, t$$

4.3.1.7 Results of the Linear Programming Model for Coal Blending

Solver of Microsoft Excel was applied to solve this linear programming model and yield results. The results of the linear programming model are shown in Tables 4-13 to 4-16. The calculation employ linear programming to define blending portions from existing production plans by considering coal blend product type and coal loading area.

Table 4-13: Summary of EBIT for Each Coal Product and Coal Loading Area

Coal Product	1	2	3	4	5	6	7
Coal Loading							
1	458,650	478,617	452,454	474,764	NF	NF	460,262
2	462,758	481,335	453,020	477,614	NF	NF	458,985
3	456,647	470,541	451,239	463,164	NF	NF	461,150
4	453,292	480,637	450,518	470,336	NF	NF	451,013
5	456,960	**487,508**	455,091	472,467	NF	NF	451,833

According to Table 4-13 above, the linear programming used to calculate the blending program for each coal source from the mines to blending each product at various coal loading facilities. The results from the calculation show that the coal blended at coal loading area number 5 (Boct Area) for Product type 2 can bring the company maximum EBIT as compared to other scenarios. Table 4-14 shows the portion of coal blending at each location for Blended Coal Product Type 2 to create maximum EBIT for the company while Table 4-15 shows the remaining products at each location which should be directly sold to customers.

Table 4-14: Coal Blending Portion for Maximum EBIT

Production Schedule (Product Blended)		Index	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	Total
Indominco			**210.782**	**261.584**	**143.547**	**82.770**	**129.730**	**228.259**	**767.350**	**268.780**	**194.831**	**79.693**	**14.364**	**124.674**	**-**	**2,506.363**
West Block PAMA		1	2.833	58.277	24.147	-	29.242	20.608	563.812	8.039	10.820	-	-	59.535		777.313
West Block Ketadin		2	207.949	203.306	119.315	82.770	71.735	205.740	202.612	214.337	180.112	79.693	14.364	65.138	-	1,647.070
East Block		3	-	-	0.085	-	28.753	1.911	0.926	46.405	3.899	-	-	-	-	81.980
Wash Coal		4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IMM Other1		5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IMM Other2		6	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IMM Other3		7	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Trubaindo			**232.033**	**262.089**	**178.245**	**160.317**	**164.571**	**285.856**	**50.936**	**52.339**	**190.481**	**43.275**	**38.209**	**107.503**	**-**	**1,765.854**
North Block		8	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dayak Besar		9	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Biangan		10	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LCV -LS		11	25.352	17.829	19.910	2.578	13.758	119.777	-	17.572	88.677	28.588	-	32.148	-	366.187
HCV -LS		12	23.786	23.017	4.658	45.358	22.813	0.079	0.004	-	-	-	-	-	-	119.715
HCV -HS		13	182.895	221.243	153.677	112.381	128.000	166.000	50.932	34.767	101.805	14.688	38.209	75.355	-	1,279.952
TCM Other1		14	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TCM Other2		15	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TCM Other3		16	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TCM Other4		17	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bharinto			**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Bharinto		18	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bharinto Other1		19	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bharinto Other2		20	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bharinto Other3		21	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bharinto Other4		22	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Jorong			**162.485**	**183.080**	**88.471**	**84.864**	**72.937**	**155.070**	**90.937**	**55.656**	**126.000**	**42.142**	**8.636**	**44.937**	**-**	**1,115.216**
JBG product		23	162.485	183.080	88.471	84.864	72.937	155.070	90.937	55.656	126.000	42.142	8.636	44.937	-	1,115.216
JBG Other1		24	-	-	-	-	-	-	-	-	-	-	-	-	-	-
JBG Other2		25	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Embalut			**129.182**	**129.500**	**129.370**	**135.600**	**132.862**	**58.412**	**44.680**	**-**	**14.719**	**14.274**	**48.198**	**120.983**	**-**	**957.781**
EMB North		26	80.775	80.898	80.824	84.738	84.001	23.403	44.680	-	10.833	8.967	2.163	65.232	-	**566.514**
EMB South		27	48.407	48.602	48.546	50.862	48.861	35.009	-	-	3.886	5.306	46.035	55.751	-	**391.267**
EMB Other		28	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Others			-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other1		29	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other2		30	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other3		31	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other4		32	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SubTotal		END	**734.482**	**836.253**	**539.633**	**463.551**	**500.101**	**727.597**	**953.903**	**376.775**	**526.031**	**179.384**	**109.407**	**398.097**	**-**	**6,345.214**
Blended CV	kcal/kg	CV	6,250	6,250	6,250	6,250	6,250	6,250	6,250	6,250	6,250	6,250	6,350	6,250	-	
Blended TS%	%	TS	0.90	0.90	0.90	0.82	0.90	0.86	0.80	0.84	0.83	0.90	0.90	0.90	-	
Blended ASH%	%	ASH	5.87	5.79	6.01	5.64	5.19	5.49	5.26	5.83	5.52	5.06	4.89	5.43	-	

Table 4-15: Remaining Product for Direct Sale

Remaining (to sell as separated products)	Index		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN		Total
Indominco			**786**	**732**	**938**	**1,025**	**1,014**	**892**	**432**	**1,022**	**1,005**	**1,213**	**1,274**	**1,052**	**-**		**11,384**
West Block PAMA	1	5	556	448	534	557	539	521	1	556	502	547	541	474	-		5,774
West Block Ketadin	2	5	-	-	98	117	152	-	-	8	-	130	179	119	-		803
East Block	3	5	230	284	305	352	323	371	431	457	504	536	554	460	-		4,807
Wash Coal	4		-	-	-	-	-	-	-	-	-	-	-	-	-		-
IMM Other1	5		-	-	-	-	-	-	-	-	-	-	-	-	-		-
IMM Other2	6		-	-	-	-	-	-	-	-	-	-	-	-	-		-
IMM Other3	7		-	-	-	-	-	-	-	-	-	-	-	-	-		-
Trubaindo			**280**	**255**	**391**	**336**	**333**	**250**	**484**	**467**	**334**	**473**	**482**	**414**	**-**		**4,499**
North Block	8		-	-	-	-	-	-	-	-	-	-	-	-	-		-
Dayak Besar	9		-	-	-	-	-	-	-	-	-	-	-	-	-		-
Biangan	10		-	-	-	-	-	-	-	-	-	-	-	-	-		-
LCV -LS	11	5	142	68	63	167	186	80	190	162	91	145	185	153	-		1,633
HCV -LS	12	4	100	123	169	125	147	170	170	165	165	165	165	165	-		1,828
HCV -HS	13	5	38	64	160	44	-	-	124	139	77	162	132	97	-		1,037
TCM Other1	14		-	-	-	-	-	-	-	-	-	-	-	-	-		-
TCM Other2	15		-	-	-	-	-	-	-	-	-	-	-	-	-		-
TCM Other3	16		-	-	-	-	-	-	-	-	-	-	-	-	-		-
TCM Other4	17		-	-	-	-	-	-	-	-	-	-	-	-	-		-
Bharinto			**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**		**-**
Bharinto	18		-	-	-	-	-	-	-	-	-	-	-	-	-		-
Bharinto Other1	19		-	-	-	-	-	-	-	-	-	-	-	-	-		-
Bharinto Other2	20		-	-	-	-	-	-	-	-	-	-	-	-	-		-
Bharinto Other3	21		-	-	-	-	-	-	-	-	-	-	-	-	-		-
Bharinto Other4	22		-	-	-	-	-	-	-	-	-	-	-	-	-		-
Jorong			**23**	**6**	**157**	**134**	**146**	**47**	**0**	**53**	**-**	**98**	**132**	**89**	**-**		**885**
JBG product	23	3	23	6	157	134	146	47	0	53	-	98	132	89	-		885
JBG Other1	24		-	-	-	-	-	-	-	-	-	-	-	-	-		-
JBG Other2	25		-	-	-	-	-	-	-	-	-	-	-	-	-		-
Embalut			**0**	**0**	**0**	**0**	**2**	**76**	**96**	**141**	**126**	**126**	**91**	**28**	**-**		**686**
EMB North	26	1	-	0	0	-	1	61	43	88	77	79	85	28	-		**461**
EMB South	27	1	0	-	-	0	2	16	53	53	49	47	6	-	-		**225**
EMB Other	28		-	-	-	-	-	-	-	-	-	-	-	-	-		-
Others			**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**		**-**
Other1	29		-	-	-	-	-	-	-	-	-	-	-	-	-		-
Other2	30		-	-	-	-	-	-	-	-	-	-	-	-	-		-
Other3	31		-	-	-	-	-	-	-	-	-	-	-	-	-		-
Other4	32		-	-	-	-	-	-	-	-	-	-	-	-	-		-
SubTotal	END		**1,088**	**993**	**1,486**	**1,495**	**1,495**	**1,266**	**1,012**	**1,682**	**1,465**	**1,910**	**1,979**	**1,584**	**-**		**17,454**
Blended CV kcal/kg	CV		6,224	6,285	6,244	6,182	6,163	6,190	6,264	6,233	6,225	6,229	6,240	6,276	-		
Blended TS% %	TS		1.09	1.15	1.11	1.07	1.00	1.09	1.31	1.12	1.15	1.12	1.15	1.16	-		
Blended ASH% %	ASH		5.25	5.09	5.27	5.20	5.13	4.86	4.76	4.85	4.81	4.96	4.89	4.70	-		
Blended.... %			-	-	-	-	-	-	-	-	-	-	-	-	-		

Table 4-16: EBIT from Optimization at Each Location

IMM Mine West Area	Unit	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Total
Revenue	1000 USD.	42,436	34,161	48,235	51,410	52,721	39,744	52	43,040	38,278	51,612	54,914	45,232	501,834
Production cost	1000 USD.	6,657	5,359	7,566	8,065	8,270	6,235	8	6,751	6,005	8,096	8,614	7,095	78,721
Selling cost	1000 USD.	6,750	5,434	7,672	8,178	8,386	6,322	8	6,846	6,089	8,210	8,735	7,195	79,824
Other cost	1000 USD.	258	208	293	313	321	242	0	262	233	314	334	275	3,052
OB removal cost	1000 USD.	18,332	15,051	21,498	23,214	24,986	18,749	23	18,888	17,424	23,547	22,030	13,510	217,252
Alternative transportation	1000 USD.	72	58	82	88	90	68	0	73	65	88	94	77	855
EBIT	1000 USD.	10,367	8,052	11,122	11,554	10,668	8,129	13	10,219	8,463	11,357	15,107	17,079	122,130
IMM Mine East Area	Unit	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Total
Revenue	1000 USD.	14,444	17,854	19,213	22,113	20,292	23,355	27,131	28,776	31,682	33,743	34,853	28,908	302,365
Production cost	1000 USD.	2,347	2,901	3,122	3,593	3,297	3,795	4,408	4,675	5,148	5,483	5,663	4,697	49,128
Selling cost	1000 USD.	2,372	2,931	3,155	3,631	3,332	3,835	4,455	4,725	5,202	5,540	5,722	4,747	49,646
Other cost	1000 USD.	107	132	142	163	150	172	200	212	234	249	257	213	2,230
OB removal cost	1000 USD.	5,177	4,851	5,752	6,800	6,488	7,321	7,966	8,210	9,034	9,529	9,365	8,409	88,904
Alternative transportation	1000 USD.	30	37	40	46	42	48	56	59	65	70	72	60	625
EBIT	1000 USD.	4,412	7,002	7,004	7,881	6,983	8,184	10,046	10,893	11,999	12,872	13,773	10,782	111,832
TCM Mine	Unit	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Total
Revenue	1000 USD.	22,372	20,865	32,074	26,902	26,721	20,564	38,996	37,696	27,246	38,267	38,816	33,516	364,036
Production cost	1000 USD.	3,874	3,541	5,424	4,653	4,622	3,467	6,710	6,469	4,623	6,553	6,678	5,746	62,360
Selling cost	1000 USD.	2,792	2,597	4,001	3,356	3,326	2,544	4,871	4,709	3,390	4,782	4,850	4,181	45,401
Other cost	1000 USD.	130	119	182	156	155	116	225	217	155	219	224	192	2,087
OB removal cost	1000 USD.	5,536	5,243	7,689	8,025	8,615	5,923	11,844	12,182	7,760	9,899	8,831	7,523	99,072
Alternative transportation	1000 USD.	3,438	3,225	4,888	4,142	4,174	3,285	5,947	5,736	4,221	5,805	5,908	5,143	55,913
EBIT	1000 USD.	6,601	6,139	9,891	6,570	5,830	5,229	9,400	8,383	7,096	11,008	12,324	10,731	99,203
JBG Mine	Unit	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Total
Revenue	1000 USD.	898	236	6,265	5,332	5,808	1,892	2	2,128	-	3,905	5,281	3,554	35,303
Production cost	1000 USD.	332	87	2,316	1,971	2,147	699	1	787	-	1,443	1,952	1,313	13,049
Selling cost	1000 USD.	136	36	950	808	880	287	0	323	-	592	801	539	5,351
Other cost	1000 USD.	26	7	183	156	170	55	0	62	-	114	155	104	1,033
OB removal cost	1000 USD.	134	32	866	759	852	264	1	774	-	1,569	2,012	1,419	8,682
Alternative transportation	1000 USD.	84	22	583	496	540	176	0	198	-	363	491	330	3,283
EBIT	1000 USD.	186	52	1,368	1,142	1,219	411	0	(15)	-	(177)	(129)	(152)	3,905
EMB Mine	Unit	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Total
Revenue	1000 USD.	5	4	3	0	145	4,681	5,855	8,619	7,717	7,737	5,587	1,722	42,076
Production cost	1000 USD.	1	1	0	0	21	690	864	1,271	1,138	1,141	824	254	6,207
Selling cost	1000 USD.	1	1	0	0	20	642	803	1,182	1,059	1,061	766	236	5,772
Other cost	1000 USD.	0	0	0	0	4	132	166	244	218	219	158	49	1,190
OB removal cost	1000 USD.	2	2	1	0	55	1,734	2,106	3,101	2,776	2,565	1,862	543	14,747
Alternative transportation	1000 USD.	1	0	0	0	16	500	626	921	825	827	597	184	4,496
EBIT	1000 USD.	1	1	1	0	29	981	1,290	1,900	1,701	1,924	1,379	456	9,664
Product 1	Unit	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Total
Revenue	1000 USD.	56,041	63,806	41,174	35,369	38,158	55,516	72,783	28,748	40,136	13,687	8,348	30,375	484,140
Production cost	1000 USD.	9,304	10,635	6,663	5,691	6,061	9,506	11,634	4,682	6,957	2,304	1,265	4,739	79,441
Selling cost	1000 USD.	6,945	8,036	5,188	4,261	4,722	7,103	10,750	4,043	5,180	1,780	1,017	3,887	62,911
Other cost	1000 USD.	619	681	477	447	452	521	563	214	351	131	118	370	4,945
OB removal cost	1000 USD.	15,249	17,911	11,699	9,985	11,983	17,143	28,805	10,452	13,165	4,646	2,256	7,846	151,141
Alternative transportation	1000 USD.	5,960	6,576	4,387	4,187	4,062	5,822	2,265	1,347	3,952	1,178	995	2,941	43,673
EBIT	1000 USD.	17,965	19,966	12,760	10,799	10,878	15,420	18,765	8,009	10,531	3,648	2,697	10,592	142,029
Total EBIT	1000 USD.	39,532	41,213	42,146	37,945	35,607	38,354	39,514	39,390	39,790	40,632	45,151	49,490	487,508

According to Table 4-16 above, the company's EBIT from the additional blending process to improve product type can be up to 488 million USD. The additional EBIT is significantly higher than that of the existing operations. The next topic will discuss the results of linear programming compared with original plans.

4.3.1.8 Comparison of Linear Programming Plans and Previous

Next, a comparison between the plans resulting from linear programming and the plans in actual operation using the current decision logic as of January 2010. The coal tonnage from IMM mine used for blending coal product type 2 was 2,506 K.tons, while the coal tonnage from TCM mine used for blending coal product type 2 was 1,765 K.tons. JBG mine also use coal for blending 1,115 K.tons to produce coal product type

2 coal and EMB mine should transport coal for blending at 957 K.tons. Product type 2 coal will use coal from various sources for blending to create approximately 6,345 K.tons of coal and the remainder of coal from each mine will be planned for direct sales to customers as originally planned. The coal facility for blending coal leading to maximum EBIT for the company is Boct. The EBIT from blend coal from each mine is 488 million USD which is higher in comparison to the original plan which yielded 451 million USD. The company can obtain approximately 8.20% additional benefits in comparison to original plan.

The results of the linear programming according to the assumption explained in Chapter 1 indicate an opportunity to blend coal by use of high quality coal products to blend with low quality coal products to obtain coal blends with CV of approximately 6300 kcal/kg and sulfur content of less than 0.8%.

In next chapter, the dynamic coal blending procedure will be proposed to handle the uncertainty of coal mismatching with plans. The dynamic coal blending procedure will help planners update information and calculations as they obtain information to support decision-making for solving problems in the case of production mismatching with plans.

4.3.2 Dynamic Coal Blending Procedure

As mentioned in chapter 4.2, reducing impact of mismatched production from operation and marketing is to formulate dynamic coal blending procedure. This study will formulates a dynamic coal blending procedure to get benefit by reduce additional cost such as penalty and demurrage charge from delay or mismatch coal schedule to customers.

The main concept for reduce impact of mismatched production is to improve communication and information transfer between operation and marketing then create revise plan to reduce impact as much as we can. This study will apply collaborative planning, forecasting and replenishment (CPFR) theory for formulate dynamic coal blending procedure. The dynamic coal blend procedure will adapt existing work process of this studied company by add more activities for revise blending plan by using linear programming which practical to implement in this company, this procedure aims to use update information from operation and marketing then create adjustment of production and sale plan by blending to avoid penalty or demurrage charge from customers. The detail dynamic coal blending procedure illustrated as figure 4-7 below.

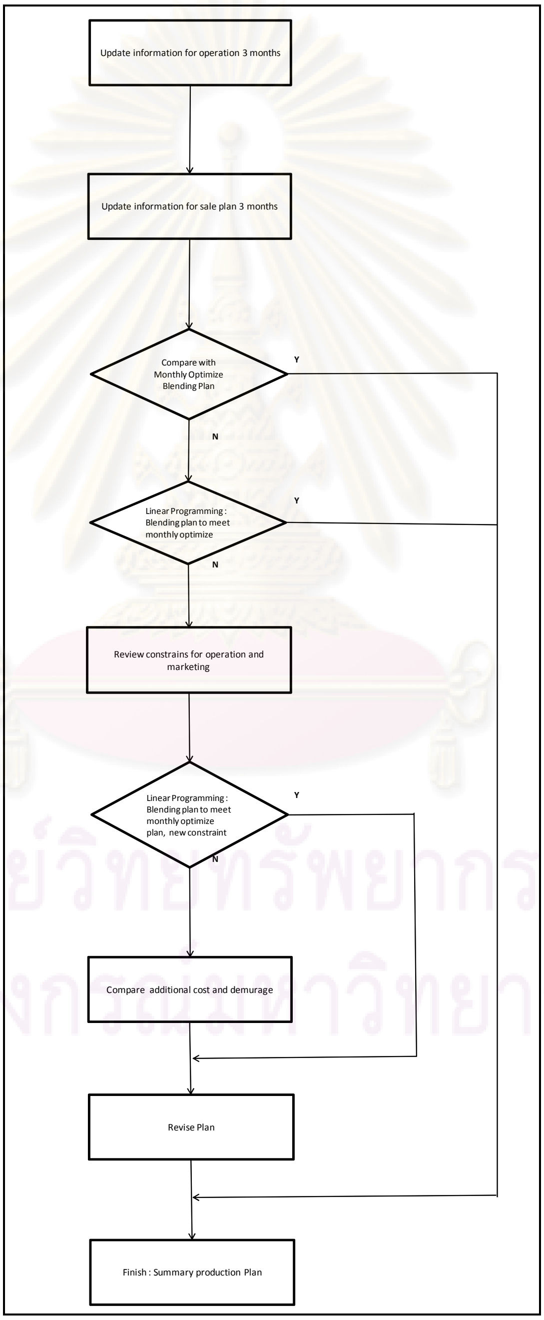


Figure 4-7: Dynamic coal blending procedure

From figure 4-8, the procedures of dynamic coal blending can be explained as follows:

Process 1: Update operations information for 3 months rolling plan, the information that will get in this stage is the forecast production plan base on update conditions of each mine site. There may have change from original plan due to many factors and it will lead to mine production output difference from original plan. The update information in this stage are expect coal production and coal quality specification of each mine. These information will use for create dynamic blending plan. Figure 4-8 below illustrates the example of information preparation of this stage.

PRODUCTION PLAN							
PRODUCTION PLAN: JUNE 2010							
Coal Mined	**Type of Product**	**Quantity**	**CV**	**Ash**	**Ts**	**IM**	**TM**
	ROM 1 - LCV LS						
	ROM 2 - LCV HS						
	ROM 3 - MCV LS						
	ROM 4 - MCV HS						
	ROM 5 - HCV LS						
	ROM 6 - HCV - HS						
	Total						
Coal Product	**Type of Product**	**Quantity**	**CV**	**Ash**	**Ts**	**IM**	**TM**
	TCM LCV						
	TCM HCV-LS						
	TCM HCV-HS						
	Total						
PRODUCTION PLAN: JULY 2010							
Coal Mined	**Type of Product**	**Quantity**	**CV**	**Ash**	**Ts**	**IM**	**TM**
	ROM 1 - LCV LS						
	ROM 2 - LCV HS						
	ROM 3 - MCV LS						
	ROM 4 - MCV HS						
	ROM 5 - HCV LS						
	ROM 6 - HCV - HS						
	Total						
Coal Product	**Type of Product**	**Quantity**	**CV**	**Ash**	**Ts**	**IM**	**TM**
	TCM LCV						
	TCM HCV-LS						
	TCM HCV-HS						
	Total						

Figure 4-8: The format of update production plan information

Process 2: Update information of sale plan for 3 months rolling plan, the information that will get in this stage is the sale plan which consist of the sale volume that already commit with customers and the sale volume that not commit with customer yet. The update information in this stage are sale volume and coal quality specification required from customers. Figure 4-9 below illustrate the example of sale information of this stage.

SALE PLAN

LOADING PLAN: JUNE 2010 - Total TCM	
Type of Product	**Quantity**
TCM LCV	
TCM HCV-LS	
TCM HCV-HS	
Total	

LOADING PLAN: NOVEMBER 2010 - updated				Loading Point: BOCT		
Type of Product	**Quantity**	**CV**	**Ash**	**Ts**	**IM**	**TM**
TCM LCV						
TCM HCV-LS						
TCM HCV-HS						
Total						

LOADING PLAN: JULY 2010 - Total TCM	
Type of Product	**Quantity**
TCM LCV	
TCM HCV-LS	
TCM HCV-HS	
Total	

LOADING PLAN: JULY 2010 - updated				Loading Point: BOCT		
Type of Product	**Quantity**	**CV**	**Ash**	**Ts**	**IM**	**TM**
TCM LCV						
TCM HCV-LS						
TCM HCV-HS						
Total						

Figure 4-9: The format of sale plan information update

Process 3: Compare updated production and sale plan with original optimize blending plan, in case that the updated production and sale plan match with original optimize blend plan, then go to final process for summary production plan for next month. In case that the updated production and sale not match with original optimize blend plan, go to next process to calculate new blending plan to meet original optimize blending plan.

Process 4: Linear programming was applied for define revise blending plan to meet target of original optimize blend plan. The linear programming calculation in this stage have objective function which is maximize the revenue, the decision variable is the coal tonnage for blending, the constraints have 4 main groups which are tonnage of raw material from mine must follow with update production plan, a coal loading capability is not exceeded, the specification of blending product must within range of product type specification and non-negative constraint of the variable.

If the linear programming can solve the problem then go to final process which is summary monthly production plan. If the linear programming can't solve the problem then go to next process which is review constraints for minimum requirement from customer.

Process 5: Updated information for commit sale volume, the commit sale will used to be constraints for linear programming calculation. In this stage the blending optimization will use for define blending plan to meet commit sale plan. The linear programming in this stage have objective function which is maximize the revenue, the decision variable is the coal tonnage for blending, the constraints have 5 main group which are tonnage of raw material from mine must follow with update production plan, a coal loading capability is not exceeded, the specification of blending product must within range of product type specification, non-negative constraint of the variable and the final blended production must meet volume committed customer.

If the linear program can solve problem, then go to process revise sale plan. If the linear programming can't solve problem, then go to process compare and make decision for delay shipment, get penalty from customer or demurrage charge.

Process 6: Decision making for delay shipment or get penalty from customer , in this stage is preparation information for additional cost which come from delay of delivery coal to customer, the demurrage charge from owner charter for delay coal loading, the cancel customer cost which is cost for cancel coal delivery to customer. The information from blending optimization will use for further calculate the impact to company. Then select the alternative that lower penalty cost for company then go to process revise plan.

Process 7: Revise plan, based on all process above the revise plan stage is the stage that summary revise blending plan production miss match in this stage.

Process 8: Summary production, based on all process above, the summary production plan will summary production plan that create benefit to company base on update information. The all process will repeat to calculate in every month for create dynamic blending plan.

4.3.3 Implementation Dynamic Coal Blending Procedure

This study use updated information from July until September 2010 for implement dynamic coal blending procedure. The implementation dynamic coal blending procedure has done follow steps as mentioned above;

Process 1 Updated operation information, the updated operation information of production on July until September illustrate as table 4-17 to 4-20 below.

Table 4-17: IMM Mine Updated production plan on July until September 2010

IMM Mine	Unit	JUL	AUG	SEP	OCT	NOV	DEC
WEST PAMA AREA							
Over burden revoval	1000 bcm	8,594	8,597	7,814	8,334	7,967	7,563
Coal Mine	1000 tons	511	601	532	547	541	534
CV	Kcal/kg	6,291	6,226	6,275	6,217	6,256	6,268
TS	%	0.73	0.67	0.92	0.88	0.81	0.78
Ash	%	5.79	6.51	4.97	5.65	5.46	5.43
WEST KETADIN AREA							
Over burden revoval	1000 bcm	3,106	3,584	3,313	3,841	2,427	0
Coal Mine	1000 tons	232	249	202	210	194	184
CV	Kcal/kg	6,291	6,226	6,275	6,650	6,732	6,779
TS	%	0.73	0.67	0.92	1.22	1.55	1.70
Ash	%	5.79	6.51	4.97	5.03	4.09	3.46
EAST AREA							
Over burden revoval	1000 bcm	3,903	4,421	4,451	4,659	4,579	4,111
Coal Mine	1000 tons	264	361	380	536	554	460
CV	Kcal/kg	5,892	5,978	6,005	5,955	5,991	6,037
TS	%	1.69	1.87	1.82	1.72	1.80	1.74
Ash	%	3.59	4.96	4.05	4.32	4.67	4.13
TOTAL IMM							
Over burden revoval	1000 bcm	**15,602**	**16,602**	**15,578**	**16,834**	**14,972**	**11,675**
Coal Mine	1000 tons	**1,007**	**1,211**	**1,114**	**1,293**	**1,288**	**1,177**
CV	Kcal/kg	**6,186**	**6,152**	**6,183**	**6,178**	**6,214**	**6,257**
TS	%	**0.98**	**1.03**	**1.23**	**1.29**	**1.35**	**1.30**
Ash	%	**5.21**	**6.05**	**4.66**	**5.00**	**4.92**	**4.61**

Table 4-18: TCM Mine Updated production plan on July until September 2010

TCM Mine	Unit	JUL	AUG	SEP	OCT	NOV	DEC
LCV AREA							
Over burden revoval	1000 bcm	2,133	2,208	1,987	1,761	1,553	1,544
Coal Mine	1000 tons	198	211	125	174	185	185
CV	Kcal/kg	6,132	6,213	6,194	6,273	6,250	6,253
TS	%	0.97	0.73	0.79	0.79	0.80	0.80
Ash	%	4.67	5.60	3.81	5.22	4.99	5.00
HCV AREA							
Over burden revoval	1000 bcm	2,133	2,208	1,987	1,761	1,553	1,544
Coal Mine	1000 tons	97	117	187	165	165	165
CV	Kcal/kg	6,770	6,715	6,670	6,760	6,753	6,754
TS	%	1.06	0.76	0.75	0.77	0.77	0.78
Ash	%	4.38	4.98	4.16	4.33	4.17	4.20
HCV HS AREA							
Over burden revoval	1000 bcm	2,133	2,208	1,987	1,761	1,553	1,544
Coal Mine	1000 tons	74	157	161	177	170	172
CV	Kcal/kg	6,851	6,712	6,950	7,052	7,011	7,050
TS	%	3.08	1.38	1.64	1.70	1.70	1.80
Ash	%	4.77	5.56	4.45	4.58	4.72	4.96
TOTAL TCM							
Over burden revoval	1000 bcm	**6,400**	**6,624**	**5,961**	**5,283**	**4,660**	**4,632**
Coal Mine	1000 tons	**369**	**485**	**473**	**516**	**520**	**522**
CV	Kcal/kg	**6,444**	**6,496**	**6,639**	**6,696**	**6,658**	**6,674**
TS	%	**1.42**	**0.95**	**1.06**	**1.10**	**1.09**	**1.12**
Ash	%	**4.62**	**5.44**	**4.16**	**4.72**	**4.64**	**4.73**

Table 4-19: JBG Mine Updated production plan on July until September 2010

JBG Mine	Unit	JUL	AUG	SEP	OCT	NOV	DEC
LCV AREA							
Over burden revoval	1000 bcm	766	941	1,016	1,336	1,276	1,271
Coal Mine	1000 tons	9	58	64	140	141	134
CV	Kcal/kg	5,283	5,273	5,320	5,308	5,392	5,367
TS	%	0.46	0.45	0.32	0.34	0.39	0.47
Ash	%	4.82	5.05	4.94	5.02	4.35	4.56
TOTAL JBG							
Over burden revoval	1000 bcm	**766**	**941**	**1,016**	**1,336**	**1,276**	**1,271**
Coal Mine	1000 tons	**9**	**58**	**64**	**140**	**141**	**134**
CV	Kcal/kg	**5,283**	**5,273**	**5,320**	**5,308**	**5,392**	**5,367**
TS	%	**0.46**	**0.45**	**0.32**	**0.34**	**0.39**	**0.47**
Ash	%	**4.82**	**5.05**	**4.94**	**5.02**	**4.35**	**4.56**

Table 4-20: EMB Mine Updated production plan on July until September 2010

EMB Mine	Unit	JUL	AUG	SEP	OCT	NOV	DEC
NORTH AREA							
Over burden revoval	1000 bcm	746	748	751	749	744	799
Coal Mine	1000 tons	71	73	40	88	87	93
CV	Kcal/kg	5,926	5,836	5,880	5,925	5,865	5,763
TS	%	0.15	0.15	0.15	0.16	0.16	0.15
Ash	%	5.41	6.70	6.48	5.91	6.67	8.00
SOUTH AREA							
Over burden revoval	1000 bcm	527	529	525	427	428	387
Coal Mine	1000 tons	26	34	54	53	52	56
CV	Kcal/kg	5,866	5,883	5,912	5,938	5,885	5,812
TS	%	0.16	0.16	0.16	0.17	0.16	0.16
Ash	%	5.32	5.39	5.23	4.98	5.29	6.29
TOTAL EMB							
Over burden revoval	1000 bcm	**1,273**	**1,277**	**1,277**	**1,176**	**1,172**	**1,186**
Coal Mine	1000 tons	**97**	**107**	**94**	**140**	**139**	**149**
CV	Kcal/kg	**5,910**	**5,851**	**5,898**	**5,930**	**5,873**	**5,781**
TS	%	**0.16**	**0.16**	**0.16**	**0.16**	**0.16**	**0.15**
Ash	%	**5.39**	**6.29**	**5.76**	**5.56**	**6.15**	**7.36**

Process 2 Update sale information, the sale information update of commit sale plan on July until September illustrate as table 4-21 below

Table 4-21: Updated commit sale plan on July until September 2010

Total Production	Index		JUL	AUG	SEP	OCT	NOV	DEC
Indominco			**150**	**150**	**150**	**1,213**	**1,274**	**1,052**
West Block PAMA	1		50	50	50	547	541	474
West Block Ketadin	2		50	50	50	130	179	119
East Block	3		50	50	50	536	554	460
Trubaindo			**150**	**150**	**150**	**473**	**482**	**414**
LCV -LS	11		50	50	50	145	185	152
HCV -LS	12		50	50	50	165	165	165
HCV -HS	13		50	50	50	162	132	97
Jorong			**-**	**-**	**-**	**98**	**132**	**89**
JBG product	23		-	-	-	98	132	89
JBG Other1	24		-	-	-	-	-	-
JBG Other2	25		-	-	-	-	-	-
Embalut			**-**	**-**	**-**	**126**	**91**	**28**
EMB North	26		-	-	-	79	85	28
EMB South	27		-	-	-	47	6	-
EMB Other	28		-	-	-	-	-	-
Blended Product			**250**	**250**	**250**	**179**	**109**	**399**
Product	29		250	250	250	179	109	399
SubTotal	END		**550**	**550**	**550**	**2,089**	**2,088**	**1,982**

Process 3 Compare updated production and sale plan with original optimize blend plan: In this case, the updated production and sale plan during July until September still don't match with original optimize blend plan. Then go to next process which is using linear programming to calculate revise blending plan to meet target of original optimize blending plan.

Process 4 Using linear programming for calculates to define new blending template to meet target. In this case, the linear programming can't solve problem which use updated production and sale plan then define blending template to meet original optimize blending plan. Table 4-22 and 4-23 below shows the result of linear programming calculation.

Table 4-22: Result from linear programming calculation for blended product

Production Schedule (Product 1)		Index	JUL	AUG	SEP	OCT	NOV	DEC
Indominco			**85.396**	**19.131**	**24.316**	**111.015**	**126.559**	**168.393**
West Block PAMA		1	19.158	1.583	2.393	-	84.521	151.889
West Block Ketadin		2	19.158	1.584	2.393	111.015	42.038	16.504
East Block		3	47.081	15.964	19.530	-	-	-
Wash Coal		4	-	-	-	-	-	-
IMM Other1		5	-	-	-	-	-	-
IMM Other2		6	-	-	-	-	-	-
IMM Other3		7	-	-	-	-	-	-
Trubaindo			**101.681**	**93.298**	**162.267**	**63.593**	**82.733**	**209.451**
North Block		8	-	-	-	-	-	-
Dayak Besar		9	-	-	-	-	-	-
Biangan		10	-	-	-	-	-	-
LCV -LS		11	-	-	-	63.593	57.854	79.889
HCV -LS		12	77.948	51.984	58.279	-	-	-
HCV -HS		13	23.733	41.314	103.987	-	24.879	129.561
TCM Other1		14	-	-	-	-	-	-
TCM Other2		15	-	-	-	-	-	-
TCM Other3		16	-	-	-	-	-	-
TCM Other4		17	-	-	-	-	-	-
Bharinto			-	-	-	-	-	-
Bharinto		18	-	-	-	-	-	-
Bharinto Other1		19	-	-	-	-	-	-
Bharinto Other2		20	-	-	-	-	-	-
Bharinto Other3		21	-	-	-	-	-	-
Bharinto Other4		22	-	-	-	-	-	-
Jorong			**9.000**	**20.582**	**64.000**	**44.566**	**38.420**	**94.018**
JBG product		23	9.000	20.582	64.000	44.566	38.420	94.018
JBG Other1		24	-	-	-	-	-	-
JBG Other2		25	-	-	-	-	-	-
Embalut			**90.279**	**48.474**	**93.931**	**11.850**	**18.414**	**71.902**
EMB North		26	64.279	19.692	39.931	8.534	0.026	16.151
EMB South		27	26.000	28.782	54.000	3.315	18.388	55.751
EMB Other		28	-	-	-	-	-	-
Others			-	-	-	-	-	-
Other1		29	-	-	-	-	-	-
Other2		30	-	-	-	-	-	-
Other3		31	-	-	-	-	-	-
Other4		32	-	-	-	-	-	-
SubTotal		END	**286.356**	**181.486**	**344.514**	**231.023**	**266.127**	**543.764**
Blended CV	kcal/kg	CV	6,250	6,250	6,250	6,250	6,250	6,250
Blended TS%	%	TS	0.98	0.80	0.84	0.88	0.90	0.92
Blended ASH%	%	ASH	4.80	5.40	4.83	5.11	4.90	5.21
Blended....	%							

Table 4-23: Result from linear programming calculation for direct sale product

Remaining (to sell as separated products)	Index	JUL	AUG	SEP	OCT	NOV	DEC
Indominco		**922**	**1,192**	**1,090**	**1,182**	**1,162**	**1,009**
West Block PAMA	1	492	599	530	547	456	382
West Block Ketadin	2	213	247	200	99	152	167
East Block	3	217	345	360	536	554	460
Wash Coal	4	-	-	-	-	-	-
IMM Other1	5	-	-	-	-	-	-
IMM Other2	6	-	-	-	-	-	-
IMM Other3	7	-	-	-	-	-	-
Trubaindo		**267**	**391**	**310**	**452**	**437**	**313**
North Block	8	-	-	-	-	-	-
Dayak Besar	9	-	-	-	-	-	-
Biangan	10	-	-	-	-	-	-
LCV -LS	11	198	211	125	110	127	105
HCV -LS	12	19	65	128	165	165	165
HCV -HS	13	50	116	57	177	145	42
TCM Other1	14	-	-	-	-	-	-
TCM Other2	15	-	-	-	-	-	-
TCM Other3	16	-	-	-	-	-	-
TCM Other4	17	-	-	-	-	-	-
Bharinto		**-**	**-**	**-**	**-**	**-**	**-**
Bharinto	18	-	-	-	-	-	-
Bharinto Other1	19	-	-	-	-	-	-
Bharinto Other2	20	-	-	-	-	-	-
Bharinto Other3	21	-	-	-	-	-	-
Bharinto Other4	22	-	-	-	-	-	-
Jorong		**-**	**37**	**-**	**95**	**103**	**40**
JBG product	23	-	37	-	95	103	40
JBG Other1	24	-	-	-	-	-	-
JBG Other2	25	-	-	-	-	-	-
Embalut		**7**	**59**	**0**	**129**	**121**	**77**
EMB North	26	7	53	0	79	87	77
EMB South	27	-	5	-	49	34	-
EMB Other	28	-	-	-	-	-	-
Others		**-**	**-**	**-**	**-**	**-**	**-**
Other1	29	-	-	-	-	-	-
Other2	30	-	-	-	-	-	-
Other3	31	-	-	-	-	-	-
Other4	32	-	-	-	-	-	-
SubTotal	END	**1,196**	**1,679**	**1,400**	**1,858**	**1,822**	**1,438**

Then go to next process which is linear programming calculation to meet minimum commit target volume.

Process 5 Use linear programming for calculates to define new blending template to meet minimum commit target. In this case, the linear programming can solve problem which use updated production and sale plan then define blending template to meet minimum commit volume. Table 4-24 and 4-25 below illustrate the result of linear programming calculation.

Table 4-24: Result from linear programming calculation for blended product to meet commit volume

Production Schedule (Product 1)	Index	JUL	AUG	SEP	OCT	NOV	DEC
Indominco		**650.484**	**24.812**	**41.772**	**135.540**	**273.212**	**533.599**
West Block PAMA	1	409.394	11.278	-	-	192.097	533.500
West Block Ketadin	2	182.000	11.278	-	129.341	81.116	0.097
East Block	3	59.090	2.256	41.772	6.199	-	0.002
Wash Coal	4	-	-	-	-	-	-
IMM Other1	5	-	-	-	-	-	-
IMM Other2	6	-	-	-	-	-	-
IMM Other3	7	-	-	-	-	-	-
Trubaindo		**70.647**	**124.135**	**191.818**	**146.392**	**127.415**	**206.862**
North Block	8	-	-	-	-	-	-
Dayak Besar	9	-	-	-	-	-	-
Biangan	10	-	-	-	-	-	-
LCV -LS	11	0.006	-	-	146.392	119.272	97.337
HCV -LS	12	46.908	16.708	112.290	-	-	28.248
HCV -HS	13	23.733	107.426	79.528	-	8.143	81.277
TCM Other1	14	-	-	-	-	-	-
TCM Other2	15	-	-	-	-	-	-
TCM Other3	16	-	-	-	-	-	-
TCM Other4	17	-	-	-	-	-	-
Bharinto		**-**	**-**	**-**	**-**	**-**	**-**
Bharinto	18	-	-	-	-	-	-
Bharinto Other1	19	-	-	-	-	-	-
Bharinto Other2	20	-	-	-	-	-	-
Bharinto Other3	21	-	-	-	-	-	-
Bharinto Other4	22	-	-	-	-	-	-
Jorong		**9.000**	**25.953**	**64.000**	**56.416**	**52.068**	**62.655**
JBG product	23	9.000	25.953	64.000	56.416	52.068	62.655
JBG Other1	24	-	-	-	-	-	-
JBG Other2	25	-	-	-	-	-	-
Embalut		**96.950**	**78.380**	**93.940**	**-**	**4.767**	**75.017**
EMB North	26	70.950	44.380	40.000	-	0.026	19.267
EMB South	27	26.000	34.000	53.940	-	4.740	55.750
EMB Other	28	-	-	-	-	-	-
Others		**-**	**-**	**-**	**-**	**-**	**-**
Other1	29	-	-	-	-	-	-
Other2	30	-	-	-	-	-	-
Other3	31	-	-	-	-	-	-
Other4	32	-	-	-	-	-	-
SubTotal	END	**827.081**	**253.279**	**391.530**	**338.348**	**457.462**	**878.132**

Table 4-25: Result from linear programming calculation for direct sale product to meet commit volume

Remaining (to sell as separated products)	Index	JUL	AUG	SEP	OCT	NOV	DEC
Indominco		**357**	**1,186**	**1,072**	**1,157**	**1,015**	**643**
West Block PAMA	1	102	590	532	547	348	0
West Block Ketadin	2	50	238	202	80	112	184
East Block	3	205	359	338	530	554	460
Wash Coal	4	-	-	-	-	-	-
IMM Other1	5	-	-	-	-	-	-
IMM Other2	6	-	-	-	-	-	-
IMM Other3	7	-	-	-	-	-	-
Trubaindo		**298**	**360**	**281**	**370**	**393**	**315**
North Block	8	-	-	-	-	-	-
Dayak Besar	9	-	-	-	-	-	-
Biangan	10	-	-	-	-	-	-
LCV -LS	11	198	211	125	28	66	88
HCV -LS	12	50	100	74	165	165	137
HCV -HS	13	50	50	81	177	162	91
TCM Other1	14	-	-	-	-	-	-
TCM Other2	15	-	-	-	-	-	-
TCM Other3	16	-	-	-	-	-	-
TCM Other4	17	-	-	-	-	-	-
Bharinto		**-**	**-**	**-**	**-**	**-**	**-**
Bharinto	18	-	-	-	-	-	-
Bharinto Other1	19	-	-	-	-	-	-
Bharinto Other2	20	-	-	-	-	-	-
Bharinto Other3	21	-	-	-	-	-	-
Bharinto Other4	22	-	-	-	-	-	-
Jorong		**-**	**32**	**-**	**84**	**89**	**71**
JBG product	23	-	32	-	84	89	71
JBG Other1	24	-	-	-	-	-	-
JBG Other2	25	-	-	-	-	-	-
Embalut		**0**	**29**	**0**	**140**	**135**	**74**
EMB North	26	0	29	-	88	87	74
EMB South	27	0	-	0	53	48	0
EMB Other	28	-	-	-	-	-	-
Others		**-**	**-**	**-**	**-**	**-**	**-**
Other1	29	-	-	-	-	-	-
Other2	30	-	-	-	-	-	-
Other3	31	-	-	-	-	-	-
Other4	32	-	-	-	-	-	-
SubTotal	END	**655**	**1,607**	**1,353**	**1,751**	**1,631**	**1,104**

Then go to process 7 and 8 which are prepare revise and summary production plan.

In summary, from case study, the coal production from mines have less tonnage compared with original plan which lead to miss match of coal tonnage between sale plan and actual operation. The coal dynamic blending procedure was applied in order to help coal scheduler to make decision based on value and systematic method. The procedure for adjust blending scenario can't help to full fill demand from sale plan due to less tonnage from operation. But the adjust scenario blending can help to blend coal to meet committed tonnage volume that company already agreed with customer. The dynamic coal blend was implements in studied company to help management to make decision for adjust production plan that more systematic and base on value management. In next chapter, all the work done in Chapter 1 through Chapter 4 will be concluded. In addition, comment and suggestions are address as well.

CHAPTER V

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This research proposes to develop coal blending operation model to increase profit from coal blending program to studied company. The current coal schedule system, coal delivery schedule is done according to the experience of the coal scheduler. There is no scientific method to help judging whether or not the existing system is appropriate or it is done in the logical way. Moreover, the coal supply to customer from mine site during operation has fluctuated. There are many factors that affect the production performance which lead to mismatch production between operation and sale plan. The coal blending operation model is developed for assists the company to plan, control and manage uncertainties from coal operations.

In this research, we use linear programming algorithm help to define blending scenarios from existing production plan for increase additional benefit from blending operation. The objective function of linear programming is to maximize profit of company and the decision variables are coal tonnage from each mine to each coal loading point for blend each type of blending product in monthly basis. In this case of research, the raw coal tonnages from each mine have total 9 types. The coal loading port locations for this study has 5 areas while the coal product types have 7 types. The constraints for linear programming of this study have 5 main group which are tonnage of raw material from mine must follow with update production plan, a coal loading capability is not exceeded, the specification of blending product must within range of product type specification, non-negative constraint of the variable and the final blended production must meet volume committed customer. A tool called Solver of Microsoft Excel is applied to generate the result

The comparison between the plan as a result of the linear programming and the plan in actual operation by using an existing plan as of January 2010, the EBIT from blending coal from each mine is 488 million USD which higher compare with original plan is 451 million USD. The company can get additional benefit about 8.20 % compare with original plan.

Moreover, this research also proposes dynamic coal blending procedure which have main concept for reduce impact of mismatched production by improve communication and information transfer between operation and marketing. The dynamic coal blend procedure will adapt existing work process of this studied company, this procedure aims to use updated information from operation and marketing then create adjustment of production and sale plan by blending to avoid penalty or demurrage charge from customers. This study was use updated information from July until September 2010 for implement dynamic coal blending procedure. The result of implement show that the dynamic coal blending procedure can't help company to get maximum benefit as plan due to there are many changing of factors such as production volume, coal quality change from plan. But the dynamic coal blend that was implements in studied company can help management to make decision for adjust production plan that more systematic and base on value management.

In summary, this research can identify the blending scenario for company to create additional benefit. But during implementation period, there are many factors that can't control which lead to changing of assumptions and constraints. So the assumptions and constraints setting should reflect the real operation that will return better result of calculation and practical to implement. Next topic will discuss about the recommendation of this research.

5.2 Recommendations

This research explains the implementation of the blending operation model for studied company. It also recommends further work that can add value to this research.

5.2.1 Implementation of Coal Blending Operation

Data collection. The most difficult part of this research is data collection. This research collects some data from actual operation where came from various departments which consume time and need to check accuracy of these information. Hence, in order to improve working efficiency of the company as a whole, a center database system should be formally set, continue update and always available for use.

Limitation of linear programming software, In doing this research, the linear programming software is necessary. This study use Microsoft Excel Solver to calculate linear programming algorithm. However there are limited quantities of constraints and decision variable for calculate base on Microsoft Excel Solver. Hence, if it possible, full package of linear programming software should be provided.

Accuracy of operation cost, the accuracy of operation costs is necessary for consider and calculate maximum value of profit to company. The poor operating cost estimate may cause mislead of calculation for optimization.

Accuracy of forecast production plan, the forecast of production plan is necessary for define blending scenarios. The accuracy of forecasting is important for calculate blending scenarios and reduce mismatch production between operation and marketing function.

Accuracy of assumptions, the assumption is necessary for define blending scenarios. The accuracy of assumptions is lead to accurate result. The coal operation model should allow user to adjust assumptions base on real condition that will return better result from calculation.

5.2.2 Extension of the Coal Blending Operation

There are several areas for further research for the problem reviewed in this paper. One area for future research includes developing more blended products scenarios. Secondly, additional raw coal source for blending.

Additional blended product, the additional blended production type is necessary for improve blending operation model. There are alternatives to blend product more than one type for create additional value. The result may cause the company get higher profit from blending more product type.

Additional raw coal for blending, the improving linear programming software package can help to calculate more decision variables. The additional decision variable can help us to add more raw coal type for blending. The additional raw coal type for blend can lead to more alternatives to blend the coal and get better result from calculation.

All works done in Chapter 1 through Chapter 5 are the attempts to formulate the coal blending operation model for Banpu public company to achieve the purpose of the study. Besides the plan proposed and operating cost estimate, other information provided in this thesis maybe used as a primary reference in other related work as well.

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Appendix

Appendix : Transportation cost of each mine

Table A- 1: Alternative transportation cost to coal loading area of IMM

IMM Mine	Unit	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Alternative Blending													
Barge Transportation to Destination													
Barge to Muara Jawa	**FC.sales**	6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11
Barge to Muara Berau	**FC.sales**	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37
Barge to Samarinda	**FC.sales**	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37
Barge to Jorong	**FC.sales**	7.01	7.01	7.01	7.01	7.01	7.01	7.01	7.01	7.01	7.01	7.01	7.01
Barge to Bct	**FC.sales**	5.05	5.05	5.05	5.05	5.05	5.05	5.05	5.05	5.05	5.05	5.05	5.05
Barge to Boct	**FC.sales**	-	-	-	-	-	-	-	-	-	-	-	-
Transhipment Cost/ Unload to Coal Terminal													
Muara Jawa	**FC.sales**	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Muara Berau	**FC.sales**	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Samarinda	**FC.sales**	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Jorong	**FC.sales**	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Bct	**FC.sales**	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Boct	**FC.sales**	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Port/ Coal Terminal Charge													
Bct Charge	**FC.sales**	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50
Boct Charge	**FC.sales**	-	-	-	-	-	-	-	-	-	-	-	-
Alternative Blending and Loading at Coal Terminal													
Bct Blending	**FC.sales**	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Boct Blending	**FC.sales**	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13

100

Appendix : Transportation cost of each mine

Table A- 2: Alternative transportation cost to coal loading area of TCM

TCM Mine	Unit	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Alternative Blending													
Barge Transportation to Destination													
Barge to Muara Jawa	FC.sales	8.29	8.29	8.29	8.29	8.29	8.29	8.29	8.29	8.29	8.29	8.29	8.29
Barge to Muara Berau	FC.sales	8.65	8.65	8.65	8.65	8.65	8.65	8.65	8.65	8.65	8.65	8.65	8.65
Barge to Samarinda	FC.sales	8.65	8.65	8.65	8.65	8.65	8.65	8.65	8.65	8.65	8.65	8.65	8.65
Barge to Jorong	FC.sales	9.41	9.41	9.41	9.41	9.41	9.41	9.41	9.41	9.41	9.41	9.41	9.41
Barge to Bct	FC.sales	7.20	7.20	7.20	7.20	7.20	7.20	7.20	7.20	7.20	7.20	7.20	7.20
Barge to Boct	FC.sales	6.62	6.62	6.62	6.62	6.62	6.62	6.62	6.62	6.62	6.62	6.62	6.62
Transhipment Cost/ Unload to Coal Terminal													
Muara Jawa	FC.sales	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Muara Berau	FC.sales	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Samarinda	FC.sales	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Jorong	FC.sales	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Bct	FC.sales	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Boct	FC.sales	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Port/ Coal Terminal Charge													
Bct Charge	FC.sales	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50
Boct Charge	FC.sales	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50
Alternative Blending and Loading at Coal Terminal													
Bct Blending	FC.sales	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Boct Blending	FC.sales	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13

101

Appendix : Transportation cost of each mine

Table A- 3: Alternative transportation cost to coal loading area of JBG

JBG Mine	Unit	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Alternative Blending													
Barge Transportation to Destination													
Barge to Muara Jawa	**FC.sales**	9.48	9.48	9.48	9.48	9.48	9.48	9.48	9.48	9.48	9.48	9.48	9.48
Barge to Muara Berau	**FC.sales**	10.12	10.12	10.12	10.12	10.12	10.12	10.12	10.12	10.12	10.12	10.12	10.12
Barge to Samarinda	**FC.sales**	10.12	10.12	10.12	10.12	10.12	10.12	10.12	10.12	10.12	10.12	10.12	10.12
Barge to Jorong	**FC.sales**	3.58	3.58	3.58	3.58	3.58	3.58	3.58	3.58	3.58	3.58	3.58	3.58
Barge to Bct	**FC.sales**	7.44	7.44	7.44	7.44	7.44	7.44	7.44	7.44	7.44	7.44	7.44	7.44
Barge to Boct	**FC.sales**	8.12	8.12	8.12	8.12	8.12	8.12	8.12	8.12	8.12	8.12	8.12	8.12
Transhipment Cost/ Unload to Coal Terminal													
Muara Jawa	**FC.sales**	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Muara Berau	**FC.sales**	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Samarinda	**FC.sales**	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Jorong	**FC.sales**	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Bct	**FC.sales**	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Boct	**FC.sales**	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Port/ Coal Terminal Charge													
Bct Charge	**FC.sales**	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50
Boct Charge	**FC.sales**	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50
Alternative Blending and Loading at Coal Terminal													
Bct Blending	**FC.sales**	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Boct Blending	**FC.sales**	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13

Appendix : Transportation cost of each mine

Table A- 4: Alternative transportation cost to coal loading area of EMB

EMB Mine	Unit	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Alternative Blending													
Barge Transportation to Destination													
Barge to Muara Jawa	FC.sales	6.42	6.42	6.42	6.42	6.42	6.42	6.42	6.42	6.42	6.42	6.42	6.42
Barge to Muara Berau	FC.sales	7.04	7.04	7.04	7.04	7.04	7.04	7.04	7.04	7.04	7.04	7.04	7.04
Barge to Samarinda	FC.sales	7.04	7.04	7.04	7.04	7.04	7.04	7.04	7.04	7.04	7.04	7.04	7.04
Barge to Jorong	FC.sales	7.37	7.37	7.37	7.37	7.37	7.37	7.37	7.37	7.37	7.37	7.37	7.37
Barge to Bct	FC.sales	5.10	5.10	5.10	5.10	5.10	5.10	5.10	5.10	5.10	5.10	5.10	5.10
Barge to Boct	FC.sales	4.52	4.52	4.52	4.52	4.52	4.52	4.52	4.52	4.52	4.52	4.52	4.52
Transhipment Cost/ Unload to Coal Terminal													
Muara Jawa	FC.sales	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Muara Berau	FC.sales	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Samarinda	FC.sales	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Jorong	FC.sales	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Bct	FC.sales	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Boct	FC.sales	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Port/ Coal Terminal Charge													
Bct Charge	FC.sales	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50
Boct Charge	FC.sales	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50
Alternative Blending and Loading at Coal Terminal													
Bct Blending	FC.sales	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Boct Blending	FC.sales	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13

BIOGRAPHY

Mr. Jamon Jamuang was born on December 12, 1978 in the city of Nakhonratchasima. He obtained a Bachelor Degree of Engineering in Mining Engineering from Chulalongkorn University, Thailand in 2000. Since then he worked for BANPU Public Company. In 2007, he enrolled as a part-time student working toward a Master's degree in engineering management at the Reginal Centre of Manufacturing Systems Engineering, Chulalongkorn University (Thailand) and University of Warwick (United Kingdom).