 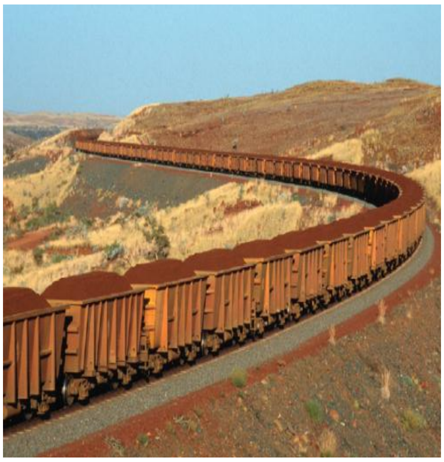 

Multimodal coal transportation in Indonesia

Master thesis in Urban, Port and Transport Economics

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Abstract

Multi Criteria Decision Analysis has been used to assess the potential of multimodal coal transportation in Indonesia. The analysis is based on a financial and qualitative comparison of different transportation modalities. The findings on optimal distances of road and belt conveyor transport have been extended based on varying throughput levels of coal, in order to determine their competitiveness. The qualitative aspects have been assessed researched based on a survey about the state of affairs and market risks in Indonesia.

The analysis revealed that mine operators are risk averse and look for a quick return on the invested capital. It has also been concluded that the dependence on road transport is increasing, due to the lack of government moderation. The government must work on ensuring a more safe and reliable business environment for the private sector to invest into in the Indonesian market.

Acknowledgments

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Acronyms

CAPEX	Capital expenditures
CIF	Cost, insurance, freight
CO2	Carbon dioxide
FDI	Foreign direct investment
FOB	Free on board
GDP	Gross domestic product
MCDA	Multi Criteria Decision Analysis
MtpA	Million tonnes per annum
NOX	Mono-nitrogen oxides
NPV	Net Present Value
OPEX	Operational expenditures
PM2.5	Pollution particulate <2.5 micrometers, EU standard
P2P	Pit to port
PwC	Pricewaterhouse Coopers
ROI	Return on investment
TNO	Netherlands Organization for Applied Scientific Research TNO
TPH	Tonnenes per hour
SO2	Sulphur dioxide

Terminology

CAPEX	Capital Expenditure is a business expense incurred to create future benefit i.e. acquisition of assets that will have a useful life beyond the tax year. Examples are expenditure on assets like building, machinery, equipment or upgrading existing facilities so their value as an asset increases. (NYU, 2013)
CIF	CIF is a form of a contract which requires the customer to bear the risks and costs of the transportation (Robinson, 2007)
Dedicated node	Nodes are the beginning, end and transshipment points for transportation between geographic areas that are fully owned and potentially used by a single user
FOB	FOB means "free on board" requiring the mining operator to bear the risks and costs of moving the cargo to the terminal and on to the ship (Robinson, 2007)
Intermodal network	Logistical system, which is connected by two or three more modes that enable cargo to move to another node in one trip from origin to destination (Lubis, et al. 2005)
Link	A path over which a modality moves to transport cargo, such as road, rail, river, sea, pipeline, or belt conveyor (Ligteringern, 2009)
Mine operator	A company that owns the mine is financially responsible for mining of the product
Modality (mode)	Defines which transport system is employed, such as rail, truck, barge, or belt conveyor
Multimodal network	A transport system usually operated by one carrier with more than one mode of transport (Lubis, et al. 2005)
OPEX	Operational expenditure is the money the business spends in order to turn inventory into throughput. Operating expenses also include depreciation of plants and machinery, which are used in the production process (NYU, 2013)
Pit to port	The chain of transportation from the mine to the shipping facility
Transshipment	Transfer of a shipment from one carrier, or more commonly, from one vessel to another (businessdictionary, 2013)

Chapter 1 Introduction

The introductory chapter of this thesis will:

- explain the business, academic and social relevance of this research,
- introduce the main area of interest and its problems,
- present the chosen research approach,
- explain the structure of the thesis.

1.1 Relevance of the research

1.1.1 Business relevance

The business model of management consulting has grown tremendously (Sager, 2013). A recent survey carried out by Source Information Services, showed that:

- 80 percent of US corporate clients will not decrease budget spending on the external advice,
- half will increase their spending by more than 50 percent on consultation.

Such a trend is present in every region in the world, since statistics on European and Asian market also confirm the growing role of consultancies. When examining Asian markets, a country like Indonesia, which is expected to enter the top 10 leading economies of 2030 (Oberman, 2012), is leading the top five fastest-growing country markets for consulting services (Deloitte, 2013). One of the leading engineering and project management consultancies Royal HaskoningDHV, the strategy for the future concentrates on the Indonesian market. In order to establish its goals for the future, it needs to:

- eliminate the gap in knowledge and expertise available within the company, due to a recent merger,
- systematically accumulate relevant knowledge about the Indonesian market.

This thesis aims at collecting all the relevant information in the fields of mining, transportation, and working environment in Indonesia into one place. This will directly contribute the strategic value of the company sources and improve its long-term competitiveness in the Asian markets.

1.1.2 Academic relevance

This theses aims to:

- apply multimodal transport knowledge on dry bulk as the previous literature concentrates on containerized cargo transportation,
- determine at what transport quantities modalities must be switched as previous quantitative models concentrate on examination of optimal distances of modalities,
- develop Multi Criteria Decision Analysis (MCDA) on Indonesia due to lack of academic literature on East Asia Pacific region.

1.1.3 Social relevance

The Indonesian economy is developing exceptionally fast. In order for a consultancy to provide advice that would deliver long-term results, it is important to assess the competitive advantages that are driving the Indonesian economy. Indonesia had a GDP of 878.04 billion US dollars in 2012 (World Bank, 2013). The Indonesian economy has become significantly dependent upon the success of its mining industry:

- The mining sector contributes around six percent to its GDP.
- A fifth of the incoming Foreign Direct Investment is directed to the mining sector (Winzenried, 2012).

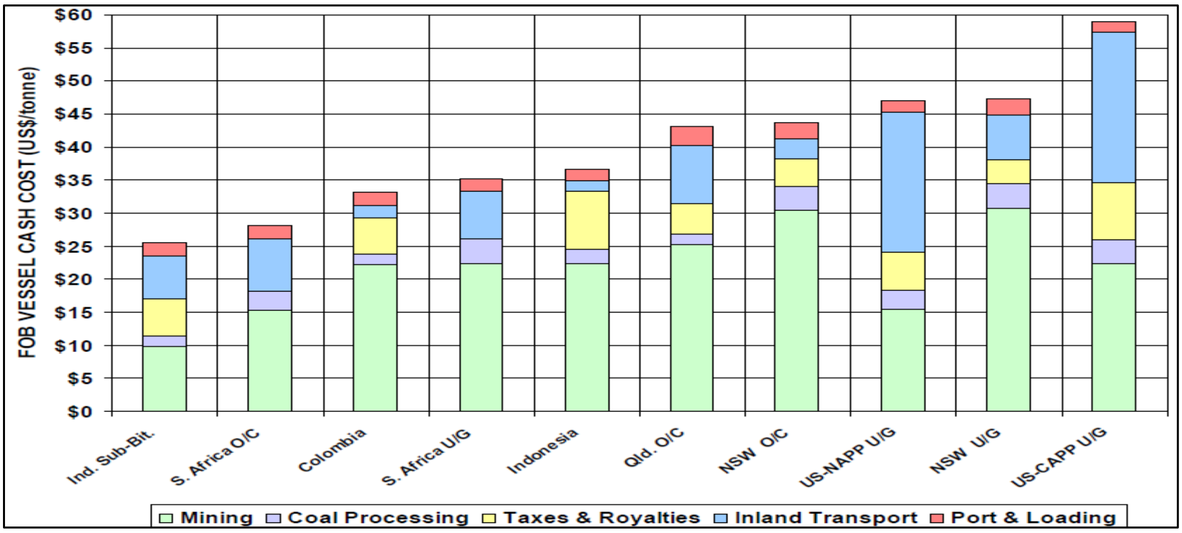
Due to the fast growing population and large reserves of natural resources, many international investors direct their investments into Indonesia. Mining is viewed as one of the main drivers of Indonesian economy.

Before the global crisis the Australian economy was leading the mining exports. Today the Indonesian steaming coal exports amount to 309 million tons per year (world coal association, 2013). It can be explained by:

- Indonesia's close proximity to the largest consumer markets of India and China,
- The favorable export policy,
- Rich reserves of natural resources.

Biljon (2011) indicated transportation logistics and costs play a significant role in the feasibility and sustainability of a mining venture. For Indonesia, which is leading the world's exports of coal, it is essential to work on sustaining this position. Regions like South Africa pose a threat to Indonesian mining, as it can offer lower production costs as shown in Figure 1 (Devon, 2010). Therefore, Indonesian companies need to eliminate all the inefficiencies in transportation costs, despite the rising labor and fuel costs.

Figure 1 Mining production cost comparison between different regions



(Source: Devon, 2010)

In the past, the Indonesian transportation sector was almost fully liberalized. Nowadays it is highly dominated by private toll roads (Lubis, et al. 2005). The current lack of coordinated spatial planning significantly decreases the potential of Indonesia to keep the prices of their main export products to a minimum. As indicated by Lubis there exists an urgency in the successful implementation of multimodal transport in Indonesia, as it would:

- directly benefit the competitiveness of their national products,
- provide faster transit of goods,
- minimize the loss of time, money, and cargo (ETAMAD, 2013),
- reduce the logistical chain costs (UNESCAP, n.d.).

1.2 Context and problem definition

In the period between 2002 and 2011, mining companies were racing to meet the growing demand, while facing increasing costs and decreasing the productivity (Jackson, et al. 2012). As a consequence, when the demand slowed down, companies were left with major inefficiencies in their supply chain operations. As indicated by Keith (2013) back in 1998 plant equipment and machinery made up some 60 percent of a mine's development cost while infrastructure (such as transport including energy) made up around 40 percent. By 2011 infrastructure represents around 80 percent of development costs and plant and machinery taking up only 20 percent. Nowadays the transportation and logistical costs are becoming an incremental determinant of whether a mine operator chooses to take up new projects. According to Biljon (2011) transportation part of a mine logistical chain has a direct impact on the mine productivity, its operating costs, product quality and its final market price. As a result, the role of transportation cost minimization and optimization has become a major source of attention.

In the past, mine sites were located in close proximity to the sea ports, nowadays these types of locations have become more rare. In case of Indonesia the distances used to vary between 10 and 35 km, but nowadays the distances reach beyond 75km (Ewart, 2009). Devon (2010) aimed to present the comparison of inland hauling lengths between different regions; his findings indicated that distances for Indonesian market can reach up to 500 km. Consequently, due to the growing dependency on road transport, this raises the environmental threat (Kim, et al. 2009).

In order to reduce the existing pollution and control CO2 emissions, different policies aim at increasing the market shares of non-road freight transport modes by focusing on the inter-, or multi-, modal freight transport systems (Kim, et al. 2009). Increased cooperation and collaborative multimodal transportation systems can be seen as a potential solution to decrease the logistical costs and maintain or even improve the logistical services. The necessary synchronization between expensive but fast and flexible means of transport and inexpensive, but slow and inflexible means can be combined (Groothedde, et al. 2005).

Various researchers have developed advanced algorithmic models to determine which transportation modes are most sustainable and provide the largest cost savings (McCann, 2001; Sahin, et al. 2009; Beresford, et al. 2011). In contrast to this, the industry's possibilities of actually employing these models are viewed as limited, due to:

- The high complexity,
- Lack of their transparency,
- The unique characteristics of projects.

This thesis will aim at suggesting possible solutions for the mining industry while controlling for the above-mentioned limitations.

By applying the examination of transport infrastructure and locational characteristics of the Indonesian market, it can be determined whether multimodal transport can solve the rising costs and whether the companies and state are interested and able to develop this potential. Therefore, the next section will present the main objectives and research questions formulated for this research, which will then be followed by a presentation of the chosen approach.

1.3 Research objectives and questions

The objectives of this master thesis are to:

- Assess the importance of quantitative and qualitative factors for logistical design of transportation chains,
- Derive a framework to determine at what throughput quantities of coal different transportation modes must be used,
- Explore the potential of multimodal transportation networks in the Indonesian market,
- Assess the potential of multimodal transportation networks for coal transportation in the Jambi region.

This thesis will aim to answer the following questions:

"What are the problems in developing multimodal coal transportation from pit-to-port in the Republic of Indonesia?"

This will be achieved by dividing the research into three sub-questions:

- What are the factors that influence the logistical design of transportation chains?
- At what throughput quantities of coal are certain modalities most commonly employed?
- To what extent do qualitative and quantitative factors affect the potential of multimodal transport networks for coal transportation in Indonesia?

1.4 Research approach

As the thesis consists out of several parts, it is important to explain how each of them is related and help to draw a final conclusion. Therefore, each of the important aspects will be defined one by one.

1.4.1 Concept of multimodality

Different researchers have attempted to define the concept of multimodality, depending on the context of their own research, such as:

Multimodal Transport: a transport system usually operated by one carrier with more than one mode of transport under the control or ownership of one operator. It involves the use of more than one means of transport such as a combination of truck, railcar, aeroplane or ship in succession to each other and provides a connection from origin to the destination (Lubis, et al. 2005, UNESCAP, n.d.).

Multimodal transport has mainly been applied to container transportation that is assembled at the origin and transported as the same unit. The supply chain of dry bulk is different as it can be loaded, reloaded, or mixed at transshipment locations. Therefore, physically it may not be the same unit of cargo, but the concept of a multimodal supply chain can still be used, as several consecutive modalities are used in within the same supply chain. This way a mine operator becomes a multimodal transport operator, who can define individual contractual agreements with transport operators and providers like railway or barge transport, or assume the whole responsibility by himself; employing a personal multimodal transport chain.

1.4.2 Relevant dry bulk commodity

While in the past different authors have explored various potential strategies of multimodal transport networks for Indonesia (Lubis, et al. 2005), it appears that the actual implementation of these strategies have been limited. This can be due to the broad scope of the proposals that lack the precision and a specific subject in question. As a result, this thesis will narrow the scope of the research and aim at evaluating the potential of multimodal transportation for thermal coal exports from Indonesia.

1.4.3 Chosen research framework

After reviewing different methodologies used for multimodal dry bulk transportation, it was evident that most of the models used are either purely quantitative or qualitative. Furthermore, while the academic literature on USA and Australian mining markets is quite rich, there is significantly less literature on Asian mining markets. After combining these two conclusions, it seemed necessary to address the issue and develop a framework that would not only combine the quantitative and qualitative aspects, but would be applicable on Indonesian market. The Multi Criteria Decision Analysis (MCDA) was chosen for this research.

Due to the framework of MCDA, the research was initially split into two parts.

For the quantitative part of the analysis, a cost comparison between the most common coal transportation modalities was made to assess their costs and benefits. This allows an assessment of the costs of transportation of different coal quantities in order to determine at what throughput the modality should be switched.

To arrive at the necessary entries for the MCDA, a qualitative list of factors was collected into a survey. Respondents were asked to score the factors, indicating the importance of this factor to determine the potential of multimodal dry bulk transportation development in Indonesia.

Finally, the MCDA was applied combining the findings from quantitative and qualitative parts. As a result, MCDA concluded what are the current bottlenecks for multimodal dry bulk transportation in Indonesia.

1.5 Structure of the thesis

After defining both the concepts and approach chosen for this research, a final structure of the thesis can be presented, outlining what chapters a reader can expect while reading this thesis.

Chapter 2 will present the methodology used for this research, while Chapter 3 will evaluate factors important for logistical transportation chain designs. Chapter 4 will evaluate coal transportation modalities and Chapter 5 will present the case study and apply the framework of comparison between the modalities from Chapter 4. Chapter 6 will present the survey and discuss its findings. In Chapter 7 findings from Chapter 6 and Chapter 5 will be combined into a MCDA. Chapter 8 will provide a conclusion, discuss the limitations of this research and suggest ideas for further research.

Chapter 2 Methodology

This chapter will explain the methodology used in this research.

2.1 The method for the analysis

The aim of this thesis is to identify possibilities on how to control the increasing costs of mine operators for coal transportation in Indonesia. While it would seem that only a few factors would be involved in such decision, the reality is more complex. When talking about mining projects a few similarities can be identified, as both are subject to:

- Many sources of uncertainty and risks,
- Long term operations,
- Capital intensive investments,
- Many contradictory views (Loken, 2005).

The problem involves the Indonesian natural resource management, as mine operators are transporting coal that is mined from their grounds. Due to the large power in the hands of the private sector in developing the infrastructure, this becomes a more regional or even national concern of urban planning and transportation development in Indonesia. As it concerns the transportation of coal, it immediately involves the energy consumption and the environmental threat caused by cargo transportation. As a result, it involves the policy makers regarding the sustainable development and energy planning. Therefore, it can be evaluated as an issue of regional importance.

The problem that a mine operator is facing actually requires much broader examination. This means that while a mine operator could only concentrate on the cost examination to control the growing transport expenditures, other parties might bear different interests in mind. According to Loken (2005) decision makers aim to choose for an optimal solution, while this solution only exists if a single criterion is considered. Unfortunately, when looking at situations nowadays, no one problem is that simple, as it is likely to pose conflicting or even non-commensurable objectives for the decision makers.

When looking at the nature of the problem in question, it seems to fit under the type of problem defined by Montis (1999). "*In case of decisions where conflicting economic, environmental, societal and technical objective are involved, Multi Criteria Decision Analysis tools are necessary to support the decision making*." While a mine operator would purely concentrate on the financial nature of his decision, government and local communities might favor a more sustainable but slightly more expensive solution for the problem.

MCDA has become a popular tool of analysis to solve economic, social and even construction problems (Brauers, 2008). Already in 1990, research by Petry concluded that "*classical economic analysis and optimization techniques are not sufficient to assist decision makers in development planning and policy making"*. Only looking at financial comparisons or basing the judgment on surveys and questionnaires, would not provide the optimal solution for the long term. As a result, MCDA is being characterized as a more rational, explicit and efficient approach suitable for complex decision making (Pohekar, et al. 2008). Figure 2 gives two examples when a cost comparison has been carried out on selecting a modality for coal transportation. It allows concluding that especially due to only concentrating on the financial aspects of modalities, the broader picture is excluded from the analysis. If in the past the traditional methods of cost and profit optimization have been enough to survive, nowadays these methods prove to be insufficient (Korpela, et al. 2008). Neither location specifics nor views on environmental sustainability or risks and uncertainty are captured in the financial overview of a modality.

Figure 2 Examples of methodologies used for transportation research in mining industry

Example 1

The approach designed by Sevim & Sharma (1991) allowed for a comparative economic analysis of transportation systems in surface coal mining. The goal of this research was to compare the costs and distances for coal transportation between three comparative transport modes, such as truck haulage, belt conveying, and coarse-coal slurry transportation. The research aimed at evaluating each of the modes based on its operations and costs, in order to advise which should be used in surface coal mines.

Example 2

A comparable research was carried out by Sahin & Yilmaz (2009), aiming to compare road, rail, and sea transportation of cargo. The method employed started with defining relevant mathematical equations that determine different factors like annual capital costs, operational and maintenance costs, etc., which afterwards were applied to each of the transportation modes, based on predetermined values of the necessary coefficients. As a result, the aim was to examine how the unit transportation costs of either cargo or passengers are affected by the fullness of the modality employed.

MCDA has been characterized as a method in assisting parties to make decisions, when conflicting interests are at stake. According to Loken (2007) MCDA allows to break a more complex problem into smaller pieces, then after evaluating and weighting each of the smaller aspects, it presents the most feasible solution. Therefore, MCDA captures the preferences and opinions of all the decision making parties, allowing for a uniform decision to be made at the end.

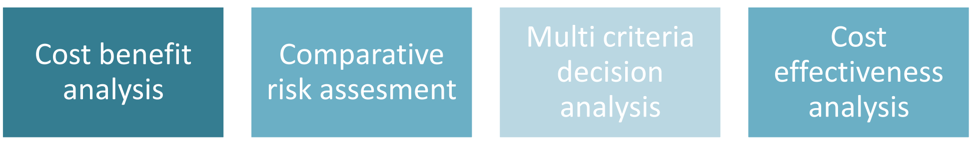
MCDA has been applied to different fields of research, such as:

- Governmental policy making,
- The development and transport planning (Petry, 1990),
- Sustainable energy decision making (Pohekar, et al. 2003; Wang, et al. 2009),
- Natural resource management (Mendoza, et al. 2006)
- Environmentally sustainable transport system planning (Yedla, et al. 2003)
- And even road design (Brauers, et al. 2008).

This makes it applicable and relevant for this research as it touches upon each of the subjects. When offering several possible methods of a similar nature to MCDA, Montis (2000) indicated that MCDA can be chosen in cases when a finite number of options are determined, out of which one option can be chosen. This yet again applies to this thesis, where several logistical chains will be evaluated based on multiple criteria, while a single option will be preferred. Additionally, Munda (1995) highlighted a strong advantage of MCDA of being able to include and compare factors of varying kind, such as:

- "*Costs and benefits of a case, project or an option,*
- *Environmental quality in physical and qualitative terms,*
- *Social impact in non-monetary terms,*
- *Even the verbal descriptions of aesthetics.*"

Looking at the literature on comparable methods to MCDA it distinguishes between four the most commonly used approaches:



A complete overview is presented in Appendix Table 14. As many views important for decision-making are hard to monetize, the approach chosen in this research must:

- Allow to compare quantitative and qualitative factors,
- Include Indonesian market characteristics,
- Identify the problematic issues for transportation and infrastructure development,
- Rank the possible alternatives, and suggest the most optimal solution,
- Be transparent and easy to use.

It allows one to conclude that in addition to the above mentioned reasons, MCDA is the most suitable approach as it:

- Accommodates the quantitative and qualitative aspects into the analysis,
- Allows to capture technical complexity into the analysis,
- Stimulates learning about the problem (Stewart and Beltonne, 2002),
- Is a transparent, systematic, and simple (Dodgson, 2009).

Therefore, for the examination of the multimodal coal transportation in Indonesia, a MCDA will be used. Different approaches can be followed in using MCDA, which is why the next section will outline the specific steps of the method used in this research.

2.2 Research approach

In order to apply MCDA to evaluate the potential of multimodal coal transportation, a specific method of analysis must be followed (Wang, et al. 2009):

- Criteria selection,
- Criteria weighting,
- Evaluation,
- Final aggregation.

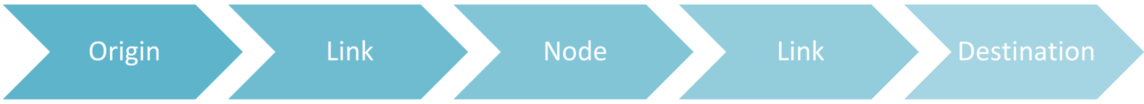
Each of the steps requires a different approach and will be explained in more detail in this section.

To develop criteria for MCDA an exploratory literature study is required. In order to evaluate the potential of multimodal coal transportation, the nature of dry bulk supply chains has been examined. This has helped to outline the most determining factors influencing the design of transportation chains.

The factors have been grouped into categories of a quantitative and qualitative nature. Qualitative factors will be even further regrouped based on the subject. This will allow a closer examination of each of the categories as different methodologies are required and have been used for their assessment.

According to the literature, the main elements present in logistical chain designs are (Christopher, 2005):

- Links like road, rail, barge, belt conveyor actually transport the cargo
- Nodes like ports, transshipment, storage locations facilitate the loading, unloading, stacking and/or storage of the cargo



Each of the elements has been discussed based on qualitative and quantitative examination.

Quantitative factors have been examined based on logistical composition of transport chains, as costs incurred at each of the elements can be calculated and compared. Based on academic literature it is possible to identify the main cost categories for links and nodes, where comparable cost frameworks have been designed. This has been achieved by consulting experts in person or over the phone at Royal HaskoningDHV and Delft University of Technology:

- Bos, C. Project Manager, Maritime and Waterways, Royal HaskoningDHV,
- Calitz, F. Civil Engineering, Transport at Royal HaskoningDHV,
- Hiltermann, J. Dry bulk consultant, Heavy Industry, Logistics, Royal HaskoningDHV,
- Joubert, P. Pavement engineer, Transport, Royal HaskoningDHV,
- Vermij, H. Project Director, Maritime and Waterways at Royal HaskoningDHV,
- Interview with Prof. Lodewijks from Delft University of Technology.

By identifying the main cost elements, it is possible to compare the costs of different logistical chains. The cost comparison will be based on throughput quantities of coal, as it will allow concluding at what throughput quantities each of the modality is more optimal to use.

In order to carry out the quantitative analysis, a case study on Indonesian market has been designed. The case study proposes several logistical chains that can be used for coal transportation. Although, there are several options available, only the most feasible logistical chains have been further analyzed. By comparing the costs of different designs, the most cost effective transport chain for a specific output quantity has been identified.

To develop a systematic weighting of criteria, a survey on Indonesian markets has been designed. The survey is composed to evaluate the qualitative factors that have been identified in the academic and industry literature, in order to judge their applicability to the Indonesian market.

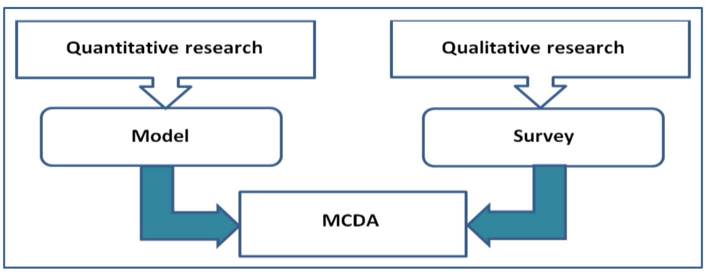
The survey consists of a list of collected factors has been emailed to ten potential respondents. Respondents have been identified by discussing their suitability with experts in the department at Heavy Industry and Logistics within Royal HaskoningDHV:

- Hiltermann, J. Dry bulk consultant, Heavy Industry, Logistics, Royal HaskoningDHV,
- Simons, B. Director Business Unit, Heavy Industry, Logistics, Royal HaskoningDHV,
- Van de Sande, T. Dry Bulk & Logistics Engineer, Heavy Industry, Logistics, Royal HaskoningDHV.

The goal has been to identify experts who are the most familiar with the Indonesian market and would be interested to share their knowledge. In the survey, respondents have been asked to score the factors, indicating how critical they are for the potential of multimodal coal transportation in Indonesia. Based on the individual grading, average scores can be obtained, translating them into comparable weightings. More detailed explanation about the sample, grading, and data collection has been presented in Chapter 6.

The evaluation and aggregation of the final decision by using MCDA will be applied on the previously mentioned case study on the Indonesian market. By including the cost comparison and weightings from the survey, not only a financial comparison can be carried out, but specific market and locational factors can be included into the final decision. This allows one to draw a conclusion about the potential of multimodal transportation networks to decrease the growing transportation costs for the mining industry. The visual representation of the steps taken in the analysis is shown in Figure 3.

Figure 3 Visual representation of the approach in this thesis



Chapter 3 Transport chain design

The goal of this chapter is to identify factors that influence the design of transportation chains. To arrive at the list it is necessary to examine what is the role of transportation within the context of a supply chain and logistics. The necessary relations will be determined in the beginning of this chapter, while the second part of the chapter will concentrate on the examination of the relevant categories of factors.

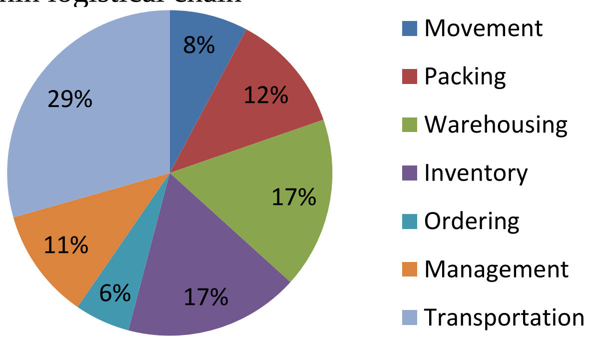
3.1 Supply chain management

The practice of supply chain management has become a dominant part of today's business environment. Robinson (2010) concluded that competition on an individualistic firm level has ceased to exist, due to more integrated and more global competition between the supply chains. Management practices are driven by customer value maximization and constant strive to become more effective, in order to achieve a stronger competitive position. Already in 1998, Ross had defined the supply chain management as "*a management philosophy that seeks to unify the collective productive competencies within and outside the enterprise into a highly competitive, customer-enriching supply system focused on developing innovative solutions, products, services, and information to create unique, individualized sources of customer value*."

Different variations in the division of activities within a supply chain have been proposed. Korpela (2008) proposed to split it into three stages of procurement, production and distribution, while Thomas (1996) has split it into purchase, manufacture and transport. Handfield (2013) has given more detailed division into activities like product development, sourcing, production, and logistics. Though, the main idea behind any type of the division is that while in the past each of these activities was managed separately, nowadays it is practically impossible to draw a line between each other. Due to constant information exchange and flow of resources between the activities, there exists a great logistical dependency within the whole chain.

Both logistics and transport have been identified as activities present within the supply chain (Thomas, et al. 1996; Handfield, 2013). Based on the findings of Tseng (2005) transportation is an integral part of the logistics chain as it links the separate activities. Transportation costs represent from one to two thirds of the total amount of costs directed to logistics as shown in Figure 4, while logistics costs are around 30 percent of the total cost of goods sold (Wang, et al. 2004; Tseng, 2005). This means that better organized and optimized transportation chains are able to produce cost savings and improve the performance of the whole supply chain.

Figure 4 The percentage of each costs incurred within logistical chain



(Source: Tseng, et al. 2005)

The type of a strategy used to design a supply chain is of critical importance to achieve an efficient supply chain performance. Mining companies employ a practice of demand driven supply chain designs, concentrating on the improving of customer service at the same time valuing their own profitability (Accenture, 2012). According to Wang (2004) the critical objective of supply chain management is to meet the demand more efficiently. This means that not only the customers must be satisfied with the service, but

- Operational costs and working capital must be decreased,
- The speed of operations must be optimized,
- The specific product characteristics have to be taken into account for the design of a supply chain (Wang, et al. 2004).

3.1.2 Distribution network design

When looking at the literature about problems in distribution network designs, these problems mainly look at finding the optimal solution how to transfer the cargo from the production facility to the client, while minimizing the overall costs (Ambrosino and Scutella, 2005). This is precisely the problem faced by mine operators in Indonesia, trying to find an optimal transportation chains in order to control for the increasing transport costs. Chopra (2003) has concluded that distribution is the key driver of the profitability of a company, as it has a direct impact on the performance as it determines:

- The supply chain responsiveness,

- The customer experience,
- The final price of a product.

As a result, not more than one company in the same industry is using the same design of the distribution channel, as each can face different problems or concentrate on a separate business niche. Therefore, the factors important for varying distribution chains will differ based on a different channel design. As mentioned earlier, the effective design and integration of all the activities within a logistics chain is the key in reducing the operational costs (Wang, et al. 2004) and improving the competitive advantage.

When evaluating transportation chains of mine operators in Indonesia, different factors will be influencing its logistical chain design from mine operators in Australia or South Africa. Therefore, the specific factors present at this location must be taken into account when designing a transportation chain for the Indonesian market.

3.2 Factors determining the design of transportation chains

The design of the transportation chain is of great strategic importance as major costs can either be saved or lost due to the chosen logistical chain. Numerous factors can affect this decision. A significant capital investment is necessary to construct the transportation chain, it is essential to choose for the most effective alternative in the first place. Though, it can be questioned whether any constructed logistical chain can be evaluated as the best alternative for the long term, as due to the market dynamics, change is the only constant faced by market participants (Coyle, 2011).

De Vries (2000) has outlined different factors that are important determinants for the design of logistical chains. These factors are outlined in Figure 5. His findings have been rather general and can be applicable to almost any transportation chain in question. Emmett (2009) on the contrary has aimed at taking more specific approach and concentrated on the physical characteristics of cargo when designing a transport chain. For instance, characteristics of a product have been explicitly mentioned by four of the six authors, while the remaining two indirectly include aspects such as the size of the order (De Vries, 2000) and practical value of cargo (Kuipers, 2004). Based on Figure 5, it can be seen that several factors overlap in the findings of different authors, though the context and the application in each of the papers might be slightly different.

Figure 5 Factors affecting the design of logistical chains

Lubis, et al. 2005

- Characteristics of a product,
- Characteristics of modes,
- Distance.

Kuipers and Eenhuizen, 2004

- Market power,
- The practical value,
- Uncertainty in demand,
- The degree of specialization,
- The cost level,
- The logistics focus.

Meuwissen, 2005

- Destination of the cargo,
- Characteristics of a product,
- Efficiency of the port.

De Vries, 2000

- Transport costs,
- Handling costs,
- Stock costs,
- Costs for collecting / distribution of cargo,
- Speed,
- Flexibility,
- Reliability,
- Risk of damage,
- Perishability,
- Interest costs,
- Safety.

Chance of congestion/delays,
Damage to the environment,
Connections in the seaport,
Image,
Loading restrains,
Habituation,
Traditions,
Manner of packaging,
Size of order,
Law,

Emmett, 2009

- Characteristics of a product.

Cullinane and Toy, 2000

- Cost,
- Speed,
- Transit time reliability,
- Characteristics of a product,
- Service.

Authors like Banomyong (2000) and Kuipers (2004) have been more specific in their findings by concentrating on specific locational characteristics that must be taken into account in the design of logistical chains. Banomyong (2000) has mentioned factors like:

- Commercial practices have to be worked out,
- Administrative requirements must be aligned,
- Transport infrastructure has to be constructed and available for use.

When evaluating the logistical design of multimodal transportation networks, especially the intensive co-operation and co-ordination between different parties and respective modalities is required. Similarly as for supply chain management, for the design of the transportation chain the interaction between different activities or parties determines the success of its performance.

Based on the factors listed in Table 5 and conclusions of Wang (2004), Kuipers (2004), Bontekoning (2004) and Christopher (2010), factors influencing the design of transportation chains can be split into categories:

For instance, factors affecting the logistical network design are more quantitative, while factors relating to multi-actor and risk management sometimes are rather difficult to express into monetary terms. Therefore, for the purpose of analysis each of the factors has been categorized based on their quantitative or qualitative nature, and will be analyzed separately in each of the following sections.

3.2.1 Physical characteristics of coal

The type of the commodity has a determinant role in what mode of transport can be used for its transportation due to its physical characteristics (Emmett, 2009). These characteristics and their respective definitions are presented in Table 1.

Table 1 Physical characteristics of a cargo with definitions

Term	Definition
Value	Monetary or material worth
Weight	Mass of the cargo
Volume	Size of cargo
Density	Mass per unit of volume
Perishability	Degree of spoilage or decay
Hazardousness	Degree of pollution or explosiveness

3.2.1.1 Value of thermal coal

Overall, coal is one of the largest and most commonly used fossil fuel that generates around 23 percent of the world's energy (Baker, 2013). There are two types of coal available: thermal and coking coal, the uses of these differ:

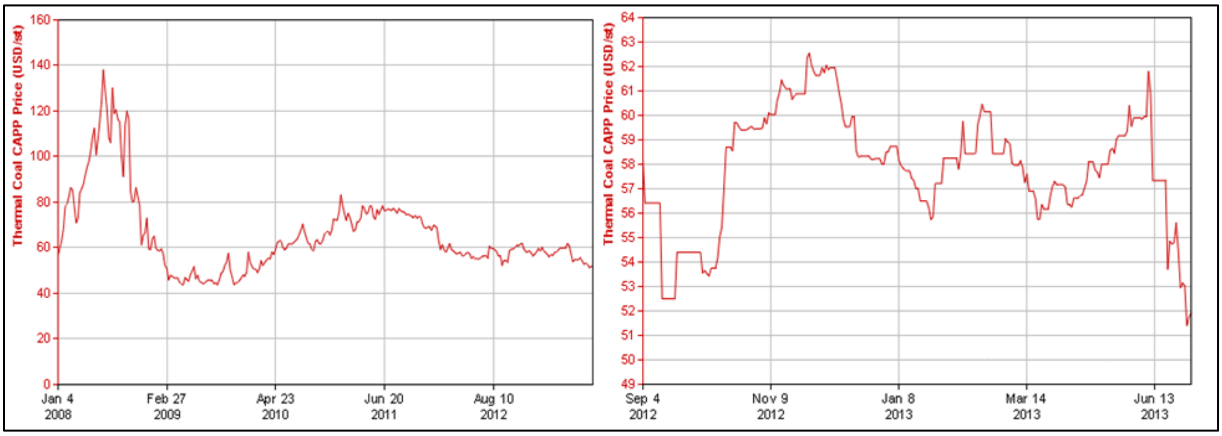
- Thermal coal also known as steam coal is mostly used for electricity generation for public and private use,
- Coking coal is used for iron and steel production.

Due to the increasing environmental concerns, the demand for thermal coal can be subject to decrease, leaving the market oversupplied with a relatively cheap source of energy.

Jonkeren (2011) based his research on the classification of the commodities into high and low value groups, presented in Appendix Table 15. According to this classification, coal is classified as a low value commodity. For example, if coal is currently traded at 85$/t, gold is currently priced at 1,333 $/oz (gold price, 2013), presenting a significant difference in both value and traded quantity.

As it can be seen from Figure 6, coal prices have fluctuated greatly during the years. The price has significantly dropped when compared to 2008, when the price was close to 140$/t., whereas on 16th October the price of thermal coal was 80$/t (IHS, 2013). When looking at the price movements over the last year, it can be seen that there have been fluctuations, and this summer the coal price hit its absolute low. This can be explained by the existing oversupply of cheap thermal coal on the market (Chotimah, 2013). Though, the price has slightly recovered over the last couple of months.

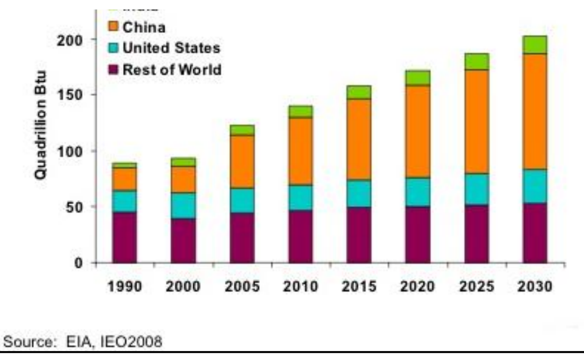
Figure 6 Left: 5 Year Thermal Coal CAPP Price, right: 1 Year Thermal Coal CAPP Price



(Source: InvestmentMine, 2013)

When looking at market forecasts for the future, its outlook seems rather weak, due to increasing environmental concerns, rising production costs, and carbon emission taxes (McCarthy, 2013). However, due to developments in markets like China and India the demand seems to continue holding up as shown in Figure 7. Therefore the price of thermal coal will fluctuate around 80$/t, at least until the 2015. Therefore, for Indonesian mine producers it is important to keep their costs as low as possible in order to remain competitive for the customers whose base is predicted to start shrinking in the future.

Figure 7 World coal consumption, 1990-2030



3.2.1.2 Weight and volume of coal

Due to the low density and large quantities required for energy generation, coal is transported in very large quantities. The shipments of coal are large and heavy, they require significantly more space, not using it effectively as it would be used in case of iron ore transportation. This is especially relevant for road and belt conveyor transport as more space has to provided.

Figure 8 Density of thermal coal and iron ore

(Source: Ligterningen and Velsink, 2012)

3.2.1.3 Perishability of coal

When evaluating the perishability of a cargo, it is possible to differentiate between two cases. For example, newspapers or flowers must be delivered on time, as it is of use only within a fixed amount of time. Cargo like coal does not fit into this category as a potential delay will not cause significant spoil to the product.

An alternative is to evaluate how long a respective commodity can be stored for it not to spoil. By looking at food or flowers, these goods can be stored for a short while. Cargo like coal can be stored for a comparatively long term, but is limited by the conditions and the way of storage (Okten, et al. n.d.). For instance, for coal the degree of coal burn can be affected, or due to direct exposure to rain, the water contents will be too high, immediately decreasing its price on the market.

3.2.1.4 Hazardousness of coal

Many dry bulk cargoes have hazardous properties or their properties can change during the transportation. The main worries regarding dry bulk transportation include:

- It is impossible to determine the exact weight of the load,
- Residues can harm the next cargo,
- Due to the incorrect loading, the barge can be damaged (UNESCAP, n.d).

When examining coal's physical properties, it is:

- Self-heating, emits methane, and contains sulphur, that causes corrosion of steel that comes into contact with it (UNESCAP, n.d)
- Coal is a very dusty commodity to transport, in many cases it is handled wet.

3.2.2 Multi-actor management

Multimodal transportation is a complex system, as the performance of one element will directly affect the result of the whole process. Bontekoning (2004) highlighted a few factors that are essential for multimodal transportation:

- High degree of synchronization of schedules,
- Efficient and well defined division of tasks,
- Well-functioning multi-actor management,
- Highly organized handling operations at transshipment points.

The list summarizes the general factors that have to be worked out to function effectively. It is not feasible to state which factors are most important as the relevance and applicability is case dependent. However, issues like contractual rights and mutual alignment of interests are a starting point of any collaboration.

Negotiated the contract is an essential determinant of how risks and costs of the cooperation are allocated. Bontekoning (2004) stated that for an effective cooperation to exist, interests, tasks, and rights have to be clearly defined and allocated between the parties. For instance, a barge departure schedule is dependent upon the timely arrival of a truck or train. If cargo is delivered late, barging has to be delayed, potentially causing losses. By working out the contractual relations that include synchronization of time schedules, the logistical chain will deliver favorable results.

The contract defines which party is responsible for moving the cargo and who bears the costs. There are two types of contracts, namely “Free On Board” and “Cost, Insurance, Freight”. In the mining industry, the majority of contracts are negotiated under FOB, where the mining operator bears the costs and risks of transporting the cargo.

The role of governmental support is essential for the mining industry. Institutional bodies bear the power to ease the bureaucratic processes and dictate the regulatory system that can improve the business climate for international companies. The image of the mining industry can be an influencing factor as local communities play a strong role in the decision making process. In the first instance it seems that mining operators are purely profit driven, bringing negative externalities to the area. At the same time, not only national governments are able to enjoy favorable tax returns, but local communities have access to job opportunities.

Therefore, if the interests of all the actors are aligned, mining projects can bring long-term benefits to the regions.

Kirkpatrick (2006) indicated that foreign direct investments directed to infrastructure directly corresponds to the quality of the regulatory environment. The quality of Indonesian regulatory environment is widely criticized, serving as a likely explanation of the underdeveloped state of the infrastructure (Meyrick, 2012; World Bank, 2007). Due to the past decentralization of governmental involvement, there exists a significant lack of adequate coordination between different governmental agencies (Bappenas, 2011). This can be partly seen as an explanation of the scattered infrastructural development of Indonesian market as certain authorities are assigned more resources for the construction of the new infrastructure (Mustajab, 2009). Especially, due to the fact that such a large extent of capital lies in the hands of the private sector, an appropriate structure within the public finances could decrease the existing gap between both sectors for the future.

For the logistical chain to deliver results, management issues have to be worked out and interests aligned, as even within the simplest transport chains several parties are involved:

- Government
- Local community
- Transporting parties
- Mining operators.

3.2.3 Risk management

Reliability has been indicated by authors like De Vries (2000) and Culianne (2000) as important aspects that influence the design of a logistical chain. The authors differentiate between different types of reliability, addressing actors or the environment. It is evident that even though differentiating between aspects, the most important is the final service. Therefore, aspects such as:

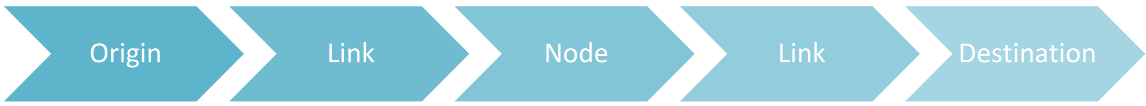
have become of great importance when assessing the risk management of the logistical chains (Sevim, 2007; Kuipers, 2004).

When transporting dry bulk cargo, speed and timely operations are important, especially when each of the parts of the chain are directly linked with each other. By engaging in such a chain, the operator must account for flexibility and agility of its operations, in case there is a delay, or the uncertainty of demand has become an issue. Only by controlling negative effects, is it possible to design a more safe and reliable logistical chain. However, each of the cases differ specifically, while for one it might be that security and flexibility are more important, but for another reliability of the operations is more crucial.

3.2.4 Logistical network design

The common parties involved in logistical chains for coal transportation are nodes and links:

- Links like road, rail, barge, belt conveyor actually transport the cargo
- Nodes like ports, transshipment, storage locations facilitate the loading, unloading, stacking and/or storage of the cargo



3.2.4.1 Road and rail infrastructure

Compared to countries in the East Asia Pacific, the overall quality of the Indonesian infrastructure is significantly lagging behind (World Bank, 2005). To a great extent it can be explained by the fragmented government involvement in the provision of the infrastructure. A large part of the road and rail infrastructure was privatized and has been largely dominated by private sector. As a result, currently 100% of all Indonesia's expressways are toll roads that to a large extent are being used by a single party (Meyrick, 2012). Companies tend to concentrate on road haulage, causing significant overloading of trucks. In return, truck overloading decreases the road safety. Due to the uneven distribution of infrastructure, congestion levels in certain areas are skyrocketing, hampering both costs and reliability of the schedules (Meyrick, 2012). These issues can be addressed by:

- Implementation of an infrastructure master plan,
- More effective use of multimodal transportation schemes.

The lack of capacity and current infrastructure limitations, are seen as major limitations for the further development of railway infrastructure. Passenger transport is being prioritized over freight transportation (Meyrick, 2012). Furthermore, the outdated construction of the existing light-weight infrastructure is a significant drawback to increasing the market share of railways

(HWTSK, 2010). The whole provision of the railway infrastructure and its operations is in hands of a single party, hampering more effective use of railway infrastructure (Meyrick, 2012). The current income generated by railways is extremely low, due to very cheap costs of usage. Therefore, no financial capital is generated that can be invested into updating and expanding the rail network.

Additionally, the existing accessibility of ports by rail is poor, which is yet another limitation for joint use of different modalities to transport cargo to the port. Taufik (2002) in his research indicated that by investing additional capital into railways, it would provide 11.3 times higher savings than investments into the road infrastructure. This means that in case of Indonesia, multimodal transportation strategy would not only benefit the mining sector, but encourage the overall development of the whole transportation sector.

3.2.4.2 Ports and customs

The general view on Indonesian common user ports is relatively negative. Due to neglectful provision of the state, the performance levels and reliability of port terminals are critically low, encouraging private mining operators to develop dedicated terminal points, in order to avoid the existing supply of services (Wignall, et al. 2012). As indicated by Nathan Associates (2011) Indonesian supply chains are at risk due to the increasing delays and bottlenecks experienced at domestic ports, in turn raising the costs and risks of entering the grounds of the Indonesian market. This infrastructure can be seen as a sunk cost if a decision has been made to switch to either a different location or to a different partner (Bontekoning, et al. 2004).

Partly due to the situation at the common user ports, the quality at customs is being widely criticized, due to the lack of administrative requirements necessary for custom clearance in Indonesia. The lack of standards and harmonization of rules creates a complex regulatory environment that is filled with extensive bureaucracy and overcomplicated business environment (OECD, 2012). As ports and customs are of critical importance for successful functioning of logistical chains, the existing issues can create significant problems for the potential of multimodal transportation.

3.2.4.3Transshipment

Literature highlights the importance of ports and transshipment points as determining factors in the design of the logistical networks (Bontekoning, 2004; Beresford, 2009). In Indonesia transshipment terminals are mainly used due to depth restrictions in the ports, as large sea going vessels are not able to enter the ports.

In order to combine several modalities, transshipment infrastructure is required. The proximity to the required infrastructure can be a determining factor to a large extent in the final design of the logistical chain (Kuipers, 2004). If potential transfer is readily available, it can provide significant cost savings. A transshipment terminal must:

- Facilitate the transfer of cargo,
- Offer fast and reliable services,
- Meet industry standards,
- Employee qualifies and skilled workers.

Significant costs can be both incurred and saved at this location, as the success of its operational efficiency is essential for the potential of a successful logistical chain (Beresford, et al. 2009). The advantage of employing transshipment terminals is that the mine operator does not have to invest any capital in construction as transshipment terminals can be rented from separate companies. The lease is priced as cost per tonne, which includes costs like labor, equipment, and fuel. Terminals are installed rather quickly allowing for a quick start of operations.

3.3 Conclusion

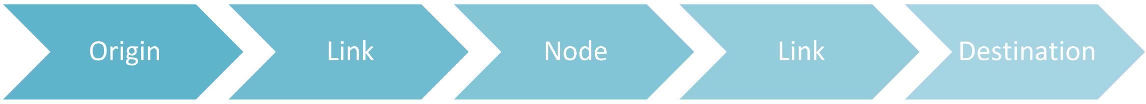
Based on the examination of factors affecting the design of transportation chains, it has been possible to characterize the Indonesian market as:

- Lacking coordination between market players,
- Lacking regulatory environment,
- Facing serious bottlenecks in the infrastructure.

The nonexistent coordination between the governmental institutions, a private and public sector shapes the current market. Though relevant factors have been identified, the actual weight of each of the factors has not been identified. This will be done in the following chapters. The next chapter will go more into detail of the logistical costs examination.

Chapter 4 Review of modalities for coal transportation

This chapter will evaluate the costs incurred for logistical design of a transportation chain. The diagram has shown the main elements present in the logistical chain and this chapter will concentrate on more detailed examination of links.



The cost of nodes will be included into analysis and reviewed in connection with inland waterway transport. Literature on pit to port coal transportation presents various modalities

that are used within industry. The most common modalities for coal transport in Indonesia are:

Each of the modalities requires different infrastructure investments as well as specific location characteristics. This section of the thesis aims at looking at different characteristics of each of the modalities:

- Physical advantages and logistical disadvantages,
- Optimal distances,
- Capital and operational expenditures.

Capital expenditures (commonly referred to as CAPEX) include the construction of the infrastructure and purchasing the capital necessary to transport the cargo. Operational expenditures (commonly referred to as OPEX) include the costs of maintaining the infrastructure and operating the capital used to transport the cargo.

4.1 Road transport

4.1.1 Advantages of road transport

Researchers have analyzed potential advantages of road transport and weighted their potential benefits (Emmett, 2009; Beresford, 2011), concluding that:

- Road transport is the most flexible, quick and reliable means of transportation,
- Road transport infrastructure does not require an extensive front end investment, allowing for a quicker start of operations with lower cost commitment, Lansen (Interview, 2013),
- Due to the relatively low operational costs in developing countries, companies can exploit low fuel and labor costs,
- Road transport offers just in time delivery and is able to react to market changes in a timely manner.

4.1.2 Disadvantages of road transport

The global concern of increasing road transport dependence is due to the growing environmental threat, noise, accidents, and congestion existing on the roads (Verhoef, 1997).

Road transport has been viewed as the most rapidly growing pollutant to the environment (Kim, et al. 2009). The results of research carried out by CE (2011) representing each of the modalities and indicating their respective environmental threat are presented in Table 2. As can be seen, road emissions are seen as leading compared to other modalities. Due to the growing dependence on road transport, rising congestion is damaging to the environment.

Table 2 Emission factors well-to-wheel for heavy bulk transport

Vehicle type	CO2 (g/tkm)	SO2 (g/tkm)	PM2.5 (g/tkm)	NOX (g/tkm)
Truck>20t	124	0.11	0.022	1.0
Train, diesel	16	0.018	0.0063	0.22
Pushed Convoy 2x2	16	0.022	0.0078	0.20
Conveyor belt	0.023-0.055[1]	n/a	n/a	n/a

(Source: Lodewijks, 2006; CE, 2011)

The accident rate on the roads can be used as a highly representative indication of both the state of the roads and the existing regulatory practices. Traffic accident is one of the main causes of death in Indonesia (Tjahjono, 2009), as in 2005 around 30,000 people died in the road accidents. This can be explained by a rapid growth of vehicles participating in the traffic, traffic intensity and the poor quality of the roads. The report "East Asia and Pacific Infrastructure Department" has indicated that compared to other states in the region, Indonesian road network is in a very poor state, being the third lowest after Vietnam and Philippines (World Bank, 2005).

Higher levels of heavy truck traffic require significant operational expenditures due to the increased deterioration of the used infrastructure (AWO, 2013). Supporting the finding that operational expenditures are much higher when compared to rail or barge transport.

4.1.3 Optimal distance of road transport

Road outperforms other modalities only if the inland leg is not very long (Beresford, 1999). Compared to other modalities, road transport has very high operational costs, relative to its fixed costs. Therefore, when used for larger distances, the increase in costs is relatively high (Sevim, et al. 1991). Sahin (2009) in his research revealed that:

- If the distance of the trip is larger than 350 km; road transport is less competitive when compared to rail or inland waterway transport.

While Manurung (2012) concluded that:

- In the Indonesian market, road haulage can only remain competitive between 0 and 10 km.

[1] Transport loss factor can be used as comparable indication as even thou belt conveyor ha no environmental harm, the energy that is required for its generation emits certain emissions. Transport loss factor of belt conveyor is in the same range as for road, but due to cleaner means of generations, emissions are limited

This fact has also been confirmed by Sevim (1991) who also indicates that truck haulage experiences much faster cost increases compared with conveyer belt transport. This is confirmed by Beuthe (2001), whose research concentrated on assessing the elasticity of road transport, indicating that the elasticity declines over the longer distances as other modalities become more attractive for cargo transportation. As a result, for short- to medium-term, road haulage can be used as a preferred alternative (Beresford, 2011).

4.1.4 Capital and operational expenditures

In order to determine at what distances or at what throughput quantities of a mine the road transportation must be used, cost expenditures of employing truck haulage must be determined. By gathering all the costs, based on the distance of a route and throughput that is transported via that route, it is possible to arrive at cost per tonne.

Each of the two categories can be split into several smaller cost categories as shown in Table 3. Each of these elements in CAPEX incurs significant costs, which are sometimes available per km or per unit. Thus by adding all of these costs together and dividing by the distance it is possible to arrive at the cost per km, which is the most widely used indicator for cost of the road between road engineers. The last entry in CAPEX is the cost of purchased capital, which would include the cost of purchased trucks.

The cost of maintenance (a) in OPEX in this case is determined by expenses into road, bridges, cross sections, or tunnels, which is expressed as a percentage of its CAPEX. For instance, maintenance of bridges will be a % of its CAPEX. Depreciation (a) is dependent upon each of the elements separately as the lifetime depends on the case, and is calculated based on its individual CAPEX divided by its lifetime, if there is no salvage value.

If the company is renting capital at the cost per unit, then labor and maintenance are included into the cost, while the only additional cost is the fuel, which can be determined by price per t/km.

On the contrary if the capital is bought, then the company must pay for the labor, fuel, maintenance (b), and depreciation (b). Depreciation and maintenance are calculated similarly as for the infrastructure, while the cost of labor has been averaged per day. This is due to the fact that there are several types of employees in employment by the company, thus it is more optimal to separately calculate the cost per day incurred.

Table 3 Capital and operational cost framework for road transport

CAPEX		
Class	**Sub-class**	**Unit**
Earthworks	Vertical plane Horizontal plane	$/km
Sub-grade preparation		$/km
Sub-base material preparation and placement		$/km
Base preparation and placement		$/km
Surface material preparation and placement		$/km
Berm placement		$/km
Ditching		$/km
Cross sections		$/cross section
Bridges	Small bridge Large bridge	$/bridge $/bridge
Underpass		$/underpass
Capital	Trucks	$/unit
OPEX		
Maintenance (a)	Road Bridges Underpass	% of CAPEX
Depreciation (a)		years
Capital renting	Trucks (incl. labor)	$/truck
Fuel		$/t/km
Depreciation (b)	Trucks	% per MtpA
Labor		% daily average
Maintenance (b)	Trucks	CAPEX/Years

(Tannant, et al. 2001;Thompson, n.d.)

4.2 Railway transport

4.2.1 Advantages of railway transport

Blauwens (2010) concluded that railway transport has a superior role when compared to road in-land transport, as it is more suitable for large volume and heavy haul cargo transportation. An individual carrying capacity of a single wagon is at least 130t though due to the density of coal around 60t can be loaded and it is possible to connect around forty wagons in a single trip. This allows for a significant load of coal to be transported in a single trip. As a result, the cost per transported tonne is significantly lower when compared to road transport.

When compared to road transport, railway is seen as more environmentally friendly and less polluting compared to inland waterway transport, as shown in Table 2. When comparing road and rail transport, rail has five times less reported accidents in the period of four years, as indicated by Kruse (2007). By removing the existing traffic intensity from the road, road accidents rankings can potentially be decreased.

Therefore, when the distance to the destination and quantity of dry bulk increases, it becomes more profitable to run a train, requiring less handling costs per tonne compared to road haulage (Carpenter, 1994).

4.2.2 Disadvantages of railway transport

First of all, it must be highlighted that building a new rail infrastructure is a large and highly costly investment that accounts for 80 percent of the combined capital and operational costs. It can be seen as a possibility if the time span and forecasted quantity of the cargo is sufficient to cover the investment (Emmett, 2009). This is viewed as one of the most threatening factors to mining companies, to commit to an expensive front-end investment. This might explain the fact that rail share of the port-related container freight market is very small, estimated at just 0.3 percent in the Indonesian market (Van der Ven 2009). Additionally, the existing fragmented availability of rail infrastructure and lack of regulatory environment, limits its employment by the private sector in the Indonesia as indicated by Lansen (Interview, 2013)

It is considered that it decreases the attractiveness of the area for people to reside as rail is noisy and can become damaging for the natural land resources within the area (Carpenter, 1994). Especially, if accidents take place, railways are usually alarmingly near to the local communities, posing threats to the area (AWO, 2013). On top of that, due to the construction of the railway tracks, the ecological habitat, water, soil and air quality is damaged.

4.2.3 Optimal distances of railway transport

Beuthe (2001) and Oum (1979) concluded that rail transport is more suitable to carry large quantities of heavy materials over long distances. The optimal distances vary between 300 and 600km:

- Hansford (1990) concluded that the breakeven distance for rail using is at 400-480 km,
- Kilvingtonne (1990) concluded that the switch should be made when the distance reaches 300 km,
- Seymer (1992) suggested that the breakeven distance must be around 600 km.

Carpenter (1994) estimated that breakeven points are subject to decrease if the operational costs of road transport would rise, or if the environmental effect will become a more important concern for the future. This confirms findings of Manurung (2012), indicating 50 km as the breakeven point for rail transport in Indonesian market.

4.2.4 Capital and operational expenditures

Similarly, as for road transport, railway cost expenditures are calculated almost the same as for the road transport. As the construction of rail requires different works and materials; the majority of costs are calculated per km as shown in Table 4. Instead of using trucks, rolling stocks and locomotives are required to transport cargo, which if purchased are charged a price per unit of locomotive and rolling stock. In this case, the mine operator must cover labor, maintenance, fuel, and depreciation of the purchased capital. If the locomotives and rolling stock are leased, only fuel and rent cost applies.

For a more detailed description, the previous section on road transport can be used.

Table 4 Capital and operational cost framework for railway transport

CAPEX		
Class	**Sub-class**	**Unit**
Formation	Sub-grade Ballast	$/km
Ballast preparation and placement	Sub-ballast Ballast	$/km
Sleepers purchase and placement		$/km
Rail purchase and placement		$/km
Train signaling	System	$/km
Communication system	System	$/km
Tunnels		$/km
Capital	Locomotives Rolling stock	$/unit
Bridges	Small bridge Large bridge	$/bridge $/bridge
Capital	Locomotives Rolling stock	$/unit
OPEX		
Maintenance (a)	Railway system Bridges Tunnels	% of CAPEX % of CAPEX
Depreciation (a)		CAPEX/ Years
Capital renting	Locomotives Rolling stock	$/unit $/unit
Energy	Fuel	$/t/km
Maintenance (b)		% per MtpA
Labor		$ daily average
Depreciation (b)		CAPEX/Years

4.3 Inland waterway transport

4.3.1 Advantages of inland waterway transport

The potential of barge transport to carry almost all types of cargo ranging from liquid and dry bulk to containers highlights its presence in the worldwide markets (Wiegmans, et al. 2007). When large volumes of traffic flows have to be transported, barge transportation provides an alternative how to avoid congestion:

- On the road.
- Within the port areas.
- In the corridors that serve further hinterland (Fremont, et al. 2009).

Moreover, low operating costs make inland waterway transport a highly competitive transportation mode (Konings, 2009). Barge transport can be characterized by high fixed costs, while the further variable costs are relatively lower as shown in Table 5. This decreases cost per km if the transport distance is increased (Fremont, et al. 2009). This way economy of both scope and scale can be achieved.

Table 5 Costs of a unit of cargo in rail, road, and inland waterway transport (excl. cost of labor)

Modality	Investment cost	Fuel cost	Maintenance and operations	External cost
Inland waterways	26%	32%	35%	7%
Road transport	14%	60%	17%	9%
Rail transport	22%	46%	30%	2%

(Source: Sahin, et al. 2009)

Moreover, the shipping capacity of both infrastructure and vessels for inland waterways has not yet been reached, granting potential for further expansion (Konings, 2009). In case of Indonesia, Lansen (Interview, 2013) explained that inland waterways bears the largest potential for in-land transportation in the Indonesia, but due to the existing lack of governmental support and public and private partnerships, for a single party to cover both the capital as well as operational costs is too expensive.

Researchers (Rutten, 1995; Wiegmans, et al. 2007) have identified inland waterways as:

- Safe and reliable mode of transportation,
- Suitable for dangerous dry bulk cargo transportation,
- Sustainable, energy efficient and less polluting (excl. transshipment).

As a result, an increasing usage of inland waterway transport should be stimulated by public institutions in order to mitigate increasing congestion and limit the curb carbon footage (Sulaiman, et al. 2011).

4.3.2 Disadvantages of inland waterway transport

Inland waterways are described as:

- Relatively slow,
- Providing limited coverage,
- Usage possible only if water access available, otherwise a continuous and capital expensive dredging is required,
- Affected by seasonal changes which causes OPEX to increase, due to extensive dredging requirements (Trusty, et al. 1998).

For companies operating in Indonesia, this can be a serious challenge as some parts of the largest inland waterways are not sailable during the biggest part of the year.

There exists a high controversy in the literature regarding the sustainability and environmental impact of inland waterway transportation (RIVM, 2002; Konings, 2009). The majority of research findings have described barge transportation as more sustainable and environment friendly modality, compared to road or rail. At the same time, this conclusion has received a lot of criticism, indicating that a large part of calculations, do not account for transshipments required by barge transport (TNO, 2005; Geerlings, et al. 2010). Moreover, it is important when evaluating multimodal transport networks, as several changes in modalities are required.

4.3.3 Optimal distances of inland waterway transport

Past research has shown that barge transport should be only used for distances over 500km (PRC, 2006). This confirms the conclusion drawn by Sahin (2009) that for barge shipping the cost reduction becomes more evident when examining longer rather shorter distances. Due to the more integral role of inland waterway transport and potential cost savings on longer distances, the inland waterway transport nowadays is able to compete with door-to-door transport on distance of even 20-40 km (PRC, 2006; Leinbach, 2009). If the access is available and no extensive dredging is required.

4.3.4 Capital and operational expenditures

The cost of CAPEX consists of river works, navigation aids, and road are unit dependent. This is due to the fact that road, river works, and navigation aids are dependent upon the length of the waterway.

While for each of the terminals, a full cost must be calculated and included into the framework.

In case the company purchases barges and tugs, this capital goes under CAPEX and is calculated based on cost per unit. In that case, in OPEX the cost of fuel (b), maintenance (b), labor (b) and depreciation (b) must be calculated, leaving rented capital as 0. The cost of fuel is calculated based on cost per liter and total distance travelled by barges, maintenance is calculated as a percentage of CAPEX and depreciation is spread over the lifetime of purchased capital.

Furthermore, OPEX is presented in Table 6. For the maintenance (a) and energy (a), the cost can be expressed as a percentage from CAPEX of each of the elements, namely road, terminals, river works and navigation aids, while for depreciation it is calculated based on the lifetime of each of the terminals, accounting for their salvage value at the end of operations. The cost of labor (a) is calculated based on the daily average incurred at each of the terminals. This is due to the fact that employees hold different ranks; therefore it is more optimal to calculate what the combined daily cost is.

There is an entry for rented capital, which means that if company does not purchase the equipment, it rents it. This means that the cost of labor and maintenance is already included in that too, and company pays an annual rent for that. The only additional cost that company still needs to cover is the cost of fuel (b), which is calculated based on cost per liter and total distance sailed.

Table 6 Framework for inland waterway transport

CAPEX		
Class	**Sub-class**	**Unit**
River works	Dredging	$/m3
Navigation aids		$/km
Barge loading terminal	Dredging and Reclamation Mooring facilities Storage yard Equipment Utilities	$
Barge transshipment terminal	Dredging and Reclamation Mooring facilities Storage yard Equipment Utilities	$
Floating terminal	Mooring facilities Floating Storage Equipment	$
Road	Road	$/km
Capital	Barges Tugs	$/ unit
OPEX		
Maintenance (a)	River works Navigation aids Barge loading terminal Barge transshipment terminal Floating terminal Road	% of CAPEX
Energy (a)	Barge loading terminal Barge transshipment terminal Floating terminal	% of CAPEX
Labor (a)	Barge loading terminal Barge transshipment terminal Floating terminal	$ daily average
Depreciation (a)	Barge loading terminal Barge transshipment terminal Floating terminal	CAPEX/years
Capital renting	Barges (incl. tugs, labor)	$
Energy (b)	Fuel	$/l
Maintenance (b)		% CAPEX
Labor (b)		$ daily average
Depreciation (b)		CAPEX/Years

4.4 Belt Conveyor transport

4.4.1 Advantages of belt conveyor transport

Belt conveyors are by far the most widespread transportation system used across the mining and mineral processing industries, due to their efficient and continuous transport (Wheeler, et al. 2008). They can facilitate large range in its conveying capacity. In times when climate protection is not a sufficient reason for heavy investments into energy efficient technologies, the rising energy costs in transportation serves as a large motivation for mining companies to look for potential alternatives to save costs (Günthner, et al. 2010), due to which belt conveyors are becoming more attractive.

Conveyor systems have significantly lower operational and personnel costs compared to road transport. Operational costs amount to 10 percent of the combined capital and operational costs, which make an attractive modality (Dilefeld, et al. 2009). Due to the limited involvement of personnel, it can be seen as rather safe modality. If the infrastructure is well maintained, the operational expenses can be kept to a minimum. As a result, academic literature proves that the system's availability can be kept up to 90% and less than 2% of time is lost due to unplanned outages (CEMA, 2007; Zamorano, 2008).

It can be concluded that belt conveyer can be characterized as a reliable way of dry bulk transportation. Furthermore, belt conveyor systems are being continuously improved by various innovations. For instance, the literature has presented belt conveyors with low ranging resistance which allows for 50% cost savings, showing the potential to achieve larger energy savings when compared to alternative modalities (Hager, 1993). Additionally, potential sources of cost savings due to increasing conveyor distances are being widely researched.

4.4.2 Disadvantages of belt conveyor transport

The most commonly addressed disadvantages of belt conveyors are:

- Belt conveyors require a substantial front end investment, which is why investment cannot be spread out during the operating life of the belt (Rieber, at al. 1977)
- Once the belt is installed, it is fixed and it is extremely difficult to relocate or adapt its mechanical capabilities to varying cargo capacities
- Due to the extended distances, the technical complexity is increasing
- Due to operations in difficult terrains with limited accessibility, it requires more time to fix a failure (Siemens, 2013).
- Thorough up-to-date maintenance has to be in place, providing reliable functioning of the whole system.
- A single failure within the system can threaten the functioning of the whole system.

It can be concluded that the profitability of the whole investment, is highly dependent upon the amount of mishaps in the conveyor belt system. In order to limit the impact, a suitable substitute has to be constantly in place, in case the conveyor system fails. However, this is not always a feasible alternative. In that case, large quantities of stock can be placed at the mine or terminal, as a buffer against possible failures in the system.

4.4.3 Optimal distances of belt conveyor transport

In the past, the length of the belt conveyor was relatively limited and was more suitable for usage within the mines, while nowadays the system's lengths have reached 100 km, becoming more suitable for long distance transport. The conveyor system can be composed out of several flights which each can reach the length of 35 km. Moreover, in times when mines are located further into the hinterland in locations with very difficult terrain, belt conveyors can be seen as a suitable alternative. Savim (1991) concluded that a belt conveyor system has significantly lower costs compared to other modalities at distances up to 10 km. As can be seen, in the 90's, the optimal distances of belt conveyor transport were ranging between 8 and 20 km (Edgar, 1983), while nowadays these distances are reaching up to 100 km (Barbero, et al. 1985). This shows how the nature of operations has evolved over time. Roberts (1981) has indicated, even though belt conveyor have always been seen as an appropriate solution for short distances, their long distance application is increasing.

Thus, it can be concluded that belt conveyors are an investment that can pay for itself only through long-term planning, medium distances, and high volumes of cargo.

4.4.4 Capital and operational expenditures

Compared to inland waterway transport, a conveyor belt framework is slightly less complex. As can be seen in Table 7, it consists from two main categories. Each of the CAPEX categories can be calculated as percentage from the cost of mechanical and structural Construction and Installation.

OPEX consists of three main entries as shown in Table 7. Similarly as in the case with inland waterways the cost of maintenance can be expressed as a percentage from CAPEX, while the cost of electrical energy is based on the quantity transported over the conveyor. Thus, it is calculated based on the unit cost of electricity combined with consumption of power based on transported capacity. The last entry, depreciation is calculated based on the lifetime of various structures, and must be depreciated over years of operations, accounting for a salvage value.

Table 7 Capital and operational cost framework for belt conveyor transport

	CAPEX	
Class	Sub-class	Unit
Earthworks	Site preparation Access route creation Installation of security Placing of signs	% of Structural &Mechanical cost
Bulk earthworks	Cutting into ground Excavation	% of Structural &Mechanical cost
Civil construction	Footings Slabs Pilings	% of Structural &Mechanical cost
Structural & Mechanical Construction & Installation	Head section Tension system Intermediate section Tail section Rubber belt Drive unit Fluid coupling/ Frequency controller Additional items	$
Electrical power supply	System	% of Structural &Mechanical cost
Control System	System	% of Structural &Mechanical cost
Transport & Erection	Transport and Erection	% of Structural &Mech. cost
	OPEX	
Maintenance	**Scheduled** **Unscheduled** Consumables	% of CAPEX
Electrical Energy Consumption		Per MtpA
Depreciation	Structural &Mechanical Construction &Installation Civil construction Electrical power supply Control System	% per MtpA

4.5 Discussion

For short to medium term road haulage can be used as the most suitable alternative (Beresford, 2011). Compared to rail infrastructure that accounts for 80 percent of the combined CAPEX and OPEX, for road it barely reaches 50 percent (Emmett, 2009). The basis has to be laid down initially, however its further upgrade can be carried out in the long term, due to the elastic nature of the market. But if the production of the mine is subject to increase in the future, road haulage is not seen as an economically or environmentally friendly alternative for long-term dry bulk transportation.

Compared to road haulage, rail transport requires significantly less operational expenditures being only 20 percent of the combined OPEX and CAPEX (Emmett, 2009). Due to the large share of front-end capital investment required for the start of the operations, operational costs of labor represent a rather small share, requiring a single train operator to transport 4,000t of cargo (Runhaar, 2002). Even though, rail transport can be seen as more sustainable and environmentally friendly, road transport keeps dominating the transport sector (EC, 2008). This is due to:

- Loss of reliability
- Loss of flexibility
- Lack of speed
- Poor image
- Lack of service quality
- Lack of stability of the pricing system (Runhaar, 2002)

Due to large shipments of bulk cargo, barge transportation is a suitable alternative due to economies of scale and lower transportation costs, compared to rail or roads. Barge transport appears to be nine times more economical than truck, and over two times more efficient than rail (Caria, 2013). It can be concluded that compared to rail, the optimal distances are rather comparable, while the main advantage that inland waterway transport is less expensive infrastructural investment, if waterways are available in the area.

Barbero (1985) proved that if the conveyor belt is compared to road haulage, 85% of energy costs and 90% of operational and maintenance costs can be saved, especially if the distances are increased. Similar reasoning was applied to rail transport, facing 150% to 300% higher operating costs per tonne if the transporting distance is less than 20 km, compared to belt conveyor. Another advantage is that in comparison to road or rail, there is no time lost due to loading or unloading of cargo (CEMA, 2007).

4.6 Example of a comparison between road and belt conveyor

This chapter has explained that due to varying optimal distances of each of the modalities, it can be concluded that for short distance transport mine operators must choose between road and belt conveyor transport, while for larger distances the decisions lies between rail and inland waterways. This comparison will concentrate on short distance transport and compare road and belt conveyor transport of coal.

The comparison of optimal distances has mainly relied on a cost comparison of constructing and running the infrastructure, while the amount of cargo to be transported is highly important. Therefore, this comparison will be carried out on the same distance but on varying amount of coal. A more detailed explanation together with relevant assumptions and results are outlined in Appendix B.

Though, based on the distance of 8km, belt conveyor is able to offer a lower cost per tonne if the amount of coal is increasing beyond 14 million tonnes per annum (MtpA). This can be explained by large operational expenditures required for road transport. While for belt conveyor the most costly part is the actual infrastructure cost, if the amount of transported cargo is increased, the capital cost does not arise as steep, therefore, decreasing the cost per tonne of coal.

However, this is a very detailed example, which means that by varying the distance or other input parameters, if the road transport becomes able to offer a lower cost per tonne, a mine operator will favor the road transport. This means that regional governments must incentivize the private companies to switch to more sustainable modes like belt conveyors.

4.7 Conclusion

While road and belt conveyors are seen as more competitive over shorter hauls, railways and inland waterways hold a better position over longer distances, due to lower OPEX. This allows one to conclude that the existing differences in optimal transportation distances provides support to the theory that there exists a potential to exploit the advantages that would be offered by multimodal transportation.

The goal of the chosen approach has been to design an applicable framework for comparing the costs of transportation of dry bulk via different modalities. In order to arrive at a financial comparison of each of the modalities, it is necessary to follow an approach that would allow capturing all of the expenses into a single framework. Based on the designed frameworks, the actual calculations on the introduced case study will be carried out.

An overview summary of characteristics identified in the chapter and by Manurung, 2012; and Kruse, et al. 2007 are provided in Table 8.

Table 8 Comparison between each of the modalities

Description	Road haulage	Rail transport	Inland waterway	Conveyor belt
Carrying capacity	50t	130t/per wagon	1,750 tonnes	Continuous
Type of material	Dry bulk	Dry bulk	Dry bulk	Dry bulk
Material size	Free	Free	Free	Limited
Hauling distance[2]	0 - 35 km	300-600 km	500km	0 – 10 km
CAPEX	Relatively low	Highest	Higher than road	Higher than road
OPEX	Highest	Lower than road	Lower than road	Lowest
Elasticity	Elastic for long haul	Inelastic for long haul	Inelastic for long haul	Elastic for long haul
Flexibility	+++	+	+	+
Reliability	++	++	++	+++
Safety (Fatalities in 4 years**)**	5,480	1, 008	8	0[3]
Fuel Efficiency (t.km/l**)**	155	413	576	n/a
Emissions **(**g/t.km of C02**)**	64.96	24.39	17.48	n/a

[2] Distances are applicable to Indonesian market
[3] Hilterman, J. Dry Bulk Consultant, Heavy Industry and Mining, Royal HaskoningDHV

Chapter 5 Case study for coal transportation in Jambi region, Indonesia

The aim of this chapter is to present the case of pit to port transportation of coal within the Jambi region in Indonesia. The main issue that must be determined is what logistical chain must be used for which stage of operations. This will not only determine which transportation chain is the most cost effective, but allow one to derive at what throughput quantities the modalities may have to be switched. The relevant location details are outlined in this chapter regarding the mine site and infrastructure available in the region. The next section will outline the assumptions for case study. The final section will present the results.

5.1 Coal transportation from pit to port

5.1.1 Mining activities

The specific mine for further analysis is located in the Jambi region on the island of Sumatra. As can be seen in map the region has direct access to open water from the East side approx. 350 km from the eastern coast-line. While the rest of the region is relatively flat, in the West there is a mountain range, it is not suitable to transport coal over the road. Currently the mine does not have any direct access to inland waterways, rail, or significant roads.

Figure 9 Jambi region, Indonesia

As the mine operating company has signed a concession agreement for 15 years, this can be viewed as a long-term project.

The mine operator is planning to start production in two stages:

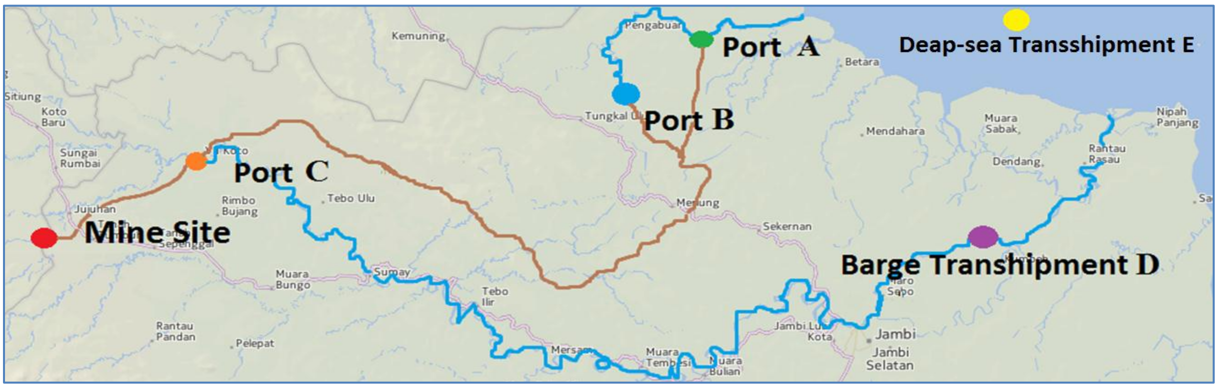
- Stage I: 6 MtpA are transported for 3 years
- Stage II: 10 MtpA are transported until the end of operations.

5.1.2 Existing infrastructure

The road that could be potentially used to reach the ports or inland waterways is in a poor state, meaning that either an existing road should be upgraded or a completely new road infrastructure would have to be constructed. In some parts of the area, public road must be used. The road fee applies for using this network.

Due to the nature presevation in the area, the mine operator is not allowed to construct a railway. All relevant port and transshipment locations are marked by letters in the map of Jambi region in Figure 10.

Figure 10 The location of mine site and existing/potential infrastructure



Due to depth restriction closer to the coast, a transshipment reminal is rented to transfer coal from barges to sea going vessels. The mine operating company is renting a deep water transshipment facility at point E which is located 50 km off the coast. At this location coal can be loaded into Panamax ships 65,000 DWT and exported further overseas. This location can be reached by barges of 8,000 DWT.

A river in the area (Batang Hari) is located 63 km from the mine at its nearest point, where a port terminal could be constructed in the location Port C. No infrastructure has been constructed that would be capable of loading coal into the barges at this location, neither is there an available road infrastructure to reach the location. Furthermore, as the loading terminal would be located in the hinterland, depth limitations limit barges to a maximum capacity of 2,000 DWT. For larger barges to reach the location an additional transshipment location must be constructed further downstream at the location Port D.

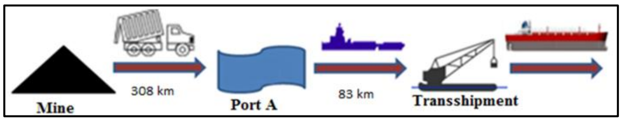
An alternative is construct a port located 300 km from the mine site, which lies along the river system called Pengabuan/Tungkal (Port Location A). The depth allows 8,000 DWT barges to sail throughout the whole year.

The river system Pengabuan/Tungkal continues further into hinterland. It could be possible to construct a port that would be located closer to the mine. This location would be called Port B and would be located 280 km from the mine. The depth of the river allows the use of barges 8,000 DWT throughout the whole year.

5.1.3 Proposed logistical chains for coal exports

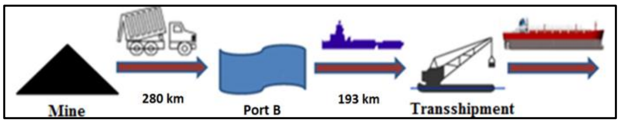
Based on the available infrastructure, potential alternatives, and the planned throughput of the mine, it is possible to outline several alternative routes of coal transportation from mine to the transshipment point. All of the 13 possible option shave been presented in Appendix Figure 15. Although, 13 options are available, only 10 will be further analyzed based on costs as the length of belt conveyors based on the current technological developments are not able to reach 300 km in its length. The designed options together with a short description are presented next.

Option 1



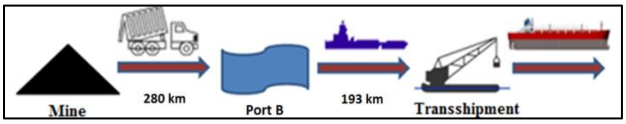
All three stages of throughput can be exported through Port A. A road infrastructure must be constructed of 308km to reach the location. A terminal must be constructed at Port A that would allow for 8,000DWT barges to load in order to sail 83 km to the deep-sea transshipment location E.

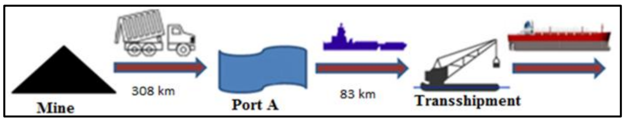
Option 2



All three stages of throughput can be exported through Port B. The advantage over Port A is that it is located closer to the mine, which means that 280 km road infrastructure must be constructed to reach the location. A terminal must be constructed at Port B that would allow for 8,000DWT barges to load in order to sail 193km to the deep sea transshipment location E

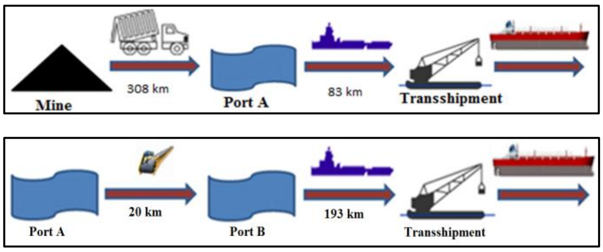
Option 3





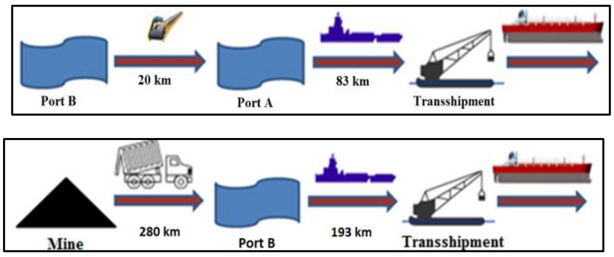
All three stages of throughput can be exported via both Ports A and B. This means that the throughput can be evenly split between both ports, not putting as much pressure on a route that would employ a single port.. This means that CAPEX of the 280 km has to incurred only for one of the routes as both use the same roud infrastructure, while the additonneal road infrasttucture is only 30 km to reach the Port A. The costs of barging need to be calculated for each of the ports.

Option 4



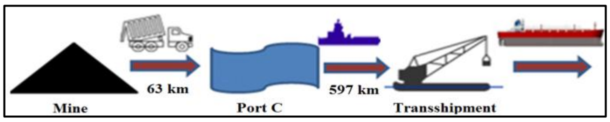
Option 4 proposes to employ both ports A and B to transport coal, similarly as in Option 3. The only difference is that instead of using road transport between the ports, a conveyor belt infrastructure can be used from Port A to Port B. This means that road must be constructed only to the Port A. The plan for barging is exactly the same as in Option 3.

Option 5



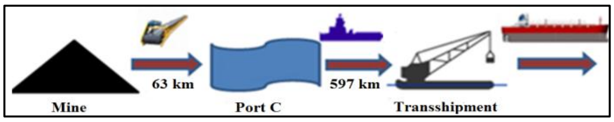
Option 5 employs a similar logistical chain as in Option 4, but instead of transporting coal by belt conveyor from Port A to Port B, coal is sent from Port B to Port A. This chain has been proposed to due shorter road infrastructure necessary to reach Port B, compared to Port A. The barging plan is exactly the same as in Option 3.

Option 6



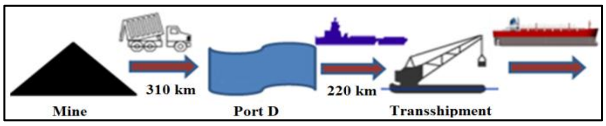
All three stages of throughput can be exported through Port C. A road infrastructure must be constructed of 63 km to reach the location. A terminal must be constructed at Port C, though compared to Ports A and B only 2,000DWT barges are able to sail from Port C towards the deep see transshipment location E.

Option 7



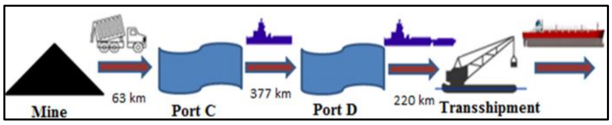
All three stages of throughput can be exported through Port C. This logistical chain is similar to Option 6, but instead of using road a belt conveyor is used instead. The rest of the chain remains unchanged.

Option 8



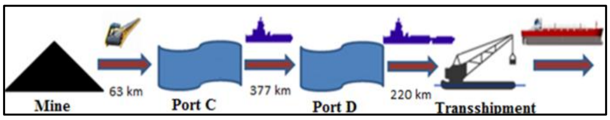
All three stages of throughput can be exported through Port D. A road infrastructure must be constructed of 310 km to reach the location. A terminal must be constructed at Port D and, due to more depth, larger barges of 8,000DW can be used at this location, compared to Port C. From Port D coal would be transported by barging for 220 km until the deep-sea transshipment location E.

Option 9



Similar to the route described in Options 6 would be proposed for this opetion. Due to the depth restrictions at Port C, it would be possible to initially load coal on 2,000 DWT barges, then sail to Port D where coal would be transshiped into 8,000DWT barges. This would allow a larger quantity to be transported in a single trip to the deep sea transshipement location E. The road transport would be used to reach the Port C.

Option 10



Here, a similar logistical chain to Option 9 would be used, while the only difference is to substitute the first 63 km with belt conveyor instead of road transport. The remaining logistical chain is unchanged.

5.2 Assumptions for the case study

Assumptions depend upon the modality discussed; therefore each of the sections below concentrates on a separate modality. Due to the chosen case study, railway transport has not been incorporated into the analysis. The assumptions are based on internal knowledge of experts at Royal HaskoningDHV and can be altered by user of the model. Pricing is based on the Indonesian market.

5.2.1 General assumptions

- One way transportation nodes will be analyzed, namely from the mine to the port. In contrast to other terminals, dry bulk export or import chains are most commonly designed for one way traffic, as the design has a direct influence on the overall allocation of the components within the chain (Ligteringen, 2009),

- The mining operator covers all the costs of transportation from the mine to the port, based on FOB contracts,
- No specific location for storage/handling/change of modality is taken into account,
- Seasonality in demand is not taken into account,
- Single currency is used for the analysis, namely USD ($),
- The incurred costs are yearly,
- 10% preliminarily added on top of the final cost, to account for risk,
- Calculated costs are yearly and based on the carried capacity,
- Capacity is fixed at 6MtpA and 10MtpA,
- No capital is purchased, and rental expenditures include of capital, labor, and maintenance
- Deep- sea transshipment is rented for a fixed cost of 5 $/t, which includes maintenance, labor, depreciation, energy.

5.2.2 Assumptions for road transport

- Maintenance of road is 10% of CAPEX per year
- Lifetime of the road is 15 years with no salvage value, thus calculated on yearly basis
- Cost of km of road is $1million, composed out of
    - Earthworks
    - Sub-grade preparation
    - Sub-base material preparation and placement
    - Base preparation and placement
    - Surface material preparation and placement
    - Berm placement
    - Ditching
- Only 60t trucks are used

- OPEX calculated based on:
    - Number of trucks required
    - Carrying capacity of a truck
    - Price of truck rental that includes fuel, labor, capital, maintenance of 0.068$/t.km
    - Total distance of all trucks
    - Cycle time
    - Road fee per cycle $1.30 of a trucks

5.2.3 Assumptions for inland waterway transport

Table 9 Assumptions for inland waterway transport

CAPEX		
Class	**Sub-class**	**Unit**
River works	Dredging	3 $/m3
Navigation aids		450 $/km
Barge load terminal		$20,900,000
Capital renting	2000 DWT 8000 DWT	$5,041 per annum per barge $12, 103 per annum per barge
Energy	2000 DWT 8000 DWT	$126 $/h $252 $/h
Road	Road	50% from road CAPEX
OPEX		
Maintenance	River works Navigation aids Barge load terminal Road	10 % of CAPEX 1.5 % of CAPEX 3 % of CAPEX 1.5 % of CAPEX
Energy	Barge load terminal	1 % of CAPEX
Labor	Barge load terminal	120 $ daily average
Depreciation	Barge load terminal	CAPEX/15 years

- Salvage value of barge load terminal, barge transshipment terminal, and floating terminal is $0,
- Barge load terminal at Port A, B, C requires 150 employees per terminal,
- Barge transshipment terminal at Port D costs 3 $/t, which includes maintenance, labor, depreciation, energy.

5.2.4 Assumptions for belt conveyor transport

Table 10 Assumptions for belt conveyor transport

CAPEX		
Class	Sub-class	Unit
Earthworks	Site preparation	50 % road construction costs
Bulk earthworks	Cutting into ground	50 % road construction costs
Civil construction	Footings, Pilings, Slabs	10 % Structural & Mech. cost
Electrical power supply	System	10 % Structural & Mech. cost
Control System	System	10 % Structural & Mech. cost
Transport & Erection	Transport & Erection	15 % Structural & Mech. cost
OPEX		
Maintenance		0.5% per added 1 MtpA
Electrical Energy Consumption		$/kwh 0.08
Depreciation	Structural & Mechanical	10% salvage value

5.3 Results

This section of the chapter provides an overview of the cost per tonne, depending on the planned stage of production. Table 11 presents the cost per tonne of each of the logistical chains and narrows down to a cost per tonne of each of the modalities used in transportation. Similarly, as for the Stage I the same calculation is provided in Table 12 for the Stage II. This allows not only to conclude which logistical chain is more cost efficient in but indicates whether different logistical chains must be employed for each stage.

Table 11 The cost per tonne per logistical chain to transport 6MtpA

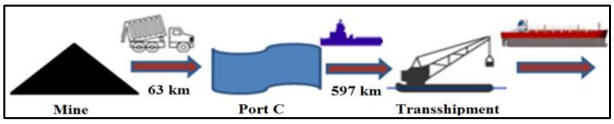
Option	**Road transport ($/t)**	**Inland waterways ($/t)**	**Belt conveyor ($/t)**	**Transshipment ($/t)**	**Unit price ($/t)**
1	90.67	5.68		5.00	101.35
2	82.35	6.56		5.00	93.91
3	191.85	22.32		10.00	224.17
4	90.67	22.32	14.52	10.00	137.51
5	82.35	22.32	14.52	10.00	129.19
6	17.80	18.27		5.00	41.07
7		24.13	40.57	5.00	69.70
8	93.05	11.66		5.00	109.71
9	17.80	17.60		8.00	43.40
10		23.46	40.57	8.00	72.03

Table 12 The cost per tonne per logistical chain to transport 10MtpA

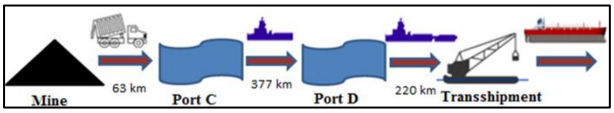
Option Nr	Road transport ($/t)	Inland waterways ($/t)	Belt conveyor ($/t)	Transshipment ($/t)	Unit price ($/t)
1	64.31	3.67		5.00	72.97
2	58.40	4.54		5.00	67.94
3	134.01	14.25		10.00	158.26
4	64.31	14.25	7.64	10.00	96.20
5	58.40	14.25	7.64	10.00	90.29
6	12.75	14.73		5.00	32.23
7		18.25	25.20	5.00	48.45
8	66.69	7.07		5.00	78.76
9	12.75	13.92		8.00	24.67
10		17.44	25.20	8.00	50.64

In Table 11 it can be seen that Option 6 offers the lowest cost per tonne of 46.10$/t, though it is closely followed by Option 9 which offers a cost of 48.43$/t.

Option 6:



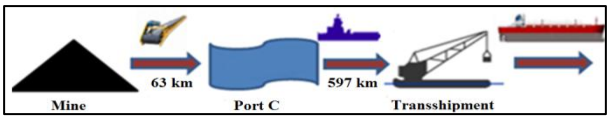
Option 9:



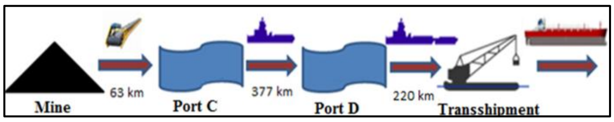
In Option 6 2,000DWT barges are used to transport all 6MtpA to the transshipment location, but the difference between Option 6 and 9 is not as large. This is because the same route is used, though in Option 9 additional transshipment is required which increases the cost per tonne by $3.

Overall there are four options that currently allow transporting 6MtpA under the market price of coal, Options 6, 9, 7 and 10.

Option 7:



Option 10:



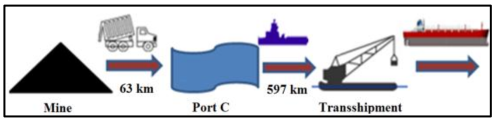
Though the price in Options 7 and 10 is higher than Option 6 and 9, they could be considered as alternatives. The reason of this cost increase compared to Option 6 and 9 is that instead of using road transport, belt conveyor is employed to carry 6MtpA. Based on the conclusion drawn in the previous chapter, it can be concluded that 6MtpA is too small amount to carry, which is why the cost per tonne is significantly higher compared to road or inland waterway transport.

For the throughput of 10 MtpA, more options become feasible as seven out of ten options offer a cost per tonne lower than the market price of coal. For the previous throughput, Option 6 was leading the alternatives while Option 9 was a close follower, for the throughput of 10 MtpA, the roles are reversed. In this case, the belt conveyor is able offer a more competitive price compared to road transport. If the profit margins between the all the seven alternatives are compared, already previously identified Options 6, 9, 7 and 10 are the dominating alternatives.

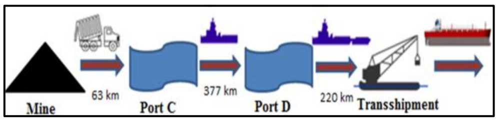
5.4 Conclusion

Based on the cost comparison of each of the options, it can be estimated that if:

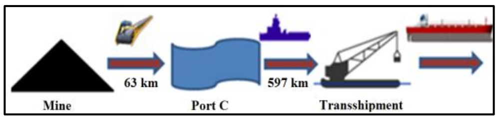
- Option 6 is employed over all 15 years of operations, then the average cost per tonne over both stages would be 33.99$/t



- Option 9 is employed over all 15 years of operations, then the average cost per tonne over both stages would be 28.42$/t



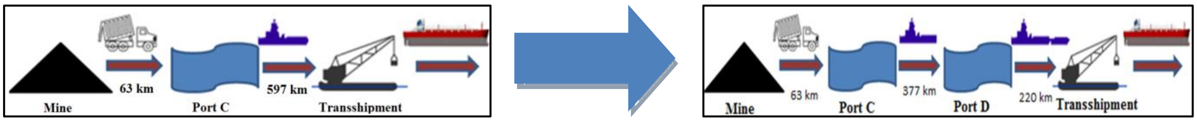
- Option 7 is employed over all 15 years of operations, then the average cost per tonne over both stages would be 52.70$/t



- Option 10 is employed over all 15 years of operations, then the average cost per tonne over both stages would be 54.792$/t

It can be seen that Options 9 is the one able to offer the largest profit margin, compared to other alternative logistical designs.

On the other hand, it can be concluded that for the first years while the throughput is relatively low, the Option 6 could be used to transport coal, while after the throughput has reached 10MtpA, logistical chains would be switched.



Additionally, this would yield a lower cost per tonne over the 15 years of 27.95$/t.

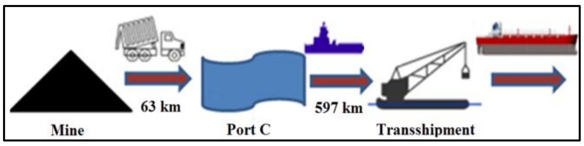
In Appendix C, the net present value (NPV) is calculated for the Option6, 9 and switching from Option 6 to Option 9 after three years. These three have been chosen as they yield the lowest cost per ton. It can be concluded that indeed by switching after three years, NPV is maximized at each of the discount rates used in the calculations.

If mine operator can negotiate the start of operations and directly start with export of higher than 10MtpA, its profit margin will be significantly higher, compared to if the starting exports are 6MtpA.

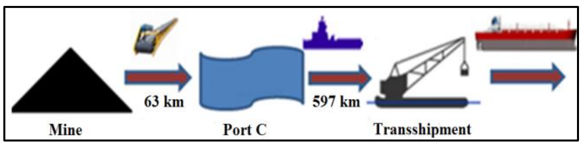
This conclusion would be only valid if a mine operator only looks at cost elements involved into the decision process. Therefore, MCDA is necessary to evaluate whether only based on the cost comparison a mine operators will make a selection of a logistical chain in Indonesia.

A selection of four alternatives will be analyzed in MCDA. Only options that were already feasible in the first stage will be compared, as the alternative options would not be considered by a mine operator if there are options that would yield a profit margin. The four options that will be analyzed in the MCDA are:

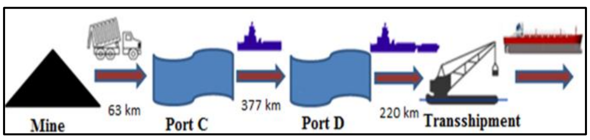
Option 6



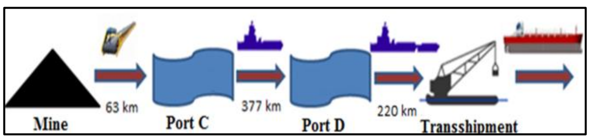
Option 7



Option 9



Option 10



Chapter 6 Survey on the Indonesian market

This chapter of the thesis presents the qualitative analysis in a form of a survey. The first section presents the list of factors that has been assessed by chosen respondents. The second section explains the methodological approach to the grading scheme and the type of respondents gathered for the survey, this will be followed by a section that presents the results. The final section will discuss the results and assess the potential of multimodal network development for Indonesian market.

6.1 Factors affecting multimodality for Indonesian market

By gathering the impression of the private sector it is possible to assess what complicates doing business in Indonesia. The initial list of factors based on academic literature has been presented in Chapter 3, highlighting the main four categories:

After consulting experts at Royal HaskoningDHV[4] and literature available on Indonesian market (Meyrick, 2012), the initial list of factors has been redesigned. As the initial categories are quite general, too many factors would be covered by each, more representative and smaller categories have been created.

Product characteristics have been excluded from the survey, as the aim of the survey is to reveal the information about the Indonesian market, and not about specific product. The category of multi actor management has been split into two groups: institutional risks and logistical dependency.

Factors from multi actor and risk management are divided over three groups:

- Logistical dependency,
- Performance risks,
- Institutional risks.

Logistical chains where several parties are involved are affected by the state and performance of the partners, having a direct influence on the performance of the company itself. Logistical network design has been split into two categories: financing and readiness of the

[4] Bos, C. Project Manager, Maritime and Waterways Royal HaskoningDHV
Hiltermann, J. Dry bulk consultant, Heavy Industry, Logistics at Royal HaskoningDHV

infrastructure. The decision regarding the design is mainly based on costs and what infrastructure is already available or can be quickly constructed.

The factors have been grouped into five general categories:

More detailed composition of each of the categories is shown in Figure 11.

Figure 11 Grouping of factors into categories

1. Logistical dependency

a. Switching costs
b. Liabilities and performance guarantees
c. Long term strategy
d. Reliability of business partners
e. Unreliability of node operators
f. Cultural differences with partners
g. Business ethics
h. Logistical and operational mismatch in time between parties
i. Different strategic/operational views
j. Lack of service quality
k. Trust
l. Communication between parties
m. Poor coordination
n. Synchronization between the start of operations

2. Performance risks

a. Loss of flexibility
b. Loss of agility
c. Accidents with employees
d. Damage to local community
e. Damage to cargo
f. Environmental threat
g. Existing climate (rainy season)
h. Sustainability of operations
i. Damage to image/reputation
j. Operational delays
k. Schedule reliability
l. Mismatch between start of operations and availability of infrastructure

3. Financing

a. Expenses
b. Revenues
c. Short term profits
d. Long term profits
e. Capacity prioritization over sustainability

4. Readiness of infrastructure

a. Lack of incentives for private sector to invest into multimodal transportation
b. Lack of master planning of infrastructure
c. Imbalanced distribution of infrastructure
d. Lack of modal interconnectivity
e. Passenger train prioritization over cargo
f. Reliance on road transport
g. Potential of inland waterway employment
h. Extensive custom procedures

5. Institutional risks

a. Lack of legal framework
b. Institutional blockages
c. Lack of regional government support
d. Political stability
e. Uncoordinated info between state and private sector
f. Lack of compliance standards
o. Organizational bureaucracy

6.2 Methodology

6.2.1 Sample

Each project in consultancy business is different and requires a consultant to develop an expertise to provide a client with an objective recommendation. As a result, due to extensive work on Indonesian market, chosen respondents have an objective view on the state of its affairs. As Royal HaskoningDHV does not invest financial resources into projects themselves, they can be considered free from financial bias. Being a consultant, the respondent is able to objectively and neutrally assign the scoring as he/she is not biased due to the internal interests of the company.

The list was sent to ten respondents to collect their opinions about the potential of multimodal dry bulk transportation in Indonesian market. Based on their expertise, respondents can be grouped into:

- A group of respondents who are native Indonesian residents and have lived in Indonesia the majority of their life:
    - Darmawan, A. Business & Project Manager, Maritime and Waterways, Indonesia,
    - Saleh, P. Project Director, Heavy Industry and Logistics, Indonesia,
- A group of respondents who have worked or are working at the location for during their career:
    - Dirkmaat, A. Consultant, Infrastructure- Design and Realization, Indonesia,
    - Lansen, J. Project Manager/Port Engineer/Coastal Engineer/ IWT Specialist, Maritime and Waterways, Vietnam,
    - Simons, B. Director Business Unit, Heavy Industry and Mining, Indonesia
    - Steutel, W. Director Business Development, Heavy Industry and Logistics, the Netherlands,
- A group of respondents who are located in the Netherlands offices, but who have extensively travelled to Indonesia while working on different projects:
    - Bos, C. Project Manager, Logistics, Port Planning, Economics, Maritime and Waterways, the Netherlands,
    - Elzinga, T. Project Manager, Maritime and Waterways, the Netherlands,

- Hiltermann, J. Dry bulk consultant, Heavy Industry and Logistics, the Netherlands.

6.2.2 Data collecting

The collected list of factors was sent via email to ten potential respondents. The example of the emailed file can be found in Appendix Figure 16. In the email it was noted that respondents can choose between two options:

- Provide their individual scorings and send them back via email,
- Upon a request, a conference call can be scheduled, to discuss the list and assign the scores.

Finally, nine scorings were obtained:

- Wybe de Jager[5] preferred to have a discussion providing more general market insights. It was conducted by Jan Hiltermann[6] in Jakarta, based on the guidelines prepared by Evija Belanina. In the text his comments are referred to as an interview.
- 7 of the respondents chose the first option and sent their individual scorings by email.
- With Joost Lansen[7] a discussion via phone was scheduled, after which the grading was sent back via email. In the text his comments are referred to as an interview.
- Theun Elzinga[8] was interviewed in person at Royal HaskoningDHV Rotterdam office by Evija Belanina.

6.2.3 Grading scale

The responses were collected based on the grading scheme between 1 and 5. This allowed each of the respondents to express their opinion on the subject based on their knowledge and experience in the Indonesian market. However, at the same time is kept in mind that the familiarity with Indonesian market differs between the respondents. As a result, when evaluating individual responses there appears to be a significant difference in assigned grading.

Grade 1 = Unimportant

Grade 2 = Slightly important

Grade 3 = Important

Grade 4 = Very important

Grade 5 = Critical

By grading each of the factors between 1 as the lowest grade and 5 as the highest, it would be possible to calculate what percentage of the final decision represents each of the categories.

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5 De Jager, W. Project Manager, Heavy Industry and Mining, Royal HaskoningDHV

6 Hiltermann, J. Dry bulk consultant, Heavy Industry and Mining, Royal HaskoningDHV

7 Lansen, J. Project Manager /Port Engineer/Coastal Engineer Maritime and Waterways, Royal HaskoningDHV

8 Elzinga, T. Project Manager, Maritime and Waterways, Royal HaskoningDHV

6.3 Results

The average scores assigned by respondents can be seen in Appendix Figure 17. From these, factors that have received the highest and lowest scores are shown in Figure 12:

Figure 12 The highest and lowest graded factors

The highest scores

- Lack of master planning of infrastructure
- Revenues
- Political stability
- Institutional blockages
- Lack of regulatory framework

The lowest scores

- Damage to cargo
- Organizational bureaucracy
- Cultural differences
- Business ethics
- Different strategic views

Although respondents had assigned factors on a scale from 1 to 5, the average grades fall into a range from 2.38 and 4.00. For results and weighting to be more representative for the MCDA, the scale of average grades will be changed[9]. The new grading can be seen in Appendix Figure 18.

Based on the new scale and proposed grouping of factors, average scores and weightings of each of the categories have been calculated. The weighting is especially relevant for MCDA in the next chapter. Results can be seen in Figure 13.

Figure 13 Evaluated categories with average grades and developed weightings

Logistical dependency	Performance risks	Financing	Readiness of infrastructure	Insititutional risks
• Average score 3.04 • Weight 18%	• Average score 3.00 • Weight 17%	• Average score 3.96 • Weight 23%	• Average score 3.60 • Weight 21%	• Average score 3.59 • Weight 21%

As can be seen in Figure 13, the category that has been assigned the largest scores is financing with an average of 3.96. It is followed by readiness of infrastructure which has received almost the same average as institutional risks. As a result, their weighting for the MCDA is the same. The next category is logistical dependency, which has an average of 3.04, which again is closely followed by performance risks of an average of 3.00. Therefore, the weightings range between 23 percent for financing and 17 percent for performance risks.

[9] For the new scoring, the value of 2.38 is assigned 1.00 while 4.00 is 5.00. Based on formula: 5x(Old score-2.38)/ (4.00-2.38) a new score can be calculated

6.4 Analysis

Financing issue is evaluated as the most influential factor in determining the potential of multimodal dry bulk transportation. The mining operators are risk averse, which means that they will be hesitant to commit to heavy financial commitments, as their main interests are:

- Fast Return on Investment (ROI)
- Lowest CAPEX alternatives when choosing the required infrastructure.

De Jager indicated that as the amount of Chinese companies operating in the Indonesian market has significantly increased during the years, their business culture is dominating the mining sector (Interview, 2013). Chinese companies are mainly looking for alternatives that will yield the lowest CAPEX. This explains why the majority of operators favor road transport, though its OPEX is much larger than for other modalities. Despite the fact that we are looking at one of the most capital rich companies in the world, every project is reviewed with caution and aims at portfolio differentiation in order to spread the risk.

Due to no master plan of infrastructure, there is no systematic development of transportation networks in Indonesia. This factor has been assigned the second highest scoring.

The poor state of currently available infrastructure of inland waterways and railways are the reasons for the heavy financial investment that is necessary to increase their usage. The using of inland waterways is highly affected by the seasonality. Due to the varying water levels in rivers in some regions inland waterway transport can be not usable for more than 6 months a year. This means that every year extensive dredging is required which for an individual party is too heavy of a capital burden. Lansen stressed as long as there will be no governmental institution that would coordinate and encourage private parties to use both of the modalities, the presence of inland waterways in transportation networks will be limited (Interview, 2013).

Factors indicating the unreliability of state and lack of legal framework are closely following the readiness of the infrastructure. If a company does not trust the political stability of the regulatory environment, it will significantly limit its investment as there are no guarantees for the continuation of the operations. This is supported by de Jager that the existing corruption especially at the lower levels of governmental institutions is a large limitation (Interview, 2013). The lack of moderation from the government side indicates that public sector is not prioritizing the private sector in the development of transportation networks, which is a significant disadvantage as a large extent of the infrastructure is in hands of the private sector.

The riskiness of operating in the Indonesian market can be evaluated as one of the leading factors in affecting the potential of multimodal dry bulk transportation development. This supports the viewpoint of Lansen and de Jager, that mining companies are risk averse (Interview, 2013).

Multimodal transport networks require cooperation and reliance on service delivery from all the parties. When discussing this issue with de Jager and Lansen, they both explained that due to the lack of an information platform that would allow for private parties to easier communicate with one another, it is difficult to identify potential partners (Interview, 2013). As a result, it happens more as a coincidence. This supports the missing role of moderator, indicating that the low score of this group can be explained by the faulty regulatory environment by the state.

The performance is directly linked with the image and reputation of a company. Due to the increasing attention being paid to sustainability and environmental matters, accident rate and damage created to the local environment must be controlled. De Jager (Interview, 2013) explained that local communities are in possession of a very strong lobbying power. Communities are very fragmented in these regions and as a result local communities:

- Influence the property rights on land, which is in the main interest of mine companies looking for potential land legs to use for pit to port transport,
- Influence assigning of permits,
- Have the power to affect the timing of the start of operations.

Potential performance risks can decrease the flexibility and business agility of the company. Cooperation with another party requires increased complexity in coordination. If parties have not aligned schedules or performance guarantees, mismatch in operations or delivery schedules will create financial losses. Though such performance of a company is essential, it is not evaluated as a problem why mining operators would not engage into multimodal dry bulk transportation.

6.5 Discussion

Respondents gathered for the survey have different experience levels in the Indonesian market. This reveals why some factors have been scored differently. However, due to the small sample of the survey, differences between the groups will not be discussed. The groups are of different size, which can bias the results into the direction of the majority score.

The scoring of factors differs, as the respondents represent different areas of work like engineering, economics, and management. This has allowed the development of weights for MCDA, as well as analyzing the categories in more detail in order to evaluate the actual relationships between factors.

Neither of the factors has received an average score under 2, which confirms the viewpoint of Ade Darmawan[10] that the identified factors are all relevant and it is very difficult to precisely state which factor is more relevant and which is less. This explains why based on the initial scoring, neither of the factors has earned a rank as critical problem of employing multimodal transportation networks in Indonesia.

Evaluating individual grading, it can be derived that especially costs and risks are the main concerns for mine operators. This has been validated by experts, findings in both academic and industry reports (World Bank, 2005 and 2007, Meyrick, 2012). While contradictory to the academic literature highlighting the role of environmental threat and increasing attention paid to sustainability in operations, scoring revealed that these factors are not seen as concerns in achieving multimodal transportation.

6.6 Conclusion

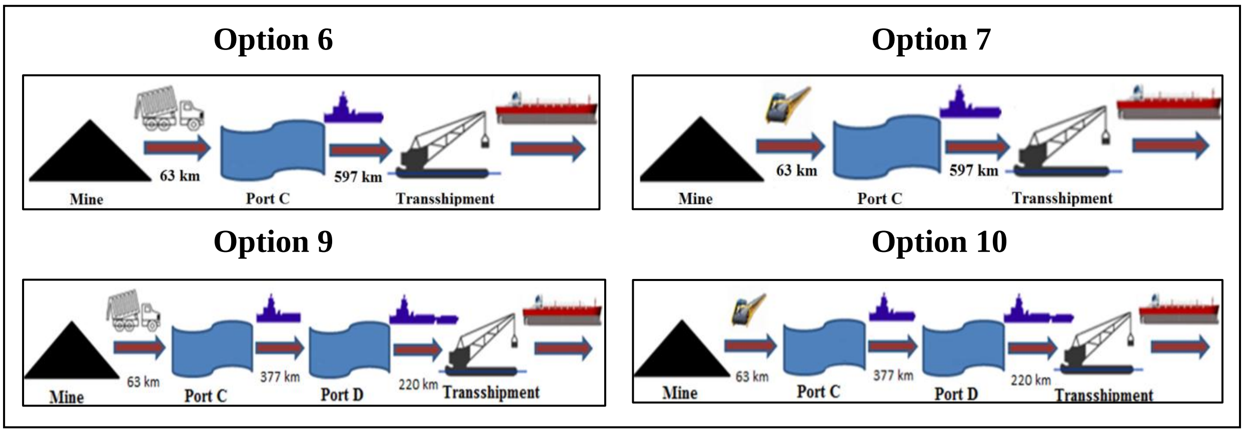
After evaluating the results of the survey, it is possible to conclude that:

- Mining companies are risk averse, they will avoid situations that increase the risks which potentially causes loss of financial resources to the company,
- Operators look for fact ROI, low CAPEX, due to the existing financing risks, what explains why road transport is dominating the transport sector,
- Poor quality and coordination of infrastructure is a huge drawback as a significant capital investment is required to encourage the private sector to differentiate by using inland and railway transportation,
- Lack of regulatory environment and political stability as major drawbacks for parties to cooperate and invest capital into infrastructure due to the fear of discontinuation of operations in the long term,
- Lack of governmental moderation of employing different modalities or helping for private sector to better communicate, slows down the potential developments of more efficient transportation chains.

10 Darmawan, A. Business Manager & Project Manager, Maritime & Waterways, Royal HaskoningDHV

Chapter 7 Multi Criteria Decision Analysis

Chapter 7 will apply the MCDA on the case study. Ten options have been presented as potential logistical chains. As 6 of the options after the calculations appear to be more expensive than the actual price of coal, these are not considered feasible anymore. Therefore, only 4 options will be analyzed by the MCDA.



The first section will introduce the methodology behind the MCDA, while the next section will apply it and further discuss the results.

7.1 Methodology

The process of MCDA is described in Figure 14. Steps 1, 2, 3, and 5 have already been carried out in the previous chapters of this thesis. This chapter will finalize the steps 4 and 6, to arrive at the valuation of each of the logistical chains.

Figure 14 Method for Multi Criteria Decision Analysis

1. **Establish the decision context**
2. **Identify the options to be appraised.**
3. **Identify objectives and criteria**
4. **"Scoring". Assess the expected performance of each of the options against each criteria. Then assess the value associated with the consequences of each option for each criterion.**
5. **"Weighting". Assign weights for each of the criterion to reflect their relative importance to the decision.**
6. **Combine the weights and scores for each option to derive an overall value.**
7. **Examine the results.**

(Source: Dodgson, 2009)

The weighting required in Step 5 has been identified based on the results of the survey which revealed the weight of each of the categories:

Logistical dependency	Performance risks	Financing	Readiness of infrastructure	Insititutional risks
• Weight 18%	• Weight 17%	• Weight 23%	• Weight 21%	• Weight 21%

The scoring required in step 4 will be based on assigning grades for each of the options. The grading will be between 1 and 5, where 1 is the lowest and 5 the highest score.

Based on the weightings the alternatives will be evaluated and an option with the highest score will be the one most likely chosen by a mine operator in Indonesia. The grading will be done by the author of this thesis, based on the findings in the interviews and academic literature.

7.2 Grading and reasoning

Based on the information gathered during the process of writing the thesis, it is possible to reflect on this knowledge. This will be done by applying the MCDA on the four options of logistical chains identified as financially feasible for transporting coal from mine to the transshipment location. The grading explained in previous section has been applied on each of the logistical chain options. The assigned grades are presented in Table 13.

Table 13 MCDA applied on the logistical chains 6, 7, 9, and 10

Category	Weights	Option 6	Option 7	Option 9	Option 10
Logistical dependency	**18%**	**3**	**4**	**2**	**3**
Performance risks	**17%**	**3**	**4**	**2**	**4**
Financing	**23%**	**4**	**2**	**5**	**2**
Readiness of infrastructure	**21%**	**5**	**2**	**4**	**2**
Institutional risks	**21%**	**4**	**2**	**3**	**2**
			Total		
		19	**14**	**15**	**14**

It can be seen that based on the total score (before weighting) that option 6 has received the highest grading. A more detailed reasoning must be explained based on each of the categories.

For the category logistical dependency, Option 7 has received a score of 4, while Options 6 and 10 are scored as 3 and Option 9 as 2. Option 7 has received a highest score compared to other options, as:

- Belt conveyor is used instead of road transport, decreasing the external dependency, compared to Option 6,
- Compared to Options 9 and 10, a single port is used in the chain, decreasing the dependence on a double amount of nodes.

The Option 9 has received the lowest score as it is dependent upon the road transport and cargo must be loaded at two port facilities, while Options 6 and 10 encounter only one of these two things, receiving a slightly higher scoring.

The category of performance risks is scored exactly the same as the previous category, due to the same reasoning.

In the category financing, Option 9 has received the highest grade as when both stages where combined, it was able to offer the least expensive logistical chain. Option 9 has been a close follower in each of the stages receiving a score 4, while Options 7 and 10 became an alternative only at the throughput levels of 10 MtpA. Therefore, they are scored as the least favorable from the available options receiving a score of 2.

For the category readiness of infrastructure Option 6 has received a highest score, as road infrastructure can be constructed much quicker compared to belt conveyor. And compared to Option 9, a single port facility is necessary, allowing the transportation chain to become operational faster. As a result, Options 7 and 10 have received the lowest scores, as the construction of belt conveyor is considerably slower than construction of road or port terminal.

Finally, for the category institutional risks, none of the options has received a highest score, because this risk is present for any of the logistical chains. Option 6 has received a highest score because of the least front-end investment required compared to alternative options. In the Option 7 and 10, belt conveyor must be finalized before the start of operations, but as mine operators are risk averse and lack the reassurance about the long-term continuation of the operations; such front-end capital investments are avoided.

After applying the developed weighting on each of the options, the final ranking with scores is:

1. Option 6: 3.86
2. Option 9: 3.32
3. Option 7: 2.70
4. Option 10: 2.52.

It can be concluded that even after applying the MCDA the ranking of options has changed. Even though a financial category bears the highest weight, categories like institutional risks and reediness of the infrastructure are as important, which has caused Option 9 to drop to a second place. This allows concluding that in some cases, mine operators might not favor the cheapest alternative as other factors can appear as important for choosing a logistical chain in Indonesia.

7.3 Conclusion

It can be concluded that a mine operators will choose a logistical chain in Option 6 as it:

- Is the least exposed to external and institutional risks,
- Is the least complex and can be constructed the fastest.
- Might not be the cheapest logistical alternative, but is the one least exposed to external risks and threats, as even if by switching option a higher NPV can be achieved, this would mean that company is more exposed to risks.

By combining this conclusion with findings of a survey, it can be concluded that due to no guidance or regulatory framework, logistical chains involving road transportation will dominate the transportation sector in mining industry. Even though, more sustainable and possibly less damaging to the environment possibilities would be available.

Chapter 8 Conclusion, Limitations, Further research

8.1 Conclusion

The mining industry is facing a confidence crisis (PWC, 2013). Over the years major mining corporations have enjoyed a steep increase in their assets and revenues. The scenery of today has changed. Indonesia has become a strong player in the mining world due to:

- Its rich reserves of natural resources,
- Undeveloped and less restricted infrastructure
- Low labour costs

attracting investment inflows from the largest mining companies. Industry forecasts show that the Indonesian economy holds a strong potential for the future.

In order to sustain the competitive position of the Indonesian mining industry, mine operators must ensure that in times of increasingly rising transportation costs, Indonesian logistical chains are able to offer more competitive prices. The aim of this thesis has been to identify the possibilities of controlling the increasing costs of mine operators.

In order to decrease the transport costs while at the same time solving national transportation problems, a multimodal transportation network of coal flows has been presented as a potential solution, based on the findings in academic literature. Therefore, the goal has been to identify the problems present in Indonesian market to evaluate the potential of multimodal coal transportation. To achieve the goal, a Multi Criteria Decision Analysis has been chosen as an approach for this thesis. It allows combining financial factors comparing the cost expenditures with locational factors of doing business in Indonesia.

To identify and evaluate the problems present in Indonesian market, the factors influencing the design of logistical chains have been categorized into:

Each of the categories includes factors of different nature, therefore both quantitative and qualitative research methods have been applied to arrive at the factor evaluations.

For the financial assessment of modalities, a transparent and user friendly framework has been designed. By assessing the operational and capital expenditures a comparison was made between four modalities:

The analysis revealed:

- Road and belt conveyor transport are more competitive over short distances compared to barging and railway
- Road transport has the largest OPEX compared to belt conveyor, railway and barging
- If inland waterways are available, operators should go for barging as it offers the smallest cost per tonne compared to road, conveyor belt, and railway
- The increasing lengths and amount of cargo transported by of belt conveyors decrease the cost per km, making it more competitive with road haulage in the long term.

As the optimal distances of each of the modalities differ, the conclusion is that there exists a potential to combine them into multimodal transportation networks. Additionally, not only optimal distances determine what modality can be employed, as has been shown in this research.

The throughput quantity of a mine and its scope of operations have a direct influence on the design of a logistical chain. This has been shown by assessing the competitiveness of road and conveyor belt transport on a short distance, concluding that belt conveyor transport can offer a lower cost per tonne if the transported amount of cargo goes beyond 14 million tonnes per annum.

The potential of combining modalities is not only based on financial comparison. Mine operators also are risk averse, which means that they will be hesitant to commit to heavy financial commitments, as their main interests are:

- Fast Return on Investment (ROI),
- Lowest CAPEX alternatives when choosing the required infrastructure.

Therefore, the private sector must be incentivized by the regional or national government to switch to more sustainable means of transportation. This would decrease the environmental threat to the area and to the local communities.

However, not only the financial factors play a role in choosing for a logistical chain, as risks and state of the available infrastructure are as important in determining the final decision. The Indonesian market has many drawbacks that limit the interest of mining companies to invest into more sustainable and long-term infrastructure. The analysis showed that mining operators would be interested to cooperate, but due to the lack of incentives and no moderation from the state, the willingness is diminished.

It can be concluded that multiple factors influence the potential of the multimodal transportation network development in Indonesia. It has been shown that financial factors are as important as the aspects concerning the state of the infrastructure, and institutional risks. Though one is clear, without a strong public coordination things will not function for a greater good of the Indonesian economy. The public sector must ensure the reliability of affairs:

- For companies to feel secure about their investment and control for risks
- For residents to enjoy the benefits of an international environment
- For the regional development of Indonesia.

8.2 Limitations

Due to the chosen scope and timing of this thesis, there are several limitations that have to be explained:

- The model developed in this thesis is limited to the analysis of links, while the cost expenditures of storage are not been included into the analysis
- The framework of the analysis does not account for timing of operations and is not discounted over time
- The list of factors sent to respondents can carry a certain bias as the author has a limited familiarity with Indonesian market and all the information has been gathered based on interviews and findings in the literature
- As all of the respondents are from consulting businesses, increasing more variety in the responses from mining and transport companies and public authorities would have increased the validity of the findings.

8.3 Further research

The chosen topic of the thesis allowed for deeper insight into Indonesian transportation market. Along the way of writing several recommendations have been formed for further research into pit to port transportation in Indonesia:

- Including slurry pipeline would be an advantage as in the USA and Brazil it is widely used for coal transportation
- More detailed costs incurred at nodes have been excluded from the analysis. This way potential cost savings at these locations could be further assessed for the full advice on logistical chain cost expenditures.
- Potential inland waterway and rail network design studies could be carried out in order to assess in what regions and how these networks could be implemented
- The concept of dry ports is growing in its applicability in different regions of the world, while studies on the Indonesian market are limited. Addressing its potential in Indonesia would be an interesting aspect for the future of logistical chains in Indonesia.

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Chapter 10 Appendix A

Table 14 An overview of the most commonly used methodologies

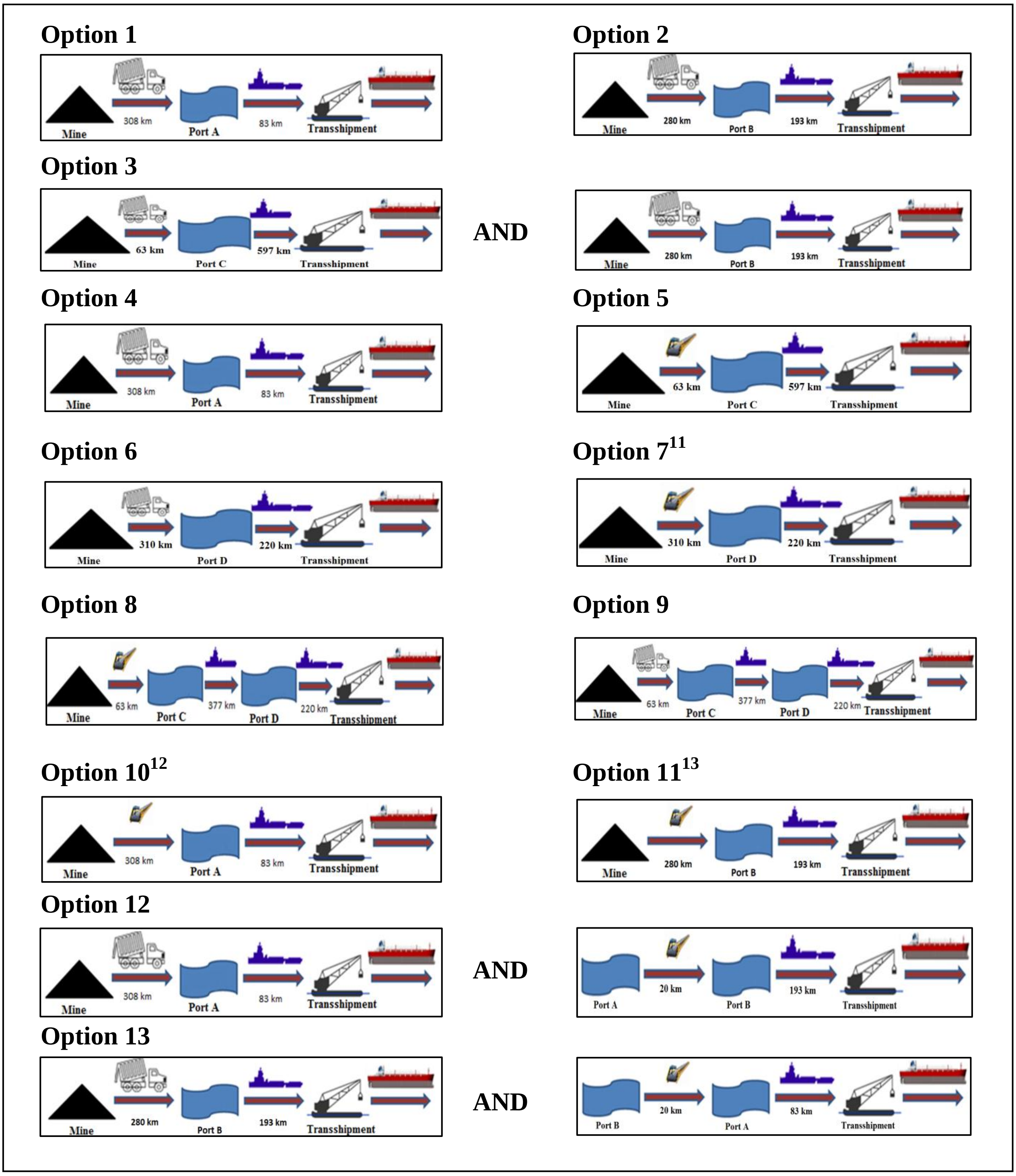
Method	Definition	Advantages	Disadvantages
CBA	The economic technique applied to public decision making that attempts to quantify the advantages and disadvantages associated with particular project (Alberini, n.d.)	• Stimulates comparisons • Transparent • Simple to use (CoA, 2006) • Consistent tool for analysis • Captures broader picture with more decision making parties (Fulop, 2005)	• -Subjective • -Impossible to monetize reliably • -Excludes relationships between the factors (CoA, 2006)
CRA	CRA refers to a variety of tools developed by scientists to use when human health, safety, business or the environment are at threat, allowing multiple hazards to be assessed with a common framework (Anderson, et al. 2000)	• Informative • Weights the countervailing risks • Provides a sense of perspective • Attempts to capture the full picture • Systematic approach to the analysis (Renn, 1985)	• Unclear way in which it combines performance on criteria • Less structured • Subjective • Accounts only for risks (Linkov, et al.
MCDA	MCDA is an approach with a goal of providing an overall ordering of options from the most to the least preferred option, seeking to take explicit account of multiple criteria in helping groups explore decisions that matter (Beltonne, 2002; Mussen, et al. 2009)	• Simple, transparent, systematic, stimulates the learning about a problem, risks, uncertainty • Links technological performance info with decision criteria and weightings • Visualizes and quantifies trade-offs involved in the decision-making (Beltonne, 2002; Mendoza, 2006) • Stimulates collective decision making	• -Obtained weightings might be not representative • -Overly detailed examination • -Subjective (Beltonne, 2002)
CEA	Where there are alternative options to achieve a specific objective, but where objective cannot be valued, CEA can be used to assess the least cost way of achieving the objective (Dodgson, 2009)	• Applicable in situations when factors hard to monetize • Benefits expressed in physical units thus not affected by monetary terms (CoA, 2006)	• Subjective • Distinction between outcomes and outputs blurred • Captures only a part of full picture

Table 15 Groupings of commodities based on NSTR

NSTR	Description	Example
0	Agricultural products and life animals	Grain
1	Foodstuffs and animal fodder	Hay, corn
2	Solid mineral fuels	Talc, gypsum
3	Petroleum products	Gasoline, diesel
4	Ores and metal waste	Iron ore, coal
5	Metal products	Steel
6	Crude and manufactured minerals, building materials	Wood, rocks
7	Fertilizers	Granular Triple superphosphate
8	Chemicals	Phosphorus, acids
9	Machinery, transport equipment, etc.	Cars, cranes

(Source: Jonkeren, et al. 2011)

Figure 15 An overview of all the logistical chain options, with indication which are not feasible



[11] Not feasable as belt conveyor in such distance is too expensive based on current technology

[12] Not feasable as belt conveyor in such distance is too expensive based on current technology

[13] Not feasable as belt conveyor in such distance is too expensive based on current technology

Figure 16 The scoring file sent to respondents

The aim of this list of factors is to assess the potential of multimodal transport chains for coal transportation within Indonesian market. By grading each of the factors between 1 as the lowest grade and 5 as the highest, it would be possible to determine what factors currently are the main drawbacks for employing the multimodality in Indonesia. By grading each of the factors, weighting and percentages can be calculated, indicating what are the currently the largest problems of actual employment of multimodal transportation in Indonesia, based on your experience!

The results should represent the grading based on these explanations:

Grade 1 = Unimportant

Grade 2 = Slightly important

Grade 3 = Important

Grade 4 = Very important

Grade 5 = Critical

1. **Logistical dependency**
    a. Switching costs
    b. Liabilities and performance guarantees
    c. Long term strategy
    d. Reliability of business partners
    e. Unreliability of node operators
    f. Cultural differences with partners
    g. Business ethics
    h. Logistical and operational mismatch in time between parties
    i. Different strategic/operational views
    j. Lack of service quality
    k. Trust
    l. Communication between parties
    m. Poor coordination
    n. Synchronization between the start of operations

2. **Performance risks**
    a. Loss of flexibility
    b. Loss of agility
    c. Accidents with employees
    d. Damage to local community
    e. Damage to cargo
    f. Environmental threat

g. Existing climate (rainy season)
h. Sustainability of operations
i. Damage to image/reputation
j. Operational delays
k. Schedule reliability
l. Mismatch between start of operations and availability of infrastructure

3. Financing

a. Expenses
b. Revenues
c. Short term profits
d. Long term profits
e. Capacity prioritization over sustainability

4. Readiness of infrastructure

a. Lack of incentives for private sector to invest into multimodal transportation
b. Lack of master planning of infrastructure
c. Imbalanced distribution of infrastructure
d. Lack of modal interconnectivity
e. Passenger train prioritization over cargo
f. Reliance on road transport
g. Potential of inland waterway employment
h. Extensive custom procedures

5. Institutional risks

a. Lack of legal framework
b. Institutional blockages
c. Lack of regional government support
d. Political stability
e. Uncoordinated info between state and private sector
f. Lack of compliance standards
g. Organizational bureaucracy

Figure 17 Categories with average scores of factors before adjustment

1. Logistical dependency	**Average score**
a. Switching costs	**3.00**
b. Liabilities and performance guarantees	**3.44**
c. Long term strategy	**3.25**
d. Reliability of business partners	**3.56**
e. Unreliability of node operators	**3.50**
f. Cultural differences with partners	**2.50**
g. Business ethics	**2.63**
h. Logistical and operational mismatch in time between parties	**3.44**
i. Different strategic/operational views	**2.63**
j. Lack of service quality	**3.00**
k. Trust	**3.63**
l. Communication between parties	**3.33**
m. Poor coordination	**3.56**
n. Synchronization between the start of operations	**3.44**
2. Performance risks	
a. Loss of flexibility	**3.44**
b. Loss of agility	**3.56**
c. Accidents with employees	**2.88**
d. Damage to local community	**3.13**
e. Damage to cargo	**2.38**
f. Environmental threat	**2.75**
g. Existing climate (rainy season)	**3.50**
h. Sustainability of operations	**2.71**
i. Damage to image/reputation	**3.13**
j. Operational delays	**3.86**
k. Schedule reliability	**3.56**
l. Mismatch between start of operations and availability of infrastructure	**3.38**

3.	**Financing**	**Average score**
a.	Expenses	**3.67**
b.	Revenues	**3.89**
c.	Short term profits	**3.44**
d.	Long term profits	**3.78**
e.	Capacity prioritization over sustainability	**3.11**
4.	**Readiness of infrastructure**	
a.	Lack of incentives for private sector to invest into multimodal transportation	**3.63**
b.	Lack of master planning of infrastructure	**4.00**
c.	Imbalanced distribution of infrastructure	**3.33**
d.	Lack of modal interconnectivity	**3.25**
e.	Passenger train prioritization over cargo	**3.29**
f.	Reliance on road transport	**3.78**
g.	Potential of inland waterway employment	**2.88**
h.	Extensive custom procedures	**3.29**
5.	**Institutional risks**	
a.	Lack of legal framework	**3.86**
b.	Institutional blockages	**3.86**
c.	Lack of regional government support	**3.75**
d.	Political stability	**3.88**
e.	Uncoordinated info between state and private sector	**3.07**
f.	Lack of compliance standards	**3.00**
g.	Organizational bureaucracy	**2.44**

Figure 18 Categories with average scores of factors after adjustment

	Average score
1. Logistical dependency	
a. Switching costs	**2.53**
b. Liabilities and performance guarantees	**3.62**
c. Long term strategy	**3.15**
d. Reliability of business partners	**3.91**
e. Unreliability of node operators	**3.77**
f. Cultural differences with partners	**1.30**
g. Business ethics	**1.62**
h. Logistical and operational mismatch in time between parties	**3.62**
i. Different strategic/operational views	**1.62**
j. Lack of service quality	**2.53**
k. Trust	**4.09**
l. Communication between parties	**3.35**
m. Poor coordination	**3.91**
n. Synchronization between the start of operations	**3.62**
2. Performance risks	
a. Loss of flexibility	**3.62**
b. Loss of agility	**3.91**
c. Accidents with employees	**2.23**
d. Damage to local community	**2.85**
e. Damage to cargo	**1.00**
f. Environmental threat	**1.91**
g. Existing climate (rainy season)	**3.77**
h. Sustainability of operations	**1.81**
i. Damage to image/reputation	**2.85**
j. Operational delays	**4.65**
k. Schedule reliability	**3.91**
l. Mismatch between start of operations and availability of infrastructure	**3.45**

3.	**Financing**	**Average score**
a.	Expenses	**4.19**
b.	Revenues	**4.73**
c.	Short term profits	**3.62**
d.	Long term profits	**4.46**
e.	Capacity prioritization over sustainability	**2.80**
4.	**Readiness of infrastructure**	
a.	Lack of incentives for private sector to invest into multimodal transportation	**4.09**
b.	Lack of master planning of infrastructure	**5.00**
c.	Imbalanced distribution of infrastructure	**3.35**
d.	Lack of modal interconnectivity	**3.15**
e.	Passenger train prioritization over cargo	**3.25**
f.	Reliance on road transport	**4.46**
g.	Potential of inland waterway employment	**2.23**
h.	Extensive custom procedures	**3.25**
5.	**Institutional risks**	
a.	Lack of legal framework	**4.65**
b.	Institutional blockages	**4.65**
c.	Lack of regional government support	**4.38**
d.	Political stability	**4.70**
e.	Uncoordinated info between state and private sector	**3.07**
f.	Lack of compliance standards	**2.53**
g.	Organizational bureaucracy	**1.15**

Figure 19 Example of inland waterway calculation[14]

The example of calculations is based on Option 7.

Inland waterways	Tons per annum									
CAPEX	1000000	2000000	3000000	4000000	5000000	6000000	7000000	8000000	9000000	10000000
Road	31500000	31500000	31500000	31500000	31500000	31500000	31500000	31500000	31500000	31500000
River works	18000000	18000000	18000000	18000000	18000000	18000000	18000000	18000000	18000000	18000000
Navigation aids	268650	268650	268650	268650	268650	268650	268650	268650	268650	268650
Load terminal	20900000	20900000	20900000	20900000	20900000	20900000	20900000	20900000	20900000	20900000
OPEX										
Maintennace	2903529,75	2903529,8	2903529,75	2903529,75	2903529,75	2903529,75	2903529,75	2903529,75	2903529,75	2903529,75
Energy	209000	209000	209000	209000	209000	209000	209000	209000	209000	209000
Labor	5040000	5040000	5040000	5040000	5040000	5040000	5040000	5040000	5040000	5040000
Depreciation	1393333,333	1393333,3	1393333,333	1393333,333	1393333,333	1393333,333	1393333,333	1393333,333	1393333,333	1393333,333
Capital rent	65533	131066	196599	262132	327665	393198	458731	524264	589797	655330
Fuel	8502984	17005968	25508952	34011936	42514920	51017904	59520888	68023872	76526856	85029840
Total	88783030,08	97351547	105920064,1	114488581,1	123057098,1	131625615,1	140194132,1	148762649,1	157331166,1	165899683,1
Preliminary	8878303,008	9735154,7	10592006,41	11448858,11	12305709,81	13162561,51	14019413,21	14876264,91	15733116,61	16589968,31
Total +preliminary	97661333,09	107086702	116512070,5	125937439,2	135362807,9	144788176,6	154213545,3	163638914	173064282,7	182489651,4
Cost per ton	**97,66**	**53,54**	**38,84**	**31,48**	**27,07**	**24,13**	**22,03**	**20,45**	**19,23**	**18,25**

[14] More detailed calculations are available upon the request

Chapter 11: Appendix B

Chapter 4 has discussed various advantages of different modalities used for coal transportation. This chapter will further build upon the findings and try to assess at what throughput capacities of a mine belt conveyor is more attractive over road transport. The first section will explain the reasoning behind this assessment, while the next section will outline the assumptions. This will be followed by section on results and a conclusion.

11.1 Road and belt conveyor transport

Chapter 4 presented different optimal distances for using various modalities for coal transportation. The conclusion explained that railway becomes more competitive over longer distances due to heavy CAPEX investment. If the mine site has an access to inland waterway, this modality should be used as it offers the lowest cost per tonne. Road and belt conveyor transport are evaluated as competitive only over short distances.

Road transport has been characterized as rather fast and relatively cheap option for a short term. Compared to alternative modalities, its infrastructure can be built quickly and requires less capital investment. However, its operational costs are significantly higher compared to other modalities due to large consumption of fuel and labor needed. Additionally, its environmental threat is being increasingly noted by the industry and national policy makers.

Literature discussed how belt conveyors are increasingly becoming competitive with road transport over short distances. The comparison of optimal distances has mainly relied on a cost comparison of constructing and running the infrastructure, while the amount of cargo to be transported is highly important. Therefore, this comparison will be carried out on the same distance but on varying amount of coal.

11.2 Assumptions

The cost of capital and operational expenditures are highly location specific, as determined by interaction between different elements. As a result, the evaluation will be applied on the Indonesian transportation market. A fixed distance and throughputs of a mine have been chosen for the analysis. The cost estimations are market dependent and based on the internal knowledge at Royal HaskoningDHV. The input variables can be altered by individual himself within the designed framework of analysis.

11.2.1 General assumptions

- The distance will be fixed at 7800m, which is the standard length of a single flight belt conveyor, from the point A to B, without any stops.
- The throughput quantity of a mine is fixed and will range between 4 and 20 million tonnes per annum.
- No costs incurred at nodes are taken into analysis.
- Seasonality in demand is not taken into account.
- Single currency is used for the analysis, namely USD ($).
- 10% preliminary added on top of the final cost, to account for risk.
- Calculated costs are yearly and based on the carried capacity.

11.2.2 Assumptions for road transport

- Cost of km of road is $1million is composed out of
  - Earthworks
  - Sub-grade preparation
  - Sub-base material preparation and placement
  - Base preparation and placement
  - Surface material preparation and placement
  - Berm placement
  - Ditching
- The cost of road construction, maintenance and depreciation remains the same over all the throughput quantities
- OPEX road: 10% of CAPEX
- Depreciation: straight 15 years with no salvage value
- No capital purchased
- Type of truck: 30t
- OPEX calculated based on:
  - Carrying capacity of a truck
  - Price of truck rental that includes fuel, labor, capital, maintenance of 0.21$/t.km
  - Total distance of all trucks

11.2.3 Assumptions for belt conveyor transport

Table 16 Technical specifications

Length	**7800 m standard length**
Width	Variable (as narrow as possible)
Speed	Variable (4-7 m/s)
Through angle[15]	35 degrees
Idler spacing[16]	3m top, 6m bottom
Belt strength[17]	Variable
Utilization	6000 hours per year
Elevation[18]	+10m
Capacity (MtpA/ tph)	4/666 8/1000 8/1333 10/1666 12/2000 14/2300 16/2666 18/3000 20/3333

[15] The angle of a belt side idlers
[16] The distance between pulleys which are moving the belt and cargo forward
[17] Some belts will require a higher belt strength which are more expensive – the price of the belt is a significant part of the entire mechanical price, therefore the belts of 2000tph and above are somewhat underpriced based on the current method of calculations
[18] The height difference between the head section and the tail section required for discharge

Table 17 Different specifications of each of the belt conveyors

Belt conveyor capacity	Belt width	Belt speed	Belt type	Required Power (kW x no. of motors)	Selected motors (kW x no. of motors)	Price mechanical installation
666 tph	600 mm	5,10 m/s	St 2000	182,79 X 5	200 x 5	€ 8.784.900
1000 tph	650 mm	6,20 m/s	St 2500	267,16 X 5	300 x 5	€ 9.972.000
1333 tph	800 mm	5,25 m/s	St 2800	325,59 X 5	355 x 5	€ 12.378.700
1666 tph	800 mm	6,55 m/s	St 2800	391,79 X 5	400 x 5	€ 12.093.700**
2000 tph	1000 mm	4,85 m/s	St 2800*	429,25 X 5	450 x5	€ 15.166.800
2333 tph	1000 mm	5,65 m/s	St 2800*	500,48 X 5	560 x 5	€ 15.188.800
2666 tph	1000 mm	6,45 m/s	St 2800*	571,71 X 5	630 X5	€ 15.191.900
3000 tph	1.200 mm	4,95 m/s	St 2800*	597,60 X5	630 X5	€ 17.803.300
3333 tph	1.200 mm	5,50 m/s	St 2800*	663,95 X 5	710 X 5	€ 17.828.000

Table 18 Belt conveyor transport

CAPEX		
Class	Sub-class	Unit
Earthworks	Site preparation	50 % road construction costs
Bulk earthworks	Cutting into ground	50 % road construction costs
Civil construction	Footings, Pilings, Slabs	10 % Structural & Mech. cost
Electrical power supply	System	10 % Structural & Mech. cost
Control System	System	10 % Structural & Mech. cost
Transport & Erection	Transport & Erection	15 % Structural & Mech. cost
OPEX		
Maintenance		0.5% per added 1 MtpA
Electrical Energy Consumption		$/kwh 0.08
Depreciation	Structural & Mechanical	10% salvage value

11.3 Results

Table 19 Road transport [19]

Road transport					MtpA				
CAPEX	4000000	6000000	8000000	10000000	12000000	14000000	16000000	18000000	20000000
Road construction	7800000	7800000	7800000	7800000	7800000	7800000	7800000	7800000	7800000
Capital	0	0	0	0	0	0	0	0	0
OPEX									
Depreciation of road	520000	520000	520000	520000	520000	520000	520000	520000	520000
Maintenance of road	780000	780000	780000	780000	780000	780000	780000	780000	780000
Truck rental	6552000	9828000	13104000	16380000	19656000	22932000	26208000	29484000	32760000
Total	15652000	18928000	22204000	25480000	28756000	32032000	35308000	38584000	41860000
Preliminary	1565200	1892800	2220400	2548000	2875600	3203200	3530800	3858400	4186000
Total +prelim	17217200	20820800	24424400	28028000	31631600	35235200	38838800	42442400	46046000
Cost per ton	4,30	3,47	3,05	2,80	2,64	2,52	2,43	2,36	2,30

Table 20 Belt conveyor[20]

Belt conveyor					MtpA				
CAPEX	4000000	6000000	8000000	10000000	12000000	14000000	16000000	18000000	20000000
Earthworks	3900000	3900000	3900000	3900000	3900000	3900000	3900000	3900000	3900000
Bulk earthworks	1950000	1950000	1950000	1950000	1950000	1950000	1950000	1950000	1950000
Civil construction	878490	997200	1237870	1209370	1516680	1518880	1519190	1780330	1782800
Structure and mechanical costs	8784900	9972000	12378700	12093700	15166800	15188800	15191900	17803300	17828000
Electrical power supply system	878490	997200	1237870	1209370	1516680	1518880	1519190	1780330	1782800
Control system	878490	997200	1237870	1209370	1516680	1518880	1519190	1780330	1782800
Transport	263547	299160	371361	362811	455004	455664	455757	534099	534840
Erection	1317735	1495800	1856805	1814055	2275020	2278320	2278785	2670495	2674200
OPEX									
Maintenance	377033,04	618256,8	966819,04	1187433,8	1556327,5	1699765,4	1841710,8	2253921,9	2417658
Energy	438696	641184	781416	940296	1030200	1201152	1372104	1434240	1593480
Depreciation	35139,6	39888	49514,8	48374,8	60667,2	60755,2	60767,6	71213,2	71312
Total	19702520,64	21907889	25968226	25924781	30944059	31291097	31608594	35958259	36317890
Preliminary 10%	1970252,064	2190788,9	2596822,6	2592478,1	3094405,9	3129109,7	3160859,4	3595825,9	3631789
Total +Preliminary	21672772,7	24098678	28565048	28517259	34038465	34420206	34769454	39554085	39949679
Cost per ton	5,42	4,02	3,57	2,85	2,84	2,46	2,17	2,20	2,00

11.4 Conclusion

The calculations in this chapter revealed that:

- For distance of 7.8km belt conveyor will become more attractive over a long term operations if the throughput quantity would increase beyond 14MtpA,
- Capital expenditures required for constructing the belt conveyor system, for relatively smaller amounts of throughput makes it too costly for a mine operator to choose for its usage,
- If the cost per tonne of employing road transport is lower than for belt conveyor, private companies will favor the road transport. Therefore, it must be incentivized by the regional or national government to switch to more sustainable means of transportation.

[19] More detailed calculations are available upon a request
[20] More detailed calculations are available upon a request

Chapter 12: Appendix C

In order to determine which option is the preferred one, the net present value (NPV) of each of the logistical chains must be determined. The NPV will be calculated for Options 6, 9 and switching from Option 6 after three years to Option 9, as these options yield the lowest cost per ton. Net present value covers all the revenues and costs over the whole project lifetime. The project can be considered profitable if NPV is larger than the actual investment as otherwise more money would be made by simply putting the investment into a bank. In order to discount future cash flows, a discount rate is used, which is in a form of the interest rate established by central bank.

12.1 Assumptions

- Formula used:

$$NPV = \sum_{t=0}^{n} \frac{(\text{Benefits} - \text{Costs})_t}{(1 + r)^t}$$

where:
r = discount rate
t = year
n = analytic horizon (in years)

- Corporate tax rate= 25%
- As discounting factor three options will be used:
    - 5%
    - 10%
    - 15%

Different discount rates are used due to fluctuations in the interest rates. As the future is more difficult to predict especially in developing countries, the discount rate must be estimated larger than for developed countries. The discount rate that can be used nowadays is closer to 10%. If discount rate is higher, it means that NPV value will be lower due to more risk involved.

- Market price of coal: 85$/t
- Depreciation method: straight method

12.2 Results

Table 21 NPV of each of the Options 6, 9 and switching from Option 6 to Option 9 after three years

Option 9	
Discount rate 5%	NPV= $ 3,833,741,818
Discount rate 10%	NPV= $ 2,652,869,858
Discount rate 15%	NPV =$ 1,918,271,643
Option 6	
Discount rate 5%	NPV=$ 3,428,176,627
Discount rate 10%	NPV=$ 2,388,684,301
Discount rate 15%	NPV=$ 1,740,124,238
Switch from Option 6 to Option 9 after 3years	
Discount rate 5%	NPV=$ 3,862,295,074
Discount rate 10%	NPV=$ 2,678,944,501
Discount rate 15%	NPV=$ 1,942,211,258

12.3 Example of calculations

These calculations are if mine operator would choose Option 6 for all 15 years

Discount rate: 5%

Figure 20 Example of NPV calculations

							Years									
Elements	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**Sum**
Revenues	510000000	510000000	510000000	850000000	850000000	850000000	850000000	850000000	850000000	850000000	850000000	850000000	850000000	850000000	850000000	
Costs	246420000	246420000	246420000	322300000	322300000	322300000	322300000	322300000	322300000	322300000	322300000	322300000	322300000	322300000	322300000	
CF	263580000	263580000	263580000	527700000	527700000	527700000	527700000	527700000	527700000	527700000	527700000	527700000	527700000	527700000	527700000	
CF-depr	257986667	257986667	257986667	522106667	522106666,7	522106666,7	522106666,7	522106666,7	522106666,7	522106666,7	522106666,7	522106666,7	522106666,7	522106666,7	522106666,7	
After taks	193490000	193490000	193490000	391580000	391580000	391580000	391580000	391580000	391580000	391580000	391580000	391580000	391580000	391580000	391580000	
After Tax+depr	199083333	193490000	193490000	391580000	391580000	391580000	391580000	391580000	391580000	391580000	391580000	391580000	391580000	391580000	391580000	
Discounting	1,05	1,1025	1,157625	1,2155063	1,276281563	1,340095641	1,407100423	1,477455444	1,551328216	1,628894627	1,710339358	1,795856326	1,885649142	1,979931599	2,078928179	
PV	189603175	175501134	167143937	322153835	306813176,3	292203025	278288595,3	265036757,4	252415959,4	240396151,8	228948716	218046396,2	207663234,5	197774509	188356675,3	3530345277
NPV																3428176627