Comparative Analysis on Integrated Coal Transport Models in South Sumatra

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Abstract
Among the implementation of sustainable development in Indonesia is the effort to achieve an efficient transportation system for freight. Coal is the most valuable commodity for economic activity in South Sumatra Province and become one of the biggest coal producers in Indonesia. Coal transport activity from the production site to port before being exported are mostly using land transport via highway in South Sumatra. They have various negative impacts such as traffic jam, fatal traffic accident and also pollution. This paper attempts to compare some possible coal transport systems in South Sumatra Province combining the available transport networks namely highways, railways and waterways transit. Those possible integrated transport system model will be compared using cost calculation and technical aspect comparison analysis to measure the most system that supportive to sustainable development. The result shows that transporting coal by integrated railways and river to mother vessel transhipment has the advantage of aspects of traffic disruption and damage to the environment for short term period. Meanwhile, the coal transport of coal by railways directly to coal massive terminal servicing mother vessel transhipment has the advantage for long term period. This result can be used as the basis for policy making on how to utilize the potential waterways (river) as alternative freight transport system.

Keywords: Sustainable Development, Integrated Coal Transport, Comparative Analysis, South Sumatera.

1 Introduction
Coal is one of the potential mining commodities in Indonesia. This can be seen from the potential of new stones scattered in several islands in Indonesia, especially covering the islands of Sumatra and the island of Borneo. New stone is also one of Indonesia’s export commodities to several countries such as Japan, Taiwan, the United States and others. The amount of coal exports continues to increase every year. In 2002 total coal exports reached 73,124,900 tons and increased in 2015 to 336,970,400 tons (15). Increasing the amount of coal production, there is also an increase in the flow of coal transportation movements. In Indonesia coal transportation is generally carried out using land, train, and sea or river transportation modes. The choice of transportation mode is very dependent on the characteristics of the location and availability of modes. In addition, the choice of coal transportation modes must also consider the cost parameters and technical aspects. The existence of several alternative modes of transportation can provide an option for the coal mining industry to choose the most efficient and effective mode of transportation. The choice of coal transportation mode is influenced by the distance of transportation, road contour, amount of coal reserves, investment costs, production capacity and open pit unit costs (19).

In South Sumatra, coal is one of the valuable commodities for economic development. Based on statistical data on coal reserves in South Sumatra Province it reached 22,240 million tons (15). Coal mining in South Sumatra, which continues to increase, also has an impact on the increase in transportation traffic both on road and river transportation. Coal transportation generally uses trucks as a means of transport from the mine site to the Coal Terminal. Coal transport by truck in South Sumatra is often complained by the community along the route. Some issues emerges are road damage, traffic jam, traffic accident and other environmental impacts. Meanwhile, South Sumatra has railways and river waterways which can be used for coal transport. Since each transport modes has some disadvantages, it is important to consider some integrated transport models using the possible transport modes. This paper reviews some literatures to explore the latest theoretical perspectives and to compare some possible coal transport systems in South Sumatra Province combining the available transport network namely highways, railways and waterways transport. The results of this study are expected to enrich the sustainable transport application in various areas with similar characteristics to Indonesia. Firstly, this paper introduces the...
existing river transport characteristics in Indonesia. Second part will analyse and discuss the appropriate sustainable transport indicators for the rural river transport in Indonesia. The concluding remarks will be the final part of this paper to promote the application of sustainable transport as a part of inclusive transport development.

2 Literature Review

2.1 Coal Transport

In some coal-producing countries and have large coal reserves, they use several modes of transportation of coal by railroad, barges, trucks, trains, and coal mud pipelines. The choice of mode is associated with the efficiency and cost-effectiveness of transport with low costs and large transport volumes. Then the various alternative modes have their respective competitiveness related to coal transportation.

2.1.1 Rail Transport

The mode of railway transportation is one of the modes of coal transportation that is widely used in several countries such as the United States, Australia, China and India. More than 1 billion tons of coal per year are transported by railroads in many coal producing and user countries in the world (32). In United States, rail transportation plays an important role in the coal transportation system. About 95% of coal transported by rail in the United States moves in highly productive train units and operates within 24 hours (4). This shows the dominant use of railroad transportation as a mode of coal transportation in the United States. The dominance of the railroad as a main carrier is expected to continue in the future (4). This also happens in Australia, that trains are the dominant mode of coal transportation. One of the main railway lines in the coal transportation system in Australia is Aurizon Rail, which is one of the largest railroad transporters in the world from mine to port for export markets (4).

2.1.2 Truck

Trucks are one of the modes of transportation that are often used in coal transportation. Usually trucks are used in areas that have not been reached by trains or other transportation. In addition, trucks are generally used to transport coal from the station before coal is sent to the final destination. Although more flexible cruising roaming of coal using trucks is more limited in volume compared to the amount of coal transportation using trains or sticks in one go. Due to route flexibility and low capital investment, trucks can economically move coal around 100 miles per trip in a relatively small amount of transportation (4). In the study conducted by (19) found that trucks are superior in coal transportation.

2.1.3 Transport by Barge and Ship: Water Transport

Sticks are an alternative way of transporting coal, especially in watersheds. About 10% of total coal shipments in the Americas are carried out using barges (31). In several other countries in the world also use barges as coal transportation such as in China and Indonesia. In Indonesia the use of barges as a mode of coal transportation such as those found on the islands of Borneo and Sumatra, which are used as coal transportation in river flows. Barge transportation systems are influenced by river flow, flow characteristics, weather and market conditions (4). In the amount of carrying capacity, sticks have a greater carrying capacity compared to trains and trucks. Big sticks can carry the amount of coal equivalent to 15 carriages or 58 truckloads (4). Therefore, sticks can be said to be one of the most effective modes of transportation compared to other modes, of course, if supported by available infrastructure and network systems.

2.2 Sustainable Transport

Transportation systems that support the flow of goods and services, create jobs and encourage economic growth, and produce negative impacts on the environment and society (7, 20). Transportation has a critical effect on the sustainability aspect, because vehicles on the highway are the main source of pollution (9, 13, 26). This then encouraged the development of a sustainable transportation system.

Sustainability is a concept that integrates economic, environmental and social dimensions (6, 8, 26). Sustainable transportation is a system of mobility of economic and social activities with resource management and environmental protection to maintain current and future needs (23). According to Litman (2007) sustainable transportation is affordable transportation considering aspects of human health and ecosystems, operating efficiently, low in emissions and waste, and minimizing consumption of non-renewable resources.

The issue of sustainable transportation in the coal mining sector is one of the important issues in reducing environmental quality. Increasing the amount of coal demand also increases coal transportation traffic, this will have an impact on the environment and society such as pollution and congestion (see also 24). Coal mining companies must be able to apply sustainable transportation in the coal transportation system. The challenge of companies in sustainable transportation is not yet able to understand and define the objectives of sustainable transport practices and measure and determine their efficiency (20). The main problem faced by the coal transportation system is the lack of availability of appropriate transportation modes and road connectivity, especially in remote areas (9).

The coal shipping system is generally a complex and integrated shipping system by several modes. The alternative sorting of coal transportation modes must consider social, economic and environmental parameters, so that a sustainable transportation system can be realized. The development of coal transportation systems is directed at environmental protection, speed of delivery, minimum transportation costs, and increased traffic safety (9). On the other hand the use of sustainable transportation not only provides benefits to the community and the environment but to the company itself. The establishment of a sustainable transportation system helps companies to increase the utilization of company assets, increase capacity, reduce labour costs, and minimize fuel costs (26).
2.3 Road Cargo Transport Problems

The current population growth is getting higher. The current world population is estimated at 7.6 billion, and is expected to increase to 11.2 billion by 2100 (30). This will cause the increased potential of the movement of people and goods in the future. Therefore infrastructure, facilities and modes of movement of people and goods need to be prepared to meet needs in the future. But not only that, the negative impact of various modes of transportation needs to be considered so that it does not have a massive impact on the environment.

One of the traffic problems on the road is the transport of goods where at the metropolitan area level in developing countries, on average 40% - 50% of the volume of goods transported from commercial vehicles moving to the city center, 20% - 25% move out of center, and the rest of 25% - 40% move within urban areas (3). At the same time, freight traffic, especially in urban areas, can cause problems such as congestion and delays where in most cities the average freight vehicle uses at least 20% - 40% of the road space causing congestion (5). This is because the road infrastructure system in urban areas is not able to accommodate the burden of road users not only for the activities of urban communities but also for freight activities.

Goods transport vehicles which generally have large capacity can make traffic speeds hampered. Excessive freight loads also tend to slow down the flow of traffic, especially if the occurrence of damage and vehicle accidents or slowdown in the area of the hill and segment with a perforated road and if loading and unloading activities are not organized efficiently, the use of road space will not be optimal (12).

Other issues of freight transport are air pollution and energy consumption where freight transport accounts for 20% - 40% of CO2 emissions and is a significant source for NOx and SO2 (5). Diesel-engine vehicles also contribute 50% of particulate emissions as a cause of respiratory illness and can damage historical buildings and other cultural assets (3). On the other hand, freight transport, especially in urban areas including heavy vehicle travel, also involves 31% of energy use (3).

In addition, trucks and pick-up trucks are also sources of noise / vibration pollution, where studies show that the adverse effects of noise on health and quality of life are very serious, such as stress and increased blood pressure (hypertension) and reduced concentration residents in carrying out their activities. The vibration pollution from freight transport can adversely affect various buildings either public or public buildings, especially in historic buildings whose construction is vulnerable to age (12).

Another important thing is that heavy truck vehicles increase the potential for damage to road infrastructure especially when there is overload and poor technical condition or roadworthiness, thus exacerbating the extent of road damage and shortening road service life (5), which averages 52% of trucks in Indonesia is over 45% over the allowed load limit. From the safety aspect, in many places, public transport does not use special roads, so it is mixed with passenger vehicles, motorcycles, pedestrians or cyclists that can lead to an increased risk of accidents and physical injuries (12).

The impact of this freight is contrasted with the expectation that in the transportation sector it is also applied the concept of sustainable development which has actually been raised since 1987 by World Commission on Environment and Development (2). From these facts, efforts to realize sustainable transportation can be done, among others, by combining the river transport network and road transport in the form of intermodal transportation. It is expected to maintain the advantages of river transportation mode and reduce the various externalities of road transport mode. On the other hand, various land uses related to the economic activities of the community are expected to survive and interact with the integration between the river transport network and the road transport, especially for freight activities.

2.4 River Transport Characteristics

Meanwhile, In some watery countries such as Indonesia, roads sometimes could not reach rural areas so that the role of river or inland water transport has become so important to serve the accessibility of passengers and goods in remote areas (21). Meanwhile, river transport in Indonesia is also relatively neglected with a lot of problems. The number of river vessels and the length of navigable rivers are continuously declined. In Palangkaraya, the model share for river transport is only 3.75 % and the Musi River has a large tidal range so that it is not navigable for all times (29). In other locations, some river channels have been eroded due to the movement of the ship (28) and experience severe sedimentation problem (17).

River transport has almost similar characteristics to railways transport since it can only serve catchment area along the river channel. Usually, river transport activity is managed traditionally without fixed route and regular schedule while advanced river transport surely can serve fixed route and regular schedule. River transport ship is generally constructed from wood with various types (14).

Technically, river transport has some potential advantages compared to other modes. Commercial modern water transport could reliably serve passengers and goods with low pollution and scheduled activity (22). From environmental perspective, river transport actually supports the sustainable transport from ecological and economic aspect since it is efficient on fuel consumption (25) and environmental friendly (11).

In areas with naturally available rivers for transportation, it is not necessary to build new infrastructure except quays and navigation signs. In India, for same transport path length, the cost of developing river transport is only about 5% to 10% compared to the cost of developing a 4-lane highway or a railway network. River infrastructure only needs to be maintained at a low cost since for the same transport path length, river transport maintenance costs only about 20% of the road maintenance cost (1). River transport is also a transport mode with some characteristics which corresponds to the concept of sustainable transportation where it is environmental friendly and efficient in energy consumption (11).

Development of river transport is also important for the preservation of cultural and tourist development because
many cities in Southeast Asia region were built closed to river in early civilization, such as Ho Chi Minh City or Bangkok as waterborne city (10). River transport mode in Indonesia is quite still prospective because it can load large quantities of goods with relatively small environmental impact (29). River transport can also exist as an alternative solution for traffic congestion and road damage problem (14).

3 Methodology/Materials
This study tries to compare integrated transportation system models through cost calculation and comparative analysis of technical aspects with the aim of measuring the transportation system model that best supports sustainable development. Therefore, in this study using a mixed approach method that is quantitative and qualitative methods. The qualitative approach is used to calculate the financing analysis of transportation modes, while for the qualitative approach in the form of qualitative descriptive analysis to describe comparisons of technical aspects. In financing analysis, the calculation uses 3 scenarios, first using land routes (trucks to Palembang then from Palembang using barges to Tanjung Carat); second, using the mode of railroad transportation to Tanjung Carat; and third through the land route to Palembang then using barges to STS. This research was conducted on coal transportation systems in the South Sumatra Province. Data collection is done using secondary and primary data collection techniques. Secondary data collection in the form of data related to information on coal shipping systems and their financing. While collecting primary data to confirm financing and field observations related to the coal transportation system.

4 Results and Findings
4.1 Musi River Characteristics
Musi River is one of the rivers located in South Sumatra Province and is the longest river on the island of Sumatra. This river divides Palembang City into two parts, namely across the ilir in the north and opposite the Ulu in the south. The river spring is sourced from the Kepahiang area, in Bengkulu Province. This river is the estuary of nine major tributaries, namely Komering River, Rawas River, Batanghari River, Leko River, Lakitan River, Kelingi River, Lamatang River, Semangus River, and Ogan River. The existence of the Musi River is very important for the community because besides being used for water resources, it is also used as an alternative means of transportation.

Musi River long ago been used by the local community and visitors as a means of transportation. There is a type of transportation used as shuttles at Musi River that for passenger and freight transport. The role of transport in the region Musi River shipping channel is quite an important role in serving the needs of the movement of people, especially to support the needs of the movement of passengers and goods. In addition to being used by the community as a means of transportation, the Musi River is also used by several industries as a means of transportation for industrial goods transportation.

Musi River shipping channel of river transport this airport to transport passengers and goods. Different types of ships sailing in the Musi River shipping channel downstream i.e. Jukung ships to transport goods and speedboats for transporting passengers. The Musi River has quite dense shipping conditions with cargo throughput of goods in 2013 reaching 8,776,633 tons (27). This shows that the Musi River is an alternative mode of transportation that is widely used by the community, industry and mining companies in South Sulawesi Province.

The existence of major Bom Baru Port on Musi river in Palembang City make the river has a vital role as a hub port for marine transportation, including for export and import of goods. In addition, this port is also used for shipping various industrial commodities such as cement, coal, oil and gas and from several piers in Palembang City and surrounding areas. Ships that can sail on the river Musi up and around Palembang are vessels with maximum size of 181 meters LOA with a maximum draft of about 7 meters.

Ship traffic in Bom Baru Port, Palembang in 2013 decreased by 19.16%, both from overseas and domestic. Overseas shipping visits fell from 692 units in 2012 to 674 units in 2013. Meanwhile, shipping flow in the country dropped from 2,231 units in 2012 to 1,689 units in 2013.

Foreign trade activities both imports and exports are carried out in Bom Baru Port increased 187.63%. Imports decreased from 615 343 metric tons in 2012 to 577 685 metric tons. Export cargo activity increased from 1,507,455 metric tons in 2012 to 5,528,055 metric tons in 2013. Loading and unloading activities for the benefit of domestic trade at Bom Baru port increased by 65.07%, where the loading increased from 1,779,173 metric tons in 2012 to 2,483,534 metric tons in 2013. The unloading activities rose from 3,968,691 metric tons to 7,004,429 metric tons. Cumulative foreign trade activities and domestic conducted at the Bom Baru port is an increase of 98.12%, which rose from 7,870,662 metric tons in 2012 to 15,593,703 metric tons in 2013.

4.2 Coal Transport in South Sumatra
The mining sector in South Sumatra is quite good with the production of petroleum, natural gas and coal. The dominant is coal where in 2014 its production amounted to 27,004 million ton. This figure increased from 24 million tons in 2013. The coal reserves in South Sumatra are estimated to reach 22.24 billion tons. The mining sector in South Sumatra is quite good with the production of petroleum, natural gas and coal. The dominant is coal where in 2014 its production amounted to 27,004 million ton. This figure increased from 24 million tons in 2013. The coal reserves in South Sumatra are estimated to reach 22.24 billion tons.

Based on data obtained from the Directorate General of Mineral and Coal in 2015 data on coal traffic through Bom Baru port, Crude Palm Oil (CPO) data from Indonesia Oil Palm Statistics 2014 through Bom Baru port, container traffic data from IPC 2015 through Bom Baru port and vehicle traffic from Polda 2015 through Bom Baru Port as described in the previous description, the loading and unloading of goods consisting of Coal, CPO, Container, and the vehicle is planned to be placed at Tanjung Carat Terminal, taking into consideration the depth at Terminal Tanjung Api that do not meet the technical requirements. The condition of coal
transport network in South Sumatera Province at present is very diverse because of the transportation of coal in various ways and various tools. At present coal transportation uses truck, railways, barge and vessel. How to transport in various ways can be done collaboration or arguably interrelated. From quarry, coal is generally transported by trucking by road across the provincial road to several loading point terminals along the Musi River such as Muara Lematang and in Gandus. In addition to using roads, a small portion of coal transportation uses Railway line from Muara Enim to Kertapati Station and then transported by barge with a maximum size of 7,500 DWT (with LOA: 91.4m, B: 24.4m, and maximum draft: 4.3m) or other barges measuring 5,000 and 2,000 DWT, downstream of the Musi River. Downstream of the Musi River is then transferred through the ship to ship transhipment (STS) directly from barge to large bulk carrier vessels to be exported to destination countries such as China, India and the countries others in Southeast Asia. Coal Cargo to be served by Port of Tanjung Carat is fully planned to come from hinterland in South Sumatera like Tanjung Enim, by using river transportation through Musi River.

Figure 1: Loading and unloading of coal in South Sumatra (in million tons) (Source: PT Indonesia Pelabuhan Company II)

Figure 2: Coal Transport Network in South Sumatra (Source: Office of Local Planning Board, South Sumatra Province, 2017)
The use of this means of river transportation, assumes an increase in the Lematang River and Musi River in the form of navigation signs, dredging and widening of river bodies, and other improvements. With the transportation of coal through the river by using barges, in the dry bulk terminal area of course also needed anchorage to accommodate the barge - the barge is there. Coal transport flow is a coal distribution channel using various methods such as truck, conveyor / belt conveyor, barge and vessel. The use of ways in the distribution of coal adjusts to conditions and locations so that the coal process of each company is different. Mine distribution is carried out for the transport of coal in domestic loading and export loading. The following is a coal transport flow scheme.

### 4.3 Cost Analysis of Coal Transport in South Sumatra

Calculation of financing from coal transportation is carried out based on 3 scenarios, the first using the land route i.e. trucks up to Palembang next from Palembang by barge to Tanjung Carat, the second scenario using rail transport mode to Tanjung Carat, and the third by land until Palembang and then use barge up to STS. Here is a cost calculation of the first scenario cost.

#### 4.3.1 Truck and Barge Scenario to Mother Vessel Transhipment / STS

The analysis of the financing of coal freight with scenarios using trucking up to coal terminal then using barge to Tanjung Carat for mother vessel transhipment / STS cost calculation is as follows. The analysis results of transportation financing for the cost of trucks and barges for aircraft carrier transhipment / STS shows that the total cost for Banyuasin Quarry Site is IDR 576,638 / ton, with detailed costs for land travel with a distance of 318 Km is IDR 338,000 / ton and for waterway with a distance of 61.5 Nm at a cost of IDR 47,859 / ton. While other additional costs are coal surveyors IDR 3,371 / ton and the transhipment cost is IDR 107,882 / ton. In Lahat Quarry Site the calculation of the cost is IDR 103,599 / ton with detailed costs, namely for the cost of sea travel with a distance of 17 Nm is IDR 38,618 per ton, coal surveyor cost is IDR 3,371 / ton and the transhipment cost is IDR 53,936 / ton.

#### 4.3.2 Railways and Barge Scenario to Mother Vessel Transhipment / STS

The analysis of the financing of coal freight with scenarios using railways up to coal terminal then using barge to Tanjung Carat for mother vessel transhipment / STS cost calculation is as follows (Table 2).

![Figure 3: South Sumatra Coal Transport Scheme](image)

Table 1: Cost Calculation of Truck + Barge Cost Requirement to Mother Vessel Transhipment / STS

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Formula</th>
<th>Cost (Rp/ton)</th>
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Figure 3: South Sumatra Coal Transport Scheme
Table 2: Cost Calculation of Railways + Barge Cost Requirement to Mother Vessel Transhipment / STS

<table>
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Lahat Quarry Site

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Table 3: Cost Calculation of Railways to Future Coal Terminal Transhipment

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Lahat Quarry Site

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<td>Railway distance (km)</td>
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<td><strong>IDR 103.599</strong></td>
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</table>

In the second scenario analysis using the train to the coal terminal then the barge to Tanjung Carat shows that the total cost required for the Banyuasin Quarry Site is IDR 576,036 / ton with the fee for the cost of using the train is IDR. 38,000 / ton, use of barges of IDR 7,339 / ton, coal surveyor costs of IDR 3,371 / ton and for transhipment costs IDR 107,882 / ton. In the same scenario, the cost for the Lahat Quarry Site is IDR 107,569 with detailed costs for water use using IDR 2,294 / ton, coal surveyor costs IDR 3,371 / ton and transhipment costs IDR 53,936 / ton.

4.3.3 Railways to Future Coal Terminal Transhipment

The analysis of the financing of coal freight with scenarios using railways up to coal terminal then using barge to Tanjung Carat for Future Coal Terminal Transhipment cost calculation is as follows (Table 3).

In the third scenario cost analysis the total cost for Banyuasin Quarry Site is IDR 489,923 / ton, with details, for the cost of using the railway line reaching IDR 38,000 / ton, the coal surveyor costs is IDR 3,371 / ton, and the transhipment cost is IDR 53,936 / ton, whereas for Quarry Site land the total cost is IDR 103,599 / ton, with the use of the IDR 38,618 / ton railroad track, coal surveyor costs are IDR 3,371 / ton and the transhipment cost is IDR 53,936 / ton.

Based on the results of the analysis of financing comparisons for the three scenarios, it shows that in the first scenario the total cost reached IDR 576,638 / ton for Banyuasin Quarry Site and IDR 103,599 / ton for Lahat Quarry Site. In the second scenario the total cost reached IDR 576,036 / ton for Banyuasin Quarry Site and IDR 107,569 / ton for Lahat Quarry Site. In the third scenario the total cost reaches IDR 489,923 / ton for Banyuasin Quarry Site and
The main obstacles of STS are the issue of supervision, monitoring of environmental aspects to prevent pollution from coal (spills etc), and legal aspect of STS activity. In addition, if there is bad weather. If rainfall is high, loading and unloading times can deviate 25 hours, and if the wave deviation is about 6 hours.

Integrated coal mooring port at major ships weighing about 50,000 to 100,000 DWT. The port is quite large and deep, which can be on land or at sea (STS). It is necessary to evaluate the advantages and disadvantages of both types of ports. Considering the site in the case study, long-term ship to ship transhipment is not recommended, this is related to several limitations and disadvantages such as potential retarding, potential environmental pollution from coal spills, and low control in the transport system. Some of the points above are not in line with the principle of sustainable transportation, as it is known that efficiency, effectiveness of transportation and protection of the environment are the basic principles of a sustainable transportation system (9, 18).

5 Conclusion
This study has conducted a comparison of coal transportation model in South Sumatra using truck - barge - mother vessel, train - barge - mother vessel and train - mother vessel. Comparison is done by using cost analysis and technical aspect analysis. Based on these considerations, the transport model by train - barge - mother vessel is the best for the short term. Meanwhile, the train - mother vessel is the best transportation model for the long term. The key findings of this study are expected to be useful for assessing the possibility of integration of coal transportation modes that have been quite varied in various regions. In addition, the findings are expected to be input for the Government and mining companies in the effort to develop an integrated coal transportation system. For the more optimal and efficient implementation of coal transportation, it is necessary to study more comprehensively the various other related aspects such as environmental, social and regulatory and institutional aspects.

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