A REVIEW OF HIGH-SPEED RAIL PLAN IN JAVA ISLAND: A COMPARISON WITH EXISTING MODES OF TRANSPORT

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ABSTRACT

In order to provide better transportation systems, Indonesian Government is planning to develop a new high-speed rail system in Java that will connect two biggest cities in Java Island, Jakarta and Surabaya, with approximately 685 kilometers of entirely new track. This paper reviewed the Indonesian Government's plan to develop the high-speed rail in term of comparison to existing modes of transport.
This study employs demands projection of high-speed rail using JETRO method and benchmarking from other countries' high speed rails. Furthermore, air pollution caused by transport mode was calculated based on the emission factor from CACP & CNT. The last is generalized cost that considers total time to travel as value of money.
It can be concluded that journey time and fare of the high-speed rail is very competitive to the air transport in Jakarta-Surabaya corridor. The journey time to travel from Jakarta to Surabaya is 4 hours and 19 minutes by high-speed train and 4 hours and 40 minutes by air. Based on the benchmarking analysis, the suitable fare for the high-speed rail should be 70% of the air transport. This study predicted that 61% of air passenger, 18% of conventional rail passenger and 12% of bus passenger will switch to the high-speed rail service in 2020. In total, the high-speed rail will have 24% of market share for the passenger transport and becomes the second largest market share after road transport (52%). The conventional rail and air transport have 14% and 9% of total market share to travel from Jakarta to Surabaya and vice versa. The high-speed rail development reduces carbon emissions caused by transportation systems in Java Island. It has been calculated that there are 2.542 million tonnages of CO_2 per annum without introducing high-speed rail, however, the CO_2 emissions decrease to 1.694 million tonnages per annum if the high-speed rail is developed in Java Island. Generalized cost of the high-speed rail is higher than road and conventional rail. However, it is lower than air transport.

Keywords: Java high-speed rail, HSR Comparison, modal share, journey time

1 INTRODUCTION

The high-speed rail system is believed to be a good solution for transportation problems, because it can minimize impacts on the environment. The UIC (2011) points out that the high-speed rail contributes the lowest carbon emissions per passenger per kilometer (ppkm). In addition, the high-speed system rail also provides higher comfort and safety than the road transport or even the conventional railway. Moreover, the high-speed rail system is very competitive to air transport, in terms of travel time and fare, within distance of 100-800 kilometers. These factors are reasons that the high-speed rail system has been broadly developed in many countries. Nowadays, many countries around the world are operating high-speed rail such as Japan, France, Germany, China, South Korea, and many more. On the other hand, not more countries are either planning or expanding their high-speed rail systems (UIC, 2011). Indonesia is one of the countries that are planning to develop high-speed rail system.

According to the plan, the high-speed rail in Indonesia will be built in the most populated island, namely Java Island. It is likely to be a good solution in fulfilling the needs of transport in the future due to the bad condition of existing transportation. Moreover, this will also bring huge impacts to the economic, environmental and social aspect of Java Island and Indonesia. However, it is likely that the high-speed rail development in Java Island will have problems due to lack of experience with the high-speed rail systems itself. This paper, however, concentrates to compare the high-speed rail with existing modes of transport which includes:

a) To compare of the high-speed rail system in terms of journey times with existing modes of transport on Java Island, especially air transport.

b) To analyze and predict the demands of the high-speed rail.
c) To analyze environmental issues, especially carbon emissions (CO_2), by introducing high-speed rail in Java Island.
d) To compare generalized cost of the high-speed rail with existing modes of transport.

In order to predict demand of the high-speed rail, it has been used two different methods namely JETRO method and benchmarking method.

1.1 JETRO Method

JETRO method (Japan External Trade Organization) is to predict how many passengers switching from buses and conventional rails to high-speed rails. There are two steps in predicting people switching from the buses and conventional rails to the high-speed rails. The first step is calculating resistance factors of the transportation modes *(R_r)*. The resistance factors are affected by total cost, total time and total distance to travel from A to B. The next step is calculating percentage of people *(P_r)* who switch from existing modes to the new modes (JETRO, 2008 in Mininda, 2010). The equations are given below.

$$P_r = \frac{R_r^{-6}}{\sum R_r^{-6}} \quad (1)$$

$$R_r = C + TD \quad (2)$$

where P_r is percentage of switching from existing transportation (%), R_r is resistance factors of transportation, C represents total costs to travel from A to B (Rupiah), T is total time to travel from A to B (minute), and D is total distance to travel from A to B (km).

1.2 1.2 Benchmarking Method

Then, the second method is to predict how many people switching from air transports to the high-speed rails. A benchmarking method has been used in this analysis. To do so, the author looks at other countries' experience in terms of mode share competition between high-speed rails and the transports.

Hirsch (2012) stated that the benchmarking method can be used to compare products or services to the toughest competitor in either intra-industry, or cross-industry. Further, this method is a good way to have a look other companies' success and implementing that to our business.

1.3 Environmental Impacts of HSR

Air pollution caused by CO_2 gives negative impacts both for people and environment. Aerias (2005) stated that it is considered to be a potential inhalation toxicant and a simple asphyxiate. In this analysis, it has been compared the CO_2 emission resulted by operation transportation systems in Java Island without introducing the high-speed rail and with introducing the high-speed rail. Firstly, it has been determined the emission factor by transportation modes. The emission factor is in kilogram of CO_2 per passenger per kilometer (kg/ppkm) that has been calculated by Centre for Clean Air Policy (CACP) and Centre for Neighborhood Technology (CNT) (2006) as shown in the following table.

Table 1. Emission factor (CO_2) in kg/ppkm (CACP and CNT, 2006)

Mode	ppmile (lbs)	ppkm (kg)
Bus	0.14	0.10
Con. Train	0.21	0.15
Airplane	0.62	0.45
HSR (TGV)	0.26	0.11

1.4 Generalized Cost

In order to obtain the generalized cost it is necessary to obtain the total trip time *(t_j, t_a, t_w and t_d)*, the value of time *(a_0)* and the average fare for each relation and each mode *(f)*. To simplify the model, some global parameters have been assumed at this stage. These all parameters will be converted to total cost, in this case is *Rp* (rupiah). Below is equation to calculate generalized cost:

$$GC = Fare + a_0(a_1 \cdot tj + a_2 \cdot ta + a_3 \cdot tw) \quad (3)$$

where *GC* is Generalized Cost (Rp), *Fare* represents total fare (fare of bus, taxi, train, airplane) (Rp), a_0 is value of time (Rp/minute), t_j is journey time (minute), t_a is access time, t_w is waiting time (minute), a_1, a_2, a_3 denote weighting factors.

2 RESEARCH METHODOLOGY

This research is started with reviewing government's plan to develop the high-speed rail in Java Island which is included in the Indonesian Railways Master Plan (2010). From the plan, it has been analyzed whether or not the high-speed rail is a good solution for Java Island in order to provide new transport system that offers high level of safety, reliability and comfort. There are several data needed such as existing transport modes in Java Island, passenger of existing transports, population and geographic of Java Island. To do so, it has been compared the new

transport system, high-speed rail, with existing modes of transport. The comparison consists of journey time, market share, environmental impact (air pollution) and generalized cost of each mode.

2.1 Scenario of Journey time in this research

Journey time is total time needed to travel from one place to another with considering access time, waiting time and travel time Figure 1 is provided to make clear understanding for the scenario of journey time.

2.2 Scenario of value of time in this research

The value of time is needed to analyze the generalized costs of each mode. To do so, it has been purposed 3 scenarios of value of time, namely low income, middle income and high income.

a) Low income; it has been assume that low income is a group of people who has income less than Rp 2,200,000.00 (based on minimum wages of DKI Jakarta).
b) Middle income is between Rp 2,200,000.00-5,000,000.00 per month.
c) Furthermore, people who have more that Rp 5,000,000.00 per month are high income.

2.3 ANALYSIS AND DISCUSSION

2.4 Journey Time Analysis of the High-speed Rail

Journey time is one of the important factors in the transportation apart of fare, reliability and availability of mode, comfort and safety. It can be used as a preference by passenger to choose what kind of transport modes would be taken for their journey. Necessarily, travel time of high-speed train cannot be compared with travel time of bus and conventional rail because the high-speed rail has faster speed. However, in this analysis a comparison is needed in order to see what extent the superiority of the high-speed rail toward the bus and conventional rail to travel from Jakarta to Surabaya as shown in table below.

In contrast to the bus and conventional rail, the high-speed rail is very competitive compared to air transport, especially in distance within 160-800 km (FRA, 2009). In order to know how much the competition, it has competed the journey time which includes access time, waiting time and travel time. The comparison against air is shown in Figure 2.

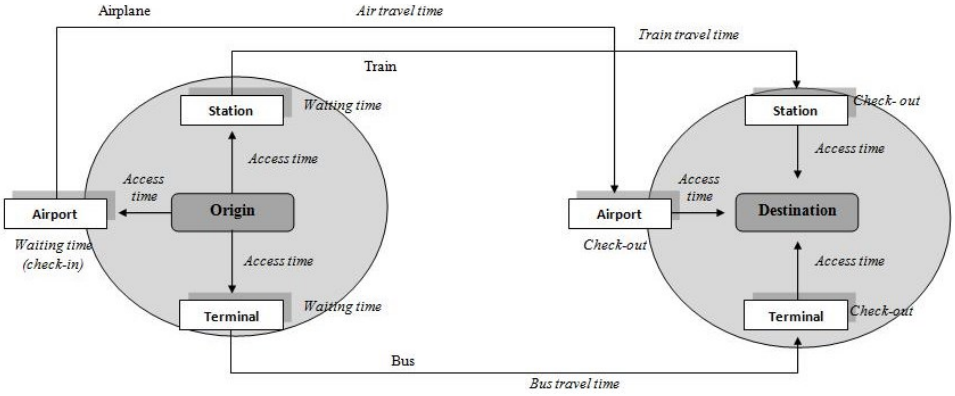

Figure 1. Scenario of journey time

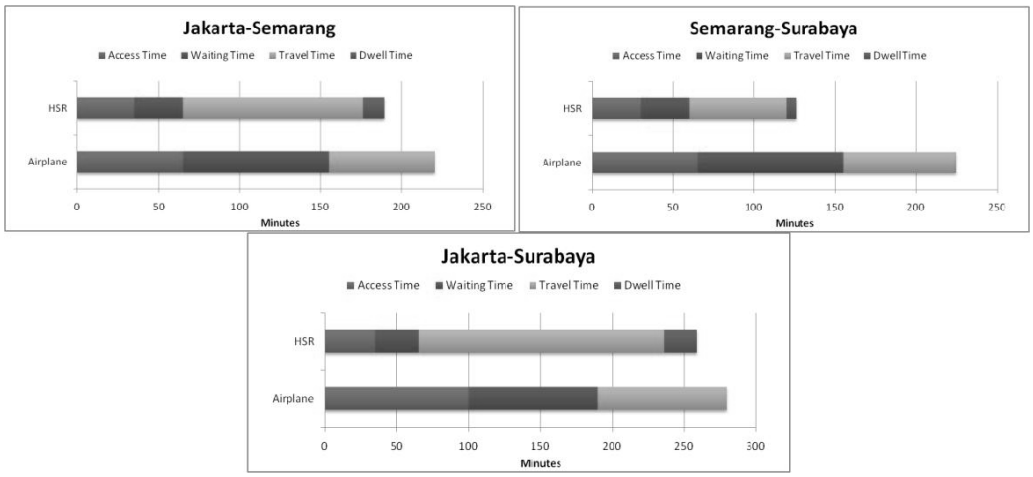

Figure 2. Journey time comparison between HSR and air

Table 2. Travel comparison between HSR and existing transports

Mode	Corridor (minute)			Total (minute)
	Jakarta-Cirebon	Cirebon-Semarang	Semarang-Surabaya	
Bus	360	240	320	920
Con. Train	180	233	242	655
HSR (TGV)	55	53	58	165

The foregoing figures indicate that the high-speed rail is very competitive toward the air transport in term of journey time. The major factor affecting that is the waiting time which includes check-in and check-out time. Another factor is access time. It is common that airports are located outside of city center. In contrast, stations generally are located close to city center. In term of journey time, it can be conclude that the high-speed rail development in Java Island will be a good option and very competitive with other modes, especially air transport.

2.5 Market Share Analysis of the High-speed Rail

Two methods have been used to predict how many passengers shift from existing modes of transport (bus, conventional rail and air) to high-speed rail system in Java Island. The first is JETRO method that has been used to predict how many passengers shift from bus and conventional rail. The second method is benchmarking method to predict passenger shifting from air to high-speed rail by looking at other countries' experience in operating high-speed rail. From the predictions, it can be concluded that the passengers switching from the bus to the high-speed rail service is as many as 12%, from the conventional rail as many as 18%, and 61% from the air transports. The prediction is shown in Figure 3 and Table 3.

Table 3. Market share with and without HSR in Jakarta-Surabaya line

Market share without introducing High-Speed Rail (million passengers)					
	2020	2025	2030	2035	2040
Bus	14.34	15.35	16.43	17.58	18.82
Con. Train	4.26	4.50	4.82	5.16	5.52
Airplane	5.89	6.31	6.75	7.23	7.74
Market share without introducing High-Speed Rail (million passengers)					
Bus	12.62	13.51	14.46	15.47	16.56
Con. Train	3.45	3.69	3.95	4.23	4.53
Airplane	2.30	2.46	2.63	2.82	3.02
HSR	6.07	6.50	6.96	7.45	7.97

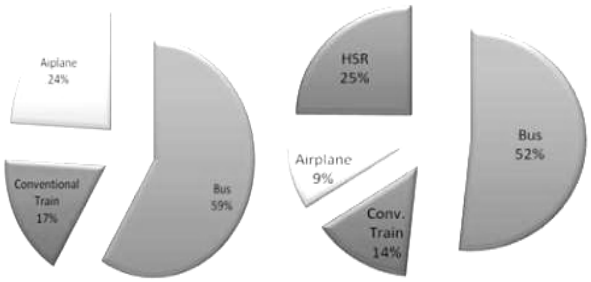

Figure 3. Modal share with and without introducing HSR

2.6 Analysis of Environmental Impacts

In this analysis, the author compares CO_2 emission resulted by operation transportation systems in Java Island without introducing the high-speed rail and with introducing the high-speed rail. The emission factor is kilogram of CO_2 per passenger per kilometer (kg/ppkm). Centre for Clean Air Policy (CACP) and Centre for Neighborhood Technology (CNT) (2006) have calculated emission factor by modes with assumption that each mode has 70% of occupancy. The result is described in table below (see Table 4).

Table 4. Air pollution comparison with and without HSR

Without Introducing High-Speed Rail (2020)			
Corridor	Mode	CO_2 (10^6 kg)	Total (10^6 kg)
Jakarta - Cirebon	Bus	307	456
	Con. Train	149	
	Airplane	-	
Cirebon-Semarang	Bus	66	1,329
	Con. Train	94	
	Airplane	1,169	
Semarang-Surabaya	Bus	59	758
	Con. Train	60	
	Airplane	638	
Total Emission (CO_2) in 2020 (10^6 kg)			2,542
With Introducing High-Speed Rail (2020)			
Corridor	Mode	CO_2 (10^6 kg)	Total (10^6 kg)
Jakarta - Cirebon	Bus	270	539
	Con. Train	123	
	Airplane		
	HSR	146	
Cirebon-Semarang	Bus	58	69
	Con. Train	77	
	Airplane	454	
	HSR	105	
Semarang-Surabaya	Bus	53	461
	Con. Train	49	
	Airplane	249	
	HSR	109	
Total Emission (CO_2) in 2020 (10^6 kg)			1,694

Table 4 shows that introduction of the high-speed rail in Java Island can reduce CO_2 emissions. Total CO_2 without the high-speed rail is approximately 2,542 x 10^6 kg. However, the CO_2 emissions go down to 1,694 x 10^6 kg if the high-speed rail is being operated (in 2020). By introducing the high-speed rail, Java Island can reduce as much as 848 x 10^6 kg (0.848 million tonnages) of CO_2 in 2020. The more passengers switch to the high-speed rail, the less environmental impacts caused by transport modes.

2.7 Generalized Cost of the High-Speed Rail

In this section, it has been calculate the generalized cost aiming to observe each mode's generalized cost in Java Island. In order to obtain the generalized cost, it is necessary to obtain the total trip time *(t_j, t_a, t_w and t_d)*, the value of time *(a_0)* and the average fare for each relation and each mode *(f)*. To simplify the model, some global parameters have been assumed at this stage. These all parameters will be converted to total cost, in this case is *Rp* (rupiah). In order to compare the generalized cost of each mode, a scenario has been proposed in this analysis. Furthermore, simplicity scenario was needed caused by data limitation of the value of time *(a_0)*. Basically, each person has different value of time. The scenario below is done to get the value of time *(a_0)* with some assumptions:

Table 5. Passenger's Value of Time

Income	Working day/month	Working hour/day	Value of time (a_0)	
			Rp/hour	Rp/ minute
< 2.2 million	22	8	12,500	208
2.2-5 million	22	8	20,455	341
>5 million	22	8	39,773	663

a) Section 1 (Jakarta-Semarang)

Table 6 is generalized cost in the first section for each mode and each level of income.

Table 6. Generalized cost in the first section

Mode	Fare		Generalized Cost (Rp)		
	Class	Cost (Rp)	Low	Middle	High
Bus	Executive	100,000	308,750	410,455	662,159
Conventional Train	Business	190,000	337,917	418,523	596,572
	Executive	130,000	457,917	538,523	716,572
Airplane	Business	625,000	805,938	871,136	990,265
	Executive	1,350,000	1,530,938	1,596,136	1,715,265
HSR	Business	437,500	516,250	549,432	617,367
	Executive	935,000	1,023,750	1,056,932	1,124,867

b) Section 2 (Semarang-Surabaya)

Table 7 is generalized cost in the second section for each mode and each level of income.

Table 7. Generalized cost in the second section

Mode	Fare		Generalized Cost (Rp)		
	Class	Cost (Rp)	Low	Middle	High
Bus	Executive	80,000	207,292	268,182	403,409
Conventional Train	Business	175,000	274,479	323,182	430,076
	Executive	245,000	344,479	393,182	500,076
Airplane	Business	1,025,000	1,190,938	1,256,136	1,375,265
	Executive	1,500,000	1,650,501	1,605,501	1,606,033
HSR	Business	175,000	236,563	261,136	309,432
	Executive	525,000	586,563	611,136	659,432

c) Section 3 (Jakarta-Surabaya)

Table 8 is generalized cost in the third section for each mode and each level of income.

Table 8. Generalized cost in the third section

Mode	Fare		Generalized Cost (Rp)		
	Class	Cost (Rp)	Low	Middle	High
Bus	Executive	200,000	473,542	621,364	962,652
Conventional Train	Business	265,000	452,083	557,386	800,473
	Executive	375,000	562,083	667,386	910,473
Airplane	Business	875,000	1,101,042	1,181,818	1,329,924
	Executive	2,100,000	2,326,042	2,406,818	2,554,924
HSR	Business	612,500	698,750	733,068	813,383
	Executive	1,470,000	1,556,250	1,590,568	1,671,383

From the analysis it can be concluded that potential demand of the high-speed rail comes from air transport in all sections. Moreover, potential demand of high-speed rail to travel from Jakarta to Semarang comes from air transport and executive class of conventional rail. Potential demand in the Section 2 comes from all modes because the high-speed rail has the lowest generalized cost. Lastly, potential demand to travel from Jakarta to Surabaya likely comes from executive conventional rail and air transport.

3 CONCLUSIONS AND RECOMMENDATIONS

3.1 Conclusions

After conducting the research, the author can sum up the results of the research into some of the following points:

a) It has been predicted that 12 % of the bus passengers switch to the high-speed rail service. Then, 18% of the conventional rails and 61% of airplanes passengers switch to the high-speed rail service. The total market share of the high-speed rail has been predicted at 25% and becomes the second largest of the market share. The largest market share in the Jakarta-Surabaya corridor is still the bus with 52%. The conventional rails and air transports will have 14% and 9% of the total market share.
b) The high-speed rail is very competitive with the air transport in all corridors (Jakarta-Semarang, Semarang-Surabaya and Jakarta-Surabaya) in terms of journey time, which includes access time, waiting time (check-in/out) and travel time, and tariff/fare. The journey time in the Jakarta-Semarang corridor is 3 hours and 9 minutes by the high-speed train and 3 hours and 40 minutes by air. In the Semarang-Surabaya corridor, 2 hours and 6 minutes by the train and 3 hours and 45 minutes by air. Furthermore, in the Jakarta-Surabaya corridor, 4 hours and 19 minutes by the train and 4 hours and 40 minutes by air. From the analysis, suitable fare of the high-speed rail should be 70% of fare of the air transport.
c) The high-speed rail development can reduce carbon emissions (CO_2) on Java Island. Without the high-speed rail, in 2020, there will be approximately 2.542 million tonnages of CO_2 per annum. However, if Java operates the high-speed rail, the emissions will go down to 1.694 million tonnages of CO_2. During 10 years operation, 2020-2030, the high-speed rail can reduce 10.9 million tonnages of CO2.
d) Generalized cost of the high-speed rail is lower than air, yet it higher than bus and conventional rail. It can be conclude that the high-speed rail has proved to be a big competitor of air for short and medium distances (corresponding to short haul flights). This success has been based in a better transport offer in terms of time, frequency, comfort and quality but also in terms of fares.

3.2 Recommendations

There are several recommendations related to the high-speed rail service on Java Island. The recommendations are for the Indonesian Government as a stakeholder to develop the infrastructure in Indonesia, especially for the high-speed infrastructure on Java Island.

a) Considering superiority of the high speed rail service in terms of journey time, market share and less environmental impacts over the existing modes of transport and other potential benefits for Java Island, the Indonesian Government should take action immediately to start the development.
b) According to the analysis, access time becomes the most importance factor for people to use the high-speed rail. Thereby, the government should take into consideration the access time in developing stations. As well as the location, the

station can be approached easily by feeders transport (bus, taxi, tram, etc.).

c) Based on other countries' experience, it is likely that the high-speed rail on Java Island can reduce demand of air transport significantly. Thereby, the Indonesian Government should make a policy like Korean Government did in order to save the competition. The high-speed rail is focused to serve passenger in Java Island, however, the air transport is focused to serve inter-island flight, as well as international flight.

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