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Cost-Benefit Analysis of High-Speed Rail Link between Hong Kong and Mainland China

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Abstract: The Legislative Council in Hong Kong has approved a funding of USD$8.60 billion to build the high-speed rail (HSR) line linking mainland China. HSR is a break-through technology that allows trains running at a speed over 250 km per hour. The most controversial part of the HSR investment is whether its cost could be compensated by the social benefits. In this study, a cost-benefit analysis of the Hong Kong to mainland HSR (HKM-HSR) line is carried out. First, all the direct and indirect costs, and social benefits are defined; then, monetary equivalents are assigned to these elements; third, all the future values are discounted into present values and aggregated. The results show that the project has a positive net present value (NPV) up to USD$2,068.49 million, which proves that the investment is worth. In addition, other transport alternatives, i.e. the existing roadway and conventional railway, are examined and compared with HKM-HSR, which unveils that HSR has the largest positive NPV among these three passenger transportation modes because of its excellent performance in ticket revenue, travel time savings and safety improvement.

Keywords: High-speed rail, transport alternatives, cost-benefit analysis, net present value.

1. Introduction

In early 2008, there were more than 10,000 kilometers of new high-speed rail (HSR) lines in operation around the world and about 20,000 kilometers were devoted to high speed services (Campos and De Rus, 2009). The HSR is a brand new rail technology developed in the 20th century, which consists of a special infrastructure that allows trains running at a speed over 250 km per hour. For medium distances (within 500 kilometers), HSR provides much competitive advantages over other transportation modes, i.e. conventional railway, roadway and air transport (De Rus and Inglada, 1997). The Legislative Council in Hong Kong approved a funding of USD$8.60 billion to build the HSR line linking the network of the Mainland on Jan 16, 2010. It will connect Kowloon, Hong Kong in the south and Guangzhou, Guangdong Province in the north.

Investing in HSR is a significant social decision. The major consideration of HSR is its high capital cost, requiring to build the high speed infrastructure at a cost substantially higher than the conventional railway. The infrastructure maintenance cost of HSR is comparable with those of the conventional railway but its building costs and the acquisition, operation and maintenance costs of specific rolling stock make it as an expensive option (De Rus, 2008). However, the public decision makers should not only focus on the financial costs, but the potential impacts on the community arising from the project as well (Damart and Roy, 2009). Practically, the major challenge is how to ensure the social benefits gained from HSR are high enough to cover its construction and operating costs. The aim of this paper is to find out whether the sum of the discounted social benefits during the lifecycle of the HKM-HSR can outweigh its investment cost. Cost-benefit analysis (CBA) is employed as an evaluation tool to compare the net present value (NPV) of all the direct and indirect costs, and social benefits. In addition, other relevant transport alternatives, i.e. roadway and conventional railway, are examined and compared.

2. Literature Review of HSR

Compared with the conventional railway, HSR adopts a break-through technology that can shorten the transportation time and thus increase its market share for medium range traveling distances. Lots of research works about economic evaluation of HSR have been conducted in the past twenty years. Nash (1991) provided a general assessment of HSR and claimed that the principal benefits of HSR were the revenue and traffic time savings. He also pointed out that there was lack of evidence in supporting that HSR would bring about any environmental and regional development benefits. At last, Nash (1991) concluded that HSR was the most cost-effective solution only for the middle distance range (around 500 kilometers) transportation. De Rus and Inglada (1997) carried out an economic evaluation of the Spanish HSR project by using the CBA method. The results recommended that the project should not be carried out in 1987 in that particular corridor due to its huge negative NPV. Brand (2011) also applied CBA to the proposed HSR in California and focused on the calculation of benefits pertaining to intercity HSR user, highway traveler, and air travelers. He drew the conclusion that the major benefits included the revenues derived from HSR user, the HSR user benefits (consumer surplus) net of fares paid, the travel time savings to urban commuters, and the value of time savings to intercity air travelers. A general review of the HSR developments in Europe was done by Vickerman (1997). He put forward two main points: first, the HSR had the natural effect of increasing the concentration of economic activities among each region; second, HSR could bring positive development benefits under a careful planning and ancillary policy intervention. Martin (1997) established a relationship between the NPV of HSR projects in terms of their social value, transportation consumers' benefits and regional economic impacts. The results showed that if the NPV was positive, the HSR project could generate regional growth even if no bottleneck existed before the project. Dijkman et al. (2000) presented a CBA of the construction of HSR linking Schiphol Amsterdam Airport and the German Ruhrgebiet. The project is proved to be unprofitable under all scenarios with a negative NPV which is mainly due to the limited travel time savings of a mere ten to fifteen minutes. De Rus (2008) summarized eight main benefits of HSR, i.e. travel time savings, increase in comfort, generation of new trips, reduction in congestion and delays, reduction in accidents, reduction in environmental impact, release of needed capacity in other transportation modes, and wider regional developments. In addition, he evaluated the HSR investment within the CBA framework and found that whether to build HSR or not was largely dependent on the existing volume of traffic, the expected travel time savings and the average willingness to pay by potential users, etc. In accordance with Nickel et al. (2009), HSR had two main types of benefits, namely the first order effects (i.e. travel time savings, emission reduction) and the second order effects (i.e. long-term and short-term job generation, attraction of new business development, and increase in property value). In addition, Janic (2011) conducted a sensitivity analysis of particular savings with respect to changes of the most influencing factors, i.e. the number of air transport flights to be substituted after evaluating the partial substitution of some air transport short-haul flights with HSR services. Results showed that the HSR substitutive capacity was not a barrier to develop air transport/ HSR substitution at the airport. Thereby, in order to check the stability and reliability of the HKM-HSR project, sensitivity analysis is applied in this study as well.

Based on the previous critical review of HSR, whether a particular HSR investment is cost-effective cannot be judged unless a full-scale evaluation is provided. However, research works about evaluation of the economic and social effects of HKM-HSR are of paucity. This paper intends to apply the CBA method to assess the HSR project in Hong Kong and determine whether the aggregated social benefits can justify its investment costs.

3. Cost- Benefit Analysis (CBA)

CBA has been widely used to support the decision making process in transportation by evaluating the potential social and economic impacts of each alternative (Tudela et al., 2006). In accordance with Auzannet (1997), CBA aims to evaluate a set of direct and indirect effects of a project, its financial and non-financial effects on a set of economic agents concerning with the investment. These effects are then synthesized, after monetary evaluation, to insure a socio-economic balance which establishes the return on the investment, with this return being estimated on the basis of specific indicators. The use of CBA can be traced back to 1930s: the American Congress indicated that the federal government should improve navigable waterways by considering flood control disposals whose expected benefits exceeded the estimated costs (Flood Control Act of 1936). Over the last decade, the accuracy of this technique has been greatly improved with the new evaluation criteria such as the measurement of the willingness to pay by the potential passengers, the reduction of carbon emission and accident risks, etc. Nowadays, CBA has become one of the most widely accepted and applied methods in project appraisal for large-scale infrastructure investments in the public sector (Nickel et al., 2009).

The proposed research framework of this paper is presented in Fig. 1. The CBA evaluation process is divided into four steps. The first is to estimate the total cost which is composed of the infrastructure costs, operating costs and external cost. All the future values are discounted into PV and aggregated as the cumulative PV of total cost (TC). By applying the same principle, the cumulative PV of total social benefit (TSB), which consists of five main components, can be worked out in the second step. The third is to subtract TC from TSB, so that the project NPV could be obtained for the project appraisal. In order to further support the approval of HSR investment, additional comparisons of HSR with other relevant transport alternatives, i.e. the existing roadway and conventional railway are performed in the fourth step.

4. Evaluation of Hong Kong to Mainland HSR

4.1. Project Description

The HKM-HSR, which will link West Kowloon Terminus in Hong Kong to the Guangzhou South Railway Station in Guangzhou Shibi, will form part of the 16,000 kilometers national HSR network (see Fig. 2). By means of this new HSR corridor, the journey time between Guangzhou and the urban area of Hong Kong would be reduced from 100 minutes to 48 minutes. The brief project data is summarized in Table 1.

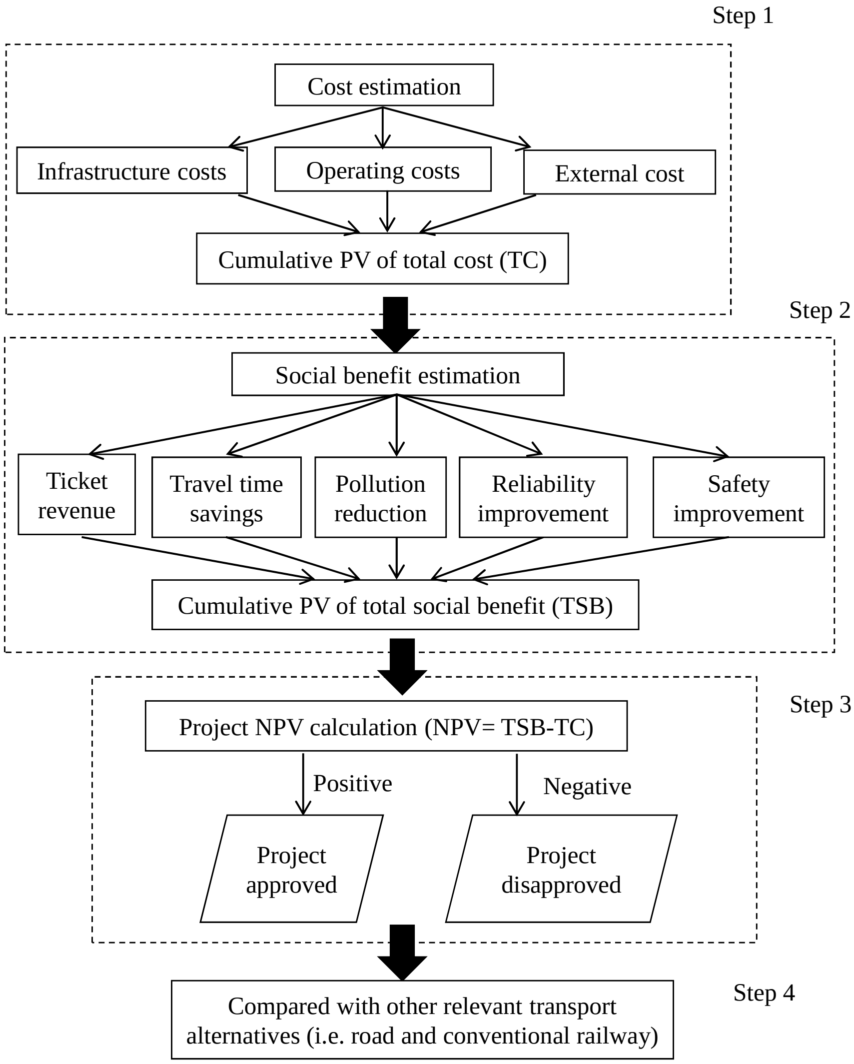

Fig. 1. The proposed research framework

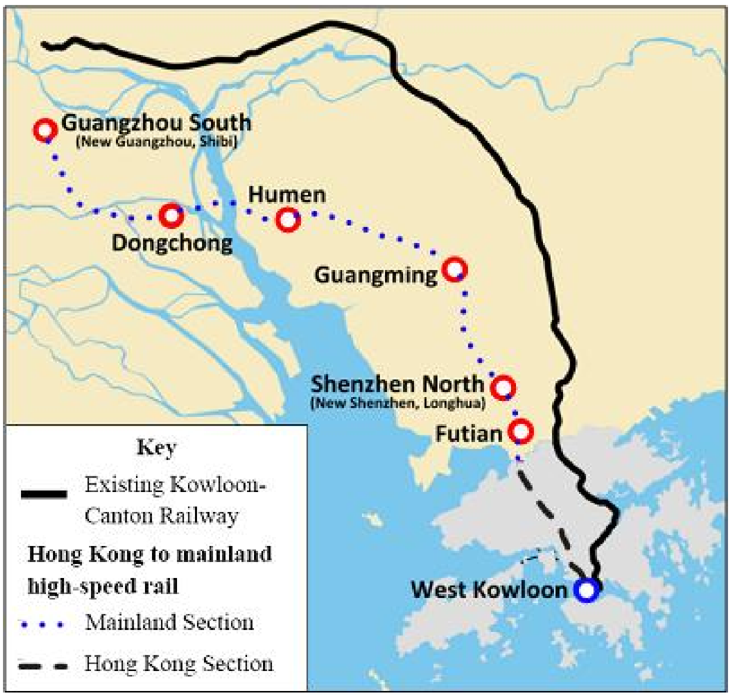

Fig. 2. Route of Hong Kong to mainland high-speed rail

Table 1. Brief data of Hong Kong to mainland HSR (Source: Highway Department of HKSAR)

Termini	West Kowloon (Hong Kong) ~ Shibi (Guangzhou)	**Speed**	Maximum operating speed 200km/h (Hong Kong Section)
Intermediate stations	Futian (Shenzhen), Longhua(Shenzhen), Humen (Dongguan)	**Estimated Journey Time**	Between Hong Kong and Futian, Shenzhen: 14min
Route Length	Approximately 26km in Hong Kong		Between Hong Kong and Shenzhen North: 23min
Scheduled Train Frequency	Minimum 3min intervals		Between Hong Kong and Guangzhou South: 48min
	90 / 24 pairs of trains between Hong Kong and Shenzhen/ Guangzhou at the initial period	**Maximum Passenger Capacity**	Approximately 10,000 passengers per hour per direction
	There is a train to Shenzhen every 15 min, and to Guangzhou every 30 min	**Commencement Date**	Jan, 2010
	33 couples of trains to 16 cities in mainland per day	**Estimated Completion Date**	2015
Job Opportunity	More than 17,000 jobs in first five years	**Passenger Flow Volume (in 2016)**	About 99,000 passengers per day travelling between HK and mainland by HSR
	About 9,000 jobs in peak-hour (in 2013);		
	About 2,000 clerical and technical/ professional stuff		
Price of The Tickets	About USD$6.42 to Shenzhen	**Project Costs**	USD $ 8.02 billion
	About USD$16.70 to Dongguan	**Carbon Emission**	15% of that of airplane
	About USD$23.13 to Guangzhou		25% of that of car/bus
Environmental Protection	Reduction of air pollutants by some 600 tonnes of NO_x and respirable suspended particulates per year and 160,000 tonnes of CO_2 per year		

4.2. Cost Estimation

The total cost of building and operating a HSR line consists of three main parts, namely infrastructure costs, operating costs and external cost (De Rus, 2008). The cost estimation of HKM-HSR line is detailed below.

4.2.1. Infrastructure costs

The infrastructure costs of a new HSR involve: planning and land costs, infrastructure building costs and superstructure costs (International Union of Railways, 2005). The planning and land costs include the feasibility studies, technical design, land acquisition, legal and administrative fees etc., and usually take up 10% of the total infrastructure costs. Infrastructure building costs involve terrain preparation and platform building, which is one of the major costs of the HSR investment and range from 15% to 50% of the total cost. Lastly, the rail specific elements such as tracks, sidings along the line, signaling systems, catenary, electrification communication and safety equipment etc., which are critical to make sure the HSR can reach a high speed over 250km per hour, are summarized as superstructure costs (De Rus, 2008). According to the Highway Department of HKSAR (2010), the construction period of the HKM-HSR line is five years (from 2010 to 2015). The total infrastructure cost/ initial outlay (C_i) is USD$8.02 billion. The planning and land costs reach up to 19% (USD$1.52 billion) and the infrastructure building costs and superstructure costs take up the rest 81% (USD$6.50 billion).

4.2.2. Operating costs

The operating costs involve three main parts: the HSR services operating costs, infrastructure maintenance cost and rolling stock maintenance cost. First, the operating costs of HSR services include the costs of labor, energy and other materials consumed by the tracks, terminal, traffic management and safety systems, etc. In accordance with De Rus (2008), the operating costs of HSR services is about USD$67,840.16 per seat per year. As a result, the annual operating cost of HSR services (Cs) is

USD$679.04 million under the assumption that 10,000 seats in service each year. Second, the maintenance cost of infrastructure is estimated at the level of USD$40,742.64 per km per year. Therefore, the annual infrastructure maintenance cost (C_{m1}) is USD$1.06 million within the 26 km length of Hong Kong section. Third, for the rolling stock maintenance cost, it is about USD$5,432.35 per seat per year. As a result, the annual rolling stock maintenance cost (C_{m2}) is USD$54.3 million. Lastly, the total annual operating cost is equal to the sum of C_s, C_{m1} and C_{m2}, that is USD$ 734.43 million. The total cumulative PV of operating costs (C_o) is worked out to be USD$ 11,575.95 million using Eq. (1).

$$C_o = \sum_{t=1}^{N} \frac{C_s + C_{m1} + C_{m2}}{(1+i)^t} \quad (1)$$

where:

i: the social discounting rate. Given the high rate of inflation in Hong Kong, 6% social discounting rate is applied in this paper (Popkin et al., 1980; Brown, 2005);

t: the *t*th year in operation;

N: the project's life expectancy is 50 (years) in this paper.

4.2.3. External cost

Building the HSR and operating trains will bring about negative environmental effects in terms of land resumption, barrier effects, visual intrusion, noise, air pollution and contribution to global warming. All of these negative effects will bear environmental costs, which are referred to be the external cost. According to De Rus (2008), the external cost of 1000 passengers per kilometer is equal to USD$14.13 per year. Since 99,000 passengers will travel between Hong Kong and the mainland by using this 26km length HKM-HSR line per day (Mass Transit Railway, 2010), the annual external cost of this project is about USD$0.07 million. Then, the cumulative PV of external cost (C_e) is USD$1.15 million.

4.2.4. Cumulative PV of total cost

The cumulative PV of the total cost (*TC*) of the HKM-HSR is equal to the sum of C_i, C_o and C_e, that is USD$19,594.57 million.

4.3. Social Benefits

The main sources of social benefits arising from the investment of HSR involve not only the general economic benefits, i.e. ticket revenue, but also the other social benefits like travel time savings, pollution reduction, reliability and safety improvement. Although some researchers believed that HSR would speed up the regional economic development, the empirical evidence suggested that transport infrastructure was only a necessary condition for economic development. It is hard to accept that HSR changes substantially the basic parameters of the regional economic development (De Rus and Inglada, 1997). Therefore, this paper only estimates the aforementioned five main types of social benefits.

4.3.1. Ticket revenue

In accordance with Highway Department of HKSAR (2009), the ticket price of Hong Kong HSR section will be "affordable" for most of the travelers with an average price of USD$17.99. In addition, about 99,000 passengers will travel between Hong Kong and the mainland using HSR each day (Mass Transit Railway, 2010). As a result, the annual ticket revenue (B_{tr}) of Hong Kong HSR section will reach USD$ 650.13 million on average.

4.3.2. Travel time savings

The total user travel time includes access and egress time, waiting time and within vehicle time. In accordance with De Rus (2008), when the original mode is a conventional railway with operating speed below 100km per hour, the HSR will save 45-50 minutes for distances in the range of 350-450 km. While comparing the HKM-HSR with the conventional railway, assuming that they both have the same access, egress and waiting time, HSR will save about 40 minutes. In addition, the average value of travel time savings (VTTS) is equal to USD$ 17.11 per person per hour with an assumption of the traffic composition of 50% business trips, 30% commuting trips and 20% others (Rotaris et al., 2010). Hence, the average annual social benefit of travel time savings (B_{ts}) could be derived as USD$412.44 million.

4.3.3. Pollution reduction

HSR is not only a high-tech transport mode but also using a sustainable and environmental friendly technology. According to Highway Department of HKSAR (2009), the carbon emission of HSR is just 15% of that of airplane and 25% of that of car. In addition, the research result of Transport Bureau of HKSAR (2000) showed that HSR could reduce the air pollutants by 600 tonnes of NO_x and 160,000 tonnes of CO_2 per year. In accordance with Maibach et al. (2007), the average value of pollution reduction in CO_2 and NO_x emissions in big cities is USD$33.95 per tonne and USD$7,741.10 per tonne respectively. As a result, the average annual social benefit of pollution reduction (B_{pr}) is about USD$ 10.08 million.

4.3.4. Reliability improvement

The unreliability in travel time is one of the biggest problems in transportation. HSR can effectively reduce such kind of uncertainty and improve the reliability level in terms of avoiding congestion and delays. Compared with roadway and conventional railway, HSR has outstanding reliability benefits which should be included in the CBA (Eliasson, 2009). The value of reliability improvement is estimated based on the ratio of VTTS, which is about 13.7% (Transport for London, 2007). Therefore, the annual social benefit of reliability improvement (B_{ri}) is about USD$56.50 million.

4.3.5. Safety improvement

HSR is one of the safest modes of passenger transportation and could help reduce the traffic accidents. The number of people killed and injured on the highway is expected to decrease by approximately 14% associated with the introduction of HSR (De Rus, 2008). The social life and property loss caused by traffic accidents is connected with the real GDP per capita (GDP pc) of the country (or district). In 2010, the GDP pc of Sweden is USD$48875, while Hong Kong's GDP pc is USD$ 31591 (IMF, 2011), 64.64% of that of Sweden. Thereby, the value of accident reduction and life saving can be estimated on the basis of recommended Swedish valuations (64.64% of those of Sweden), that is USD$2.54 million per statistical life saved, USD$0.45 million per avoided serious injury and USD$0.02 million per avoided slight injury (Eliasson, 2009). In addition, according to the Road Traffic Accident Statistics Report (Transport Department HKSAR, 2009), the annual number of people killed, serious injury and slight injury on the highways within Hong Kong are 139, 2096 and 18,903 respectively. Therefore, the annual social benefit of safety improvement (B_{si}) is about USD$245.41 million.

4.3.6. Cumulative PV of total social benefits

The cumulative PV of total social benefits (*TSB*) can be worked out as USD$21,663.06 million using the following equation.

$$TSB = \sum_{t=1}^{N} \frac{B_{tr} + B_{ts} + B_{pr} + B_{ri} + B_{si}}{(1+i)^t} \qquad (2)$$

4.4. NPV of HSR

The NPV of HSR is equal to the cumulative discounted PV of total social benefits (*TSB*, USD$21,663.06 million) minus the cumulative discounted PV of total cost (*TC*, USD$19,594.57 million). The result of this paper shows that the HKM-HSR has a positive NPV (USD$2,068.49 million), which demonstrates that the project provides net gain in benefits and thus is worth to be carried out.

4.5 Sensitivity Analysis of CBA

The accuracy of CBA is easily affected by some erratic elements such as population size, the economic growth rate, different levels of transportation services and competitive pressures exercised by alternative modes of transport (Tanaka and Monji, 2010; Bowe and Lee, 2004). In order to insure that the results of CBA is stable and reliable, sensitivity analysis is applied and to provide a general idea of the extent of the potential impacts given by the elements mentioned above.

Considering the previous discussion, the HSR services operating cost (C_s) is probably to be affected by alteration of design, duration and some other factors which usually happen during the construction process. In addition, it takes a large proportion of the total operating cost of the project. Thereby, C_s is altered in the range of -20% to +20% with an interval of 10%. The results in Table 2 show that the NPV changes from -103.49% to +103.49% accordingly, and when C_s increases by 19.33%, the NPV decreases to zero.

Annual rolling stock maintenance cost (C_{m2}) included in operating cost of HKM-HSR project is another influence parameter which has much effect on the NPV. This factor is also made to fluctuate within the bounds of -20% to +20% in Table 3, which causes the change in NPV floats between -8.28% and +8.28%. Meanwhile, the lowest NPV in this range is USD$1,897.24 million.

For the total social benefits, passenger flow per day is no doubt a crucial factor. It is revealed on the ticket revenue (B_{tr}) and has a direct impact on the total income of this project. Hence, in some sense, it plays a make-or-break role in this project. In Table 4, the NPV is estimated with every change of passenger flow by 10% in the range of -30% to +20%. It reveals that the NPV will always be positive till the passenger flow reduces by 20.20%.

In this study, a discount rate of 6% which is considered more appropriate for the project is adopted (Popkin et al., 1980). For the sake of checking the magnitude of impact on the NPV caused by different discount rates, two rates of 4.8% and 8% were selected to calculate the NPV respectively and the results are presented in Table 5.

All the analysis above indicated that the different factors which would have potential effect on the NPV of the HKM-HSR project have a great extent for changing and will not lead the project to failure.

Table 2. Sensitivity analysis of the impact of changes in C_s on net present value (NPV) of the project (USD$, million)

% Change in C_s	Actual C_s	Total Cost (TC)	NPV	Change in NPV (%)
-20	543.24	17,453.97	4,209.09	103.49
-10	611.14	18,524.27	3,138.79	51.74
0	679.04	19,594.57	2,068.49	0
10	746.95	20,664.87	998.19	-51.74
19.33	**810.28**	**21,663.06**	**0**	**-100.00**
20	814.85	21,735.17	-72.11	-103.49

Table 3. Sensitivity analysis of the impact of changes in C_m on net present value (NPV) of the project (USD$, million)

Change in C_m (%)	Actual C_m	Total Cost (TC)	NPV	Change in NPV (%)
-20	43.46	19,423.33	2,239.74	8.28
-10	48.89	19,508.95	2,154.12	4.14
0	54.32	19,594.57	2,068.49	0
10	59.76	19,680.20	1,982.87	-4.14
20	65.19	19,765.82	1,897.24	-8.28

Table 4. Sensitivity analysis of the impact of changes in population (each day) on net present value (NPV) of the project (USD$, million)

Change in passenger flow (%)	Actual passenger flow	Ticket revenue (B_{tr})	Total Social Benefit (TSB)	NPV	Change in NPV (%)
-30	69300	455.00	18,589.86	-1,005.22	-148.60
-20.21	**79002**	**518.69**	**19,594.57**	**0**	**-100.00**
-20	79200	520.00	19,614.37	19.80	-99.04
-10	89100	585.00	20,638.89	1,044.31	-49.51
0	99000	650.13	21,663.06	2,068.49	0
10	108900	715.00	22,687.91	3,093.33	49.55
20	118800	780.00	23,712.42	4,117.84	99.07

Table 5. Impact of changes in discount rate on net present value (NPV) of the project (USD$, million)

Discount rate	4.8%	6%	8%
Total cumulative present value of operating Costs (C_o)	13,832.85	11,575.95	8,984.61
Total cost (TC)	21,851.61	19,594.57	17,003.24
Total social benefit (TSB)	25,889.67	21,663.06	16,815.66
NPV	4,038.19	2,068.49	-187.58
Change in NPV (%)	12.23	0	-14.01

5. Discussion

Each mode of passenger transportation has its own advantages and disadvantages. The evaluation of the HSR investment should not focus on the sum of NPV only, but the comparison of the other relevant transport alternatives (i.e. the existing roadway and conventional railway) as well. In this section, HSR is set as a benchmark to examine and compare with the existing roadway (Lo Ma Chou, LMC) and conventional railway transports (Kowloon-Canton Railway, KCR) linking Hong Kong to the mainland (Guangzhou Termini). For the cost estimation: first, compared with the new investment of HSR, both the LMC and KCR do not require infrastructure cost/ initial outlay. Second, the operation cost of roadway is about USD$1606.06 km per year and conventional railway is just 40% of that of HSR (Chang, 2008). Hence, the annual operation cost of LMC and KCR is USD$0.35 million and USD$336.63 million respectively. In addition, the external cost of LMC is about four times that of HSR and KCR requires the same amount as that of HSR.

For the social benefits: first, the passenger flow volume of LMC and KCR is about 118,000 and 10,000 per day with average fares of USD$5.14 and USD$25.05 respectively (Mass Transit Railway, 2010). So, the annual ticket revenue (B_{tr}) is USD$221 million for LMC and USD$91.45 million for KCR. Second, the total travel time of LMC and KCR is about 3.5 hours and 100 minutes respectively. Compared with the HSR, KCR has a zero annual benefit of travel time savings (B_{ts}) and LMC, which requires a much longer travel time, has a negative B_{ts} (-USD$1.23 billion). Third, compared with the HSR, LMC has a zero annual benefit of pollution reduction (B_{pr}), reliability improvement (B_{ri}) and safety improvement (B_{si}). On the other hand, the KCR has approximate 60% B_{pr}, 75% B_{ri} and 85% B_{si} of those of HSR (Highway Department of HKSAR, 2010). The results of the cost, benefit and NPV comparison among HSR, LMC and KCR are summarized in Table 6.

As shown in Table 6, despite of the highest capital cost, the investment of HSR still provides the largest positive NPV with more than USD$ 2068.49 million among the three passenger transportation modes. Conventional railway also has a positive NPV (about USD$177.60 million) due to its balance performance in all kinds of aspects. Roadway transport is the only alternative that has a negative NPV (-USD$15885.60 million). This is mainly due to its longest travel time which causes a large negative impact on the benefit of travel time savings.

Table 6. Cost, benefit and NPV comparison among HSR and other transport alternatives

(million USD$)			Mode of passenger transportation		
			HSR	Road (LMC)	Conventional railway (KCR)
Costs:					
1	Infrastructure costs (initial outlay)	C_i	8,017.47	-	-
2	Operating costs	C_o	11,575.95	5.57	5,313.12
	· *operating cost of service*	C_s	679.04		306.82
				0.35	
	· *infrastructure maintenance cost*	C_{m1}	1.06		0.42
	· *rolling stock maintenance cost*	C_{m2}	54.32	-	29.88
3	External cost	C_e	1.15	4.62	1.15
4	**Sum of costs** (1+2+3)		**19,594.57**	**10.18**	**5,314.27**
Social benefits:					
5	Ticket revenue	B_{tr}	650.13	221.00	91.45
6	Travel time savings	B_{ts}	412.44	-1,228.32	-
7	Pollution reduction	B_{pr}	10.08	-	6.05
8	Reliability improvement	B_{ri}	56.50	-	42.38
9	Safety improvement	B_{si}	245.41	-	208.60
10	**Sum of social benefits** (5+6+7+8+9)×15.76		**21,663.06**	**-15,875.42**	**5,491.87**
	NPV (10-4)		**2,068.49**	**-15,885.60**	**177.60**

Notes: the social discounted rate is 6%, the project life time is 50 (years) and the uniform series present worth factor (USPWF) is 15.76.

6. Conclusion

Investing in high-speed rail is a significant social decision. One of the major drawbacks of HSR is its high capital cost. However, the public decision makers should not only focus on the financial cost, but also the potential positive impacts on the society. HSR can bring about some social benefits in terms of ticket revenue, travel time savings, pollution reduction, reliability and safety improvement, etc. A cost-benefit analysis of HKM-HSR line is provided in this paper. The results show that this project has a positive NPV up to USD$2068.49 million, which fully demonstrates that the investment of this HKM-HSR is worth to be carried out. Moreover, other relevant transport alternatives (i.e. the existing roadway and conventional railway) are also examined and compared with the investment of HSR. Because of the excellent performance in ticket revenue, travel time savings and safety improvement, HSR has the largest positive NPV among these three passenger transportation modes. In conclusion, HSR is the most cost-effective solution among the above three alternatives for the intercity transport between Hong Kong and Canton.

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