High Speed Train Network

Helen Hoka Osiolo, Strathmore University

Summary

In 2014, the African Union approved the plan for an African Integrated High-Speed Rail Network (AIHSRN). High speed trains of over 250 km/h are expected to be constructed but there is on-going debate on whether the costs will outweigh the benefits. In this study, a cost benefit analysis is undertaken where: all direct and indirect cost and benefits are outlined, monetized, future values discounted to present values and combined. A minimum and maximum BCR of 0.91 and 1.52 respectively are computed which signifies the importance of the project.

The problem and scope

Africa's economic growth is envisioned to have more potential growth more than the developed countries in the future. Hence, reduction of trade costs through investment in transport is viewed as a way of boosting economic growth, linking cities, accelerating urbanization and strengthening regional integration. The demand for transport services in Africa is growing, however poor quality combined with high cost transport services, distorted model split, deficiencies in policy and institutional frameworks, lack of funding and high land fragmentation frustrates the growth of the sector including related sectors. With Africa land total area of about 30.37 million km², the vast distance between North and South as well East and West, makes movement of cargo and passenger even more difficult. For example, travelling from North to South of Africa requires, not only to an itinerary for the travel days but it also requires additional days to get boundary approvals. A High-Speed Rail can offer solution to Africa's transportation challenge.

The AIHSRN is part of the African Union's Agenda 2063. The Agenda is a fifty-year plan that has s additional implications on African integration overall, beyond economic and social gains. High Speed Rail (HSR) is designed for at least 250km/h speed with dedicated rolling stocks and tracks that are of complex technology. HSR in the modern society is considered fast, safe, comfortable, efficient in both time and cost, sustainable with increased economic growth, reduced environmental impacts, and reduce delays and congestion in roads and air transport, (Angoiti, 2018; Campos et al. 2007; and Almujbah and Preston, 2019). Despite the aforementioned benefits, HSR has its own drawbacks. HSR operates at very high speed, curved tracks are avoided to enhance speed and avoid accidents, this therefore requires huge land from residential areas, agricultural land and forest land among others (Almujbah and Preston, 2019). HSR embodies a sophisticated technology that allows construction of tracks underground, on land and overpass to reduce the negative impacts on economy, social and environment. With such massive investments required, careful analysis of the benefits as well as cost is demanded. In this brief, cost benefit analysis of the HSR in selected African countries is undertaken. The objective of this study is to analyze whether investment costs in AIHSRN is surpassed by its benefits during the project lifespan using the Benefit Cost Ration (BCR).

The brief is organized as follows; computes the potential benefits of investing in high speed rail and the factors that influences the potential benefits. The factors explaining the potential cost of HSR investment are analyzed. The Benefit Cost Ration (BCR) approach is used to appraise the HSR project. The BCR results are complemented by sensitivity analysis that helps to inform decision making for investing in BCR projects.

Description of the intervention

The AIHSRN intervention aims to interconnect African capitals with each other, thus promotes trade and development of major industries in manufacturing, agriculture, forestry, fishing, mining, manufacturing, energy, tourism and financial services among others. The AIHSRN is expected to connect 54 countries, the study only provides the case for only 10 countries where 44 links estimated at 42,657 km are identified and are projected to meet a freight demand of between 156,325 - 225,637 million tonnes per year between 2020 and 2063. The project is expected to be constructed between 2020- 2024 and has a lifespan of 50 years.

To make a case for the massive investments of the AIHSRN, 10 countries selected for analysis are based on six regions/ geographical distribution of projects in Africa. Algeria is selected from Northwestern and North Central Region; Ghana and Nigeria for Western Region; Ethiopia for North Eastern Region; Kenya, Tanzania and Uganda for Eastern Region; Central Republic of Congo for Central Region; and Mozambique and South Africa for Southern Region.

Cost analysis

The infrastructure cost/initial capital outlay captures two key components; planning and land costs; infrastructure building costs and superstructure costs which constitutes about 10%-19% and 81% -90% respectively (De Rues, 2012). Infrastructure costs vary depending on land prices, amount of tunneling involved, and costs of entering large cities (Nash, 2010) and also by source of fuel required for operation and by different policies and approval processes. Literature shows that construction cost per kilometer ranging from $4 million to $74 million (Ardui and Ni, 2005). With the exception of China, construction costs were generally higher in Asia than in Europe as reported by Gourvish[90]. CPCS (2019) estimates that the initial capital outlay is estimated at $25 million per track km, however Lao estimates this cost as $20 million which this study adopts. The estimated cost of capital for links/tracks identified in the selected countries is $853,140,000,000 for 42,657km of track

The cost of rolling stock differs based on the type (i.e.: locomotive, wagons, and passenger trains) and number of units defined by the traffic volumes of specific tracks. The costs of freight locomotive, wagon and 10 car passenger train set was established to be $3,500,000, $125,000 and $40,000,000 respectively (CPCs,2019). While the rolling stock units required were specified by 0.0000000123 per net-tonne-km for freight locomotives; 0.00000061445 per net-tonne-km for wagons and 0.00000000174 per passenger-km for passenger trains. The total cost of rolling stock was estimated at $18,934,192,656 and & 27,315,022,624 depending on freight and passenger traffic.

Operation and maintenance costs captures the cost of operation for both freight and passengers, as well as for infrastructure maintenance. These costs include train crews; electricity and consumables; rail traffic control, station masters, and operations management; passenger station employee cost, rolling stock maintenance and administrative; infrastructure maintenance and administrative costs. Tao et al. (2011) estimates HSR operations cost to be a product of operating cost ($679.04 million) and 10,00 seats on service annually. While the maintenance cost of infrastructure and the rolling stock is estimated at $40,742.64 per km per year and $5,432.35 per seat per year. The CPCS estimates of $0.0187 per ton-km, $0.0183 per passenger-km and $55,458 per track-km are applied for freight operation costs, passenger operation costs and infrastructure maintenance respectively. Based on the minimum and maximum traffic estimates by link in 2018, the freight operation cost are estimated at minimum of $2,043,199 and maximum of $76,931,796 while that of passenger operation is at minimum of $39,977 and $54,981. The cost of Infrastructure maintenance is estimated at $2,365,671,906.

Literature proposes computation of residual values when appraisal period is shorter than the useful lifetime of some of the assets. Though this is different in France where, where the appraisal period is set at a fixed 20 years. Casares and Coto-Millán (2011) estimates the residual value at 10% of the value of the investment. Using a 50-year

[90] Gourvish, T(n.d). The High Speed Rail Revolution: History and Prospects Report

lifespan where re-invested is expected at 25 years for both locomotive and passenger trains, and at 20 years for wagons for the selected AIHSR project, the minimum and maximum estimated residual cost is $1,829,876,959 and $2,610,704,612 respectively.

External costs capture the negative impacts of investing on HSR projects, such as: land resumption, barrier effects, visual interruptions, noise, air pollution and contribution to global warming (Tao et al. 2011). Of the total external environmental costs, 53% of the cost is attributed to average accident cost, while average climate change cost, average air pollution cost, and average noise pollution cost is represented by 32%, 14% and 1% respectively (Almujbah and Preston, 2019). De Rus (2012) established that the external cost of 1000 passengers per kilometer is equal to $14.13 per year. The external costs for this project are estimated at a minimum of $30,807,356 and $42,369,723 depending on traffic levels.

Total cost is calculated at a minimum of $ 876,366,174,361 and maximum of $ 885,656,135,981 while the cumulative PV of total cost is about at a minimum of $917,755,589,02 and a maximum of $928,271,560,959 as shown in table 1.

TABLE 1: COST BENEFIT RATIO ESTIMATES

Benefits	Annual (US$)		PV over 50 years	
	Min	Max	Min	Max
Passenger time savings	41,332,500	55,845,833	754,563,039	1,019,517,371
Reliability	5,662,553	7,650,879	103,375,136	139,673,880
GDP from HSR industry	13,286,766,501	19,930,149,751	242,562,218,845	363,843,328,268
Increased GDP from trade	31,424,635,079	55,307,357,739	573,685,795,632	1,009,687,000,312
Road traffic injury reduction	1,081,966,125	2,163,932,251	19,752,292,937	39,504,585,874
Total Benefits	**45,840,362,758**	**77,464,936,454**	**836,858,245,590**	**1,414,194,105,705**
Annual recurrent cost	Annual (US$)		PV over 50 years	
	Min	Max	Min	Max
Freight operation cost	2,043,199	61,514,484	37,300,494	1,123,003,844
Passenger operation cost	39,977	54,981	729,824	1,003,736
Infrastructure maintenance	2,365,671,906	2,365,671,906	43,187,529,980	43,187,529,980
External cost	30,807,356	42,369,723	562,416,802	773,498,513
Total	**2,398,562,439**	**2,469,611,095**	**43,787,977,100**	**45,085,036,073**
Capital cost				
	Min	Max	Min	Max
Initial CAPEX	853,140,000,000	853,140,000,000	853,140,000,000	853,140,000,000
Rolling stock	18,934,192,656	27,315,022,624	18,934,192,656	27,315,022,624
Residual value	1,893,419,266	2,731,502,262	1,893,419,266	2,731,502,262
Total	**873,967,611,922**	**883,186,524,886**	**873,967,611,922**	**883,186,524,886**
Total cost	**876,366,174,361**	**885,656,135,981**	**917,755,589,022**	**928,271,560,959**
BCR			**0.91**	**1.52**

Benefit analysis

The main drivers of revenue estimates are the traffic levels and tariffs for both freight and passenger operations. The estimated tariff rates for both freight and passengers were assumed to be the same for all links. In addition, the average rail transport charges for freight and passenger along all the links is estimated at USD $0.080 per ton-km and $ 0.024 per passenger-km. respectively. Tao et al. (2011) uses $17.99 as average ticket price for Hong Kong which almost similar to the ticket price in Africa. Freight and passenger ticket revenue estimates are between $12,506,000,000 - $18,050,160,000 and $51,180,000 - $69,360,000 respectively. To avoid double counting, this benefit, is not incorporated in the computation of the HSR total benefits but it is captured as HSR industry contribution to GDP.

The user travel time in transportation studies is involved into many categories such as the access/egress time, waiting time, and the in-vehicle travel time. The value of time (VOT) is identified as one component in the total equation of user cost and it can be calculated by multiplying an hourly wage rate by an average ridership component (Tao et al. 2011). VOT values varies depending on as trip purpose, socioeconomic and demographic characteristics, the total duration of the trip, among others. Tao et al. (2011) observes that HSR saves about 40 minutes compared to other convectional rail and that the average value of travel time (VTTS) is estimated at $17.11 per person per hour. Dijkman et al. (2000) indicates that the time saving estimates lies between $80million-$210million and its expected to rise to $160 million to $300,000 million. This study assumes time saving of 2 minutes per km per passenger, valued at 50% of average wage rate which is calculated based on GNI per capita. This gives total time savings benefits of $41,332,50 and $55,845,833 annually. According to Tao et al. (2011) unreliability in travel time is a major concern in transportation and captures both congestion and delays. Transport for London reports of 2008 that the value of reliability improvement is estimated based on the ratio of VTTS, which is about 13.7%. Based on this, the estimated reliability improvements range between $5,662,553 and $7,650,879.

HSR is expected to enhance accessibility with critical linkages established that widens markets and increases both competitiveness and productivity in the new developed regions. However, the level and the significant of this contribution is anticipated to be low[91]. Nevertheless, literature indicates GDP growth contribution from HSRs to be about 1-3 % (Preston and Wall, 2006) and captures wider economic impacts of HSRs as an industry. The economic contribution of HSR considers direct impacts through industry operations where returns to capital and labour are critical. At the same time, it also considers indirect impacts that extends to the wider economy through demand created in upstream industries as they produce inputs to the industry (Deloitte, 2017). Recent research from china indicates that High speed rail seems to provide a 1.0% to 1.5% annual GDP boost to regional economies. Based on the recent estimates from China[92], the minimum projected potential economic growth is estimated at a minimum of $13,286,766,501 and a maximum of $ 19,930,149,751.

Transport improvements impact on labour market and consequently on labour costs. According to Ministry of Transport New Zealand (2014) improvement in transport can develop labour market catchments, increase job matching and enable business interactions. Improved transport is also associated with reduced trading costs. When transport costs fall, both domestic and international trade increases. Fall in transport costs in the UK was associated with an increase in international trade by 10%—17.5% and also GDP by about 2.5% - 4.4% (Ministry of Transport New Zealand, 2014). Using this estimate, the

[91] According to Gourvish report

[92] Retrieved from https://www.nextbigfuture.com/2010/09/chinas-building-high-speed-rail-economy.html

increased GDP from trade in this study is between $1,081,966,125 and $2,163,932,251.

Investments in HSR is anticipated to reduce road accidents. This study calculates road traffic injury reduction by summing years of life lost (YLL) with years lived with disability (YLDs) and multiplying the value by 1.3* GNI per capita with the assumption that 10-20% of injuries will be averted by the rail network. The projected road traffic injury reduction is about $1,081,966,125 to $2,163,932,251.

Total benefit estimation ranges between $45,840,362,758 and $77,464,936,454. Cumulative PV of total benefit is about at a minimum of $836,858,245,590 and a maximum $1,414,194,105,705 as presented in table 1.

Sensitivity analysis

Several factors may influence the projected CBR values estimated; risks (such as capital costs, construction costs, and operating costs), population level, economic growth level, value of time and discount rates. Literature review establishes two views about risks. One is that risk is usually embedded in the total project costs, and second, risks is considered as a contingency, estimated at 5-10 percent risk margin. Gleave (2004) observed that actual high-speed rail projects have in recent times experienced significant budget overruns, a fact which has generally not yet been fully reflected in the risk margins adopted in the appraisal frameworks. Three key risk aspects are examined in the study according to Gleave (2004): an increase capital costs by 66%, increased construction time by 2 years with construction overruns of 25% and increased operating costs by 15% which should be allowed for in line with Green Book Guidance. These risks lower the level of CBR as shown in Table 2. The CBR is insignificant to minimal risk levels of between 10%-15%. The minimum value CBR is incentive to passenger time levels when value of time increases by 50%, while when capital costs increases by 66%, the CBR falls by 38.6% to between 1.42 and 2.21 respectively. CBR is established to be more sensitive to project capital cost than annual recurrent costs. For instance, a 10% increase in capital costs leads to about 8.5% to 38.6% drop in CBR, at the same time a 10% increase in annual recurrent costs is estimated to a fall in CBR by 0.5% to 0.7%.

TABLE 2: CHANGE IN BASE BENEFIT-COST RATIO FROM ADJUSTMENTS IN DIFFERENT SENSITIVITY INDICATORS

	Minimum BCR		Maximum BCR	
Base-BCR				
	0.91		1.52	
increase in capital costs				
10%	0.83	-9%	1.39	-9%
66%	0.56	-39%	0.94	-39%
construction delays and cost overruns				
10%	0.83	-9%	1.4	-8%
25%	0.74	-19%	1.24	-19%
increase in operating cost				
10%	0.91	-0.5%	1.52	-0.5%
15%	0.91	-0.7%	1.52	0
Increase in passenger revenue				
10%	0.91	0%	1.52	0%
25%	0.91	0%	1.52	0%
increase in value of time				
10%	0.91	0.01%	1.52	0.01%
50%	0.91	0.05%	1.69	11%

Discussion

The CBR computed was based on both minimum (0.91) and maximum (1.52) projected traffics for both freight and passengers. For policy decisions, it is important to take considerations of the country specific CBRs and also the link/track specific CBRs. For example, the maximum CBR above 1 was observed in most countries except for Kenya, Mozambique, Tanzania and Uganda, Ghana and Nigeria are countries with the highest maximum CBR values at 3.9 and 3.5 respectively.

Among the links/tracks with the highest CBR are in Nigeria and South Africa at 5.47 - 8.88 and 2.81 - 4.52 respectively. Subsequently several risks factors such as capital costs, construction costs, and operating costs, traffic demand, economic growth level, value of time and discount rates are critical for investment decisions. Mozambique is among the countries with links that have the lowest CBR of about 0.03 to 0.06.

References

Aguinaldo, J. (2017). *Saudi Arabia Conducts Second High-Speed Rail Test*. Available online at: https://www.meed.com/saudi- arabia-conducts- second- high- speed- rail-test/ (accessed October 19, 2017). Frontiers in Build Environment

Almujibah, H. and Preston, J. (2019). The Total Social Costs of Constructing and Operating a High-Speed Rail Line Using a Case Study of the Riyadh-Dammam Corridor, Saudi Arabia. *Front. Built Environ. 5:79. doi: 10.3389/fbuil.2019.00079*

Booz Allen Hamilton (2007), *Estimated carbon impact of a new North-South line*. Department of Transport, UK.

Campos, J., de Rus, G., and Barron, I. (2007). *A Review of HSR Experiences Around the World.* MPRA Paper, University Library of Munich. Available online at: https://EconPapers.repec.org/RePEc:pra:mprapa:12397

Casares, P. and Coto-Millán, P. (2011). Passenger transport planning. A Benefit-Cost Analysis of the High-Speed Railway: The Case of Spain. *Atlantic Review of Economics – 2nd Volume 2011.*

CPCS (2019). *Detailed scoping Study (DSS) for Vision 2063 Africa Integrated High Speed Railway Network and Masterplan*. Working Paper 2: Link Prioritization and Recommended Pilot Projects. CPCS, Ontario.De Rus, G. (2012). *The Economic Effect of High-Speed Rail Investment*. Discussion Paper No. 2008-16. International Transport Forum. OECD, Paris

Deloitte (2017). Value of Rail: The Contribution of rail in Australia.

Dijkman, H., Koopmans, C., and Vromans, M. (2000). *Cost -benefit analysis of high-speed rail*. GB Report 00/2.

Gleave, D. S. (2004). *High speed Rail: International Comparisons. Final Report*. London

Givoni, Moshe (2006). Development and Impact of the Modern High-speed Train: A Review. *Transport Reviews, 26:5, 593-611*.

Kosinski, A., L. Schipper and E. Deakin (2010). *Analysis of high-speed rail's potential to reduce CO2 emissions from transportation in the United States.* University of California, Berkeley.

Ministry of Transport New Zealand (2014). Contribution of transport to economic development: International Literature Review with New Zealand Perspectives.

Nash, C. (2010). *Environmental and Other Co-benefits of Developing a High-Speed Rail System in California: A Prospective Vision* 2010–2050. Center for Environmental Public Policy.

Preston, J., Larbie, A., and Wall, G. (2006). *The Impact of High-Speed Trains on Socio-Economic Activity: The Case of Ashford (Kent).* Paper presented for 4th Annual Conference on Railroad Industry Structure, Competition and Investment, Madrid, 2006.

Annex

Assumptions applied to BCR

The analysis is based on a period of 50 years (2020-2050) that incorporates construction period of 5 years (2020-2024) and adopting a 5% discount rate

Links/Track, length (km) and Cost of investments, Freight and Passenger Traffic vary and are sourced from CPCS (2019)

Freight and passenger traffic vary by link and data is presented in minimum and maximum values, sourced from CPCS (2019)

Rolling stock units required were specified by 0.0000000123 per net-tonne-km for freight locomotives; 0.00000061445 per net-tonne-km for wagons and 0.00000000174 per passenger-km for passenger trains.

The costs of freight locomotive, wagon and 10 car passenger train set adopted was $3,500,000, $125,000 and $40,000,000 respectively.

Cost of operation and maintenance are: $0.0187 per ton-km, $0.0183 per passenger-km and $55,458 per track-km for freight operation costs, passenger operation costs and infrastructure maintenance respectively.

Residual value costs are estimated at 10% of the value of the investment (Casares and Coto-Millán, 2011).

External cost assumes $14.13 per year for 1000 passenger per kilometer, (De Rus, 2012)

Average rail transport charges for freight and passenger along all the links is estimated at USD $0.080 per ton-km and $ 0.024 per passenger-km, respectively.

Time saving estimates are based on 2 minutes per km per passenger, valued at 50% of average wage rate which is calculated based on GNI per capita.

Value of reliability improvement is estimated based on the ratio of VTTS, which is about 13.7%. (Transport for London report of 2008)

GDP growth contribution from HSRs to be about 1-1.5 %

HSR is expected to contribute an average of 1-3 % to GDP growth (Preston and Wall, 2006).

Increased GDP by about 2.5% - 4.4% (Ministry of Transport New Zealand, 2014).

Investments in HSR is anticipated to reduce road accidents by assuming 10-20% of injuries will be averted by the rail network.