Analysis of Driving Factors for Developing Rail Freight

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Abstract: Even though rail freight can deliver significant benefits, many railways are performing poorly while others are industry leaders. Descriptive analysis of the freight railways of selected countries reveals that long haul distance enabled by greater landmass and connectivity with neighbouring rail networks are fundamental determinants of rail freight performance. Furthermore, a country's economic status and ability to invest is also found to contribute towards rail freight development favourably. Moreover, the presence of rail friendly freight industries such as mining are potential volume generators. The paper concludes by identifying three basic factors that determine the potential of rail freight in a given country and several parameters that limit this potential and proceeds to make recommendations on how such constraints can be overcome.

Keywords: Railway, Freight, Drivers, Strategy, Performance, Global

1. INTRODUCTION

Rail freight is considered cost-effective, reliable, fast, environment-friendly, and minimizes road congestion. The carrying capacity of freight by rail has increased substantially during recent years, enabling cost-effectiveness through economies of scale, further accelerating with longer distances (Forkenbrock, 2001; Mostert and Limbourg, 2016). The railway is noted to deliver more reliable services when compared to road transport as it does not have obstacles when running on tracks that enable higher speeds. The technology has improved significantly in the industry, enabling such speeds even with heavier payloads (*Why Use Rail Freight*, 2021). Collings (2013) notes that rail freight is considered highly favourable to road transport in terms of external costs. In general, it is observed that a freight train eliminates around 50 Heavy Goods Vehicles (HGVs) from the road, thereby minimizing environmental pollution, road accidents, and road congestion. Friedrich and Quinet (2011) observe that European freight railways record the lowest external costs, including climate change, noise, air pollution, and accidents compared to road and inland waterways when compared to all other transport modes. At present, the growing congestion around city centers and sea-ports has become a critical issue in managing road transport. Therefore, the trucking industry exerts considerable pressure on road congestion due to their higher speed and shipment size when compared with road vehicles (Bryan, Weisbrod and Martland, 2007, 2012), who together with ;Kurapati *et al.*, (2017) have recommended a modal shift of freight from road to rail, and especially in the transport of freight between port and hinterlands as a viable solution for reducing road congestion.

Before 1920 and the advent of freight transport by road, rail freight had much higher mode shares. Since then, the decline has been a common attribute in many countries (Aydin and Dzhaleva-Chonkova, 2013). Since then, road transport has exploited its advantages over the railways by providing better accessibility, flexibility, directness and responsiveness.

Kaack *et al.* (2018) has determined that the global share of the road to rail modal split to be 61:39 able to maintain its competitive edge.

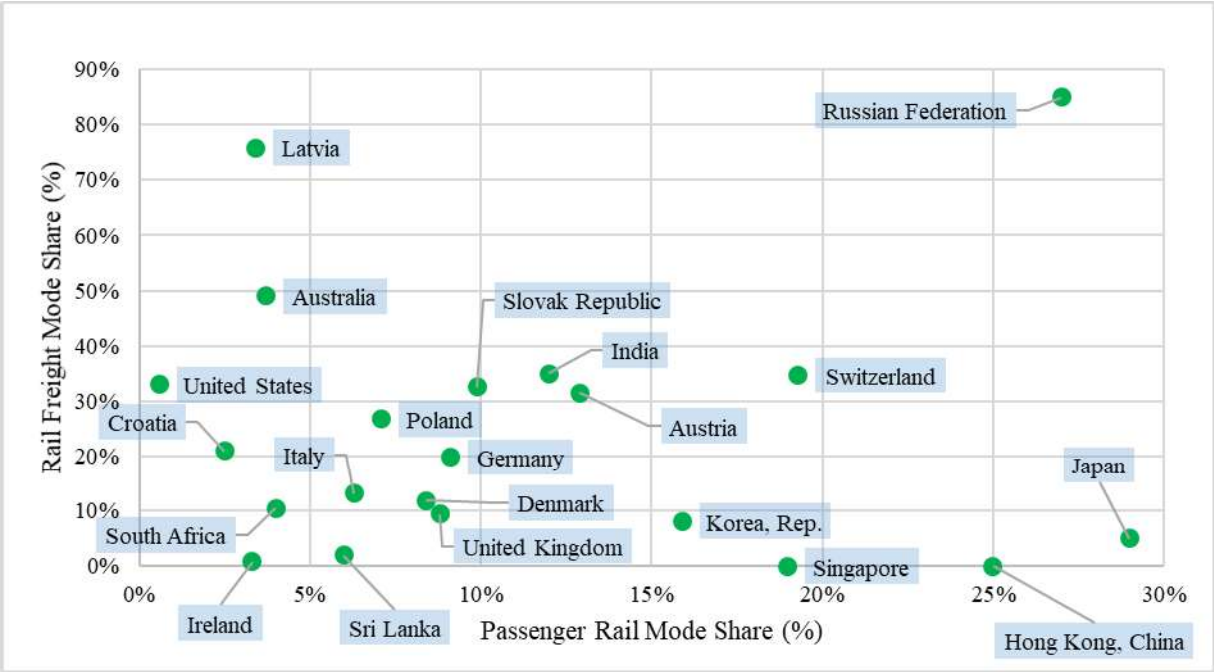

Figure 1: Comparison of freight and passenger mode share of railways (selected countries)
Sources: (Kumarage, 2010; Lee *et al.*, 2012; Murray, 2014; *Who Moves What Where: Freight and Passenger Transport in Australia*, 2016; *Statistical Year Book of Ukraine*, 2018; *Bureau of Transportation Statistics-US*, 2018; *China Statistical Yearbook*, 2019; *Eurostat Database*, 2020; *Railway, Goods Transported (million ton-km)*, 2021; Amit Bhardwaj, Shikha Juyal, Abhishek Saxena, 2018; Kim and Huang, 2019; *Passenger Transport Mode Shares in World Cities*, 2011; Lee *et al.*, 2012; Mizutani and Fukuda, 2020)

This is well illustrated in Figure 1, where the freight rail and passenger rail mode share of countries where such data is available are plotted against each other. It shows that the performances of both passenger and freight railways vary greatly. Railways in countries such as Latvia, Australia, United States, and South Africa are observed to be dominantly freight-oriented as opposed to Japan, Hong Kong, South Korea, and Singapore, where they are passenger-oriented. However, Russia, Switzerland, India, Austria, and the Slovak Republic have significant mode share in both passenger and freight, while Ireland and Sri Lanka do not perform adequately in either market.

This paper presents preliminary findings on factors that determine a country's potential for rail freight movement while also attempting to understand reasons why they may be performing below or above such expectations. These varying performances present a challenging proposition to determine the reasons for this large variance.

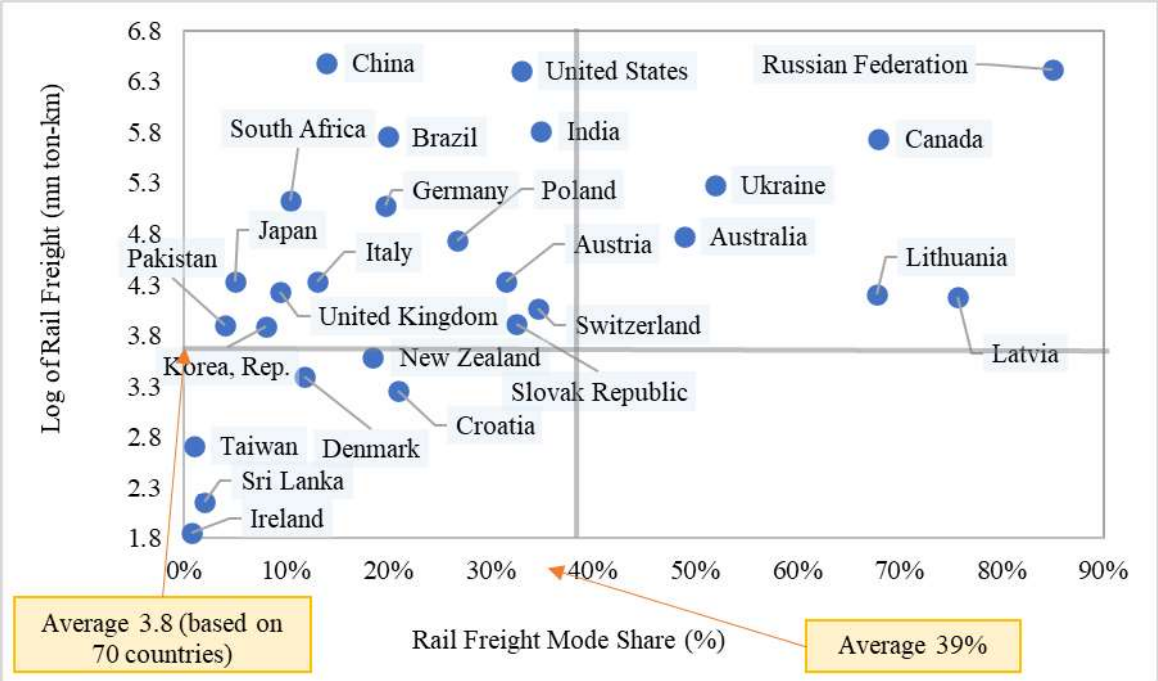

Figure 2: Railway freight performance and mode share by country

Sources: (Kumarage, 2010; Lee *et al.*, 2012; Murray, 2014; *Who Moves What Where: Freight and Passenger Transport in Australia*, 2016; *Statistical Year Book of Ukraine*, 2018; *Bureau of Transportation Statistics-US*, 2018; *China Statistical Yearbook*, 2019; *Eurostat Database*, 2020; *Railway, Goods Transported (million ton-km)*, 2021; *National Statistics, Republic of China (Taiwan)*, no date; Amit Bhardwaj, Shikha Juyal, Abhishek Saxena, 2018; Kim and Huang, 2019; Dias and Lopes, 2019; Lee *et al.*, 2012; Mizutani and Fukuda, 2020)

Figure 2 illustrates the variance of freight volumes represented by freight tom-km carried by freight modal shares for the different countries. Graphical observations place Russia, Canada, Australia, all of which are geographically larger countries to show dominating the higher quadrant of higher volumes corresponding to higher modal shares but sharing such space with geographically smaller countries such as Latvia, Lithuania and Ukraine, all of which are former constituencies of the USSR part of what is the Russian Federation today (*USSR established*, 2009). In contrast, smaller countries such as Taiwan, Sri Lanka, and Ireland, all of which are also islands not enjoying land borders, demonstrate lower performance.

This paper will study such a relationship to determine causal factors that determine the performance of rail freight of different countries that vary significantly. And also to determine possible reasons why others with similar features have underperformed.

2. METHODOLOGY

The research objective is, therefore, to identify the macro-level factors that impact the rail freight potential of each country and how the respective railways are performing relative to the potential. To achieve the stated purpose, a descriptive analysis using a quantitative analyzing process has been carried out. Thus, the quantitative data represented graphically has analytically examined to arrive at the results. In order to differentiate between fixed and variable factors, potential factors have been considered in sequence using descriptive analysis. Since data is available only from 110 countries (*Railway, Goods Transported (million ton-km)*, 2021), a stratified sampling method is used to select the sample countries representing the global profile of countries by land area, economy and rail-friendly industries. Only those

countries having significant rail freight activities since the year 2000 have been considered.

A number of different parameters such as the Logistics Performance Index (LPI) of the World Bank to test the impact of logistics performance, the population density to test the impact of population, the network density to test the impact of the extent of the rail network capability etc. were used to determine correlations with rail freight performance. However, only parameters identified in Table 1, representing land area, economy, and rail friendly industries of a country, were observed to be related. Table 1 represents the process adopted in selecting the sample representing the global population. Since there are only a few sea-locked (island) countries with relatively smaller land areas, having rail freight operations, most of the countries have been included in the sample. Even though most large countries are non-sea locked countries, the degree of land connectivity by railways has been considered. All other clusters represent a sample size varying between 33% - 42% of the global population of 110 countries for which such data is available. The most recent secondary data after 2015 from 42 countries have been considered for the analysis.

Table 1: Cluster-based sample selection

Fitting Parameters	Cluster Represented	Sample Size	Representative % of the population
Land Area	Sea locked countries	6	**75%**
	Non-sea locked small countries	31	**33%**
	Large countries	5	**71%**
	Total	**42**	
GDP per Capita	Greater than average	17	**40%**
	Less than average	25	**39%**
	Total	**42**	
Mining Production (as % of GDP)	Greater than average	11	**38%**
	Less than average	31	**42%**
	Total	**42**	

3. IMPACT OF LAND AREA AND INTERNATIONAL CONNECTIVITY ON RAIL FREIGHT

Figure 3 illustrates the relationship between the volume of rail freight and the land area of the 42 sample countries. This provides a definite graphical relationship between land area and ton-km transported by rail. It is clear that geographically large countries such as the USA, Russia, India, Brazil, and Australia carry a relatively higher rail freight volume. The haul distance was found to be a highly contributing factor for rail freight performance. Thus, the Pearson Correlation Coefficient has been calculated using a sample of 41 countries to determine the relationship between land area and average haul distance. The coefficient of 0.81 indicates a closer relationship between land area and haul distance. Since the relationship between land area and rail freight has been graphically illustrated, haul distance has been identified as one of the critical attributes of rail freight performance. Larger countries have higher haul distances favouring rail freight. Even though countries with small land areas have

a shorter distance to transport, this can be enlarged if the country has land connectivity with neighbouring countries. Thus, the land size and railway connectivity to adjacent countries are important determinants of a country's rail freight output.

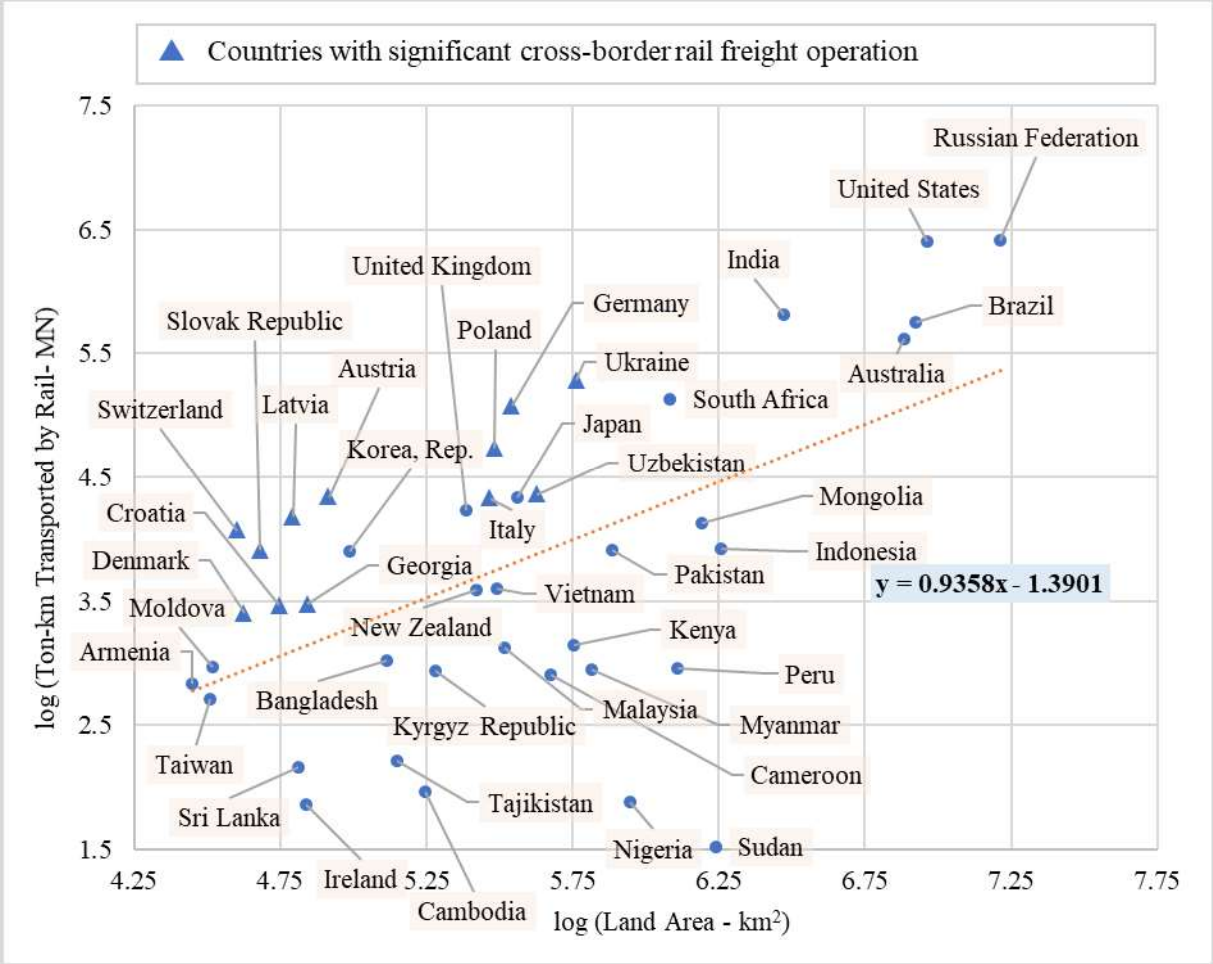

Figure 3. Rail freight volume vs. land area (selected countries)
Sources: (*Land Area*, 2018; *Railway, Goods Transported (million ton-km)*, 2021)

Figure 3 also demonstrates that European countries such as Croatia, Switzerland, Slovak Republic, Latvia, Georgia, Austria, Denmark, Italy, Poland, Ukraine, and Germany, and few other countries all of which have railway networks crossing into neighboring countries, have overperformed the potential of their own land area, while island countries and countries with no external railway linkages such as Sri Lanka and Ireland have under-performed. Thus connectivity with international railway networks has a substantial impact on rail freight operation. However, in the case of Australia, which is an island, its large landmass provides for adequate haul distance to offset the limitations of smaller island countries. It is observed that some island countries such as Japan and the United Kingdom perform better than their respective potential of the land area, while Sri Lanka and Ireland underperform. Furthermore, Taiwan and New Zealand perform close to the expected potential while Denmark and South Korea though having significant difficulty in connecting with adjacent countries, overperform, indicating there are other factors leading to such performance.

Similarly, countries such as Tajikistan, Cambodia, Nigeria and Sudan have also underperformed as even though they are relatively larger countries also having connectivity

with neighbouring countries. Additionally, most African countries, except a few like South Africa, underperform in freight railway. (*Railway, Goods Transported (million ton-km)*, 2021) Thus, Nigeria and Sudan have been unable to take advantage of the connectivity as adjoining countries do not possess well-developed freight railway systems, as in Europe.

4. IMPACT OF ECONOMY ON RAIL FREIGHT

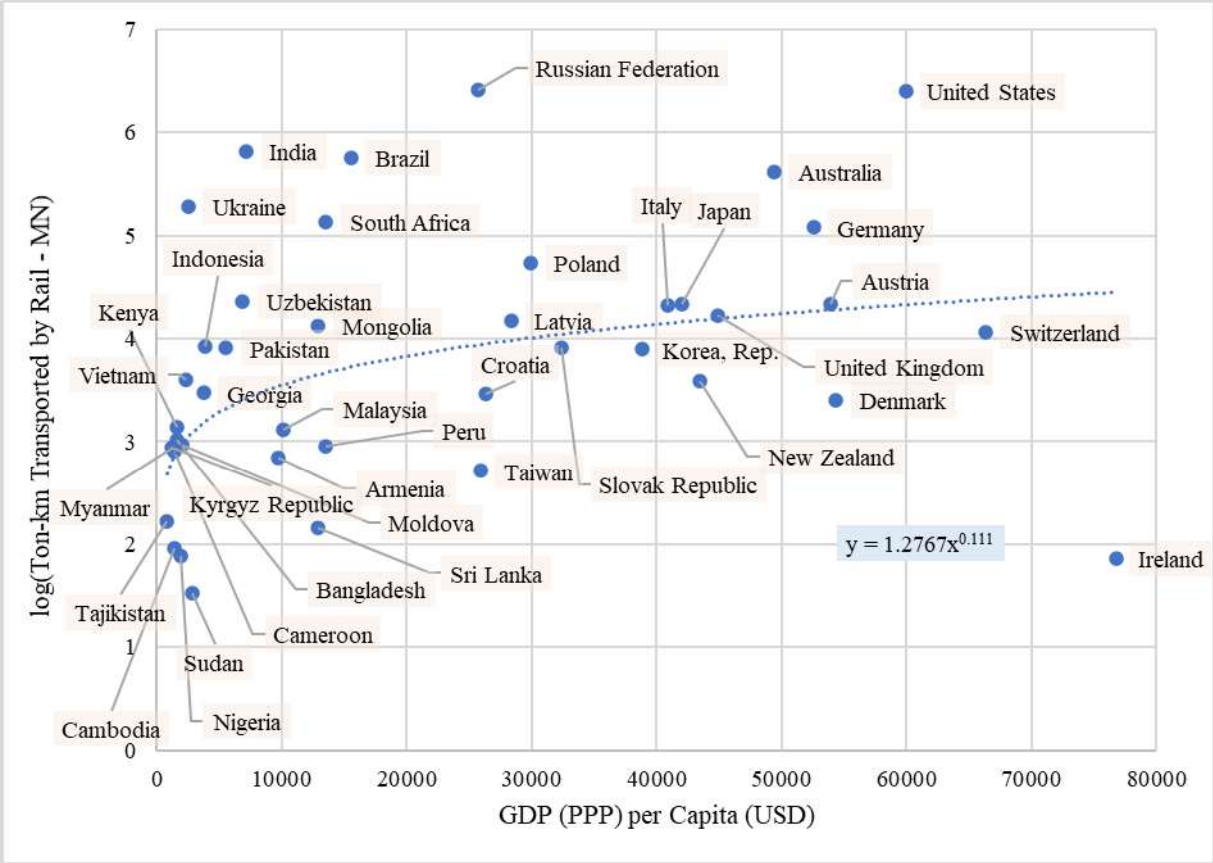

Figure 4. Rail freight performance and GDP (PPP) per capita (USD)
Source: (*GDP per Capita*, 2017; *Railway, Goods Transported (million ton-km)*, 2021)

Figure 4 shows a relationship between the economic status of a country, measures in terms of GDP (PPP based) per capita and its rail freight performance. It can be seen that the countries with higher GDP (PPP) per capita, such as the USA, Australia, Germany, Austria, and Switzerland, have created a favourable environment to perform better in the railway as measured by the freight volume. On the other hand, many countries with lower GDP (PPP) per capita, such as Nigeria, Sudan, Cambodia, and Tajikistan, have shown limited performance irrespective of their enabling larger land size.

However, Ireland though having a higher GDP (PPP) per capita, has demonstrated poor performance. In this instance, both geographical restrictions and policy decisions are possible factors. Sri Lanka and Taiwan also do not deliver adequate rail freight performance in keeping with their respective GDP per capita since the primary driving factor, land area and international railway connectivity restricts performance. In contrast, Russia though not possessing a higher GDP per capita, is the only country over-performing due to its land area and land connectivity to adjacent countries, possibly due to the pro-railway policies adopted historically (Murray, 2014). It is therefore observed that a country's economy is a vital factor

determining the volume of rail freight, possibly due to a higher level of investment in railways as a higher level of consumption resulting in rail freight volume increases.

5. IMPACT OF RAIL FRIENDLY FREIGHT INDUSTRIES ON RAIL FREIGHT

While a country's land area and connectivity to adjacent countries are found to be an enabler of rail freight, the type of cargo is also seen to play a significant part. Homogeneous goods are more attractive to the railway since the shipment sizes favour the larger capacity available with the railways. Mining freight such as coal and iron ore have been extensively transported by rail since the beginning of railways, especially between the mines and sea-ports (V. A. Profillidis, 2006). Other bulk cargoes such as timber, sugar, steel, grain, sand, salt, cement, and oil are also considered as freight types preferred by railways (*Types of Cargo Shipped by Rail Freight Transport*, 2016). Figure 5 shows that countries having well-developed industries such as mining requiring bulk transportation provide a definite advantage for rail freight.

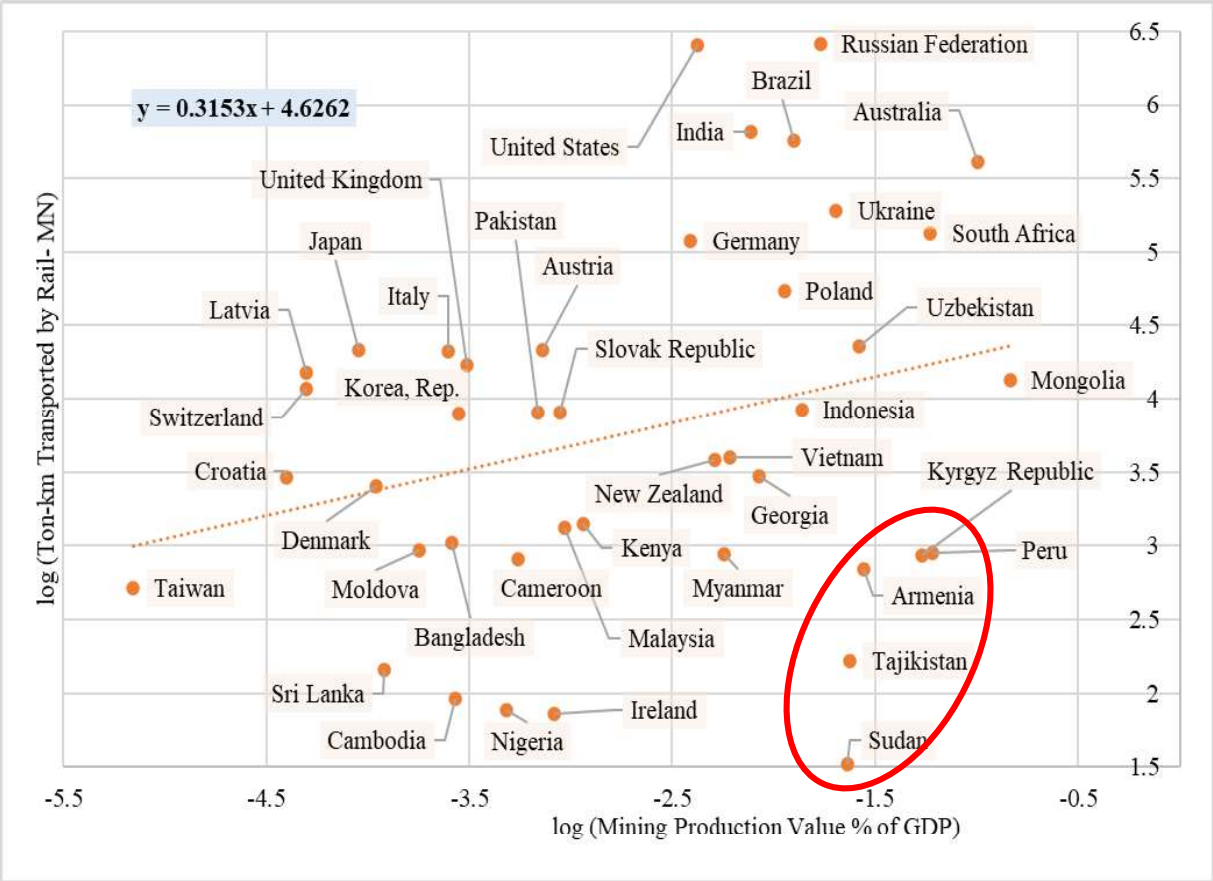

Figure **5**. Rail freight performance (in logarithm) vs. mining production (by country)
Sources:(Ericsson and Löf, 2019; *Railway, Goods Transported (million ton-km)*, 2021)
Note: Mining production includes iron and ferro-alloy metals, non-ferrous metals, precious metals, industrial minerals (incl. Diamonds.), mineral fuels, and Bauxite

Australia, Brazil and South Africa being among the leading coal and iron ore exporting countries, are dominant freight railways accounting for 75%, 77% and 60% respectively of total transport of such commodities by rail freight transport (*Statistical Report - Australian*

Railways, no date; Gregg-Macdonald, 2019; Massara, 2019). In Australia and South Africa, the rail mode share for export iron ore and coal is even higher at 80% and 100%, respectively, while in Brazil, 90% of iron ore transportation is by railways (*Company Overview-Transnet Freight Rail*, 2010; *Who Moves What Where: Freight and Passenger Transport in Australia*, 2016; da Silva, de Oliveira and Marinov, 2020).

This provides evidence that a railway can gain a better mode share if it transports coal and iron ore, whereas road transport has gained an advantage in non-bulk commodities. Thus, the ratio between bulk and non-bulk commodities in a country has an impact on rail freight performance. Thus based on the contribution of mining production South Africa, Australia and Mongolia have performed well in rail freight, underlying the impact by a greater contribution of mining production. Taiwan's, Sri Lanka's freight railway systems are further restricted due to the disadvantage of not possessing such bulk production. Even though Sudan, Tajikistan, Armenia, Peru, and the Kyrgyz Republic have noteworthy mining production, they have shown less performance in rail freight, possibly being impacted by policy or strategy factors.

6. CONCLUSION

Using a representation of 42 countries representing the global rail network profile, it has been observed through a process of descriptive and analytical analysis that land area and potential for cross-border business, economic status, and rail friendly industries are the predominant determinants of the rail freight in a country. Such factors decide the potential of a specific country to perform better in rail freight. Thus, to revive rail freight, a country must have reasonable land extend or favourable land connectivity to good railway networks in adjacent countries. Land area and connectivity to railway networks in adjacent countries are therefore primary determinants of rail freight volumes enabled by longer haul distances.

Even if the geographical status decides a countries' potential for rail freight, the ability to reach it or even exceed such potential performance appears to be determined by the status of the economy, rail-friendly industries, and other policy-related matters pertaining to that country. This explains why even though a country possesses a favourable land extent, it cannot perform adequately as observed in the case of many African countries and some Asian countries that have poor economic conditions or lack investment in railway freight infrastructure or railways as a whole such as is the case of Somalia, Niger, Bhutan etc. (Migiro, 2018).

The research concludes that the potential for rail freight is determined by several fixed factors such as the landmass and availability of rail-friendly industries. However, the potential for rail freight appears to improve with growth in economy and consumption and if greater investments are made in rail freight infrastructure. Yet other factors such as rail connectivity to adjacent countries and the status of such rail networks also seem to be enabling factors. Moreover, road transport, being a significantly competitive mode in geographically restricted countries, can be discouraged from improving rail freight performance. Moreover, sea rail tunnels, bridges, and train ferries can help to connect with neighbouring countries separated by sea, expanding the rail network of geographically restricted countries as seen in the case of the UK, Japan, Denmark, and New Zealand, which practice such initiatives to bridge the land separation between or within the country (Middlemiss, 2018). Further, in countries having the potential to grow in both passenger and freight railways, the right balance of government commitment is required to reach such potential.

7. FURTHER RESEARCH

The paper is a part of ongoing research on "An Integrated Strategy to Revive Rail Freight in Sri Lanka." A statistical analysis is currently being carried out to develop a more representative multi-factor model to represent railway freight transport performance. Furthermore, macro and micro scale strategies that can be used to enhance rail freight performance in freight constraining railways will be explored using a mixed-method using both quantitative and qualitative data for investigating policy options for developing rail freight.

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REFERENCES

V. A. Profillidis (2006) *Railway Managemet and Engineering*. Ashgate Publishing Limited.

Amit Bhardwaj, Shikha Juyal, Abhishek Saxena, A. S. (2018) *Goods on the Move: Efficiency and Sustainability in Indian Logistics*, *MOVE: Global Mobility Summit*. Available at: https://niti.gov.in/writereaddata/files/document_publication/Freight_report.pdf.

Aydin, G. and Dzhaleva-Chonkova, A. (2013) 'Discussions on rail in urban areas and rail history', *Research in Transportation Economics*. Elsevier Ltd, 41(1), pp. 84–88. doi: 10.1016/j.retrec.2012.10.002.

Bryan, J., Weisbrod, G. and Martland, C. (2012) *GUIDEBOOK FOR ASSESSING RAIL FREIGHT SOLUTIONS TO ROADWAY CONGESTION*.

Bryan, J., Weisbrod, G. and Martland, C. D. (2007) 'Rail freight as a means of reducing roadway congestion: Feasibility considerations for transportation planning', *Transportation Research Record*, (2008), pp. 75–83. doi: 10.3141/2008-10.

Bureau of Transportation Statistics-US (2018) *United States Department of Transportaion*. Available at: https://www.bts.gov/archive/publications/national_transportation_statistics/table_01_50 (Accessed: 7 July 2020).

China Statistical Yearbook (2019) *National Bureau of Statistics of China*. Available at: http://www.stats.gov.cn/tjsj/ndsj/2019/indexeh.htm (Accessed: 5 July 2020).

Collings, J. (2013) *The Benifits of Choosing Rail Freight*, *The Logistics of Logistics*. Available at: https://www.thelogisticsoflogistics.com/benefits-of-choosing-rail-freight/ (Accessed: 11 June 2020).

Company Overview-Transnet Freight Rail (2010) *Transnet Freight Rail*. Available at: http://www.transnetfreightrail-tfr.net/Aboutus/Pages/Company-Overview.aspx (Accessed: 20 August 2020).

Dias, M. de O. and Lopes, R. de O. A. (2019) 'RAIL TRANSPORTATION IN BRAZIL: CHALLENGES AND OPPORTUNITIES', *Arabian Journal of Business and Management Review (Oman Chapter)*, 8(4), pp. 40–49.

Ericsson, M. and Löf, O. (2019) 'Mining's contribution to national economies between 1996 and 2016', *Mineral Economics*. Springer International Publishing, pp. 223–250. doi: 10.1007/s13563-019-00191-6.

Eurostat Database (2020) *European Commision*. Available at: https://ec.europa.eu/eurostat/data/database (Accessed: 5 May 2020).

Forkenbrock, D. J. (2001) 'Comparison of external costs of rail and truck freight

transportation', *Transportation Research Part A: Policy and Practice*, 35(4), pp. 321–337. doi: 10.1016/S0965-8564(99)00061-0.

GDP per Capita (2017) *Worldometer*. Available at: https://www.worldometers.info/gdp/gdp-per-capita/ (Accessed: 6 August 2020).

Gregg-macdonald, M. (2019) *Transnet Integrated Report*.

Kaack, L. H. *et al.* (2018) 'Decarbonizing intraregional freight systems with a focus on modal shift', *Environmental Research Letters*, 13(8). doi: 10.1088/1748-9326/aad56c.

Kim, C. J. and Huang, M. C. (2019) *RAILWAYS AND JAPAN POST : Asian Development Bank Institute*.

Kumarage (2010) 'Review of Sri Lanka Transport Sector'. Available at: https://kumarage.files.wordpress.com/2015/03/2010-r-02-tp-kumarage-a-s-review-of-sri-lanka-transport-sector-world-bank-319pp.pdf.

Kurapati, S. *et al.* (2017) 'Exploring challenges and solutions for container transportation using rail: A modelling and simulation gaming study', *5th IEEE International Conference on Models and Technologies for Intelligent Transportation Systems, MT-ITS 2017 - Proceedings*, pp. 158–163. doi: 10.1109/MTITS.2017.8005657.

Land Area (2018) *The World Bank*. Available at: https://data.worldbank.org/indicator/ag.lnd.totl.k2 (Accessed: 22 May 2020).

Lee, D. *et al.* (2012) *Economic Growth and Transport Models in Korea*, *Korea Transport Institute*.

Massara, V. M. (2019) 'An overview about Brazilian railway system – Part II: 1930-actual', *MOJ Civil Engineering*, 5(4), pp. 97–100. doi: 10.15406/mojce.2019.05.00161.

Middlemiss, N. (2018) *Passenger and Freight Train Ferries*, *Shipping Today and Yesterday*. Available at: https://www.shippingtandy.com/features/passenger-and-freight-train-ferries/ (Accessed: 7 September 2020).

Migiro, G. (2018) *Countries Without A Railway Network*, *WorldAtlas*. Available at: https://www.worldatlas.com/articles/countries-without-a-railway-network.html (Accessed: 2 January 2021).

Mizutani, J. and Fukuda, S. (2020) 'Issues on modal shift of freight from road to rail in Japan: Review of rail track ownership, investment and access charges after the National Railway restructuring', *Research in Transportation Business and Management*. Elsevier, (April), p. 100484. doi: 10.1016/j.rtbm.2020.100484.

Mostert, M. and Limbourg, S. (2016) 'External Costs as Competitiveness Factors for Freight Transport — A State of the Art', *Transport Reviews*, 36(6), pp. 692–712. doi: 10.1080/01441647.2015.1137653.

Murray, B. (2014) 'Russian Railway Reform Programme'.

National Statistics, Republic of China (Taiwan) (no date) *Statistical Bureau, Taiwan*. Available at: https://eng.stat.gov.tw/ct.asp?xItem=41882&ctNode=6352&mp=5 (Accessed: 8 July 2020).

Passenger Transport Mode Shares in World Cities (2011) *Journeys*. Available at: http://www.ltaacademy.gov.sg/doc/JOURNEYS_Nov2011 Revised.pdf.

Railway, Goods Transported (million ton-km) (2021). Available at: https://data.worldbank.org/indicator/IS.RRS.GOOD.MT.K6 (Accessed: 2 January 2021).

da Silva, F. G. F., de Oliveira, R. L. M. and Marinov, M. (2020) 'An analysis of the effects on rail operational efficiency due to a merger between Brazilian rail companies: The case of rumo-all', *Sustainability*, 12. doi: 10.3390/SU12124827.

Statistical Report - Australian Railways (no date).

Statistical Year Book of Ukraine (2018).

Types of Cargo Shipped by Rail Freight Transport (2016) *International Forwarding Association*. Available at: https://ifa-forwarding.net/blog/european-logistics-network/types-of-cargo-shipped-by-rail-freight-transport/#:~:text=The main types of cargo,certain temperatures must be maintained. (Accessed: 6 November 2020).

USSR established (2009) *A&E Television Networks*. Available at: https://www.history.com/this-day-in-history/ussr-established (Accessed: 2 February 2021).

Who Moves What Where: Freight and Passenger Transport in Australia (2016).

Why Use Rail Freight (2021) *Rail Freight Group*. Available at: http://www.rfg.org.uk/rail-freight/why-use-rail-freight/#:~:text=Rail freight offers many commercial,of the UK to prosper. (Accessed: 2 February 2021).