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Economic Impact, Design, and Significance of Intermodal Freight Distribution in Pakistan

Rizwan Shoukat [1*]

[a]*School of Transport and Logistics, Southwest Jiaotong University, Chengdu, China*
[b]*National Engineering Laboratory of Integrated Transportation Big Data Application Technology, Chengdu, China*
[c]*Lab of National United Engineering Laboratory of Integrated and Intelligent Transportation, No. 111, North Second Ring Road, Chengdu, 610031, China*

Abstract

The goal of this study is to quantify and analyse the costs of road-intermodal freight transportation in Pakistan. For the design of the problem, a performance model is utilised, which provides calculations of the costs incurred in road and intermodal freight transports. Our research shows a big cost difference between road and road-rail freight transport. The results show that the cost of road freight transport is 1.48 million Pkr/day and the cost of intermodal freight transport is 1.26 million Pkr/day for the delivery of 220 tonnes of cargo to the consumers. The quantitative analysis of real-life data from one of Asia's leading paper and board businesses used in this study demonstrates operational benefits of more than 60% cost reductions when switching from road to intermodal freight (road-rail) transport. Sensitivity analysis is also presented to assist decision-makers in selecting the most efficient and cost-effective mode of transportation.

Keywords: Road-intermodal freight. Paper and board industries. Operational benefits. Sensitivity analysis. Economical mode

1. Introduction

The operations in transport and logistics are vital in today's economy as they are practical tools for businesses to remain competitive. Transport plays an important role in economic growth and social development. It can be defined as passenger and freight transport. Transportation has gained rapid growth in the last two decades because of the increasing distance between suppliers and customers (Demir et al., 2015). Road transport is still a very important part of freight transport in single modal or multi-model transport system from starting point to destination point. The multimodal freight transport system is preferred to create a sustainable transport system (Zhang et al., 2003).

* Corresponding author: Rizwan Shoukat (rizwanshoukat08@gmail.mail)

The road transport is the most flexible mode of transportation because of dense networking and eases to use of alternative routes. But due to increased traffic volumes causes undue delays, stops, and disruptions that result in a decrease in reliability. To improve the road transportation system, the necessary part is to understand its impact on the economy, society, and environment. Thus, the strategies and policies can be devised to decrease the impact (Dobranskyte-Niskota et al., 2009, Cottrill and Derrible, 2015). A few methods have been developed in the recent past to assess the impact of road freight transport to reduce the carbon footprints (Duan et al., 2017, Dente and Tavasszy, 2018). Transportation is responsible for the highest emissions with 28% compared to electricity with 27% and industry with 22%. The ever-growing volume of freight transport increases the GDPs of many economies and has consequences in the form of the damaging environment (Hockstad and Hanel, 2018). The central governments and companies are publishing policies for the protection of the environment in Europe. Transportation plays a huge part in the emissions of carbon dioxide responsible for climate change and its negative impact. Therefore, it would be essential to pick other transportation sources besides road transportation (Demir et al., 2015). Sector-wise research helps researchers to understand which area needs attention and improvement by policymakers. Many researchers have investigated various factors that are causing emissions of CO2 in the transport sectors (Guo et al., 2018).

In today's world, transportation has become both a cause and a result of any country's economic progress. It is now essential to integrate a country into the global economy by having the best transportation system possible. The road is the backbone of Pakistani transportation, with a 9,574-kilometer-long Motorway and National Highway network that accounts for only 3.65% of the entire road network (Finance, 2010). In Pakistan, road transport accounts for 80% of overall traffic. This has increased to 96% for freight and 91% for passenger transportation. The trucking sector in Pakistan has been fragmented into many small operators with a low barrier to entry and the world's lowest freight cost. In relation to the rest of the globe, Pakistan has the lowest road freight rate. It only costs between USD 0.019 and USD 0.025 per tonne kilometre (Sánchez-Triana et al., 2013; World Bank 2009). A few other studies conducted in the freight sector suggest the same pattern of cost in Pakistan. Pakistan is the lowest freight cost country globally for long-distance tariffs at USD 0.01 to USD 0.03 per ton kilometre (Kent, 2009). Truck transport is the most useful way of transportation because of (a) flexibility to reach most destinations; (b) ability to operate on any road in the country; (c) flexibility in increasing/decreasing speed, especially on short routes; (d) low-cost maintenance; (e) low investments. However, there are some inherent limitations of using trucks for road transport because of (a) breakdowns due to bad road conditions, (b) accidents, (c) effect of weather, (d) high greenhouse gas emissions. However, since 1970, the share of rail has been dropped dramatically due to the government's priorities towards road transport (Guoquan et al., 2014, Raeesi and O'Sullivan, 2014). The disadvantages of road transport are the advantage of rail transport, however, at the higher maintenance and investment costs (Ghiani et al., 2013).

In the last decades, an enormous increase in road freight transport has been seen in Europe. Road freight transport was counted for 65 per cent of the total transport (ton-km) in 1980. Additionally, this share has been increased by 76% in 2010 and left the share of rail 7 per cent of total traffic. However, with so many advantages of road transport, it also causes high costs, accidents, congestion, air, and noise pollutions. These conditions can be improved by calling upon other transport modes like rail, sea, and air. Intermodal

transport can be an improved mode of transport to cater to all the above-mentioned issues of road transport (Eurostat, 2013). However, the cost is the main criteria in the selection of intermodal passenger or freight transport (Bergantino et al., 2013, Danielis and Marcucci, 2007). Intermodal transport involvements in freight transport in containers by various vehicles such as trucks, rail, ship (Caris et al., 2008).

The intermodal freight transport study has achieved much consideration due to congestion on the roads, unusual costs of shipping, air pollution, and global warming concerns (Konings, 2008). Because of rising recognition, long-term importance, pace, and agility, logistic services attract firms to select intermodal freight transport and reconsider traditional systems of shipping the freight that frequently relies on trucking shipment (Morlok et al., 1995). The logistics corporations have recognised road-rail intermodal transportation or domestic container logistics as one of the most significant ways to address the issues in transport and logistics (Cole et al., 2008). The applicability of inter-modal transport and taught how to use the information from internet-based systems for the scheduling of freight in the intermodal transportation network (Southworth and Peterson, 2000). The relationship between internal and external road costs and intermodal freight transportation costs is studied. The study's findings show that as distance increases, the cost of both modes or networks decreases proportionally, resulting in distance economies (Janic, 2007). A model is developed with multi objectives to decrease the cost of transportation and travelling time (Chang, 2008). The survey presents toll charges, an administration fee of transportation, and road maintenance of transportation account for 33% of the total transport cost. Toll charges add to the total transportation cost and therefore minimise the profit margin. The price of general cargo rests low on the other hand. He analyses rates of freight drop by 0.1% every year (Liu, 2006). The surge in fuel price soaring in recent years, which raises the total price of transportation (Xu and Tang, 2008). The intermodal transport reflects one chain of transport, which has two modes of transport in one transport chain without changing the containers for products. In this mode, most routes are taken as rail, inland waterway, road, and ocean-going vessels (Macharis and Bontekoning, 2004). Alternative fuel vehicle (AFV) fleet adoption is an attractive and important measure of mitigation to minimise environmental externalities from transportation and logistics activities. However, proper ecological and economic measures should be placed to facilitate the organisations to invest in AFV. The alternative fuel vehicle routing problem is investigated to minimise fuel consumption and optimise the utilisation of alternative fuel and results show saving of 35% in the CO2 emissions and 16% in cost by using an alternative fuel vehicle fleet (Raeesi and O'Sullivan, 2014).

By following the framework of the case study method discussed in (Ellram, 1996, Eisenhardt, 1989), we want to explore the answer of correlated research question that represents the logistics company operations consideration when assessing the implementation of road-rail intermodal freight transport: "For a logistics company in Pakistan, what are the operational benefits of adopting road-rail intermodal freight transportation?" The empirical data collected from a case study can be applied to a mixture of quantitative and qualitative analyses (Hendrick and Ellram, 1993). In this study, we use quantitative data to evaluate the operational benefits in numerical and quantifiable terms. The main contributions of the study are as follows:

1. Estimating and analysing the total cost of road freight transport in Pakistan
2. Estimating and analysing the total cost of intermodal freight transport in Pakistan
3. Comparison of Intermodal-road cost

4. Sensitivity analysis

This paper is divided into four sections. Section 2 presents the study's necessary background by defining the problem and providing information about the assumptions used in this study for the formulation of the model to analyse road and intermodal freight transport costs in Pakistan. Section 3 includes the initial data used for the calculations and analysis of the problems. Section 4 depicts the results of real-life cases. Finally, section 5 presents the conclusion and recommendation for further research.

2. Problem statement

This section will define our problem and present the formulation of the cost model to measure and analyse the cost between the road and intermodal freight transport in Pakistan.

2.1 Problem definition (Road freight transport)

In our study, we present our problem of measuring and analysing the performance of the cost model. One type of product with a container capacity of 44 tons is considered for this problem. Data like distance, weight, loading cost, unloading cost, and handling cost are taken from one of Pakistan's largest logistics service providers. In the first scenario, the operation starts from satellite cities x_1, x_2, x_3, x_4, x_5 in Punjab province. Five trucks are loaded with freight from the supplier's end. This supply moves to Karachi (Sindh) province via Lahore (Punjab). This operation takes 44 hours to reach Karachi. Lastly, delivery is made to the customers in satellite cities y_1, y_2, y_3, y_4, y_5 in Sindh. Figure 1 and Figure 2 show the cost of road freight transportation.

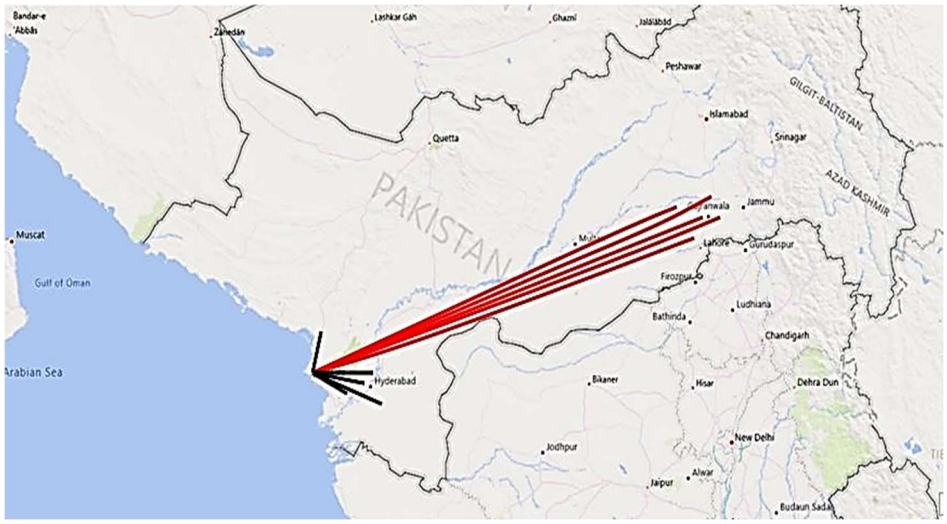

Figure 1 : Road freight transport Sindh-Punjab.

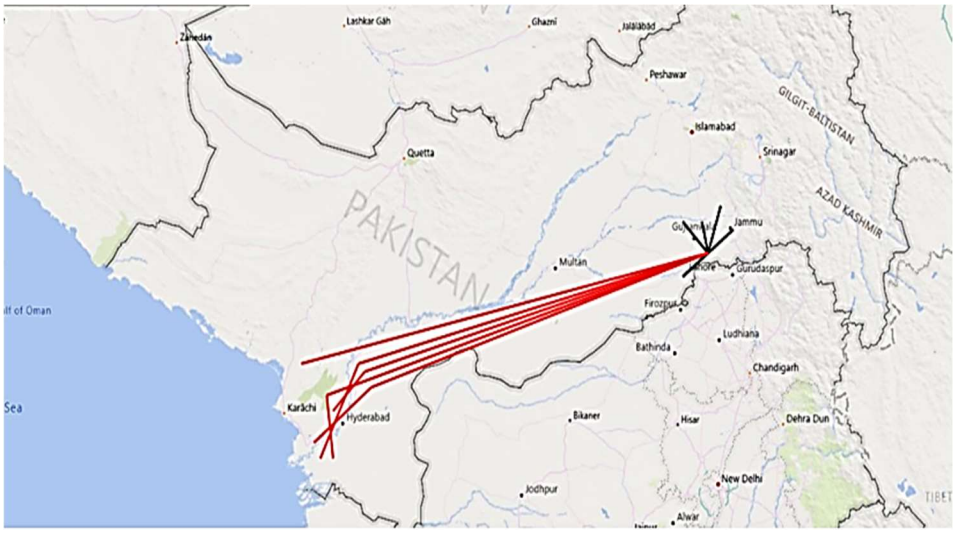

Figure 2: Road freight transport Punjab-Sindh.

In the second scenario, a backward operation starts from the satellite cities of Sindh. Freight is carried to Karachi and the satellite cities of Punjab province via Lahore. We assumed suppliers and customers in satellite cities of Sindh and Punjab.

Table 1:Distance between cities of Punjab province.

Distance (km)	*Lahore (x_0)*	*Kasur (x_1)*	*Gujranwala (x_2)*	*Sialkot (x_3)*	*Gujrat (x_4)*	*Sargodha (x_5)*
Lahore	0	51	97	140	168	187

Table 2:Distance between cities of Sindh province.

Distance (km)	*Karachi (y_0)*	*Badin (y_1)*	*Thatta (y_2)*	*Malir (y_3)*	*Sujawal (y_4)*	*Utal (y_5)*
Karachi	0	212	102	25	129	128

2.2 Intermodal freight transport

The first scenario starts from satellite cities x_1, x_2, x_3, x_4, x_5 in the Punjab province. Supplies with five trucks are transferred to Lahore railways station (LRS) via road. At LRS, containers are unloaded from trucks and loaded on the rail for dispatch to Karachi. This operation takes 18 hours to reach Karachi. From Karachi railway station (KRS), containers are loaded on trucks again for delivery to the final customers in satellite cities of Sindh (s). Figure 3 shows the distribution of intermodal freight transportation.

Figure 3: Intermodal freight transport

In the second scenario, a backward operation starts from (s). Freight moves to the capital city Karachi by road. After loading material on the rail, containers reached LRS. Lastly, five containers with supplies are delivered to the customers in the satellite cities of Punjab. The assumption applied to the model are as follows:

- 40 feet containers are considered for our study.
- Five trucks taking consignment from Punjab to Sindh & Sindh to Punjab by having same weight capacities.
- Capital to capital freight movement after dispatch from satellite cities.
- One trip of freight movement is equal to 220 tons (Punjab-Sindh, Sindh-Punjab)

3. Model formulation

W	Weight in tons
Y	Capital city (Karachi)
X	Capital city (Lahore)
x_i	Satellite cities in Punjab
y_j	Satellite cities in Sindh
L+UL	Loading and unloading cost
HC	Handling cost
Uc	Unit cost of the transfer
S	Total distance
CTT	Cost of road transport
A_1	The unit cost of highway transportation (PKR 2.5/km-ton)

$$CTT_1 = \left[\sum_{i=0}^{5} \begin{matrix} S*Uc(x_i,y_0) * W(x_i,Y)*A_1 + (L+UD) * W(x_i,Y) \\ +(HC) * W(x_i,Y) \end{matrix}\right] \quad (1)$$

$$CTT_2 = \left[\sum_{j=0}^{5} S*Uc\left(y_0,y_j\right) * W\left(X,y_j\right) * A_1\right] \quad (2)$$

$$CTT_3=\begin{bmatrix}\sum_{j=0}^{5} & S*Uc\left(y_j,x_0\right)*\left(y_j,X\right)*A_1 \\ & +(L+UD)*W\left(y_j,X\right)+ \\ & (HC)*\left(y_j,X\right)\end{bmatrix} \quad (3)$$

$$CTT_4=\left[\sum_{i=0}^{5} S*Uc(x_0,x_i)*W(Y,x_i)*A_1\right] \quad (4)$$

Equation (1) shows the cost of transfer of material between the satellite cities of Punjab (p) to Karachi in Sindh province (s). The first summation shows the cost of L&U, the second summation shows the cost of H&I of the material. Equation (2) indicates the cost of movement of material between the satellite cities of Sindh. The first summation depicts the cost of total distance covered in satellite cities of Sindh. Equation (3) shows the cost of the movement of material from satellite cities of Sindh and Lahore. The first summation shows the cost of distance, the second summation shows the cost of L&U of the material, the third summation shows the cost of the H&I of the material. Equation (4) shows the cost of distance among satellite cities of Punjab.

3.1 Cost analysis of road freight transport

CTT_1=[105,000*5+(70+70)*44*5+(255)*44*5)]
=525000+30800+56100=611900
CTT_2=30000*5=150000
CTT_3=[510000+27280+32560
=569840]
CTT_4=30800*5=154000
$TCT_T = CTT_1 + CTT_2 + CTT_3 + CTT_4$
= 611900+150000+569840+154000
= Pkr 1485740

In the cost analysis of the road freight transport from Sindh to Punjab, the total cost of movement of material (CTT_1) between (x_1, x_2, x_3, x_4, x_5) and (y_0) is 611900 Pkr/trip. This cost includes distance cost 525000 Pkr, loading & unloading cost 30800 Pkr, cost of handling & inspection 56100 Pkr. The total cost of movement of material between satellite cities of Sindh (CTT_2) is 150000 Pkr. The total cost of delivery of the material (CTT_3) between satellite cities of Sindh (y_1, y_2, y_3, y_4, y_5) and Lahore (x_0) includes distance cost 510000 Pkr, cost of loading and unloading the material 27280 Pkr, and cost of handling & inspection 32560 Pkr. The total cost of the distance between the satellite cities of Punjab (CTT_4) is 154000 Pkr. The total cost of road freight transport is 1485740 Pkr/trip (consignments of 220 tons per trip) between Punjab-Sindh and Sindh-Punjab.

3.2 Model formulation of intermodal freight transport

W	Weight in tons
Y	Capital city (Karachi)
X	Capital city (Lahore)
x_i	Satellite cities in Punjab
y_j	Satellite cities in Sindh
L+UL	Loading and unloading cost (L&U)
S	Total distance
A	Unit cost of highway transport

HC	Handling & Inspection cost (H&I)
CIT	Cost of intermodal transport
Uc	Unit cost of the transfer

$$CIT_1=\left[\sum_{i=0}^{5} S*Uc(x_0,x_i)*W(x_i,Y)\right]*A_1 \quad (5)$$

$$CIT_2=S*Uc(x_0,y_0)*\left[\sum_{i=0}^{5} W(x_i,Y)\right]*A_2 \quad (6)$$

$$CIT_3=2*(L+UL)*\left[\sum_{i=0}^{5} W(x_i,Y)\right] \quad (7)$$

$$CIT_4=(HC)*\left[\sum_{i=0}^{5} W(x_i,Y)\right] \quad (8)$$

$$CIT_5=\left[\sum_{j=0}^{5} S*Uc\left(Y_0,y_j\right)*W\left(X,y_j\right)\right]*A_1 \quad (9)$$

$$CIT_6=\left[\sum_{j=0}^{5} S*Uc\left(Y_0,y_j\right)*W\left(y_j,X\right)\right]*A_1 \quad (10)$$

$$CIT_7=2*(L+UL)*\left[\sum_{i=0}^{5} W\left(y_j,X\right)\right] \quad (11)$$

$$CIT_8=(HC)*\left[\sum_{i=0}^{5} W(x_i,Y)\right] \quad (12)$$

$$CIT_9=S*Uc(x_0,y_0)*\left[\sum_{j=0}^{5} *W\left(y_j,X\right)\right]*A_2 \quad (13)$$

$$CIT_{10}=\left[\sum_{i=0}^{5} S*Uc(x_0,x_i)*W(Y,x_i)\right]*A_1 \quad (14)$$

$$CIT_{11} = CIT_1+ CIT_2+ CIT_3+ CIT_4+ CIT_5+ CIT_6+ CIT_7+ CIT_8+ CIT_9+ CIT_{10} \quad (15)$$

Equation (5) shows the cost of distance covered by trucks by taking freight from satellite cities (x_1, x_2, x_3, x_4, x_5) in Punjab (p) towards the capital city of Sindh (s). Equation (6) indicates the cost of distance covered by freight train by taking all the material collected from five satellite cities in Punjab. Equation (7) depicts the cost of L&U the material from trucks and train before, during, and after the dispatch. Equation (8) shows the cost of H&I of the material. Equation (9) depicts the cost of travelling from KRS to satellite cities of Sindh (s). Equation (10) shows the cost of distance covered by trucks in the backward movement of consignment towards (p). Equation (11) indicates the cost of L&U before, during, and after the dispatch of the material from (s). Equation (12) shows the handling and inspection cost of the material. Equation (13) depicts the movement of freight from (s) to (p) via freight train. Equation (14) indicates the cost of travel by taking the consignment to the final customers in the satellite cities of Punjab. Equation (15) shows the total cost of road-rail freight from Punjab to Sindh (p-s) and Sindh to Punjab (s-p).

3.3 Cost analysis of intermodal freight transport

CIT_1 = [30800*5] = 154000
CIT_2 = [1210*80] = 96800
CIT_3 = 2*(70+70)*[44*5] = 61600
CIT_4= (255)*[44*5] = 56100
CIT_5= [29200*5] = 146000
CIT_6= [30000*5] = 150000
CIT_7 = (70+70)*[44*5] = 61600
CIT_8 = [180*44*5] = 39600
CIT_9 = [1210*80] = 96800
CIT_{10} = [30800*5] = 154000
CIT_T = 1262900 Pkr

In intermodal freight transport, CIT_1 shows the total travel cost in the satellite cities of Punjab to Lahore towards Karachi. The total cost (CIT_1) is 154000 Pkr. The cost of travel of rail (CIT_2) between LRS to KRS is 96800 Pkr. The cost of L&U the material (CIT_3) is 61600 Pkr. The cost of the H&I of the material (CIT_4) is 56100 Pkr. Delivering the consignment in satellite cities of Sindh is the final distance travelled by trucks to reach customers. This distance costs (CIT_5) 146000 Pkr.

The total cost of the backward movement of material includes the cost of travel cost of trucks carrying consignment (CIT_6) towards the capital city, which is 150000 Pkr. (CIT_7) shows the cost of L&U of the containers, which is 61600 Pkr. CIT8 shows the cost of H&I, which is 39600 Pkr. CIT_8 shows the cost of rail from Karachi to Lahore, which is 96800 Pkr. Lastly, consignment is delivered to the customer in five satellite cities x_1, x_2, x_3, x_4, x_5 of Punjab. The cost of delivering the shipment to the customers in Punjab is 154000 Pkr. The total cost of intermodal freight transport is 1262900 Pkr/trip.

4. Results and discussion

In this section, we studied our mathematical model by applying it to road freight transport and intermodal freight transport in Pakistan. We provided an analysis of both cases. Sensitivity analysis of the problem is given for the ease of the decision-makers to pick the best mode of transport with a minimum cost between the road and intermodal freight transport. The first objective of this paper is to estimate and analyse road freight transport costs in Pakistan. We considered the cases from (Punjab –Sindh) provinces. In this first scenario, the total cost of road freight transport is 534.8 million Pkr annually. In this scenario, five trucks transfer carried goods from the satellite cities of Punjab to five satellite cities of Sindh directly. Taking 100% capacity utilisation by the trucks, dispatch starts backwards to satellite cities of Punjab. Distance, weight, loading cost, unloading cost, handling cost, capacities of trucks & trains, containers, the demand of customers, and highway charges are included in this model.

In the second scenario of intermodal freight transport, five trucks load and move the consignment from satellite cities of Punjab and reload the consignments on railways. The rail takes this consignment to Karachi, and again, trucks are loaded with containers at KRS. Finally, trucks deliver the consignment to the customers in satellite cities of Sindh. Assuming 100% capacity utilisation of the trucks, consignment moves back to satellite cities of Punjab to the customers again by taking the same procedures of return. The total cost incurred in this movement of freight using intermodal transport is PKR 454.6 million Pkr annually. In all the scenarios, the same variables have been used to do an apple-to-apple comparison of the cost. Table 3. shows the cost incurred in road-intermodal freight transport on a daily, weekly, monthly, and yearly basis.

Table 3:Road and intermodal freight cost analysis.

Cost Saving % (Million-Pkr)	*Road Cost*	*Road-rail Cost*
Daily cost	1.48	1.26
Weekly cost	10.4	8.84
Monthly cost	44.5	37.88
Annual cost	534.86	454.64
Daily saving	0.22	
Weekly saving	1.55	
Monthly saving	6.68	
Annual saving	80.22	
Cost-saving (%)	15	

Road & intermodal freight transport in Pakistan results reveal that the cost of road freight transport in Pakistan is 15% higher as compared to intermodal freight transport. As shown in Figure 4. If we compare road freight transport with intermodal freight transport, the key difference between both the transportation modes is the distance and capacity. In the case of road freight transport, the total distance covered by trucks is larger than intermodal freight transport. Each time trucks have to carry the material from all x_1, x_2, x_3, x_4, x_5 Punjab province to reach its customer in satellite cities of Sindh province.

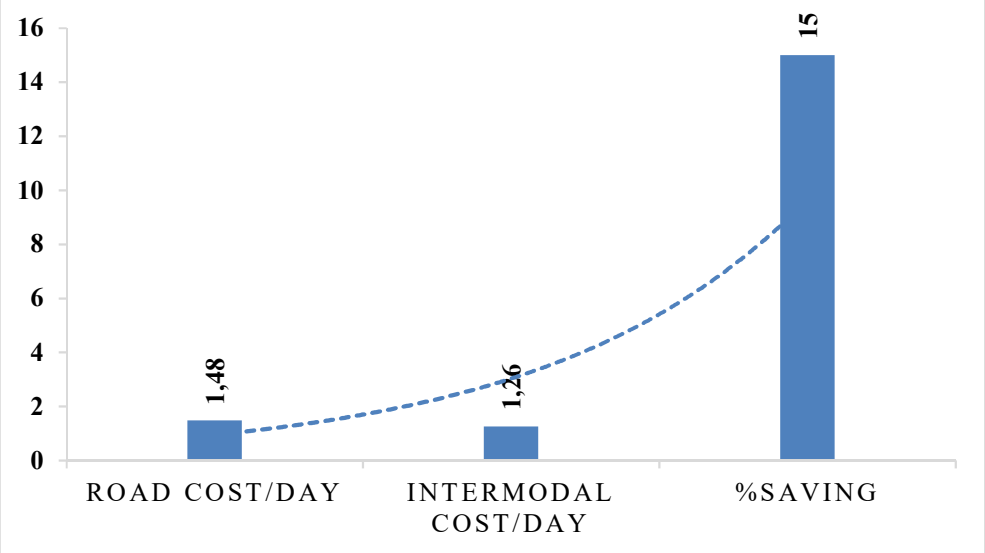

Figure 4: Road and intermodal freight cost (Million-Pkr)

Capacity in road freight transport is also a constraint because in road freight transport, the maximum capacity that can be taken by a container is 44 tons per truck. However, in the case of intermodal freight transport, the distance covered by trucks is little and trains have higher capacities to carry the materials as compared to road freight transport.

Sensitivity analysis over the capacity increase of freight train in Pakistan is presented to show changes in the overall cost of the intermodal cost.

- If we increase the capacity of the road and intermodal freight transport from 220 tons to 440 tons per day then, cost of road freight transport will be = 1.48x2 = 2.96 million-Pkr whereas cost of intermodal freight transport will be as follows:

CIT_{11} = [30800*10] = 308000
CIT_{12} = [1210*80] = 96800
CIT_{13} = 2*(70+70)*[44*10] = 123200
CIT_{14}= (255)*[44*10] = 112200
CIT_{15}= [29200*10] = 292000
CIT_{16}= [30000*10] = 300000
CIT_{17} = (70+70)*[44*10] = 123200
CIT_{18} = [180*44*10] = 79200
CIT_{19} = [1210*80] = 96800
CIT_{20} = [30800*10] = 308000
CIT_T=1839400/1000000 = 1.83 million-Pkr

As analysis depicts, the total cost of intermodal freight transport for 440 tons of consignment from Punjab-Sindh and Sindh-Punjab is 1.83 million-Pkr. The total difference in costs between the road and intermodal freight transport is 2.96-1.83 = 1.15 million-Pkr. Therefore, as we double capacity, we can save 38% of our cost by moving the fright with intermodal transport. Because trains can take massive volumes in a single trip as compared to road freight transport as shown in Figure 5.

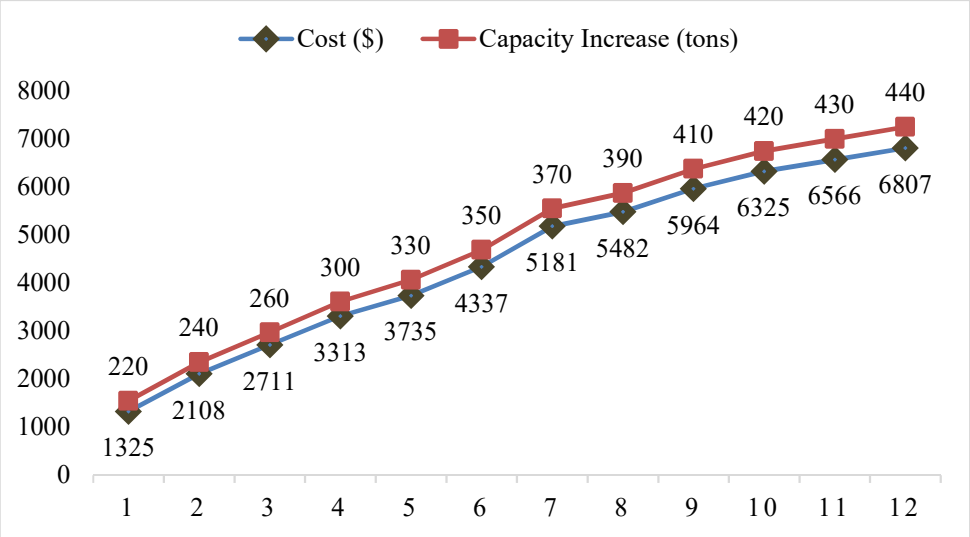

Figure 5: Capacity increased impact on the total cost

By including satellite cities of both provinces and distance between the capital cities, the total distance in the road and intermodal freight transport for the delivery of 220 tons consignment is 9635 km and 2496 km. The daily cost of both modes of transport is 1.48 million Pkr and 1.26 million-Pkr per day to take 220 tons of material. The difference between both of the distances is 9635-2496 = 7139 km/day. In road freight transport, suppliers are bearing a 74% cost on each trip. This cost can be saved by shifting the transport to intermodal transport, as shown in Figure 6.

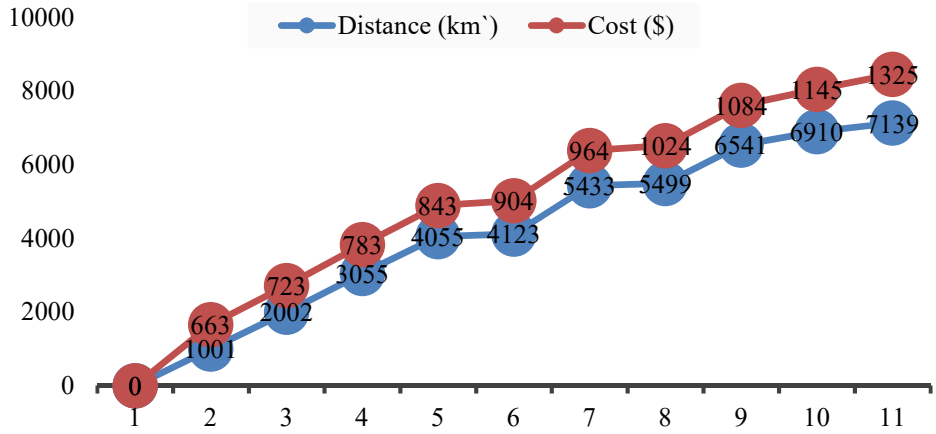

Figure 6: Distance increased impact on the total cost

5. Conclusion

As logistics services are facing global competition, intermodal transportation is receiving increased attention. Railway transport provides long-distance services that help to reduce transportation costs with an environmentally friendly solution. Road transport enables transporters to ensure flexible delivery of the products to serve a variety of locations to match fluctuating logistic demands. As results depict that intermodal transport is beneficial for safe and cheap modes of transport in Pakistan and operational benefits of road-rail freight transport with the saving of 15 per cent over road freight transport.

By integrating the uses of containers, transhipment time, and handling costs can be controlled in intermodal freight transport. Also, setting up stations that are near to the railway line and flexible transportation of freight to destinations will reduce the cost of transport. Our present study can be extended by adding factors such as labour cost, maintenance cost, cost of external damages of products, and waiting for time cost in future research. Additionally, CO_2 emission calculations are important with cost reduction.

The Ministry of Transportation in Pakistan has started working on an investment program extensively. Grown of rail & road intermodal transport is estimated to be exponential in the future.

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