

# **A comparative account on the economic and environmental efficiency of the Road and Intermodal Freight Transport Networks**

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## **Abstract**

This paper provides a comparative account on the efficiency of the two main freight transport modes {(Truck and intermodal (rail + truck))} in Pakistan. Consistent with the National Transport Policy the objective was to determine and recommend the most efficient modal choice that ensures minimum economic and environmental costs. Using data from multiple government, international (World Bank) and freight operators, we conclude that intermodal transport is a relatively green and efficient mode of transport for the longer distances from the main port city (Karachi) to the North of Pakistan (Peshawar, Rawalpindi and Lahore). Intermodal network offers economies of scale and offers sustainable movement of freight. The paper concludes with several theoretical, managerial and policy oriented implications and identifies several critical areas for future research.

Key Words: Freight transport, road, intermodal, sustainability

## **1. Introduction:**

### **1.1 Background and Context:**

The transport sector is an important contributor towards the economic development of a country. It facilitates trade, increases government revenues and creates a large number of employment opportunities and thus helps to tackle poverty. Transport contributes a significant 10% to Pakistan's GDP and approx. 20 % to gross capital formation according to the planning commission of Pakistan (2007-2012). About 6% of the people, who are employed (approx. 2.5 million people), utilize transport sector for their living as shown by afore mentioned source. An efficient and affordable transport system not only ensures employment opportunities but also aids national economic growth by lowering cost of domestic production, integrating markets, and linking people.

In the economies of regions, nations and cities, freight transportation is an important element. Through duties and taxes on its imports and production, ownership fees and licensing of modern communications facilities, the sector can prove as a chief contributor to government's revenue. Reliability of better export competitiveness is also dependent on the effective performance of the sector. Hence, a strong and economical transport system is imperative for sustainable economic development. However, in Pakistan, the performance of transport is not that much effective and encouraging to the growth of economy keeping in view the facts and figures in table 1. Pakistan is well below at different transport related parameter among other Asian comparators (World Bank, 2013) as shown in Table 1 next page.

Two major networks or modes of freight transport are operational in Pakistan that is, road and rail (World Bank, 2013). The sources of government of Pakistan (GoP) indicate that about 96% of the freight is transported through inadequate, inefficient roads causing a huge set back to the economy (GoP, 2011a). Pakistan lacks efficiency in transportation keeping in view its operational and financial efficiency and its relative role in overall economic development. In existing situation the container dwell times at ports are 7 days, 3 times that of developed countries and East Asia (Vaqaar & Ghulam, 2011). According to the authors (Ibid) road freight carries about 96 percent of cargo and takes 4-6 days between ports and north of the country, which is twice the equivalent time in Europe and East Asia. The trucking rates for high value added commodity traders are higher than India and Brazil, and same as China (where service quality is higher). Rail carries less than 5 percent of freight and takes 1 to 2 days on main line (Karachi-Lahore); and up to 16 days (Karachi-Quetta) to deliver upcountry. This is 3 times slower than China and US. Pakistan is well below the average of regional comparators when it comes to achieving a level of connectivity that can supplement economic growth in the long run (GoP, 2011).

**Table 1**

<b>Select Trade and Infrastructure Rankings for Asian Countries</b>							
	<i>Bangladesh</i>	<i>China</i>	<i>India</i>	<i>Malaysia</i>	<i>Pakistan</i>	<i>Sri Lanka</i>	<i>Thailand</i>
Logistics performance index (ranking out of 150 countries) <sup>a</sup>	79	27	47	29	110	137	35
Customs (ranking out of 150 countries) <sup>a</sup>	89	32	52	36	134	143	39
Infrastructure (ranking out of 150 countries) <sup>a</sup>	72	27	47	28	120	138	36
International shipments (ranking out of 150 countries) <sup>a</sup>	61	27	46	13	66	118	30
Logistics competence (ranking out of 150 countries)	96	29	40	31	120	141	39
Tracking and tracing (ranking out of 150 countries) <sup>a</sup>	92	29	52	41	93	142	37
Timeliness (ranking out of 150 countries) <sup>a</sup>	72	36	56	37	110	124	48
Quality of overall infrastructure (ranking out of 133 countries) <sup>b</sup>	125	66	89	27	87	63	41
Quality of roads (ranking out of 133 countries) <sup>b</sup>	95	50	89	24	65	60	35
Quality of railroad infrastructure (ranking out of 133 countries) <sup>b</sup>	65	27	20	19	51	44	52
Quality of port infrastructure (ranking out of 133 countries) <sup>b</sup>	113	61	90	19	73	43	47
Quality of air transport infrastructure (ranking out of 133 countries) <sup>b</sup>	116	80	65	27	76	64	26

*Source: WB, 2013. Page, 27.*

Research in transportation theory and economics has consistently shown synergies and scale economies when the two or more modes of transportation are used together (intermodal) for long haul freight transport (ADB 2006; Ballis 1999; Beresford 1999; Janic 2007; Kreutzberger 2006; Hanaoka & Regmi 2011; Hanssen et al., 2012).

## **1.2 Objective:**

This paper aims to develop generalized models for both road freight and intermodal freight transport. The models then would be applied to generalized and simplified configurations using data inputs from the government sources to develop a comparative account. Policy oriented analysis and interpretations of the outcome will ensure directions for bringing competitiveness and efficiency in this sector.

Section 2 provides an in-depth review of literature on the two simple forms of networks in Pakistan (Truck freight and Intermodal), their efficiency and sustainability in ensuring effective freight transport.

## **2. Review of Literature**

This section has several sub-sections. In section 1, various aspects of the two networks and their cost related dimensions are discussed and elaborated. Section 2 is focused at identifying and designing the design parameters for an intermodal terminal. These parameters are important in determining the cost and environmental efficiency of the terminal keeping in view their capacity, configuration and complexity. These aspects would then be used to determine the handling costs per unit freight. Section 3 elaborates the external and internal costs associated with the two freight transport models. In the last section a critical review of the scholarly research is provided, to compare and contrast the relative efficiency and sustainability of the two networks (road/truck freight transport).

### **2.1 Drawing the Networks:**

Janic (2007) has used some suppositions to sketch the system models for both intermodal freight transport and truck. The author claims that these suppositions simplify and regulate the sketching, estimation and deciphering of these systems. The suppositions are as follows;

#### ***2.1.1 Intermodal network:***

The network in a intermodal transportation includes multiple stages: (i) The picking up of freight in the shippers or senders' area by a truck to the intermodal terminal in the senders' zone (ii) The transshipment of the freight from the truck to the trunk-haul transshipment at the origin intermodal terminal from truck to the trunk-haul, non-road transport mode (rail, inland waterways, air); (iii) line-haul transportation between the origin and destination intermodal terminals by the trunk-haul and then to the train (iv) similarly, the transshipment of the same in the receivers' area at the destination terminal of the intermodal network from the trunk-haul to trucks; (v) and finally, the freight distribution from the destination terminal to multiple nodes by trucks in the destination area (European Commission, 2000).

##### ***2.1.1.1 Collection and distribution:***

Means of transportation of the same load and capacity factor ranging from light capacity trucks to 4 to 6 axel trucks, collect and/or distribute load units in a given zone. The origin and destination of goods is represented by network nodes. These nodes (fig. 1) represent clusters of industrial units and plants, logistics centers and warehouses, and/or freight terminals situated in

the areas of receivers and shippers. The spatial clustering of shippers and receivers is divided into different zones. The terminals in intermodal network also represent nodes but they only furnish small period storage and straight transferring/transshipment of freight. Goods flow in the two networks through standardized units/containers as elaborated in the methodology.

It is assumed that every truck makes an encircling tour of nearly equal distance at a persistent average speed. The collection stage begins from the vehicle's primary location that can be anyplace inside the 'shipper' zone represented by nodes in the diagram and finishes at the beginning's terminal of intermodal network. The network model also assumes that the distribution stage begins from the intermodal terminal of destination where the trucks are kept in group and finishes at the last receiver's reception point. Headways among the departures and arrivals of the sequential means of transportation (and thus loads) from destination intermodal terminal and at origin, respectively, are assumed to be almost independent and constant of each-other.

#### ***2.1.1.2 Line hauls between the two intermodal terminals***

Headways among sequential departures of the chief genre's vehicles among two intermodal stations are constant, thus showing the practice of numerous non-road conveyance operators in Europe to plan steady weekday facilities. The each inter-terminal means of transportation has same capacity regardless of whether it is road or rail. The mean speed and the predicted delays of the chief mode are constant and almost the same.

#### ***2.1.2 Road network***

Trucks of same capabilities and load factors move units among the source and destination regions. Items are laden on every truck for entirely one specified pair of 'regions'. The zone distance and layout among specific shippers and receivers in a particular zone critically affect the extent of vehicle trip distance. The vehicles are considered to be of uniform speed. The trucks travel among the boundaries of specific couples of the destination and origin zones alongside the similar paths at a constant line haul speed.

Built on these suppositions, Janic (2007) came up with standard model (figure 1) that offers a meek picture of these networks (intermodal and truck).

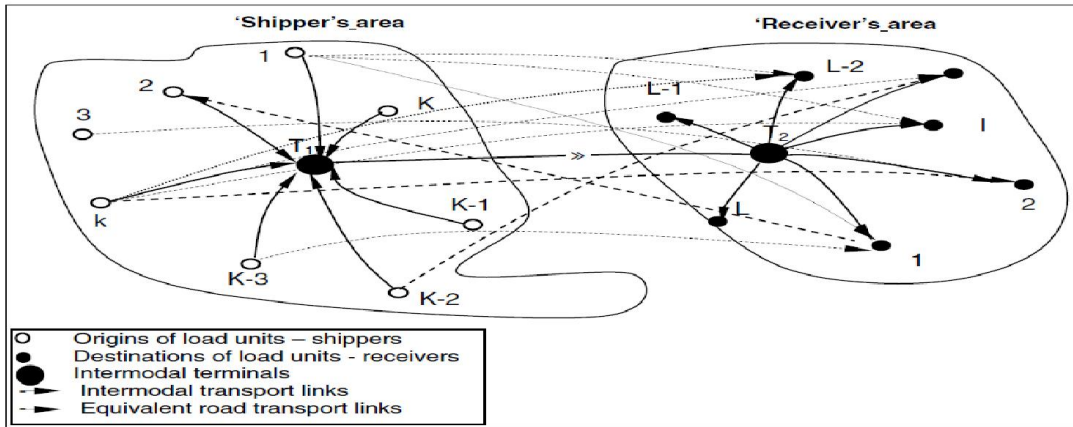


Figure 1 Source: Janic, M. (2007).

The network model as discussed previously represents a very streamlined demonstration of two freight transportation models. However, in practice, the trans-shipment of freight from a train to a truck and vice versa in intermodal transport is a complex phenomenon. There are multiple phases and stages that are integrated in a complex system and require emphasis particularly when the two freight models are considered for overall efficiency and cost comparison. The rail to road terminals offers the equipment, the operational environment and the space for conveying intermodal transport units (ITUs) among the different conveyance modes. Rail to road terminals comprise of a wide-ranging systems, extending from providing transmission between two/three modes of conveyance, to more widespread centers providing numerous value added facilities such as storage, repair, maintenance, etc. keeping in view these aspects, while comparing the generalized generalized cost model for the two modes, an additional handling cost is attributed to the intermodal network

## 2.2 Freight transport and associated costs:

Pakistan is most severely constrained by its primary resources of energy (oil and gas). About 35 percent of whole yearly commercial energy is used by transport along with consuming approximately 25 percent of the public sector growth fund per annum. A major 70 percent of public sector development fund is allotted to the communication sector and road transport. It guarantees Rs. 32.5 billion only, on the financial side, of annual revenue generation, 52 percent of which is obtained from the surcharges of POL product. Moreover the situation is even worse in railways with an accumulated deficit (2009-10) reaching 0.618 billion as stated by Asian Development Bank (2011). Poor infrastructure and bad governance cannot overcome persistent

and intensified inflation, resulting in the failure of transport system in three major areas of performance and efficiency that is at the product, financial, and operational level of inefficiencies (Tahir, 2012). The figures above only represent the internal/economic costs of the freight transport in Pakistan. The situation however, is more devastating from the welfare economics perspective when the social and environmental costs of freight transportation are taken into account. Time related costs represented by unnecessary delays, expiry and damage to the freight, disruption and delays in economic activities, pollution and community related fatalities and damages if considered may increase the costs in subject by more than 100%. This paper however, focuses only on the internal/economic and environmental costs of freight transportation only. The sections below provide a brief and comprehensive summary of both the internal and external environmental costs and their underlying elements.

### ***2.2.1 A summary of internal cost models:***

Transport capacity provision, cargo volumes and characteristics, alternatives of mode and route, customer needs and logistical constraints combine to make decision-making process regarding "which node, which mode", an extremely complex one for long-distance international freight transport. Major factors which affect the modal choice and route are: commercial considerations, customer preferences, cargo characteristics and logistical circumstances (McKinnon 1989; Beresford 1999). In an effort to develop a complete cost model for freight transport (Beresford, 1999) derived a improved form of the multimodal transportation cost model, proposed by Beresford & Dubey (1990). The author (Ibid) argues that the model is sufficiently flexible and stand-alone to be incorporated in any normal operational circumstances and supply chain of any length. Time, cost, mode of transport, distance and intermodal transfer are therefore the main components of the model. One can also come across simple cost-distance models of rail versus road (Hayuth, 1992) and (Tweddle et al., 1989) for national movements and over longer, transnational routes (Hayuth, 1987). At their core, is essentially an implicit valuation risk of loss or late arrival, deterioration in shipment expressed in terms of generalized cost of transport (Goss, 1991). Now, how does a shipper or customer decide about a specific network? A shipper or customer will have to select the respective modes fulfilling the requirements of stipulated delivery and to accordingly choose a method, mode and route of transport. The decisions will be made further complicated by factors such as perish ability, whether or not the commodity or

consignment forms part of a manufacturing or assembly process where delayed arrival may prove extremely costly and cargo value density ratio (McKinnon, 1989; Evans et al., 1995).

Pakistan's economy experiences another major cost in the transport sector caused by inefficient roads and poor railway infrastructure. According to World Bank (2013) an excess of approximately 8.5% of GDP counting up to Rupees 220 billion are imposed by inadequate system of transport further hindering economic growth and transport competitiveness. As discussed earlier this significantly higher cost structure has led to the failure of our transportation system at all three levels of performance analysis (Operational, Product and Financial).

The discussion above has only catered to only one aspect of the economic costs of transport sector in Pakistan that is the internal costs. From the perspective of welfare economics, these are not the only costs associated with the transport operations. Without questioning the fact that to achieve efficiency emitters should pay for the true costs of their actions (a core principle of economic policies such as pollution, taxes). These cost involve following major categories as argued by Ricci and Black (2005); Fixed assets/maintenance of assets, Personnel, Energy, Time, Stock turn, tax and insurance charges and organizational charges.

### ***2.2.2 A review of the external costs:***

The cost incurred by other stake holders (society) due to operations of a particular function must also be considered and internalized for adequate cost benefit analysis. These costs usually termed as external cost comprise of (for transport sector) air pollution, congestion, noise and traffic accidents (Janic, 2007). Transport contributes significantly to environmental pollution (acidification, local air pollution, ground level ozone formation and noise) causing a threat to the life and society. Because of its reliance on non-renewable fossil source of energy, transport emits huge amount of carbon dioxide (CO<sub>2</sub>) and other green house emissions. Studies have found that in addition to nitrogen oxides (NO<sub>x</sub>), non-methane volatile organic compounds (NMVOC), carbon monoxide (CO) and particular matter (PM), road transport emits 24% at an average of the CO<sub>2</sub> emission, a principle component of the green house gases (Saija & Romano, 2002). According to the authors, transport contributes significantly to environmental pollution (acidification, local air pollution, ground level ozone formation and noise) causing a threat to the life and society. They (Ibid) conducted their research in order to estimate the CO<sub>2</sub> and other pollutants' emission at local level in Italy. The authors have followed the assumption that bottom up approach will require an intensive and accurate data on the variables; fleet composition, speed



and vehicle flows etc., which may not be feasible. Therefore, using the technique of computer programming to estimate emission from road transport (COPERT), the authors have followed a modified top down approach. They have considered local information and peculiarities in order to come up with relatively reliable estimates of the parameters. The mathematical model COPERT is based on information databases with larger and wider scopes for example, national level automotive fleet. It also incorporates a number of other associated parameters, for example, fuel consumption, the emission function based on speed, the average mileage and speed for each vehicle.

However, authors like Piecyk & McKinnon, (2007) emphasize the intricacy of bringing together an precise and reliable account of emissions related data for the trucking vehicles. They posit that the estimates of emission are calculated by diverse methods and using diverse data can lead to unreliable cumulative trends and measures. In addition extensive modifications in official estimates of emissions for road freight in the recent years, have raised reservations about the trustworthiness of the earlier standards. In an effort to internalize the road freight external costs in the United Kingdom (UK) the scholars (Ibid) paid attention to three major categories of costs: environmental costs (including air pollution, climate change, accidents and noise), infrastructure costs and congestion costs. They raised two kinds of situations: a 'base-case' using vehicles' emissions data from the National Atmospheric Emissions Inventory of the government, and the other, a 'worst-case' situation, followed the supposition that all vehicles emit the maximum quantity of pollutants allowed by European Union regulations. They estimated total infrastructural, environmental and congestion costs that could be attributed to registered heavy freight means of transportation in UK. Their findings suggest that the taxes paid by heavy goods vehicles cover about 67% of the costs (in the base-case scenario). The total cost share that is internalized was different for a particular vehicle class. The lightest class of rigid trucks covered only 55% of their owed costs, but the heaviest class of rigid trucks enveloped 79%. Overall, they suggest a 50% increase in taxes should be employed on Lorries in order to fully internalize environmental, infrastructural, and congestion costs. These findings suggest that the 'polluter pays' principle when only applied in the road freight sector, may lead to market distortions with respect to other modes of freight transport (Rail, water and air with different nature and extent of externalities) will occur, causing a significant shift in modal demand.

### **2.3 Intermodal freight transport (a green efficiency perspective on freight transport):**

Intermodal freight transport, the combination and integration of several modes, with the use of loading units, has been said to be more environmentally friendly than uni-modal road transport for the carriage of goods. The political and scientific interest in this transport market is largely due to the sustainability and ecological aspect of the intermodal transportation system (Kreutzberger et al. 2003). Intermodal transport has gained prominence recently due to its potential to offer door-to-door service through the integration of various modes of transport in the logistics chain, improved coordination and services, the development of intermodal interfaces and improved cost (energy usage), emission and environmental implications (Kreutzberger, Macharis, & Woxenius, 2006). In their paper, Hanaoka & Regmi, (2011) reviewed the status of intermodal freight transport in Asia from an environmental perspective. They have examined intermodal transport opportunities presented by the development of inland dry ports in hinterland locations. The authors (Ibid) have provided comprehensive insights into the emergence of intermodal transport in Asia, highlighting the role of transport links, nodes, and services. It elucidated the potential environmental benefits of intermodal integration through the development of dry ports. They used case studies to emphasize various factors that have influenced the development and operation of dry ports and intermodal transport. In addition to focusing upon infrastructural development, this paper has also revealed the need to consider operational issues in coordination with infrastructure development. By exemplifying to the cases of the Birgunj, Uiwang, and Thailand, authors have pointed out to the fact that railway connections to dry ports can reduce freight emissions of CO<sub>2</sub> and local air pollution through a modal shift that reduces the number of long-haul trucks plying on roads.

The authors (Ibid) finally conclude that the policy issue that needs to be addressed for the development of dry ports, is coordination among the various government agencies involved in the development of dry ports, including those responsible for licensing, investment, promotion of private-sector initiatives, etc. Both government and the private sector need to work together to develop intermodal transport in Asia that not only provides access to inland and landlocked areas but also promotes environmentally friendly freight transport.

To conclude, literature regarding the relative efficiency of the two networks is not conclusive and indicate that there may be route, infrastructural and technology specific implications that may affect their performances. There are studies which are pessimistic about rail freight's potential contribution to energy usage reduction and environmental improvement (Behrends,

2012). As the accessibility of the rail network is relatively low, pick-up and delivery to and from rail terminals by diesel trucks (pre- and post haulage, PPH) are required which often take place in urban areas. Some scholars (Kreutzberger et al., 2006) therefore, argue that although total external effects are lowered, unwise use of intermodal road-rail transport (IRRT) can add to impacts in urban areas, where the negative effects of emissions, congestion and land use are most severe. On the other hand, several authors (Hanssen, Mathisen, & Jørgensen, 2012; ADB 2006; Ballis 1999; Beresford 1999; Janic 2007; Hanaoka & Regmi 2011; World Bank 2013) posit that intermodal transport may be cost efficient if the economies achieved by long haul transport are sufficient enough to offset the additional costs of trans-shipments and pre-post haulage.

To address the problem, this research focused at;

- Developing generalized simplified models for both road freight and intermodal freight transport.
- Applying the two models using data inputs from the government and other sources to develop a comparative account.

### **3. Methodology**

#### **3.1 Modeling the internal and external costs for each network:**

Janic (2006) by referring to Doganzo (1999) has developed standardized models for the internal and external costs of intermodal (rail + truck) and equivalent road freight transport networks. In addition to the generalized overall costs for each network, the models also provide a comprehensive representation of the individual components and their associated costs. We have adapted and simplified these models in view of limited data availability and nature and scope of this research. Two types of commodities, that is, coal and furnace oil are selected as freight commodities in our application of models. These commodities are selected based on their lowest perish ability and discount factor in order to standardize our cost estimation and comparison of the two models. However, data regarding both the networks are specific to the distinct components of the two networks. This is obvious as both the networks have diverse technology, actors, infrastructure and environmental conditions. The two cost models are given as under;

##### ***3.1.1 The Internal Costs:***

$$\text{Transport Costs} = (\text{Frequency (F)} \times \text{cost per frequency (C}_f\text{)}) \quad (1)$$

While Frequency = (Demand/Load Factor  $\times$  Vehicle Capacity)

While cost per Frequency = transport operations cost + Time Cost + Handling Cost

Load factor is the ratio of the average load to total vehicle freight capacity in tons or volumes (McKinnon, 2007; Elbern, 2010). This indicator is relevant normally as less vehicle kilometers (kms) are needed to transport the same volume of freight with efficient loading of vehicles. Hence increasing load factor leads to a reduction in freight traffic volumes and thus their costs (Elbern, 2010). However in Pakistan almost all of the traffic through road transport is overloaded (World Bank, 2013). According to the aforementioned source the standard axel load for truck freight is 12 tons while it usually exceeds 15 tons/axel. That is why we did not consider the load factor for the truck freight mode and frequency in equation 1 represents Demand (D) divided by Vehicle Capacity (Vc). Equation 1 then becomes;

$$(i) \quad \text{Transport Costs} = D/Vc \times C_f \quad \text{or} \quad F \times C_f \quad (2)$$

We have taken the standard freight rate for both truck network (GoP 2012) and rail freight (Pakistan Railway) as the standard costs of transport. These standard costs are then multiplied by a particular distance travelled by the two networks to compare the total, internal and external transport costs in view of the unit demand.

$$(ii) \quad \text{Time Costs} = \{D \times T\} \times (C_{td}) \quad (3)$$

(T represents time and  $C_{td}$ , Cost per unit of time per unit of demand)

As discussed earlier, we selected a standard type of freight commodity i.e coal which has relatively negligible time elasticity of demand (Bowersox, 2011). That is why we did not consider the time cost while calculating the standard economic costs for both the networks/modes.

$$(iii) \quad \text{Handling cost} = \text{Demand} \times \text{Cost per unit of demand}$$

The handling costs per ton of standard containerized freight are Rs. 1300/ton according to (Bowersox, 2011). In an intermodal network the collection and distribution steps (by trucks), also called as Pre and Post haulage (PPH) exactly represents the collection and distribution in the truck freight network. Hence we do not considered the handling costs for the collection and distribution steps of both the networks. However, the main line haul (by train) and the trans-shipment from truck to train and train to truck have unique infrastructural, technological and thus cost profile. That is why the handling costs are only considered for the trans-shipment of freight at intermodal terminals and/or dry ports. Adding the time costs and handling costs to the transport costs in equation 2 gives us the overall internal costs for the two networks individually as;

$$(i) \quad \text{Internal Costs for Truck freight} = \text{Transport Costs} \\ = (D/V_c \times C_f) \quad (4)$$

$$(ii) \quad \text{Internal Costs for Intermodal freight} = \text{Transport Costs} + \text{Handling Costs} \\ = \{(D/V_c) \times C_f\} + (3000/\text{TEU}) \quad (5)$$

As discussed in chapter 1 only 4% of the freight transport currently is done through rail keeping in view the operational and infrastructural level complexities of the network, hence limiting the demand for intermodal network too. Keeping in view the reality the authors have considered standard load units (unit demand) in place of total demand to simplify the cost comparison. Section 4.1 provides an elaboration of these standard transport load units called as Transport Equivalent Units (TEU).

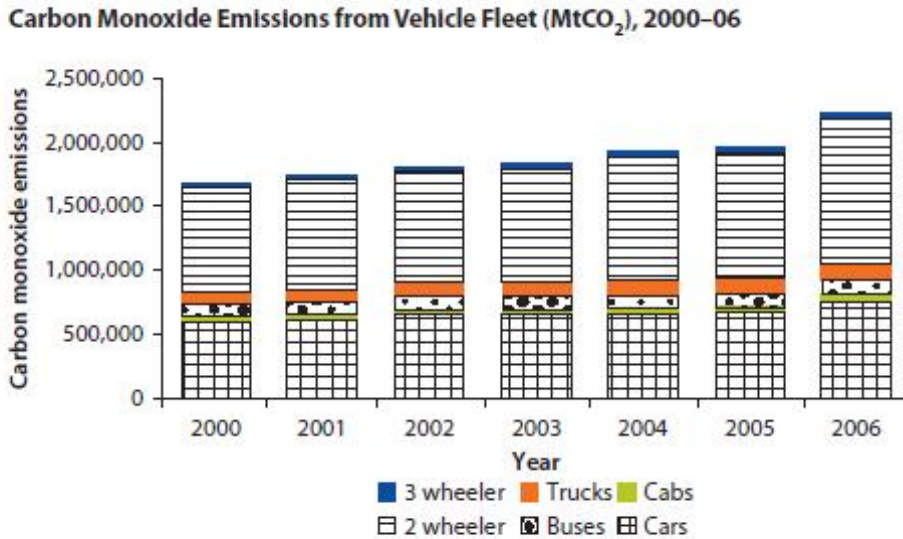
### **3.1.2 The External Costs:**

Janic (2006) has followed a four stages process for measuring the external costs. Initially, the nature and extent of the emission/burden on the society is identified. Second, they quantified the spatial concentration of these emissions in a unit space, followed by the assessment and quantification of their damages. Finally, they have assigned monetary values to the short term and long term damages. However, due to the lack of appropriate data, poor governance and infrastructure and time limitations, we have adapted the external costs from the source of World Bank (2013). The unit (ton-km) costs are then calculated based on the total capacity of the

freight mode and the standard discount rate as adapted by Pakistan Environmental Protection Agency. The next section provides a comprehensive account of the external cost components and their potential contribution to societal costs associated with freight transport.

**3.1.2.1 Air Pollution, Particulate matter, Noise and other environmental costs:**

Air pollution is amongst the most severe problem of public health in Pakistan (World Bank 2006a, 2011). Transport contributes significantly to the pollution of ambient air. With the increase of registered vehicles in Pakistan, air pollution levels also increase. Situation is worse in urban localities, mainly in heavily occupied metropolitan areas for example, Karachi, Lahore, Islamabad-Rawalpindi and Hyderabad, and Islamabad-Rawalpindi. Although trucks stand for a small portion of the vehicle fleet of Pakistan, they release toxins of local as well as global apprehension. In 2010, registered trucks stood for 3 to 3.5 percent of total registered vehicles. These trucks run on oil that contains elevated sulfur content, a major component in the development of particulate matter (PM). The majority fuel has a sulfur content of 5,000 to 10,000 parts per million in Pakistan, a level a lot advanced than Euro II, Euro III, or Euro IV standards for emission (World Bank 2006c).

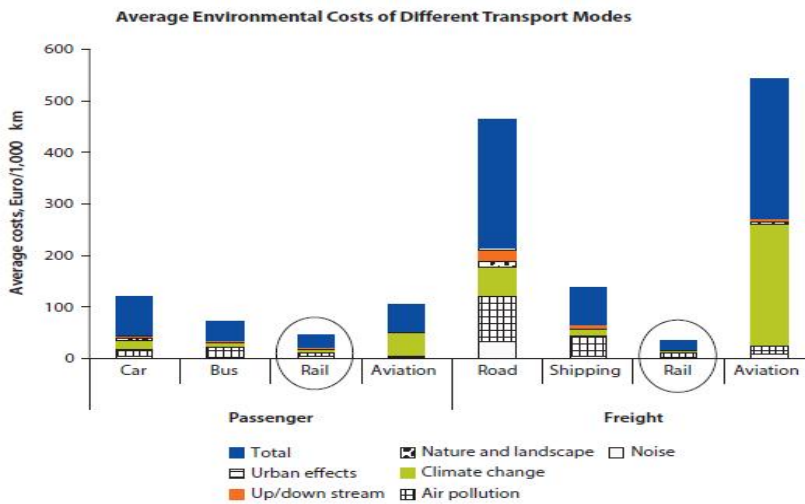


**Figure 2**

*Adopted from WB (2013) pp 85*

As evident from the figure above the truck fleet guarantees a significant contribution to the carbon monoxide emission. The above mentioned source also identified the suspended

particulate matter, non-volatile methane compounds, noise and other environmental effects ensure significant amount of costs to the society. The data regarding these environmental variables and their associated costs is very hard to obtain keeping in view the technological scope, time and other resources of this study. That is why we relied on the secondary data available regarding the environmental costs of the two networks. Figure 3 below shows the summary of environmental costs accrued to the society by different modes of transport and freight distribution.



**Figure 3**

*Adopted from WB (2013) pp 86*

Figure 3 above shows a brief summary of the associated costs for each component of the environmental pollution (air, noise, accidents etc). According to the source total environmental cost per 1000 tonne km of freight for road freight and intermodal networks are €250 and €100 (equivalent Rs. 34000 and Rs. 14,400) respectively. However according to INFRAS (2004) these costs are not static and their extent varies with respect to area (urban, rural) and kilometers travelled. Consistent with the European Environmental Protection Agency and (EEA) and Pakistan Environmental Protection Agency (Pakistan EPA) discounted these costs with standard discount rates (EEA term 030, October 2010).

#### **4. Application of the Model:**

The cost models developed and emphasized in the previous section are applied to a basic transport network from the southern coast to the north of the country (Karachi to Peshawar). The

average road distance between Karachi and Peshawar is 1400 kms approx. according to National Highway Authority website. The length of rail track is approximately 1700 km (Pakistan Railway).

#### **4.1 *The networks' load units and operations:***

The road network systems transport uses two axel trucks carrying 2 transport equivalent units (TEU=12 tonnes) which are common all over the country. The average weight of each unit is 28.6 tonnes which contains goods weighting 24 tons while the remaining 4.6 tons are tare (European Commission, 2001a).

For the road networks, two axel trucks (TEU) are considered as standard freight transport units with an average speed of the vehicle (only one stop assumption both in collection and in distribution) is taken as  $u = 35\text{km/h}$  and  $d=50\text{km}$ . While average vehicle speed from origin to final destination zone is  $v=60\text{km/h}$  in the road network. The operating cost of the vehicle is determined on the basis of vehicle full load which is equivalent to two load units of 20 feet length (2 TEUs) and are considered to be equal for both the network modes.

The handling cost is included in the vehicle cost for both transportation networks. The collection and distribution steps at both the networks represent almost similar technology and cost structure and taken as zero for both the networks. However, the transshipment costs for each intermodal terminal are taken as Rs. 3000/TEU according to the sources from Pakistan Railway. The total transshipment handling cost for 20 flat cars trains (with a load factor = 0.75) becomes Rs. 135000/terminal/frequency. The external costs for both the network are taken as a whole as mentioned earlier (World Bank, 2013). Table 2 and 3 show a summary of the different cost components for intermodal and road freight networks respectively. The data regarding the cost per ton km and their progressive adjustment with increase in distance is collected from multiple sources. These include ministry of transportation, composite schedule of rates government of Pakistan, World Bank and government and railway freight forwarders. Initially we calculated the cost per frequency (eq. 4 and 5) for both the transport modes through a simplified and standardized forms of their respective networks. Later the implications of these costs are drawn keeping in view the demand capacity and frequency of the two modes. The outcomes are summarized in table 2 below.



<b>Intermodal Freight</b>								
<i>Capacity TEU**</i>	<i>Distance kms</i>	<i>Transport Cost @16/tonne km*</i>	<i>Transshipment Handling Costs @ 3000/TEU*</i>	<i>Total internal Cost/km</i>	<i>External Costs/tonne (@ 1.5/tonne-km**)</i>	<i>Total Economic Costs</i>	<i>Economic Costs/t-km(intermodal)</i>	<i>Internal Costs/t-km(intermodal)</i>
45.0	100.0	1044000	135000.0	11790	0.0	12600	23.3	21.8
45.0	300.0	7200.0	135000.0	474.0	0.0	474.0	0.9	0.9
45.0	500.0	12000.0	135000.0	294.0	0.0	294.0	0.5	0.5
45.0	700.0	16800.0	135000.0	216.9	0.0	216.9	0.4	0.4
45.0	1000.0	24000.0	135000.0	159.0	0.0	159.0	0.3	0.3
45.0	1200.0	28800.0	135000.0	136.5	0.0	136.5	0.3	0.3
45.0	1500.0	36000.0	135000.0	114.0	0.0	114.0	0.2	0.2
<p>*Discounted 10% till 600 kms and then 5% till 1100 and then fixed</p> <p>*** Taken as Rs. 18 per TEU, consistently discounted @10 % on each 100 kms due to progressive decline in environmental costs</p>								
<b>Truck Freight</b>								
<i>Capacity tonnes</i>	<i>Distance kms</i>	<i>Transport Cost @10/tonne-km*</i>	<i>Transshipment Handling Costs @ 0000/TEU*</i>	<i>Total internal Cost/km</i>	<i>External Costs @ 3.4/tonne km**</i>	<i>Total Economic Costs</i>	<i>Economic Costs/t-km (truck)</i>	<i>Internal Costs/t-km(truck)</i>
24.0	100.0	40000.0		400.0	81.6	481.6	20.1	16.7
24.0	300.0	72000.0		240.0	73.4	313.4	13.1	10.0
24.0	500.0	97200.0		194.4	66.1	260.5	10.9	8.1
24.0	700.0	136080.0		194.4	59.5	253.9	10.6	8.1
24.0	1000.0	194400.0		194.4	53.5	247.9	10.3	8.1
24.0	1200.0	233280.0		194.4	48.2	242.6	10.1	8.1
24.0	1500.0	291600.0		194.4	43.4	237.8	9.9	8.1

\* Fixed Rs. 40000 for the first 100 kms. Then a variable cost of Rs.120/TEU-km discounted at 10% till 300 kms and then fixed.

\*\*discounted @10% till 500 kms

**Table 1**

The train consists of 20 flatcars which operate between two intermodal terminals. In this network, each car has a weight of 24 tons. The train as a whole makes the capacity that is equivalent to the 60 TEUs. The average load factor of  $k=0.75$  makes per train weight of freight equal to 540 tons. The average anticipated delay and average speed for both the networks as mentioned earlier are not taken into account. Total internal costs are adjusted for the discount rates of freight operations as specified by the government of Pakistan sources including

composite schedule of rates, Pakistan Railway and private road freight transport companies (Notes Tables 3 and 4). The estimated external cost of the train and truck are adopted from aforementioned source of World Bank (2013) as given in figure 3. These external costs as summarized earlier are incurred by the society due to global and local air pollution, traffic accident and noise pollution. These costs, according to European Environmental Agency (EEA term 030, 2006) and further verified by the Pakistan Environmental Protection Agency are discounted at a pre-specified rate on several stages on the basis of ton-kms (Notes Tables 2 and 3).

#### 4.2 Comparing the two modes:

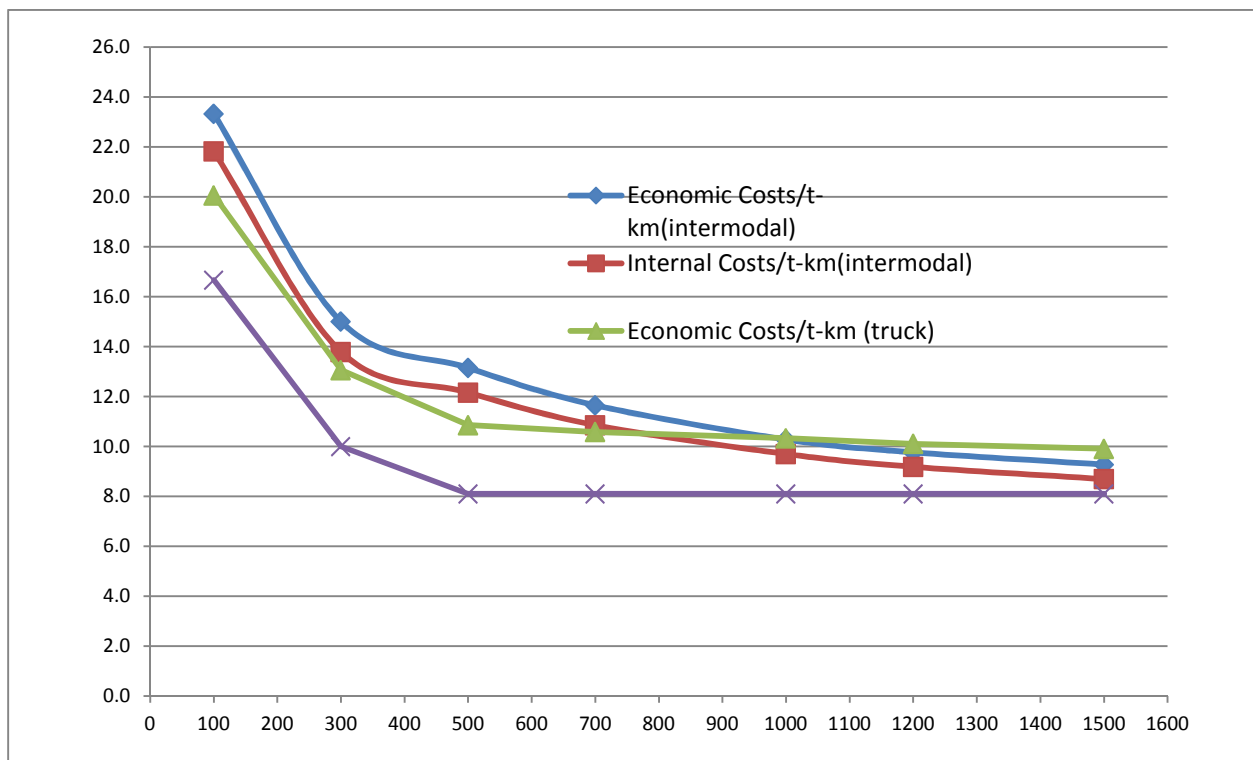


Figure 4

Figure 4 shows that if there is increase in door-to-door distance, it decreases the average internal cost at a comparatively higher rate in intermodal network that the truck based road freight transportation which indicates the economies of distance. The findings specifically imply that in intermodal network, the higher rate decrease in internal costs make the network equal to its counterpart road network at about 1000 km distance and it lower increasingly afterwards. This

implies that intermodal transport network is the competitive substitute to the long haulage transport network beyond the breakeven distance mentioned above.

The average internal cost relationship of both the networks, that is, intermodal and road transport may explain the current split partially in Pakistan between two modes as mentioned earlier (96% freight and 4% train). The road transport operational cost is much lower than its counterpart operational cost over short, medium and over some long-distances marketplaces which in turn in combination with other regulatory factors and market characteristics (higher fragmentation and clustering in Post City of Karachi and Lahore and fierce competition between smaller 1 to 3 truck owners etc) can lead to lower prices. This implies that more price sensitive and ample commodities specially at a smaller scale and over short, medium or long distances (about 90% up to 600 km) are attracted by the truck based road networks. However, in reality for a particular demand, for example, 45 TEU the number of runs for a truck (2 TEUs) are almost at minimum 20 times higher than rail transport. This implies that the extent of external costs of truck freight as indicated in our analysis may partially present the actual scenario and overall cost efficiency related implications of intermodal networks may be much higher.

## **5. Conclusion:**

As the distance between door-to-door increases, the external and internal cost sum decreases with more than proportionate. This decrease rate is higher in intermodal network which suggests that break-even is achieved at distance of 1050km which is longer than operational cost break-even distance. It is due to the fact that demand volume on these distances is usually low, prices based on full cost can affect the previously low but price sensitive demand which makes the condition complex for intermodal transportation to gain more share of market. These conditions together with the significant delays in the train transport networks (Table 4) raise many policy related questions. First, regarding the policies efficacy of government of Pakistan and World Bank that hopes to bring economies of distance and scales in the freight transport systems through a modal shift from road (96% current) to rail Freight (4% current). Second, the policy orientation to internalize trade and freight externalities in order to strengthen the intermodal transport network market position and foster sustainable development. However, our findings also provide some promising insights that support the current efficiency and environmental policy focus. Table 2 shows the full costs structure for the intermodal transport network. There is

a relatively greater decrease in the share of terminal/rail external cost as the door-to-door distances increases. The distance of the major cities like Peshawar, Quetta, Lahore, Rawalpindi are greater than approximately 1000 kms and hence may favor intermodal transport in this regard.

**Table 1**

<b>Arrival Performance for Runs during March 2008 from Karachi to Lahore</b>		
<i>Performance</i>	<i>Number of trains</i>	<i>Percent</i>
Arrived on time or earlier	3	8.57
Were late by 1–5 hours	13	37.14
Were late by 6–10 hours	12	34.28
Were late by 11–15 hours	5	14.28
Were late by 16–22 hours	2	5.71

*Source: WB (2013) pp 31*

The outcomes ensure several theoretical, practical and policy oriented implications. First, Awareness of the full costs of freight transport services should help businesses to plan and manage their logistics in a way that achieves longer term sustainability. This may involve greater use of alternative modes, their integration; more localized sourcing; improved vehicle utilization and even some relaxation of current just-in-time scheduling. Second, if the higher freight costs associated with greater internalization are passed down the supply chain, the purchasing behavior of final consumers should also become more sensitive to the environmental impact of the distribution operations that keep them supplied with goods and services. Finally, the outcomes can guide policy makers to tailor and modify current external cost internalization and regulation policies and guideline in view of other market related dynamics. Several limitations however, to the findings can be found, attributable to the variability in degree of the estimation of external cost between the two base cases. For example, if congestion costs are excluded, it appears that lorries more than cover their infrastructural and environmental costs, even in the worst case scenario. At 40% of the total external costs, congestion exceeds the share of costs attributable to environmental impacts (36%) and infrastructure (23%). Another issue is with the practical and policy implications of the findings that is, taxing road freight operators more heavily to recover a higher proportion of external costs would reduce the financial resources they have available to upgrade their fleets and introduce other ‘green’ measures.

Our paper has a number of limitations that can be focused for future research to adequately address the issue, draw cost models accurately and project policy related implications. First, our methodology does not cater to the unique technological and infrastructural constituencies of the intermodal collection and distribution steps. Future research should focus on identifying the specific route, vehicle types and extent in the collection and distribution steps of the network. Second, for road transport we have considered two axel vehicles only, while there also exist single, 3 and even four excel vehicles that may question the findings in table 3. Third, as mentioned earlier the time cost if considered may significantly change the cost structures for both the networks and thus their policy implication. This is particularly important for the intermodal freight network as evident from the figure in table 4. Special care (primary research) should be taken in using these figures as these may not match the current government's policy reforms, improvement in governance and better performance of the rail system. Fourth, we have used the data set from 2012 only for the standardization of network models and their respective costs. Future researchers must incorporate a data set of broader scope to comprehensively address the economic and monetary dynamics associated with the freight transportation with respect to time and duration. Finally future research should also take into account the fact that majority of the road freight fleet consists of vehicles that are more than 15-20 years old. This means that our estimates of the externalities associated with road freight transport may only partially represent their actual extent.

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