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A Life Cycle Cost Analysis Model of Goods Movement for the Gulf Cooperation Council Region

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Abstract

In this article, a total life cycle cost analysis (LCCA) were developed covering two transportation systems: trucking and railway within the Gulf Cooperation Council (GCC) region. GCC region is a regional intergovernmental political and economic union consists of six countries (Saudi Arabia, Kuwait, the United Arab Emirates, Qatar, Bahrain, and Oman). In general and based on statistics, the GCC regional economy is expected to grow due to the increase in aggregate supply and demand. So, there is a need to build a solid foundation of transportation systems that can help in transforming this region into a logistics hub. Therefore, different analysis were discussed in order to be able to select more reliable and appropriate mode of shipping between the GCC. Beside the main cost factors that which includes the capital, operational, maintenance and depreciation costs. Other factors such as, border delays, emissions, noise and safety factors were added to the analysis. The results shows that, shipping using trucking system can be cheaper when shipping commodities between the GCC region, but at the same time considering border delays and emission produced, railways and intermodal modal systems prove to be more reliable. Moreover, shipping bulk commodities favor the rail and intermodal systems due to the payload capacity besides the flexibility of finding the most efficient way to move the shipments between origin and destinations.

Keywords

Rail, Truck, Freight, Intermodal, Cost, Transportation, Life Cycle

1. Introduction

The development of transport activities are strongly correlated with the economic and population growth. It is visible and expected that the economies of the six Gulf Cooperation Council (GCC) countries are likely to continue developing, due to the oil and petrochemical market, tourism industry and other economic diversification. However, due to the geographic location of the area, freight transportation can be considered one of the most important systems that can be developed to meet future challenges and to support the economy of the Arabian Gulf area.

Several research studies have been carried out to determine the critical variables which effect and govern freight transportation costs. In 2001, Forkenbrock has compared the external costs of rail and truck freight transport, while considering the shipping cost [1]. This cost was inclusive of air emissions, safety, and noise factors that influence the well-being of society. This approach emphasizes the importance of acknowledging such factors when transportation strategies are designed. Several matters and challenges surrounding these factors need to be discussed when moving goods, such as green gas emission releases [2]; locating the intermodal facilities to get the maximum benefit of the current freight flow [3]; additional consideration given to economic shipping styles [3]; reliability issues that are significant to both public and private sectors; and the willingness of freight shippers to pay for faster and more reliable service [4]. In conclusion, users are required to make their mode decision in relation to all environmental costs, security matters, financial costs, weather conditions, and rules and regulation matters of freight distribution. Based on the literature, lack of costs data such as accident cost, environmental impact cost, noise cost, and depreciation data might lead to potential bias analysis [5]. On the other hand, limiting the study to one city or to a smaller amount of data also might affect the results [6]. Very limited studies have been conducted on a large network that can cover both rail and road networks [7].

A very few number of studies as well have been performed on the Arabian Gulf area on freight transportation and life cycle cost analysis, which is the main focus of this paper. The uniqueness of this area is that the countries' boundaries are open only 10 hrs a day for freight purposes and as a result shipments suffers a huge delay waiting for inspection and crossing the border, which affects decision making on transport processes in specific ways. The life cycle analysis and shipping mode selection decision can be impacted by infrastructure cost, operation and maintenance costs, depreciation cost, delay cost and other external factors (such as noise, pollution and accident costs). Unlike other studies, a total life cycle cost analysis will be included in this paper for both trucking, railway, and multimodal systems. A framework model will be developed and analyzed in order to have an efficient tool for optimization and design system strategies in future.

2. Transportation Network of Study Area

There are well-developed road transportation systems connecting the GCC countries. However, there is a need for more reliable system in terms of capacity and, transit time and environmentally to cover and support future demand. In comparing some of the GCC countries to the leading countries in transportation systems, the GCC region does not have appropriate railway system to support the future vision of transforming the area into a logistics hub. Comparing two of the GCC countries to the foreign countries that has excellent economic base that serve as logistic hubs, due to its commercial transport activities. Table 1 summarizes an overview of the key characteristics of the ground transportation of leading countries compared to UAE and Saudi Arabia.

Table 1. *Comparison of the Key Characteristics of Leading Countries Compared to UAE and Saudi Arabia, [8].*

	Australia	Sweden	UK	UAE	Saudi Arabia
Population (Million)	22.3	9.1	63.4	5.5	26.9
Area (x000 Sq-km)	7,700	450	240	84	2,100
Roadway length (x000 km)	360	570	390	4	48
Expressway length (x000 km)	20	1.9	3.5	3.5	3.9
Rail route length (x000 km)	38	13	16	0	1.4

In addition, to the existing connections between GCC countries via express highways and the current Saudi rail line, various studies have proposed connecting all six GCC countries and also connecting Asia and Africa using a rail system across Tiran and Sanafir Islands. In order to implement developments on such a large scale, a detailed life cycle cost analysis (LCCA) needs to be performed in order to achieve the highest benefits cost ratio. Figure 1 shows the current and future plans of rail freight transportation for the GCC countries.

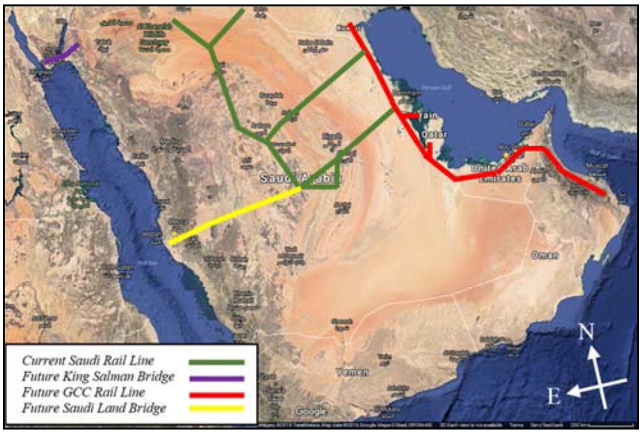

Figure 1. *Current and future rail freight lines and bridges at the GCC region [9].*

Table 2 shows the import and export statistical data for national goods in 2006 to provide an idea of the movement of goods within the GCC countries. The main commodities were gravel, stone, limestone, cement, fruits, vegetables, and containers. However, in 2016, the freight traffic forecast for the GCC region shows that the traffic will increase to more than 60,000 tons and container shipping it's expected to increase by 10 % for the next 10 years [10]. Also, there are millions of tonnes of freight trade between the GCC countries and neighboring other Arab countries.

However, all of the above quantities were shipped using various modes of transport, including vessels, rail, and trucking systems. Most international shipping was transported using ships in this particular timeframe, but at the same time carrying containers using rail and trucking systems be cheaper and faster than ships especially within the GCC area. To investigate more on how trucking and rail systems can be cost effective and timely, further discussion of a LCCA will be presented for future implementation.

3. Life Cycle Cost Analysis Overview

Freight transportation models and analysis tools can be helpful in estimating the costs benefits, and total cost assessment along with determining reliability of freight transportation. LCCA in freight transportation considers all phases including design and development, construction or production, exploitation, operational sustenance, phase-out, and disposal. The ability to arrive at correct decisions depends jointly on a sound conceptual understanding and the capability to handle the quantitative features of the analysis required in life cycle costing studies [11].

Table 2. *Import/Export data summary (x000) ton, [10].*

To From	Qatar	Kuwait	Bahrain	UAE	KSA	Oman	TOTAL
Qatar	-	43	118	11,012	879	150	12,200
Kuwait	20	-	32	22,777	1,696	52	24,577
Bahrain	55	160	-	3,391	1,060	3	4,669
UAE	436	233	461	-	3,212	515	4,857
KSA	436	460	2,147	1,729	-	244	5,016
Oman	25	81	232	940	367	-	1,645
TOTAL	972	977	2,990	39,849	7,214	964	52,964

The main purpose of a life cycle study is to assess overall energy and environmental effects of diverse substitutes so that society can meet its demand for various services with minimal impact. A number of cost classifications have come into existence to serve as a base for life cycle cost and economics. Significant factors that can alter cost estimates are geographical borders, which will be detailed further in a discussion on delays.

4. Freight Data Description and Calculation

Each mode of transport has different cost data and calculations. When performing the total life cycle cost analysis, the impact costs such as pollution, noise, and accidents as well as the depreciation and delay factors need to be considered. Transport sectors should put into consideration all aspects that might affect shipments, safety, and the environment.

4.1. Infrastructure Cost

Infrastructure costs cover capital and maintenance expenses related to constructing road and rail track networks. Previous studies focusing on the GCC region in 2010 presented the capital cost of single-track railway as well as estimation for the annual maintenance cost for rail infrastructure per kilometer, which was averaged using data provided by the freight division within the Abu Dhabi Municipality. It should be mentioned that the infrastructure maintenance cost for railway systems included the costs of periodic surveillance of the tracks and line, inspection and verification of the railway system components, as well as corrections and repairs to the railway systems. For trucking, road capital and maintenance cost per lane were calculated based on the UAE and other countries' Freight Transport report data [8].

4.2. Freight Cost

Freight costs cover all expenses related to the movement of shipments and the mode used. Different factors can affect costs, including fuel price, travelling distance, drivers' rates of pay, and the maintenance cost of the freight mode. Based on the available data from Transport division at Abu Dhabi Municipality [10], and the Global Petrol Prices in 2016 [12], freight costs using the trucking system were calculated using the following equations:

$$f\_OT = (\sum (Dp \times Fc \times Dd))/ (TSD) + (Ms)/ (A\ m) \quad (1)$$

Where;

f_OT: The total operation cost of using trucking system, Dp: Diesel price of the country (US$/Liter), Fc: Fuel consumption (Liter/km), Dd: Distance driven on each country (km), TSD: Total shipping distance (km), Ms: Monthly salary (US$), and Am: Average mileage per month (km).

$$f\_MT\ (Maintenance) = (R\ cost)/(Am) \quad (2)$$

Where;

f_MT (Maintenance): Truck maintenance cost (US$/km), Rc: Repair cost per month (US$), and Am: Average mileage per month (km).

Regarding the railway system, different assumptions were proposed to calculate freight expenses in this paper based on the data given by the Abu Dhabi Municipality about the preliminary study of the GCC railway project as follows:

- Freight trains typically utilizes two crew members and the average wages around $4,000 US$ per month per member
- There are 250 working days in the year
- Freight rail speed averaging 80 km/hr

Based on the available data of the railway system that is going to be used in the GCC region, freight operation costs using the railway system were calculated using the following equations:

$$f\_OR\ (fuel) = (\sum (Dp \times Fc \times Dd))/(TSD) \quad (3)$$

Where;

f_OR (fuel): Rail fuel cost (US$/ton-km), Dp: Diesel price of the country (US$/Liter), Fc: Fuel consumption (Liter/ton-km), Dd: Distance driven on each country (km), and TSD: Total shipping distance (km).

$$f\_OR\ (Driver) = (Ds)/(Rs) \quad (4)$$

Where;

f_(O. R) (Driver): Rail driver cost (US$/km), D. s: Monthly salary (US$), and R. s: Freight railway speed (km/hr).

$$f\_OR = (f\_OR\ Fuel) + (2 \times f\_OR\ (Driver)) \quad (5)$$

Maintenance cost, locomotives, wagons, and lubrication expenses were estimated using the following equations:

$$f\_(M.\ R)\ (Loco)=((AMC/\ AWD\ )/24)/(Rs) \quad (6)$$

Where;
f_MR (Loco): Locomotive maintenance cost (US$/km), AMC: Annual maintenance cost (US$/ Year), AWD: Annual working days (days), and Rs: Freight Railway speed (km/hr).

$$f\_MR\ (Wagon)=((AMC/\ AWD\ )/24)/(RS) \quad (7)$$

Where;
f_MR (Wagon): Wagon maintenance cost (US$/km), AMC: Annual maintenance cost (US$/ Year), AWD: Annual working days (days), and Rs: Freight Railway speed (km/hr).

$$f\_MR\ (Lubrication) = ((AMC/\ AWD)/24)/\ (RS) \quad (8)$$

Where;
f_(M. R) (Lubrication):Lubrication maintenance cost (US$/km), AMC: Annual maintenance cost (US$/ Year), AWD: Annual working days (days), and Rs: Freight Railway speed (km/hr).

4.3. External Cost

The impact of using particular freight modes needs to be considered when evaluating both modes and performing a LCCA. External factors usually include noise pollution, costs incurred by accidents as well as costs associated with emissions and climate change. Noise is mostly caused by wheel interface, horns, and bells, which can have an effect on hearing, sleeping, and can cause neurological ailments. Based on a report on the GCC railway, it has been estimated that train traffic generates about 82 dBA at 15m distances from the centerline of the track. As per World Bank guidelines, the maximum allowable Sound Pressure Level is 70 dBA during the day and night time in commercial and industrial areas. There is also a range from 55 dBA during the day and 45 dBA at night for residential, institutional, and educational areas [14]. Figure 2 shows the noise source path receiver framework.

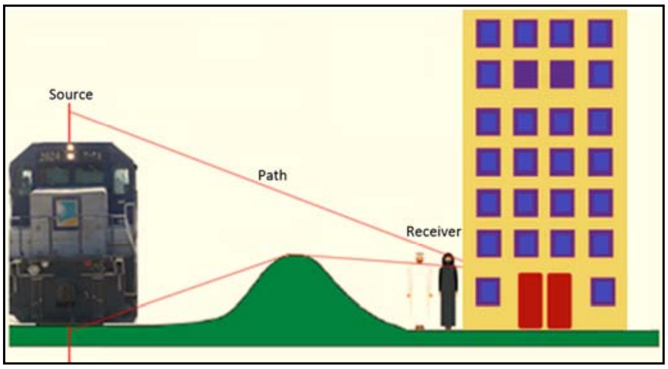

Figure 2. Noise source path receiver frameworks [10].

As per the study by the U.S. National Research Council in 1996, noise costs can be assumed to be zero in rural areas [15]. Accordingly, the noise impact costs were calculated using the following equation:

$$f\_TR\ (Noise) = (\sum\ (UDD\ x\ Avg.\ noise\ cost))/(TSD) \quad (9)$$

Where;
f_TR (Noise): Truck /Rail Average noise cost (US$/ton-km), UDD: Urban distance driven on each country (km), ANC: Average noise cost (US$/ton-km), and TSD: Total shipping distance (km).

The second factor is accident cost, which accounts for injuries, fatalities, and explosions due to the handling and movements of freight shipments. It is possible to calculate the impact cost of the accident factor based on a GCC economic study report from Abu Dhabi Municipality. In this case, international factors have been used to be scaled down to the GCC countries' level. The accident cost impact was therefore calculated using the following equation:

$$f\_TR\ (Accident) = (AAC\ x\ Dd)/\ (TSD) \quad (10)$$

Where;
f_TR (Accident): Truck /Rail Average accident cost (US$/ton-km), Dd: Distance driven on each country (km), AAC: Average accident cost (US$/ton-km), and TSD: Total shipping distance (km).

The last factor that was considered in calculating the external factor cost of a freight shipment is the pollution and emissions cost. Most transportation modes have environmental impacts, and about 27% of greenhouse gas emissions are a result of transportation systems [16]. The major direct greenhouse gas emission is CO_2. Emissions of CO_2 are directly related to the amount of fuel used to operate vehicles or locomotives. Emissions have two distinct impacts at local and global levels. Locally, they are a source of air pollution, thereby reducing air quality, and globally, they can contribute to climate change. Deterioration in human health, damage to property, and a decline in crops and agricultural production can result from global and local impacts. To sum up all external costs, the average external cost is illustrated as shown in Table 3.

***Table 3.** External Factor Cost Items Breakdown in US$ per 1,000 ton-km [8].*

Freight Mode	US$ per 1,000 ton-km		
	Noise cost	Accident cost	Emission cost
Trucking System	16.05	9.04 to 31.62	33.28
Railway System	4.63	1.18	7.39

4.4. Depreciation Cost

To complete a life cycle assessment, economic loss value over time should be considered. Depreciation expenses of operating assets can be minimized by improving maintenance programs. Based on the data that has been provided by Al-Joaan General Transport Co., UAE, and the information by the Association of American Railroads that applies an annual depreciation for a freight car which is about 3.6 percent, the depreciation costs of trucks, locomotives, and wagons can be illustrated in Table 4 assuming the following:

- The annual truck mileage is 80,000 km.
- The rolling stock annual mileage is about 240,000 km.

Table 4. *Truck and Rolling Stock Deprecation Cost US$/km, (A. A. R, Al-Joaan Co.).*

Cost	Trucking system	Rail System	
US$ per km	Truck 0.14	Locomotive 0.23	Wagon 0.006

4.5. Shipment Handling, Loading and Unloading Costs

Moving commodities from one place to another, elevating cargo container onto a rail wagon or a shipping truck and moving it to a place of rest requires specific handling processes, which play a role in loading and unloading shipments. Costs of loading and unloading vary based on the weight and the type of commodity. Shipping mode, warehouse locations, and the equipment used are central components when it comes to loading and unloading processes for goods. For this study, based on that data from the Saudi Railway Organization, 2016 and document issued by the Port of New Orleans - Louisiana, USA in 2012 the cost of Handling, Loading and Unloading for trucks vary from (US$ 79.01> 5ton> US$ 104) per Container, while the train is about US$ 58 for a 20ft Container and US$ 114 for a 45ft Container [13].

5. Freight Case Study

To compare the costs of using both trucking and rail systems, direct and indirect expenses were estimated for several shipment scenarios. Moreover, an intermodal option also has been analyzed and discussed. It is important to note that road and rail systems were developed using the Geographic Information System (GIS) to take advantage of building an effect tool for optimization and design system strategies in future as shown in Figure 3.

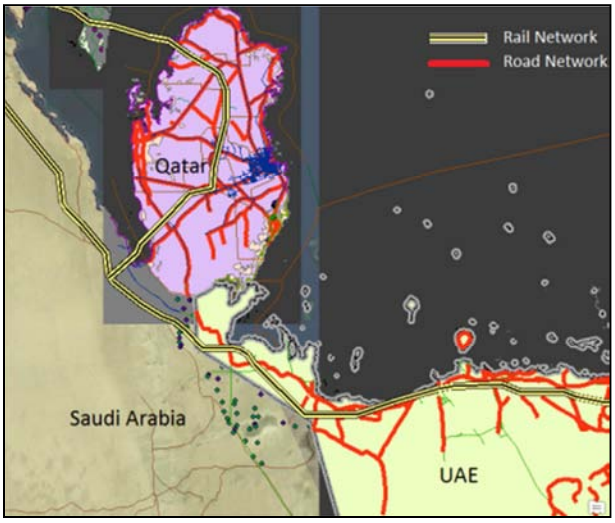

Figure 3. *GIS Road/Rail network sample.*

However, all previous cost factors and impact factors need to be considered when evaluating a freight mode selection process. Further to the previous equations, the following model framework as shown in Figure 4, were implanted to be used on for the analysis of this paper using different scenarios in order to discover the more economic and reliable way of shipping between various origins and destinations.

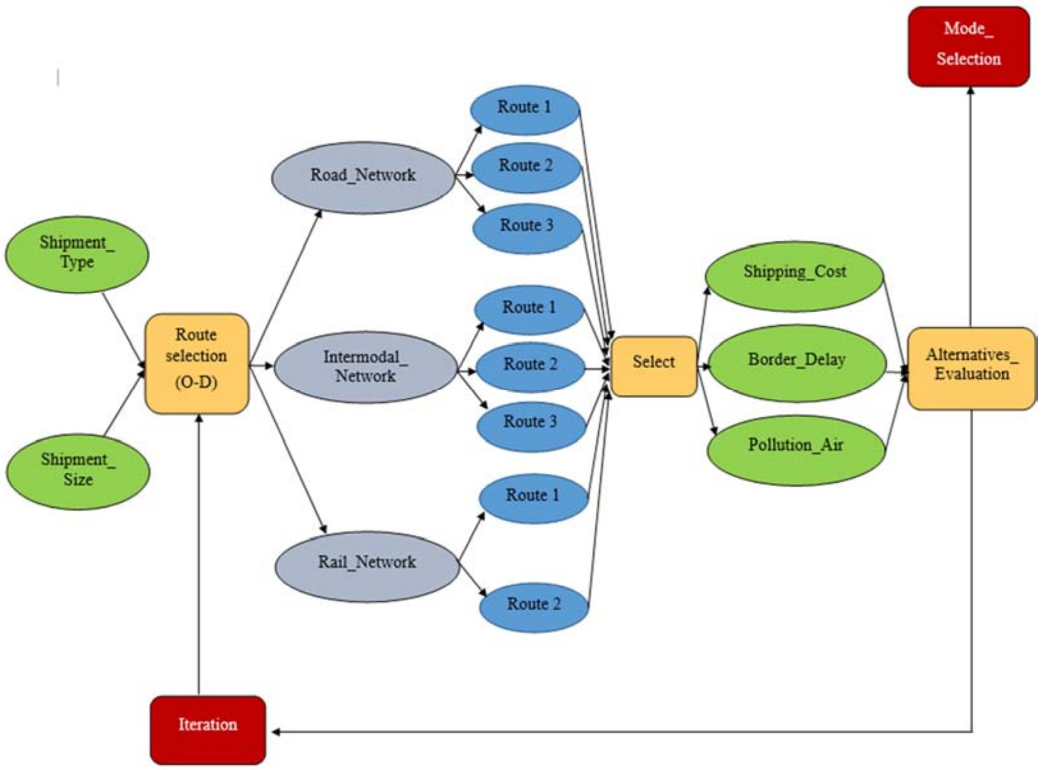

Figure 4. *Total LCCA model framework.*

Figure 5. Current land transportation systems configuration [17].

It is important to mention that, as per shipping rules and regulations, truck length must not exceed 18m (head to tail) due to border screening issues. This rule limits the types of trucks that are in-use for shipping between the GCC countries. For the LCCA purposes in this paper, a four-axle truck that can carry 23 tons was selected. With regards to rail, all analyses have been implemented based on the current information from the Saudi Railway Organization [17], and a preliminary study that has been conducted on the GCC region railway. Figure 5 shows part of the current Saudi railway system and the four-axle truck used for freight transport.

Tables 5 and 6 shows the total cost of shipping a container between various origins and destinations using trucking and rail system, respectively. The total cost for both truck and rail was calculated per the average weight of 23 tons. Unlike railway service, trucking system support door to door service. As a result, the intermodal system has been developed to calculate the multi-model combination as shown in Table 7. In addition to the LCCA, border delays still need to be considered for reliability and sensitivity analysis, which is a major issue that can differ based on shipment routes. Based on the data given by AL- Joaan General Transport in 2016, Dubai, United Arab Emeritus, trucks are sometimes delayed for up to 3 days at GCC borders, and as a result, trucking companies spend about $107 (USD) per day (on a driver's pay, food and fuel) in case there is a delay at the border. Therefore, delays can be a cost problem in certain scenarios and may affect the mode selection decision.

Table 5. Trucking Life Cost Structure US$.

Truck Freight Expenses	Origin-Destination							
	Muscat to Dubai		Kuwait to Dubai		Kuwait to Riyadh		Riyadh to Dubai	
	Distance (km)							
	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural
	312	133	392	914	157	503	260	781
Cost US$/km								
Infrastructure Cost per Truck	0.058							
Infrastructure Maintenance Cost per Truck	0.047							
Truck Capital cost	0.0612							
Truck Maintenance Cost	0.0158							
Truck Operation Cost	0.16		0.14		0.13		0.14	
Avg. Depreciation Cost	0.066							
Cost US$/ton-km								
Noise Cost	0.011		0.0048		0.0038		0.0039	
Accident Cost	0.010		0.015		0.018		0.013	
Pollution Cost	0.0058							
Trucking Border Delay Cost per day	107 US$							
Handling, Loading & Unloading Cost / Container	(US$ 79.01> 5ton> US$ 104)							
Total Life Cycle Cost US$	816.66		1379.7		772.45		1051.41	
Total Life Cycle Cost US$ With 1 day of delay	923.68		1486.7		879.45		1158.41	
Total Life Cycle Cost US$ With 3 days of delay	1137.66		1700.7		1093.45		1372.41	

Table 6. *Railway Life Cost Structure US$.*

Rail Freight Expenses	**Origin-Destination**							
	Muscat to Dubai		**Kuwait to Dubai**		**Kuwait to Riyadh**		**Riyadh to Dubai**	
	Distance (km)							
	Urban	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
	287	**123**	**364**	**848**	**196**	**622**	**347**	**810**
Cost US$/km								
Infrastructure Cost per Wagon	0.11		0.08		0.08		0.07	
Infrastructure Maintenance Cost per Wagon	0.037		0.027		0.027		0.023	
Rail Capital cost (Loco &Wagon)	0.338							
Rail Maintenance Cost	0.3333							
Rail Operation Cost (Driver)	0.2							
Depreciation Cost (Loco &Wagon)	0.46							
Cost US$/ton-km								
Rail Operation Cost (Fuel)	0.0031							
Noise Cost	0.0032		0.0013		0.0011		0.0014	
Accident Cost	0.0012							
Pollution Cost	0.0038							
Handling, Loading & Unloading Cost/ Container	US$ 58 / 20ft Container OR US$ 114 / 45ft Container							
Total Life Cycle Cost US$	826.66		2119.25		1463.62		2014.72	

Table 7. *Intermodal Life Cost Structure US$.*

Intermodal Freight Expenses (Rail part)	**Origin-Destination**							
	Muscat to Dubai		**Kuwait to Dubai**		**Kuwait to Riyadh**		**Riyadh to Dubai**	
	Distance (km)							
	Urban	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
	287	**123**	**364**	**848**	**196**	**622**	**347**	**810**
Cost US$/km								
Infrastructure Cost per Wagon	0.11		0.08		0.08		0.07	
Infrastructure Maintenance Cost per Wagon	0.037		0.027		0.027		0.023	
Rail Capital cost (Loco &Wagon)	0.338							
Rail Maintenance Cost	0.3333							
Rail Operation Cost (Driver)	0.2							
Depreciation Cost (Loco &Wagon)	0.46							
Cost US$/ton-km								
Rail Operation Cost (Fuel)	0.0031							
Noise Cost	0.0032		0.0013		0.0011		0.0014	
Accident Cost	0.0012							
Pollution Cost	0.0038							
	Distance (km)							
(Truck part)	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural
	7.5	17.5	7.5	17.5	7.5	17.5	7.5	17.5
Cost US$/km								
Infrastructure Cost per Truck	0.058							
Infrastructure Maintenance Cost per Truck	0.047							
Truck Capital cost	0.0612							
Truck Maintenance Cost	0.0158							
Truck Operation Cost	0.16		0.15		0.13		0.14	
Avg. Depreciation Cost	0.066							
Cost US$/ton-km								
Noise Cost	0.048							
Accident Cost	0.0099		0.014		0.018		0.014	
Pollution Cost	0.0058							
Handling, Loading & Unloading Cost/ Container	Trucking	(US$ 79.01> 5ton> US$ 104)						
	Railway	US$ 58 / 20ft Container OR US$ 114 / 45ft Container						
Total Life Cycle Cost US$	1081.5		2376.2		1722.35		2271.4	

As shown in Table 5,6, and 7 focusing on the second scenario (as an example), the cost of truck shipping that can carry 23 tons from Kuwait to Dubai is about 1379.70 US$. However, as the delay increases, the shipping cost increases as well reaching to 1700.70 US $ after a three days of delay at the border. Then, when using a rail system transporting for the same tonnage, the cost will be around 2119.25 US$, while intermodal system can also cost about 2376.20 US$.

While, transporting higher weights will favor rail than trucking systems especially when considering the delay factor as shown in Figure 6.

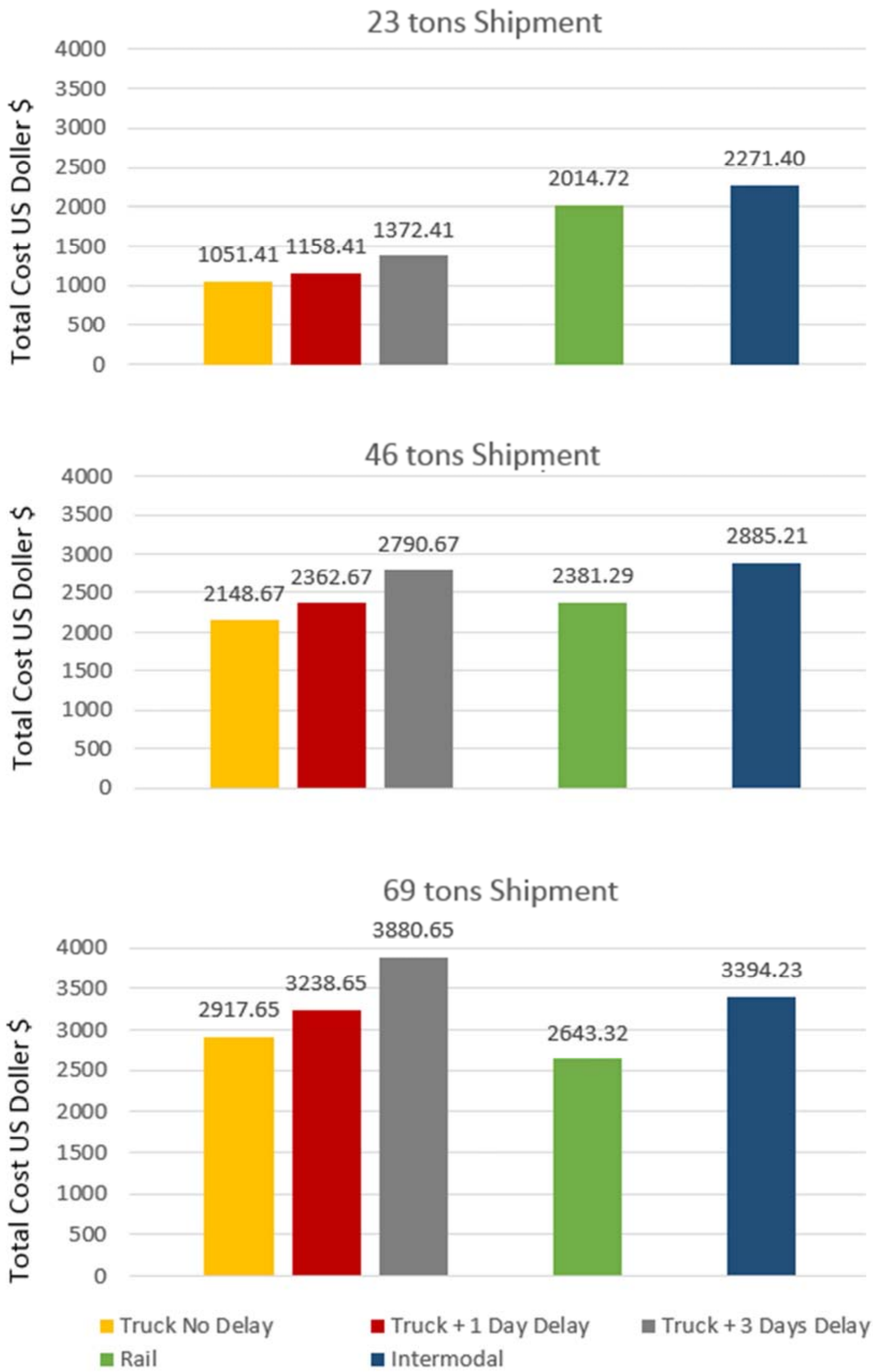

Figure. 6. *Total Shipping cost of various shipment weight from Kuwait to Dubai using trucking, railway and intermodal systems.*

So, using an intermodal system transporting from Kuwait to Dubai for bulk commodities more than 69.0 tons is more reliable to deliver the shipment supporting door to door service, rather than having a stream of trucks waiting for border clearance. Figure 7, also gives another example about the cost variance of shipping a container from Riyadh to Dubai using trucking, railways and intermodal systems.

Figure 7. *Total Shipping cost of various shipment weight from Riyadh to Dubai using trucking, railway and intermodal systems.*

In brief, considering the above model framework structure, the analysis can be made and the decision can be changed as per the traffic forecast and the user preferences.

6. Freight Selection and Evaluation Criteria

In addition to the freight life cycle cost, there are other factors that influence the selection of freight mode such as, the Environmental issues. There are different kinds of greenhouse gas emissions that can be produced by operating railway or trucking systems as shown in Table 8. The effects of environmental pollution can negatively affect air quality, human health, and can contribute to climate change, which can result in extreme weather.

Table 8. *Unit Pollutant Emission for Freight Trains and Trucking Freight [18].*

Pollutants	Freight Truck	Freight Rail
	g/ton. km	
CO	1.5	0.148
CO_2	72	38.296
NOx	1.1	0.834
HC	0.15	0.039
SOx	0.4	0.036

As per Table 8, it's clear that the pollution emitted by truck is higher than rail system which can cause a huge environmental impact. Accordingly, considering the second scenario, the amount of emission produced by truck is way more that using railways and intermodal systems as shown in Table 9.

Table 9. *Amount of Pollution produced form shipping a container from Kuwait to Dubai using Truckling, railways and Intermodal systems.*

Pollutants	Truck	Rail	Intermodal
	Kg Emissions		
CO	22.77	4.13	4.99
CO_2	1092.96	1067.54	1108.94
NOx	16.70	23.25	23.88
HC	2.28	1.09	1.17
SOx	6.07	1.00	1.23

Though, rules and regulations enforce green transportation choice which will influence the user mode selection. So rather than saving small amount of money using a trucking system, using an intermodal system can be more reliable and more environmentally friendly.

7. Conclusion

The results of performing a life cycle cost analysis of using railways and trucking systems in freight transportation supports the following conclusions:

- Shipping life cycle cost and shipping mode selection depends on different factors such as infrastructure cost, operation and maintenance cost, external costs, depreciation, potential delays, and other environmental issues.
- Looking at the shipping scenarios, using a trucking system can be cheaper for small shipping weights, although it might be not reliable in terms of distance, potential delays and pollution.
- In case of delays, intermodal systems cost less than shipping with trucking systems for bulk commodities over 46 tons. As a result, intermodal systems can be considered more reliable as they also produce lower percentages of CO_2.
- Crossing borders can cause delays which might be extended up to 3 days, and will ultimately affect the total freight cost between the GCC countries.
- Different origins and destinations within regions should be added and investigated in order to check the shipping cost of various distances, therefore making the selection of the most reliable and appropriate freight mode.

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