SUSTAINABLE DEVELOPMENT OF FREIGHT TRANSPORT USING A FASTER AND MORE ECO-FRIENDLY MODE

HAMAD ALMUJIBAH
Department of Civil Engineering, College of Engineering, Taif University, Saudi Arabia

ABSTRACT
Especially in developing countries such as Saudi Arabia, when considering an increase in rail lines it is vital to examine the freight sector's sustainable development. The aim is to transfer freight from slow modes of transport (trucks) to the faster and more eco-friendly mode of rail. This paper predicts two economic impacts from the transfer: less wear on the pavement structure of the highways, and changes in terms of time, cost, infrastructure capacity, and so on, compared to shipment by heavy trucks. Using rail can prevent damage to roads and the costs relating to heavy trucks, as well as accidents and air pollution. Various parameters are considered, such as loading and the longitudinal tire forces of trucks, the materials used in the construction of roads (e.g. asphalt) and their thickness. In this case, a 950-km length of the Riyadh–Jeddah line is used as a case study, determining the cost and time taken both before and after introducing a freight rail system. This method can be applied to the military sector to move heavy haulage and to transport minerals all over Saudi Arabia. In this case, the just-in-time (JIT) or door to door (DTD) method of delivery services is adopted, as trucks still have to drive the first and/ or last few kilometers of each railway journey. It is based on a comparative model to calculate and compare total shipping costs and transport time for road and rail transport. As a result, the total cost of transporting military vehicles/freight by rail transport is about $11,423, resulting from $1,272, $8,695, and $1,456 of fuel, labor wages, and drivers' wages, respectively, which is lower than by road transport of about $12,634, resulting from $606, $661, $8,695, and $2,672 for the fuel cost, road user charge/express tolls, labor wages, and drivers' wage, respectively.
Keywords: sustainable, freight, rail, vehicle trucks, just-in-time, door-to-door, Riyadh, Jeddah.

1 INTRODUCTION

Freight transport is the movement of goods by inland transport modes such as roads and railways on a given network, and is a key feature of supply chain management. In this case, goods can be transported through various units of transportation such as pallets, crates, containers, or cages [1]. Rail transport is regarded as one of the most environmentally friendly modes of transport, and receives attention from policy-makers due to increasing volumes of freight. It is considered as a sustainable mode of freight transport in terms of reliability, efficiency, and resilience with respect to economic factors; accessible and safe with respect to social factors; and ability to reduce pollution, climate change, and greenhouse gas emissions [2].

In Saudi Arabia, improved efficiency in the freight sector and increased regional connectivity will give the country a more central logistics role within the countries of the Gulf Cooperation Council (GCC). For example, the Landbridge railway project (Riyadh to Jeddah) could reduce the country's CO_2 emissions by 19% and fuel consumption by 17%, leading to decreases in freight transport by road and increases in delivery by rail. In 2018, around 50% of containerized goods were transported from Saudi Arabia's Red Sea ports via Makkah Province to Riyadh Province by roadway connections, as the country relies heavily on its road network, which covers 68,000 km, compared with only 4,175 km of freight rail network. There are only two important freight railways in the Kingdom: connecting the

WIT Transactions on The Built Environment, Vol 213, © 2022 WIT Press
www.witpress.com, ISSN 1743-3509 (on-line)
doi:10.2495/CR220181

commercial port of Dammam in the east to the main hub in Riyadh, and to the north-eastern mineral deposits.

2 LITERATURE REVIEW

In European Union (EU) countries, in 2020 road transport accounted for more than 77.4% of total inland freight transport, followed by rail freight and inland waterways at 16.8% and 5.8%, respectively. However, the performance of road transport increased by 12% from 2010 to 2020, while the performance of rail remained stable at 0.9% and for inland waterways decreased by 15.2% [3]. The shift of freight to rail transport will require an huge change to the railway transport sector in terms of infrastructure capacities, cost efficiency and productivity, and so on [3]. The performance of rail freight transport in various European countries is presented in Table 1, and shows a decrease in Spain, France, Italy, Switzerland, and Poland of 23%, 19%, 2%, 2%, and 3%, respectively, from 2015 to 2020. On the other hand, in Turkey, Croatia, and Finland it increased by 42%, 51%, and 15%, respectively [3].

Table 1: Performance of freight transport by rail (million tonne-km) [3].

Year	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Spain	28,960	26,504	27,654	27,161	26,268	22,254
France	102,743	96,702	98,573	89,457	91,997	83,143
Italy	92,273	92,949	94,287	97,197	94,295	90,529
Turkey	24,286	24,546	28,287	28,484	33,285	34,374
Switzerland	66,089	67,846	67,157	68,719	68,658	64,987
Poland	224,320	222,523	239,501	249,260	233,744	218,381
Croatia	9,939	9,985	12,178	13,444	14,449	14,992
Finland	33,392	36,162	38,468	40,721	38,464	38,406

Turkey connects Europe and Asia by virtue of its location, involving an increase in freight flows in this region, and the country aims to be in the world's top 10 economies by 2023. The railway sector has seen the largest growth, as it is the primary sector and many railway reforms have taken place in the country to increase productivity [4]. With over 19 billion tonnes of goods shipped every year, freight transport accounts for 6% of GDP in Europe, as 75% of all freight transport is now undertaken by road. Moreover, an estimated annual emission of 275 million tonnes of CO_2 accounts for 30% of total transport emissions for both passenger and freight transport. By 2030, freight transport is expected to increase by 30%, adding a million trucks to European roads over the next decade [5].

2.1 Rail and road transport

Rail transport plays a crucial role in constructing a more sustainable freight sector, leading to an increase in the economy of €100 billion. For example, an estimated 5000 fatalities and 40,000 premature deaths will be prevented due to fewer truck accidents and less pollution. Shifting goods from road to rail can help to reduce the negative impacts of freight transport on climate, environment, and mobility [6].

A comparative study of road and rail transport with respect to unit costs for Switzerland and the European Union (EU) countries focused on factors such as the costs of a transport corridor, depreciation of vehicles, electricity and diesel fuel, and salaries and labor for handling. For the input data of the model, road freight transport costs have independent fixed variables for the type and size of cargo, such as cost of vehicle maintenance, road tax and mandatory insurance, vehicle depreciation, driver salary, and loading and haulage fees. Also, the carrier's overhead costs include central services, management, and dispatch. The dependent variables on transport distance and the type and size of cargo include the cost of tire consumption, fuel, drivers' mandatory safety breaks, and fees for use of roads [7]. In general, more challenges are faced by rail freight transport than by road, such as flexibility, price, transport time, frequency, reliability, and so on, as shown in Table 2. By contrast, road transport has no choice to be made in advance regarding the route, yet a driver is needed for each truck, and it also involves a significant number of road transport companies.

Table 2: Comparison of the challenges for rail freight and road [8].

Category	Rail	Road
Flexibility	Path requested in advance	No request needed in advance
Flexibility and price	One locomotive and one driver for each country	One truck and one driver for the whole EU
	No door-to-door transport	Door-to-door transport
Frequency, customer service and price	Limited number of railway undertakings	Significant number of road transport companies
Price	Use of every km of track is charged	In some countries for free
Reliability and transport time	Freight is disadvantaged in terms of priority on tracks	Freight is not disadvantaged
Transport time	Trains generally need to stop to change locomotive, driver, etc.	Less frequent stops

On the other hand, the independent variables for rail transport costs include vehicle maintenance, train crew salaries, vehicle depreciation, handling fees, and overhead costs of carrier in terms of salaries of other rail employees, management, central services, building the rains, and so on. The dependent variables of rail transport costs include traction energy and the fees for using the rail route, such as those associated with the train's mileage and access [7]. Rail freight challenges involve requesting a route in advance over a limited number of railway undertakings, as it is not door-to-door transport mode. Also, there is a charge for using each kilometer of track, and freight is disadvantaged in terms of priority on the tracks, as trains need to stop often to change locomotive, drivers, and so on, compared to trucks [8].

In general, there is a trade-off between cost and service quality factors in the choice of transport mode. For any freight, the quality factors include transit time, service availability or frequency, and reliability, as the transit time offer may include express, economy, general and customized. In this case, road and rail are competitors, according to freight studies, as the price elasticities of long-distance corridors are estimated for freight across short-, medium-, and long-distance corridors [9].

Service quality elasticity is of a magnitude of 0.33 to 0.66, as shown in Table 3 with respect to medium- and long-distance transport, respectively, implying that rail freight has a limited sensitivity to service quality changes [9].

With respect to the elasticities of road and freight market, 17 freight studies from UK, Asia-Pacific, and North America were examined to estimate all major commodity groups and grain only. The price elasticities regarding grains are between −0.52 and −1.18, whereas those

Table 3: Long-run price elasticities for road and rail freight, by corridor [9].

Mode	Freight rate (short-distance corridors)		Freight rate (medium-distance corridors)		Freight rate (long-distance corridors)		Freight rate (all corridors)	
	Road	Rail	Road	Rail	Road	Rail	Road	Rail
Road	−0.36	0.35	−0.43	0.33	−1.08	0.66	−0.46	0.58
Rail	0.88	−0.93	1.08	−1.15	0.42	−0.78	1.04	−1.66

of all commodities are −0.60 to −1.52. For rail freight demand, the cross-price elasticity with respect to trucking cost is positive and significant at 10%, as the freight rate and aggregate economic activity for short-run of rail freight transport are 0.51 and −0.28, while the same elasticities in the long run are 0.84 and −0.39 [10].

Depending on the length of transport route and shipping price, users have the opportunity to optimize their transport by their choice of route within and across the countries by total transport time. In this case, the general relationship between average transit time and distance, and between average freight costs and distance, is shown in Fig. 1 for road and rail freight in Australia.

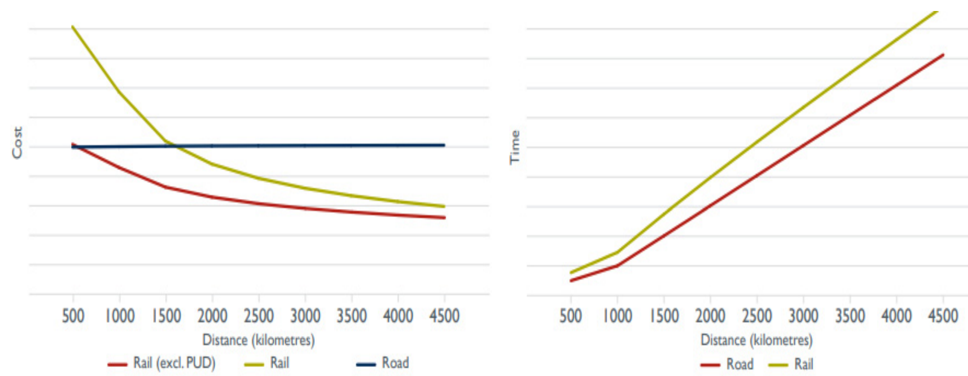

Figure 1: Average freight costs and transit times for Australian road and rail freight [9].

Over short distances, road freight was found to be the highest-cost transport mode, as the average freight cost per kilometer of road is less or more constant with respect to distance. In general, road has higher line–haul costs over longer distance and for large volumes than rail, which shows that rail is cheaper for door-to door freight haulage, especially for distances above 1000 km. In terms of handling long-haul freight, rail is the preferred mode of transport due to less damage to environmental quality [9]. In the United States, using trucks to transport coal along public road networks may have an advantage over rail in terms of negotiating more severe gradients and curves, moreover roads can be constructed more readily, at less capital investment [11].

2.2 Military logistics

Rail transport plays an important role in the military logistics system, and was used for the first time during the American Civil War between 1861 and 1865, providing efficient movement of large items over long distances. Afterwards, the advantages of trail transport started to disappear because of the development of road transport. One of the reasons behind the disappearance of rapid-movement military loads is the number of legal, physical, and regulatory barriers. The use of mass rail transport is necessitated by the movement of oversize loads and contributes to the poor condition of the road infrastructure because the first and last few km are by road [12]. The movement of military by rail transport is inherently safer and less expensive than by road. In terms of effectiveness, one rail car has the loading capacity of up to four truckloads, and it is the most cost-efficient shipping option [13]. In the United States, the movement of army vehicles by rail as shown in Fig. 2 through a Chicago suburb is a normal part of the country's training operations and equipment deliveries, as the army needs many trains to move large numbers of troops.

Figure 2: Army vehicles moving by rail across the United States [14].

The services of rail transport are mainly carried out for the Army by commercial carriers, essential to the development of overweight and oversized military equipment, including artillery and heavy tanks. During World War II, the Russian Army needed 2981 rail transports between 1940 and 1945, consisting of 22,934 railway wagons. There were used to move more than 56,000 soldiers from Poland, 47,500 personnel and family members, 952 armored fighting vehicles, and 390 mortars and howitzers, together with 202 aircraft and 144 helicopters [12].

Due to the huge capacity of military transport, rail transport can be used over medium and long distances, and is characterized by low sensitivity to weather conditions and by high efficiency and regularity. Specialist types of military rolling stock are in use, as they are usually built and operated by railway troops. The special loads demand unusual rolling stock, such as for battle tanks, which has to be determined well in advance. In this case, trains may be switched onto regional and national networks with separate regulations and standards, such as track width, heights of platforms and bridge, and speed limits [12].

For heavy equipment loaded at the military railhead by rail, the minimum transport distance is 50 km, according to the Polish Armed Forces procedures, and this is associated with higher costs. The weight and length of a military train depends on parameters related to the railway line, and it cannot exceed 600 m long with an average weight of 1,200 tons, and it has an average practical speed of 20 to 30 km/h. According to data from the Polish National Movement Coordination Centre (PLNMCC), the annual number of domestic military rail transports is between 120 and 180 trains formed of 3,000 to 4,000 carriages, compared to international transport of three to eight trains formed of 50 to 160 carriages. In this case, the types of wagons used by the army include first- and second-class passenger cars (e.g. medical evacuation, troops movement, convoys), tank cars (e.g. chemicals, fuel, water), flatcars (e.g. containers, vehicles, oversize loads), covered cars (e.g. medical equipment, ammunition, food), and other equipment (e.g. cranes and mobile ramps) [12].

2.3 Railway and mining sector

Transportation is a key aspect of every industrial project, advantageously located to have mineral products delivered by truck, railway, or other mode of transport. Rail infrastructure is often essential if a mining operation to be effective and economically feasible, and a priority in this industry is to move freight safely with optimal efficiency and capacity. In this case, Bombardier's INTERFLO system is the optimal choice for heavy haulage lines, and is supplied to the mining sector worldwide [15]. Over long distances, rail transport is the most common mode of transport for moving prepared coal from the mine to the market, and it is the most attractive for long-term and high-volume movement of coal. For example, a unit train in the United States usually has a capacity of 100 or more cars and transports 17,400 tons per 1,200 km for the round trip from mine to plant, which takes 72 hours, including 4 and 10 hours for loading and hauling coal [11]. In terms of trucks causing road damage, a study in the United States found that the impact of 9,600 cars is equivalent to that of a single 18-wheeler, and a fully loaded tractor-trailer weighs about 80,000 lb, far more than a typical passenger car at 4,000 lb. The maintenance costs of roads in the United States have risen due to freight-hauling trucks, which cause 99% of the wear and tear, as pavement damage from vehicle traffic generally depends on the number of axles and their weight [16], [17].

In Saudi Arabia, the Ministry of Industrial and Mineral Resources (MoIMR) decided to set an opening budget to support the transformation of the country's mining sector to match its national program leading to Vision 2030. The mining sector is the third pillar of Saudi industry, developing mining investment and achieving optimal utilization of mineral resources, especially with the intention to auction off 45 mining sites to investors. The Saudi goal for the mining sector is to reach a GDP contribution of $64 billion, raising the country's revenue by more than $2.3 billion and generating 219,000 new jobs by 2030 [18]. For example, the north–south train freight line is one of the two freight lines in the country as shown in Fig. 3, running 1,550 km from Al-Jalamid mine in Northern Province to Ras AlKhair in Eastern Province via Al-Jouf, Hail, AlBaithah Junction in Qassim [19].

Figure 3: Saudi minerals being transported by train [14].

The north–south freight fleet consists of 16 locomotives with a capacity of 16,000 tons, including 523 wagons dedicated to transportation of phosphates, 562 for molten sulfur, 240 for bauxite, and 589 for phosphoric acid (MGA). The East cargo line is 556 km long, starting at King Abdulaziz Port in Dammam to Riyadh, passing Al-Ahsa, Abqaiq, AlKharj, Haradh, and Al-Tawdhihiyah. It has total fleet of 2,596 cars in various sizes and types, including 858 for double-stacking containers, 135 for grain hauling, 201 for cement transportation, 60 for hauling rocks, and 47 flatbeds for transporting vehicles [19].

3 METHODOLOGY

This study estimates the total time and cost of using road trucks or rail to transport freight, and to apply it to a case study of military logistics in Saudi Arabia for the Riyadh and Jeddah corridor, using cost and time models mainly based on Microsoft Excel. The Saudi freight railways have displaced 230,000 trucks from the roads, reducing the number of trucks, improving the quality of roads, and contributing to reduce traffic accident rates. As a result, carbon emissions have been reduced by an amount equivalent to 197,000 tonnes, also saving more than 900,000 barrels of diesel for trucks' fuel, achieving environmental returns representing a reduction in CO_2 emissions. In this case, the models are integrated and can be categorized into three equations: weight, time, and cost. Each equation has components as follows.

3.1 Weight limit equation

The total weight limit of both vehicle and freight carried on a truck or train is determined using eqn (1):

$$\mathrm{W_{all}} = W_V + W_F, \tag{1}$$

where $\mathrm{W_{all}}$ = total weight of vehicle and carried freight; W_V = weight of truck or train car in tonnes. W_F = weight of carried freight in tonnes.

In this case, the weight of the train includes the weight of locomotive and the weight of cars, as shown in eqn (2):

$$\mathrm{W_V} = W_L + W_C, \tag{2}$$

where W_L = weight of locomotive in tonnes; W_C = weight of cars in tonnes.

The weight per axle is based on the weight of cars and the number of axles, as shown in eqn (3):

$$\mathrm{w} = \mathrm{W_V}/N, \tag{3}$$

where w = weight of truck or train truck per axle in tonnes; N = number of axles.

By combining the three equations above, the total weight equation is determined as shown in eqn (4).

$$\mathrm{W_{all}} = W_F + (W_L + W_C)/N. \tag{4}$$

3.2 Time equation

In the time equation, access/egress time, in-vehicle travel time, and loading/hauling time are the main components, as presented in eqn (5). In this case, access time is the time from the origin point to the main freight hub, while egress time is that from the final freight hub to the destination. The in-vehicle travel time or journey time is highly dependent on the length of the route and the operating speed of the train/truck.

$$TT_{\mathrm{OD}} = AET_{OD} + IVT_{OD} + LUT_{OD}, \tag{5}$$

where TT_{OD} = total time of freight shipping by rail or road from origin to destination; AET_{OD} = access and egress time taken for transporting freight by each mode from origin to destination; IVT_{OD} = in-vehicle time (travel time) taken by each mode from origin to destination; LUT_{OD} = loading and hauling time taken by each mode in origin and destination.

In terms of loading and hauling, the time is based on the time taken to leave the production sectors and reach the destination, and is dependent on the number of laborers, number of working hours and type of gantry crane, and its operating time.

3.3 Cost equation

The cost for each transport freight is the sum of the expenditure on the inputs of fuel price, expressway toll, labor, and external impacts, as shown in eqn (6). In this case, the cost is dependent on components such as vehicle type, distance travelled, time in use (hours), loading and hauling time (hours), carrying capacity, and average tonnage (tonne).

$$\mathrm{C_{OD}} = F_{OD} + T_{OD} + L_{OD} + D_{OD}, \tag{6}$$

where $\mathrm{C_{OD}}$ = total cost of shipment by rail or road from origin to destination; F_{OD} = fuel price needed for operating each mode from origin to destination; T_{OD} = express toll paid though the journey by each mode from origin to destination; L_{OD} = cost of labor worked for operating each mode from origin to destination; D_{OD} = driver cost for operating each mode from origin to destination.

The fuel consumption of a train or truck depends on multiple variables, such as speed, engine fuel consumption, engine power, and dimensions. For road transport, paying an express toll is necessary if trucks are to access the road infrastructure, especially heavy goods vehicles, in order for the country to recover the cost of constructing, operating, and developing the infrastructure, and the toll is based on the average loaded weight of the vehicle. In rail and road freight transport the cost for labor and drivers consists of wages, accommodation, and minor expenses related to drivers. Moreover, the cost of parameters is based on secondary data, such as the price of gasoline, express toll, number of laborers needed to transfer freight from origin to destination by either rail or truck.

The flowchart presents the integration of weight, time, and cost, as shown in Fig. 4, and the methods used in this study are explained.

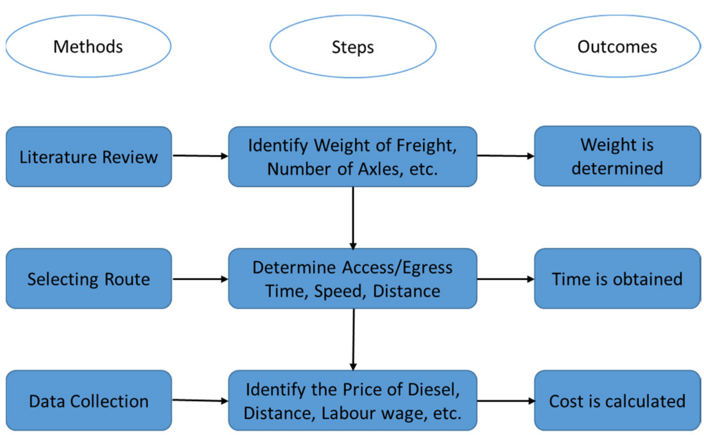

Figure 4: Flowchart of steps performed in the study.

- Sources were used to identify the weight of cars and freight carried by both rail and road transport, as well as the number of axles for trucks.
- A selection of components was needed to determine time, such as access/egress time and in-vehicle travel time, throughout the route between two cities (e.g. Riyadh and Jeddah) and determination of the corridor's length and speed for both truck and train.
- Data were collected to identify the price of diesel, distance, and wages, based on the selection of the case study of the Riyadh–Jeddah corridor.

In this case, the weight, time, and cost of both rail and road transport are determined by following the previous steps and integrating the various equations.

4 RESULTS AND DISCUSSION

To determine the estimated time and cost for transporting freight from origin to destination, the total weight of the freight rail/truck was required, based on components such as capacity, weight in tonnes, fuel price (e.g. diesel), speed, and wages. A freight train commonly carries a considerable weight from origin to destination, dependent on the length of the entire train. Efficiency is limited by the locomotive's capabilities and the railway landscape. Railway freight wagons are used to transport all types of equipment, bulky products, wheeled and tracked vehicles, containers, and so on.

This study shows that the weight of a wagon ranges from 40 to 58 tonnes, based on the length of boxes, around 11 to 15 m, while the weight of the locomotive is 215 tonnes with an assumed speed of 60 km/h. In this case, the weight of an empty freight wagon is 30 tonnes, and each can be loaded with an additional 100 to 130 tonnes. The average weight loaded is estimated at 65 tonnes per wagon, from a range of 63 and 67 tonnes. In military logistics, the weight of vehicles is divided into the classes of light (up to 20 tonnes), medium (20 to 50 tonnes), heavy (up to 100 tonnes), and super-heavy (above 100 tonnes). In this case, the average weight of these types of military vehicle is regarded as 60 tonnes, resulting from a range of 20 to 100 tonnes.

As a result, the weight of rail freight was determined on the basis of the type of freight plus the weight of the locomotive and wagon. The weight of one locomotive was assumed to be 215 tonnes and the weight of a wagon, for a flatcar, 30 tonnes, giving a total of 1,470 tonnes for 49 wagons. In terms of goods and military vehicles, the weight of goods per wagon is 65 tonnes, giving a total weight of 3,185 tonnes for 49 wagons, while the weight of a military vehicle is 60 tonnes, giving a total of 2,940 tonnes for 49 wagons. Therefore, the total weight when transporting military vehicles is 4,625 tonnes, resulting from the weight of the locomotive (215 tonnes), flatcar wagons (1,685 tonnes), and the weight of the military vehicles themselves (2,940 tonnes).

For rail freight, access and egress times are the first and last leg of a journey, and these assumed to be 10 and 15 minutes, respectively, from Riyadh to Jeddah. Travel time was calculated by dividing the distance (950 km) by the estimated speed (50 km/h), while total loading and hauling time was assumed to be the same value as on road transport, at 2.5 hours. Slower speeds by a train prevents buckling and puts less stress on the track, therefore the total travel time for rail freight transportation from Riyadh to Jeddah is about 22 hours, resulting from 0.42 hour, 19 hours, and 2.45 hours of access/egress time, travel time, and loading/hauling time, respectively.

In terms of cost for freight rail transport, there are four components: the fuel for the journey, fees for using track, if any, labor, and drivers' wages. In this case, the cost of fuel per liter was determined with respect to distance, to cover the journey from origin to destination, and diesel in Saudi Arabia costs \$0.168 per liter. However, the fuel tanks of diesel locomotives can hold only between 5000 and 6000 liters, which may be insufficient for the route. As the length of the Riyadh–Jeddah corridor is 950 km, a rail locomotive needs about 7,572 liters of diesel, at a cost of around $1272 for the whole journey. It was assumed that there are no fees in Saudi Arabia for using the track to transport freight or military vehicles from Riyadh to Jeddah. As a result, the total cost of transporting military vehicles/freight by rail transport is about $11423, resulting from $1272, $8695, and $1456 of fuel, labor wages, and drivers' wages, respectively.

For road transport, the weight of truck freight was based only on the weight of the truck itself and the actual freight. In this study, a flatbed heavy duty truck of an average weight of 16.5 tonnes was used for the comparison, resulting from values of 11.79 and 21.5 tonnes. Moreover, the weight of the goods was assumed to be the same as for rail freight transport, with the same military vehicles. The weight of the goods and the military vehicle is 65 tonnes and 60 tonnes, respectively, as each duty truck can carry only one vehicle. Therefore, the total weight of goods or military vehicle transporting by heavy duty truck is 3,994 and 3,749 tonnes, respectively, as 49 heavy trucks are needed. So, the weight of vehicle was divided by five axles to achieve a 937-tonne axle load. To determine the in-vehicle travel time for trucks, an average speed is required, and this was taken to be about 48.68 km/h, 60.45 km/h, and 45.39 km/h, respectively, for unloaded, fully loaded, and overloaded [20].

In this case, access and egress times were assumed to be zero for freight road transport, while travel speed was taken to be 60.45 km/h for fully loaded trucks within 950 km of the two cities of Riyadh and Jeddah in Saudi Arabia, giving a travel time of 15.7 hours. In order to determine the time for loading and hauling, the production rate was defined as the units of work made by a unit of equipment or a person within a specified unit of time. Loading and hauling time was found to be 2.45 hours, resulting from 2.22 hours of loading and 0.23 hours for haulage, with a production rate value of 0.75. Therefore, total time was found to be 18.2 hours, resulting from 15.7 hours, 2.2 hours, and 0.23 hour, respectively, for travel time, loading, and hauling time.

The cost of truck fuel mainly depends on the price of diesel in Saudi Arabia, at $0.168 per liter, and the length of corridor, and it costs around $607 for the whole journey. In terms of road user charges, the truck type was assumed to be powered vehicles with five or more axles, and the cost of $661 was based on the distance and the weight of military vehicles (60 tonnes), and secondary data were used. In Saudi Arabia, a truck driver typically earns around $1,336 per month and two truck drivers are needed, so the cost was doubled to give a total cost of $2,672 per month for the entire journey. It was assumed that five laborers are needed at the freight hub for loading and haulage, at a cost of $8,695 per month. As a result, the total cost of transporting military vehicles/freight by road transport is about $12,634, resulting from $606, $661, $8,695, and $2,672 for the fuel cost, road user charge/express tolls, labor wages, and drivers' wage, respectively.

5 CONCLUSION

The Saudi Arabia government plans to reduce fuel consumption by 2030 and increase deliveries by rail, reducing road freight transport. In this case, rail freight is to become an economically attractive mode of transport, giving improved connectivity, security, and efficiency. In summary, the total freight to be transported by road and rail between Riyadh and Jeddah will be 2.7 thousand tonnes and 4.6 thousand tonnes, respectively.

Rail transport takes slightly longer, at 3.7 hours slower than by truck, but the entire load of freight carrying 49 vehicles arrives at the exact same time, whereas 49 vehicles need 49 trucks. Extra time may need to be allowed to transport vehicles by road due to environmental factors such as accidents, weather (e.g. floods caused by heavy rain or sandstorms), and so on.

In terms of the total cost of transporting vehicles/goods, rail has the benefit of a lower cost of $11.4 thousands as transportation by road is $12.6 due to the total labor wages of $8.7 thousands for five laborers. The development of the freight rail sector in Saudi Arabia will help to increase the efficiency of freight transport activities, decrease fuel consumption, and reduce emissions of greenhouse gases and other pollutants, as well as reduce the damage caused to roads by heavy trucks, thereby meeting the targets for economic reform in Saudi Vision 2030.

ACKNOWLEDGEMENT

I would like to thank the Deanship of Scientific Research, Taif University, Saudi Arabia for supporting this research.

REFERENCES

[1] Archetti, C., Peirano, L. & Speranza, M.G., Optimization in multimodal freight transportation problems: A survey. *European Journal of Operational Research*, 2021.
[2] Economic and Social Commission for Asia and the Pacific, Enhancing the sustainability of freight transport in the decade of action for the sustainable development goals. https://www.unescap.org/sites/default/d8files/event-documents/ESCAP-TARN-WG-2021-4-E.pdf. Accessed on: 21 May 2021.
[3] European Court of Auditors, *Rail Freight Transport in the EU: Still not on the right* track. https://www.eca.europa.eu/Lists/ECADocuments/SR16_08/SR_RAIL_FREIGHT_EN.pdf.
[4] Railway Pro, Turkey prioritizes railway transport to increase freight flows. https://www.railwaypro.com/wp/turkey-prioritizes-railway-transport-to-increase-freight-flows/. Accessed on: 23 Jan. 2013.
[5] Union International Railways, Making international freight products and services more competitive by harmonising business, operational and information processes. https://uic.org/freight/.
[6] Rail Freight Forward, 30 by 2030: How rail freight achieves its goals. https://www.railfreightforward.eu/sites/default/files/downloadcenter/rff_cer_position_paper.pdf. Accessed on: 2 Jul. 2020.
[7] Bína, L., Bínová, H., Březina, E., Kumpošt, P. & Padělek, T., Comparative model of unit costs of road and rail freight transport for selected European countries. *European Journal of Business and Social Sciences*, **3**(4), pp. 127–136, 2014.
[8] Wang, X., Song, G., Zhai, Z., Wu, Y., Yin, H. & Yu, L., Effects of vehicle load on emissions of heavy-duty diesel trucks: A study based on real-world data. *International Journal of Environmental Research and Public Health*, **18**(8), p. 3877, 2021.
[9] Department of Infrastructure, Transport, Regional Development and Local Government, Road and Rail Freight: Competitors or complements? https://www.bitre.gov.au/sites/default/files/is_034.pdf.
[10] Khan, M.Z. & Khan, F.N., Estimating the demand for rail freight transport in Pakistan: A time series analysis. *Journal of Rail Transport Planning and Management*, **1**(14), 100176, 2020.
[11] *Britannica*, Coal transportation. https://www.britannica.com/technology/coal-mining/Coal-transportation. Accessed on: 1 May 2020.
[12] Biernikowicz, W., Rail transport in NATO's logistics system: The case of Poland. *European Research Studies,* **24**, pp. 748–761, 2021.

[13] *Building America, Proud to Serve the Military*. https://www.up.com/customers/ind-prod/military/index.htm. Accessed on 01 Jan. 2021. Eurostat Statistics, Freight transport statistics: modal split. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Freight_transport_statistics_-_modal_split.
[14] Rempfer, K., That army equipment moving by rail? Not a sign of looming martial law. *Army Times*. https://www.armytimes.com/news/your-army/2020/03/22/that-army-equipment-moving-by-rail-not-a-sign-of-looming-martial-law/. Accessed on: 22 Mar. 2020.
[15] *Railway Technology*, Industrial and mining applications. https://www.railway-technology.com/products/industrial-mining-applications/. Accessed on: 1 Dec. 2017.
[16] Murphy, B., How trucks destroy our roads and how a fee on trucks could solve state's transportation problem. https://urbanmilwaukee.com/2017/06/22/murphys-law-how-trucks-destroy-our-roads/#:~:text=An%20off%2Dquoted%20federal%20study,the%20truck%20is%20exponentially%20greater. Accessed on: 22 Jun. 2017.
[17] Luskin, D. & Walton, C.M., Effects of Truck Size and Weights on Highway Infrastructure and Operations: A synthesis report. Center for Transportation Research, Bureau of Engineering Research, University of Texas at Austin, 2001.
[18] *Asharq Al-awsat*, Saudi mineral exploration saves 25% of global spending. https://english.aawsat.com/home/article/2273561/saudi-mineral-exploration-saves-25-global-spending. Accessed on: 8 May 2020.
[19] *Saudi Arabia Railway*, Our network connectivity across the Kingdom. https://www.sar.com.sa/about-sar/ournetwork/.
[20] *Saudi Arabia Railway*, SAR trains are possible industrial. https://SARSaudiRailway/status/1531277285520711680.