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Challenges and opportunities in development sustainable transportation system in Saudi Arabia

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ABSTRACT

This paper presents the recent development of transportation system in Saudi Arabia. tabReview of transportation system developed in the last three decades including air, land, sea and rail transportation. Problems raised from each mode of transportation were addressed and possible solution were provided. The results indicate that air transportation could provide the necessary needs of the Kingdom of Saudi Arabia in international connections while domestic air transportation provide limited passenger transportation for relatively long distances. This mode is limited to high income people and cannot serve short distances in effective way. Sea transportation could provide the country with freight transport but limited to passengers only in the Golf region or in the red see with some African countries. Road and highway provide the most transportation used by the public but associated with several problems such as environmental pollution, large number of road traffic accident and became the first cause of death in the Kingdom. Bus and car public transportation need essential improvement to meet the demand and save transportation for the public. Rail transportation seems to be the most sustainable transportation in future transportation in the country. Saudi Arabia late pay attention to rail transportation and recently intensive budget invested in rail transportation. Further development in rail transportation in the Kingdom is needed.

1. Introduction

The Kingdom of Saudi Arabia (KSA) is among the biggest Arab countries and the largest Gulf Corporation Countries (GCC). KSA located between 321N and 171N latitude and 561E and 281E longitude with a population exceeding 32 million in the year 2017 and occupied a large area of 2,149,690 km2 [1][2][3]. KSA is the biggest economy in the region with a total GDP of more than 600 billion US dollar. The petroleum industry contributes for approximately 80% of budget revenues, about 45% of GDP, and more than 90% of export earnings [4]. The strategic location of the KSA forming a center of the world and could play an important role in connecting Asia, Europe, and Africa. Based on income per capita, KSA is ranked on the 18th position in the world [3]. Because of large population of the country and the high income, the transportation demand is very high in the KSA [5]. Population and economic growth maximize aggregate transport demand and leads to an increase in the investment in major project in all mode of transportation including air, sea and land transportation [6]. Road transportation absorb most of the transportation development during last three decades. This resulted in a tremendous rising of transport energy consumption [7][8][9]. This also make car ownership and mobility of vehicles is the main mode of transportation in KSA. Despite the favorable effects of these factors on the development economic condition in the country, they possess many con

effects on national communities and individual peoples, such as traffic overcrowding, accidents disaster, environmental air pollution, vast amount of energy use, noise pollution, and change of land [5].

Convincing people to Shift from ownership private car to use public transportation is quite a difficult mission for decision makers, policymakers and transportation designer and planners. The private ownership cars become the most comfortable and appropriate travel choice especially in rich countries such as KSA. This problem is escalating in KSA because experts focus attention on the need to growing acceptability of public transportation mode combine with higher efficiency, safety, and security. Cities in KSA has grown and escalated in last three decades due to uninterrupted economic growth which creating reverse impacts for air quality emissions of greenhouse gases, walkability and bicycling. Therefore, cities in KSA to a large extent appreciate uses of cars as an efficient and easy mode of transit. Though in KSA the prices of automobile and gasoline are very cheap; the undesired consequences of larger number of car ownership including traffic jam and unhealthy urban areas open the door to plan and design a sustainable public transportation mode inside and outside the urban areas and cities [10][11][12]. This paper presents a review of transportation modes in KSA and determine the con and merit of each mode in order to propose strategic decision to face the challenges of future transportation system in Saudi Arabia.

2. Method

To determine the challenges and opportunities of sustainable transportation system and mod, it is necessary to collect information about all mode of transportation in KSA and evaluate problems associated with each mode. In this study, data related to four mode of transportation have been collected including (1) air transportation such as current airports in KSA its location, services as international or domestic flights. Needs related to air transportation were also addressed; (2) sea transportation data were collected such as ports locations and functions; (3) road transportation information were gathered including highway network and traffic needs. Problems results from road transportation such as accidents traffic volume pollution and lack of quality public transportation were gathered, evaluated and addressed; (4) rail transportation data were collected including current railways; railway projects under construction, planned railways and future needs. In addition, railways distribution and con and merit of rail transportation were assessed. For each of these data problems and future need were determined and challenges of solving problems result from these transportation modes were presented. The results of data collected from these four transportation modes in KSA were summarized in next section in terms of tables and drawn in KSA maps.

2.1. Mode of transportation in KSA

In KSA, the household spends on transportation approximately 20% of the total expenditures. This makes transportation ranked the 2nd largest expenditure after housing. This agrees with other studies conducted in USA and Europe which found that transportation consumes between 15% and 25% of total expenditure. Transportation is considered as the second source of greenhouse gas emissions and environmental pollution while transportation is the first cause of death in Saudi Arabia. KSA in the last 20 years invest a huge amount of capitals in building modern transportation projects. These projects cover all mode of transportation such as roads, air, sea, and rail transportation. This section reviews the development of all mode transportation and determine the merit and con of each mode, challenges facing these mode, impact of these modes on country development plan, problems associated with each mode and determine the future need in transportation planning in Saudi Arabia.

2.2. Air transportation

Saudi Arabia is large area connecting Asia, Africa, and Europe. Therefore, Saudi Arabia invest a huge amount of money to build 23 airports in the last 30 years to meet the demand for large number of passengers traveled. The location of these 23 airports are given in Figure 1. In addition, the large area raises the need for several domestic airports to connect different region of the country. Recently another five airports were constructed. Among these new airport Amaala completed in 2019 and Neom airport expected to be completed in 2023. The total number of airports reaches 28. Four airports were international extended recently to 8 airports. The detail of international airports is listed in Table 1. Five airports were regional airports. The information of these regional airports is given in Table 3. The rest 15 were domestic airports. The data of these domestic airports are presented in Table 2.

Fig. 1. National and international airports in KSA and its location

Table 1. Main international airports in KSA and its location according city and province.

Airport	City	Province	Note
King Abdulaziz International Airport	Jeddah	Macca	The largest airport
King Khalid International Airport	Riyadh	Riyadh	The 2nd largest airport
Prince Mohammad Bin Abdulaziz International Airport	Al Madinah	Al Madinah	Mainly help in Haj and religion visitors to holy land
King Fahd International Airport	Dammam	Eastern	The 3rd largest airport
Al-Ahsa International Airport	Al-Ahsa	Eastern	-
Prince Abdul Mohsin bin Abdulaziz International Airport	Yanbu	Al Madinah	-
Prince Nayef Bin Abdulaziz Regional Airport	Buraidah	Al-Qassim	-
Amaala International Airport	Amaala	Tabuk	Under construction

Table 2. Main domestic airports in KSA and its location according city and province

Airport	City	Province	Year
Al-Baha Domestic Airport	Al Bahah	Al Bahah	1983
Al-Jawf Domestic Airport	Al-Jawf	Al-Jawf	2011
Al Wajh Domestic Airport	Al Wajh	Tabuk	1984
Arar Domestic Airport	Arar	Northern Border	1981
Bisha Domestic Airport	Bisha	Asir	1976
King Salman Bin Abdulaziz Domestic Airport	Dawadmi	Riyadh	2003
Gurayat Domestic Airport	Gurayat	Aljawf	2011
Najran Domestic Airport	Najran	Najran	2011
Al Qaisumah/Hafr Al Batin Airport	Qaisumah	Eastern	2011
Rafha Domestic Airport	Rafha	Northern Borders	1978
Sharurah Domestic Airport	Sharurah		1972
Prince Abdul Majeed bin Abdulaziz Airport	Al'Ula	AlMadinah	2011
Turaif Domestic Airport	Turaif	Northern Borders	1979
Wadi al-Dawasir Domestic Airport	Wadi al-Dawasir	Riyadh	1990
Neom Bay Airport	Neom	Tabuk	2019

Table 3. Main regional airports in KSA and its location according city and province.

Airpot	City	Province	Note
Abha Regional Airport	Abha	Asir	Under expansion project could be an international airport for the south region
Jizan Regional Airport	Jizan	Jizan	-
Ha'il Regional Airport	Ha'il	Ha'il	-
Tabuk Regional Airport	Tabuk	Tabuk	Could have potential to be an international airport for the south region
Ta'if Regional Airport	Ta'if	Mecca	-

2.3. Sea transportation

KSA forms the greater part of the Arabian Peninsula. KSA is in located in west of Asia. KSA surrounded by Jordan and Iraq from north, Kuwait, Qatar, United Arab Emirat and Omman from east, Red Sea from west and Yaman from south. KSA is a biggest and major trading country with several countries in the middle east region as well as internationally. This leads to construct 10 major ports in Gulf and Red Sea. These ports are pivotal and critical factors in the economic growth and development of the country. Sea transportation in KSA was developed to meet the demand of oil and petrochemical transport. Several main ports in KSA is in the east part in the Gulf or in the west part in Red Sea. Figure 2 shows the locations of major ports in the KSA. Table 4 includes information of the major posts in both Gulf and Red Sea.

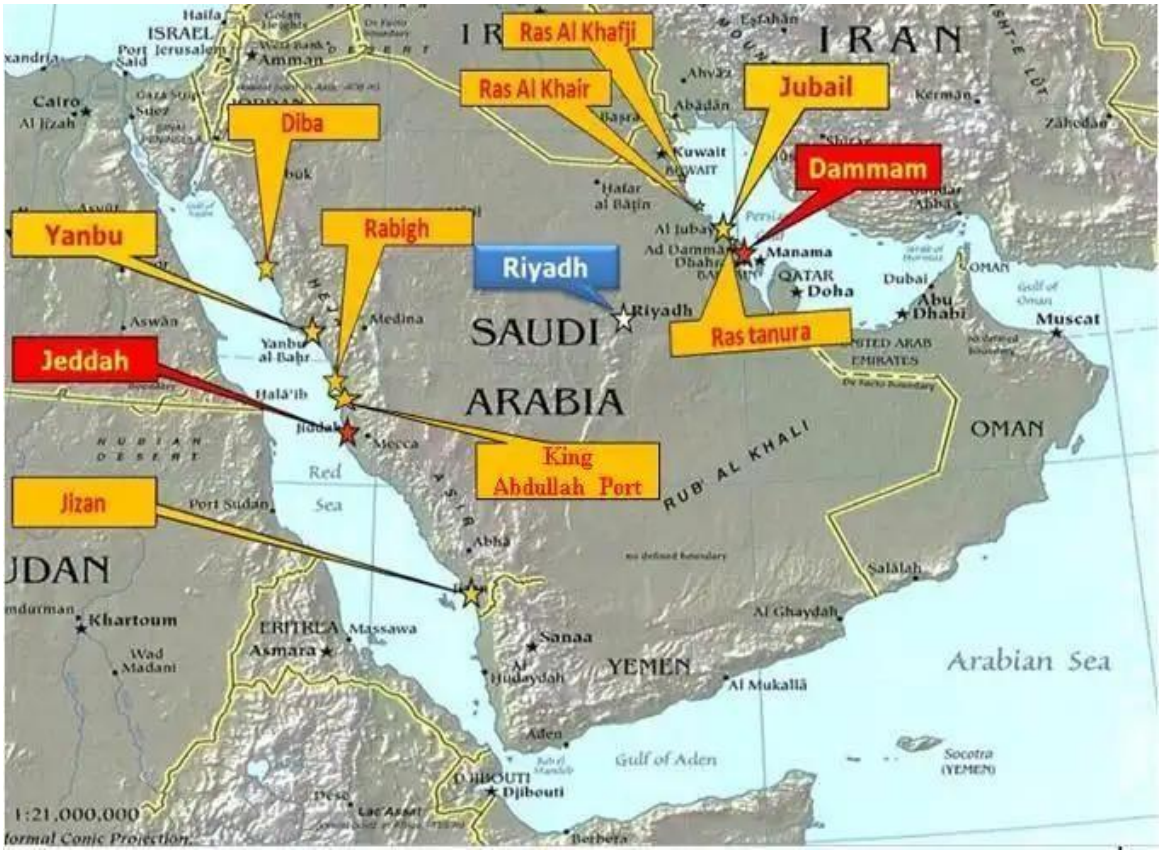

Fig. 2. Map of KSA presents the distribution of major ports in Gulf and Res sea.

Jeddah Islamic port is the most crucial port in KSA located at Red Sea. Because KSA is ranked number one among countries export gas and oil in the world, this port plays very important role in storage of gas oil as well as exportation of goods and products. The port handles about 70% of the KSA import and export goods and materials. This port became the main and busiest port in the Red Sea. The port has a large number of cargo tools which exceeds 1700 modern handling equipment. The Jeddah Islamic Port features massive warehouses to handle retention of cargo where applicable, a ship

building and repair yard, 62 berths all equipped with the latest in technology. The berths can handle everything from livestock cargo to passenger cargo and bulk grain, containers as well as general cargo. The overall capacity of the port is 130 million tones across the 5 terminals. This port is expected to employ automation at terminals with time. The second important port is King Abdulaziz Port in Damman at Gulf region. King Abdulaziz Port considered the biggest and busiest port within the Arab Gulf. This port also considers as the second busiest port in the Middle East and Africa combined. This port is ranked number two after the Jeddah Islamic Port which is number one in operations and capacity. The port becomes a good and specialized center in training Marin science and technology. Several other activities conducted in this port such as ship repair yard, re-export area, warehouses, and yards for transshipments. Sea transportation could provide the country with freight transport but limited to passengers only in the Golf region or in the red see with some African countries.

Table 4. Major ports in KSA and its location in the Gulf or Red sea.

Name of the Port	Location	City	Information
King Abdul Aziz Port	Gulf	Dammam	The main and biggest port in the gulf. This port handles a biggest share of the gas and oil export services. The port is consisted of a refrigerated cargo terminal, general cargo terminals for bulk grain, and two terminals for containers.
King Fahad Industrial Port Jubail	Gulf	Jubail	Jubail port was established and constructed to help in the increasing need for oil and gas exports. The Port is mainly created to service industrial activity in the Jubail city. Therefore, it became the main port for import raw materials to cover the industrial and factory needs.
Ras Tanura	Gulf	Ras Tanura	Ras Tanura port is constructed close to the city of Dammam, at the gulf in the north part coast. This place of KSA also several facilities for transport such as airport and highway, which could help export and import in the area. Even this port is small but it is designed to manage middle cargo. In addition, several military practices are conducted in this port.
Khafji	Gulf	Khafji	-
Khobar	Gulf	Khobar	-
Ras Al-Zour	Gulf	Ras AlZour	-
Jeddah Islamic port	Red Sea	Jeddah	The biggest and main port in Red Sea in KSA. The location of this port occupied a strategic position of international shipping routes which form an important connection of the west world with the far east countries.
King Fahad Industrial Yanbu	Red Sea	Yanbu'	The Yanbu port is the mainly port handling the export of crude oil in Kingdom of Saudi Arabia. This port also carry activities of refined petroleum products export. In addition, most of petrochemicals transport in the Red Sea performed using this port. The location of the port in very important because it is connect Suez Canal trading routes with Bab El-mandeb
Al Lith	Red Sea	Al-Lith	-
Duba	Red Sea	Duba	Dupa port was constructed and operated to help the north area of Saudi Arabia at the Red Sea. Dupa port is the near to Suez Canal, and could have good routes to several Europe countries such as Turkey, France, Italy, Spain and Greece. Dupa port have activities such as passengers and cargo services. This port is upgraded with modern infrastructures to deal with various types of cargo
Rabigh	Red Sea	Rabigh	-
Jizan	Red Sea	Jizan	Jizan port is an important port provide services in the south area of KSA at Red Sea. This location of the port could help all ships using the important ocean routes to

			Europe and many eastern countries. The size of the port is medium but equipped with pretty and modern equipment to handle and manage big size cargo and containers.
Farasan	Red Sea	Mecca	Very small port and have potential to grow.

2.4. Road transportation

Road and highway network used to determine the level of country development. Saudi arabia buids a vast road network during the last three decades. This road network connects the regions and major cities in KSA. The main roads highways exceed 700000 km in length and will continue to increase further due to the need of new urban areas and expansion of most cities in the country. These roads and highways ranges from 2 lanes to 8 lanes. Figure 3 shows Saudi Arabia map including the major roads and highways network. The main road network is given in Figure 3.

Fig. 3. Major highway and roads network in KSA

Saudi Arabia currently have large excellent road network and the focus should be shift from building new roads to maintain the existing road network to provide a good quality. The intensive investment in road network in the country drives by the higher demand in rapid economic growth in KSA because during the last 30 years the transportation of people based on ownership car. This is because the country has a high income, low fuel prices, culture and limited other mode of transportation systems such as sea and railways. In addition, the bus public transportation system is very limited and only limited to one company SAPTCO established in 1979 and it has more than 5000 buses and limited acceptable taxi transportation mode in most major cities. These conditions of highway and road transportation mode in KSA raise many problems. These problems include air

pollution, noise pollution, and vast number of road traffic accident. Road traffic accident, road traffic injuries and road traffic deaths continue to increase in the last 30 years despite all major taken to reduce this problem. Recently, reduction of road traffic accidents occurs due to new vision of KSA called 2030 and implementing new transportation strategic plan in 2018. Road traffic accidents became the first cause of death in the country and reaches 27 death per day. This is also, concluded by several studies [2][13].

2.5. Rail transportation

Railway in KSA starts in 1900 with a long rail project to connect Damascus to Medina. This railway called Hejaz railway completed in 1908. The main purpose of this rail line to carry pilgrims on the Hajj. Another project in rail was after 50 years. In 1951 a rail project was constructed to connect the port at the Gulf to Dammam city with length about 16 km then extended to Riyadh with length 450 km. Later a parallel line constructed for freight while the first used for passengers. KSA remained without railways until major rail projects starts in 21st century. These major projects were planned by the master rail plan in KSA. The plan includes several large rail projects such as North-South rail line, gulf countries line, linkage line, Haramein line connected Madinah to Jeddah and Mecca and several other rail projects. The major rail projects in KSA are listed in Table 5.

Table 5. Major rail projects in KSA

Rail Project	Cost and condition	Length and location	Note
The North-South Railway	The longest rail project cost $3.5 billion, started in 2005 and completed in 2012 for freight and for passengers in 2016.	It is a 2,400km passenger and freight rail line. The 1,418km passenger line runs from Riyadh to Al Haditha close to Jordan border.	Completed
The Haramin Railway	It still planned and under constructed	It is 450km high-speed rail link from Madinah to Makkah through Jeddah.	Completed
The Landbridge Railway	It is planned and under construction.	It is 1,100km project connecting the eastern and western from Riyadh to Mecca.	Under construction
Gulf Cooperation Council (GCC) Railway	Largest contemporary crossborder rail networks in the world. With a total price projection of over $240 billion	This rail plan to connect 6 Arab gulf countries including KSA. It is 2116 km linking all GCC countries and about 660 km in KSA.	Under construction
The Riyadh Dammam Railway	The line starts from the port in Dammam and passes through Al-Ahsa, and ends in Riyadh	It consisted of two lines. Line 1 is a 450 km for passenger and line 2 is 556 km for cargo.	Completed
Other railways planned projects	The lines are the Taif-–Abha line (706 km), the Jeddah-Jizan line (660 km), and the Yanbu–Jeddah line (350 km)	KSA also has plans to construct three lines in southern Saudi Arabia to improve the region's connectivity with the rest of the country.	Plan for future

2.5.1. Major rail transportation in KSA.

The major rail plan includes the completed rail, under construction, future planed, and other rail projects needed are summarized in Table 5. The most important rail projects in KSA are also discussed and introduced. Figure 4 shows KSA map and constructed railway project. The Figure indicate that if all major rail projects completed and the other rail project are constructed, KSA will have an excellent railway transportation system. From the Figure it is also necessary to look for the need for another two railway projects needed. One project to connect the other project to the northsouth line from Tabuk to Al-baseeta and another project to link Riyadh to the south area to Wadi Aldawaser (khamis mushait) and Najran. This will cover all the need of railway line to connect all regions and major cities in the country [14]. Additional need in rail transportation system is needed in KSA to improve public transport inside the major cities and solve the high traffic volumes in large cities such as Riyadh, Jeddah, Damman, Mecca and Madina. KSA starts solving this problem to provide high quality rail transportation in major cities. This could be sustainable transportation systems, environmentally friendly by improving ail and noise pollution results from high car traffic volume and could help in reducing the rad traffic accidents the critical problem in KSA. The project of Riyadh metropolitan will be completed in near future. Another three project were planned and designed and will be constructed

covers Dammam, Jeddah and Mecca. Further need to invest a large amount of money to develop a rail transportation in few other major cities in KSA. This include cities such as Madina, Tabuk, Kasim, and Abha. If these railways and public transport system could become fully operated and the customers have used to its tremendous advantages, the roads in most big cities and urban areas such as Riyadh will be markedly less congested and safer. The expectation is that the minority of people who feel the need to travel by car could has faster journeys, normally free of the frustrations of traffic jams [15].

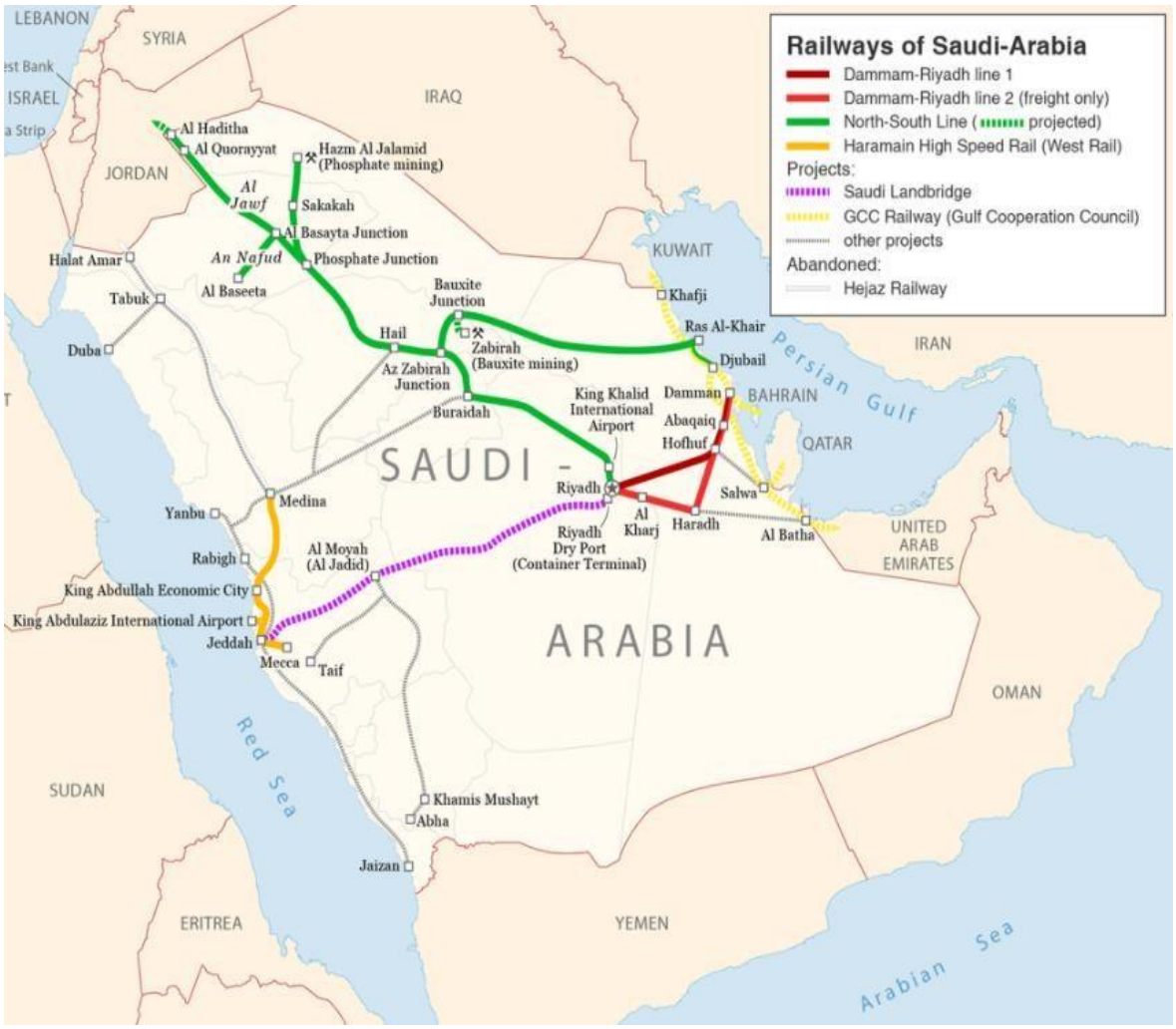

Fig. 4. Major rail transportation projects in KSA

2.5.2. Advantages of rail transportation.

Bold Mobility of humans and freights could have three possible modes of transportation such as road, water, air, or rail transportation system. Every mode of transport has its merits and con. The merits of rail transportation system make it the most sustainable mode of transport worldwide. For KSA, rail transport system could have the following advantages over other modes of transport [16].

- Dependable on Weather Conditions: Rail transportation is less influence by weather condition such as in Saudi Arabia compare with other modes of transportation. Rail transportation could run through fog, hot temperature, heavy rain, sandstorm, and dust-storm, while other land transportation like trucks are stationed until the roads and highways clear [17][18].
- Environmentally Friendly: Rail transportation also lower greenhouse gas emissions, reduce road and highway congestion, and even reduce pollution with less CO2 emission. In addition, most modern rail transportation used electricity which is environmentally friendly more than oil and petroleum fuel used by cars, trucks, and busses.

- Well Organized System: The rail transportation is well organized and better than all other modes transportation such as land, air and sea transportation. The rail transportation system has a definite and known routes and the schedules of rail transport is predesigned and planned. The service provided by rail transportation has a uniform and regular quality as compared to all modes of transportation.
- Rail transportation normally does not deal with variable and unusual traffic mode and patterns, customer will know the exact and precise scheduled departure and arrival times of freight.
- Railway transportation mode consider extremely cost effective. This is a vital and important factor to every company. Because railway could carry and move more cargo with one train while this is difficult with one truck, people and companies could save on transport costs.
- The speed of railway transportation over long distances consider the faster mode of transport than most other transportation mode, except airways. Therefore, railway could be the best choice for relatively long-distance travel.

2.5.3. Disadvantages of rail transportation.

Despite the previous advantages explained of rail transportation in general and for KSA, several disadvantages and challenges could be drawn. These disadvantages may include: Railways do not provide door to door service like road transport. The railway is required very big investment of money. The cost of railway design and construction, repair and rehabilitation cost and operating and overhead cost are tremendous high as compared to road, sea and air transportation mode. Another con of railway transportation mode is inflexibility of serving areas because of limited number of secondary rout and a smaller number of stations and substations. Its timing and routes are fixed and could not be flexible and adjusted to serve individual needs required. Railway transportation mode could not provide service from door to door because it is limited to a particular track.

3. Results and Discussion

The paper presents review of four mode of transportation namely air, sea, road and rial in KSA and discuss the advantages and disadvantages of these modes. The study also draws the future need in transportation development in the country. The results indicate the following results:

- The most mode of transportation used in KSA in ownership car in road and highway. This mode is raised several issues and problems including, large traffic volume and traffic congestion leads to environmental problems such as air pollution, noise and vast number road traffic accidents resulted in many deaths. Therefore, road traffic accidents are the first cause of death in KSA.
- Sea transportation mode in Saudi Arabia play a vital role in country economic development and form the main mode of oil and freight transportation but limited for passenger transportation except limited routes between Gulf countries and other countries at the Red Sea.
- The rail transportation seems to be the future transportation and dominant mode in KSA due to several factor. Among these factors, rail transportation is relatively fast, comfortable and suit harsh and hot environment in KSA. In addition, rail transportation is friendly to environment because it produces less air pollution and mostly it is safer and could reduce road traffic accidents and deaths which is a major challenge to Saudi government during last 30 years.
- The attention should be paid to develop and promote bus and car public transport in KSA. This may help in providing people by low cost transportation system and reduce traffic jam and traffic volume.
- Air transportation show an excellent level in development in international and domestic airport and travels. Number of airports is adequate to cover the need of the country and link the country with the rest of the world. The need may be limited to improve the service in these airports and upgrade some of the airports to increase its capacity and may some of the domestic could be changed to international airports such as one in the south of the country (like Abha) and one in the north (like Tabuk).

Table 6. Summary of challenges and opportunities in transportation in KSA.

Transportation Mode	Challenges	Opportunities	Solutions
Air transportation	The need for more international airports is crucial to meet the demand for passengers and to economic development of the country. Big investment is needed upgrade and improve the service in few airports	The location of KSA may form a hup for international flights to link the west world with the east world. This may provide KSA with a strategic position for people to travel and stop in KSA for transit.	Two new airports are under construction may solve this need. Two international airports are needed one in the north and one in the south (Abha and Tabuk is the most suitable)
Sea transportation	The 10 existing ports is quit enough but may some of these ports could upgraded to meet further increase in export and import.	Five ports in the Red sea could make KSA the most suitable country to link the travel of ships from east countries to the west world.	Develop more cruse for passengers in Gulf and red sea will solve problems in travelling between Gulf countries and between several African countries
Road transportation	Deterioration of roads and highways from heavy truck loads and harsh environment in KSA. Lack of quality bus and taxi public transit. One of the major problems is the high road accidents and death in addition to environmental pollution and traffic jam.	A big area for investment is available to establish public road transportation. Low petrol prices in KSA could easily manage the repair of the existing road networks. Using advance techniques and renewable energy could solve environmental problem. Accidents were reduced by implementing Vision 2030.	Use new Technology to maintain the quality of the existing road network and build new roads only for new urban areas and the expansion of existing urban areas. Public transportation may provide solution for traffic volume and jam. Also, could help in reducing pollution and accidents.
Rail transportation	Several railways established the challenge is to complete the planned and future railway projects. Major cities need big budget to develop its rail transportation metro.	Rail transport seems to be the most sustainable mode of transport in KSA due to the harsh environment and lack of public transport. This could help in reduce road traffic problems and environment pollution problems	Railways projects is needed to link the east and west part of KSA in the north and south part of the country.

4. Conclusion

KSA is rich with various distinct topography, harsh climate associated with rapid changes, describe as very elevated temperatures, sandstorm, and low precipitation and rainfall. Saudi Arabia is among rich Arab countries with high income and low fuel prices. This need to develop a sustainable transportation system to suit all these factors. The paper presents review four mode of transportation in KSA and discuss the advantages and disadvantages of these mode and draw the future need in transportation development in the country. The results indicate that most of transportation problems in Saudi Arabia result from lack of effective public transportation system and mainly based on ownership private cars, this leads to traffic jam, environmental problems such as noise and air pollution and high traffic accidents and deaths. These problems could be solved by further investment in developing bus and taxi public transportation and further increase of development railway transportation system which consider the most sustainable mode of transportation especially for KSA conditions. In addition, further improvement in sea and air transportation is needed which may put the country as a hup of connecting the east countries with west world according to the strategic location of the country in the center of the world.

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