



Enhancing the Development of Sustainable Modes of Transportation in Developing Countries: Challenges and Opportunities

Mohammed Dahim^{1*}

¹ Associate Professor and Vice President, King Khalid University, Abha, Saudi Arabia.

Received 23 September 2021; Revised 26 October 2021; Accepted 12 November 2021; Published 01 December 2021

Abstract

All modes of transport can be seen to bring some influence to bear on a country's economic growth, health, and environment. However, the impact differs among developing countries. This paper presents an assessment and evaluation of the development of a sustainable transportation system in the Kingdom of Saudi Arabia (KSA). For this study, data were collected about the four transportation modes of sea, air, road and rail. The data were analyzed to determine the current condition, needs, challenges, and opportunities for improvement for each mode of transportation. Problems associated with each transportation mode were addressed and solutions to overcome these problems were recommended. The results indicate that while sea transportation provides the country with freight transport, it is of limited service to passengers in the Gulf region or on the Red Sea. Air transportation meets the needs of Saudi Arabia with international connections, but domestic flights provide limited passenger transport to the wealthy and are not an effective mode of transport for short distances. Road transport is the most popular mode for the general public but is associated with numerous problems such as the environment, health, noise, a high accident rate, and being the first cause of death in the country. Rail transportation seems to be the mode which is most sustainable for the future. It is essential that KSA meets public demand for public transportation with a reliable, cost effective, and safe public transportation system.

Keywords: Air Transportation; Rail Transportation; Ports; Roads and Highway; Saudi Arabia.

1. Introduction

The transportation system plays a significant role in matters of the economy, environment, and health especially in developing countries where the population and mode of living have changed rapidly in recent years [1-2]. Current transportation systems and modes, which pose numerous economic growth and social development challenges, account for approximately 64% of world petrol consumption, 27% of all energy use, and 23% of the energy-related CO₂ emissions. The development of a sustainable public transportation system forms a crucial factor in reducing these problems [3-5]. Future transportation projects should focus on a system that is efficient, sustainable, uses less energy and produces low carbon emissions in order to mitigate climate change. Successful public transportation planning requires improved understanding of the consequences of system planning and implementation, based on analysis of the factors that affect demand.

The Kingdom of Saudi Arabia (KSA) is among the biggest Arab countries and the largest of the Gulf Corporation Countries (GCC). KSA is located between 321N and 171N latitude and 561E and 281E longitude and occupies a vast

* Corresponding author: madahim2018@yahoo.com

<http://dx.doi.org/10.28991/cej-2021-03091776>



© 2021 by the authors. Licensee C.E.J, Tehran, Iran. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC-BY) license (<http://creativecommons.org/licenses/by/4.0/>).

area of 2,149,690 km². In 2017, the country's population exceeded 32 million [6-8]. KSA is the biggest economy in the region with a total GDP of more than 600 billion US dollars and based on income per capita, it ranks 18th in the world. The petroleum industry contributes for approximately 80% of budget revenues, about 45% of GDP, and more than 90% of export earnings [9]. The strategic location of the KSA gives it an important role in connecting Asia, Europe, and Africa.

Due to the KSA's large population and high income, the demand for transportation is very high [10]. Population and economic growth maximize aggregate transport demand and leads to an increase in the investment in major projects in all modes of transportation, including air, sea and land transportation [11]. During the last three decades, the majority of transportation development has focused on road systems. Automobiles have thus become the main mode of transportation, which has resulted in a tremendous rise of fuel consumption [12-14]. favorable effects on the development of economic conditions in the country, these are accompanied by negative impacts on the nation and individuals, such as traffic overcrowding and accidents, environmental air pollution, high energy consumption, noise pollution, and alteration of the landscape [10].

The population of KSA, to a large extent, uses privately owned cars as an efficient and easy mode of transit as they are the most comfortable and convenient travel choice, especially in rich countries such as KSA. Cities in KSA have expanded rapidly in the last three decades due to uninterrupted economic growth. The fact that most of the citizens currently use their own cars for almost all of their travel needs has a serious impact on greenhouse gas emissions and resulting air quality. There are no inducements for citizens to travel short distances on foot or by bicycle, and the easiest existing way for people to cover longer distances is by car. Automobiles and gasoline are very cheap, yet the undesired consequences of privately owned vehicles being the primary mode of transport include traffic jams and unhealthy urban areas. Convincing people to shift from travelling by private car to using public transportation is proving a difficult mission for decision makers, policymakers, and transportation designers and planners. However, there is a great need to plan and design a sustainable public transportation system that will serve the citizens both inside and outside the cities and urban areas. Experts need to focus attention on developing a culture where people find using a mode of public transportation acceptable, and this depends upon there being an efficient, cost effective, safe transport system available which will take people wherever they need to go, countrywide [15-16].

This study focuses on how to expand the transportation networks of KSA and the necessary future investment in these sectors. This research seeks to bridge a gap in the existing literature about sustainable transportation systems and the investment needed to provide them. Additionally, the impacts of modes of transportation on local and regional productivity have received little attention for countries where the economy is based on oil, such as Saudi Arabia. The findings from similar studies conducted elsewhere may not be directly applicable to the situation in Saudi Arabia which is unique regarding its political stance, climate, culture, location, and budget allocation [17-19]. This paper presents a review of transportation modes in KSA and determines the advantages and disadvantages of each mode in order to propose a strategy to face the challenges of transportation systems in Saudi Arabia and how they can be improved and made more sustainable in the future.

2. Methods and Data Collections

To determine the challenges and opportunities of creating a sustainable transportation system, it is necessary to collect information about all modes of transportation in KSA and evaluate problems associated with each mode. In this study, data related to four modes of transportation, namely air, sea, road, and rail was collected. Data about air transportation covers the existing airports in KSA, including their locations, the services they provide (international or domestic flights), and the needs related to air transportation. Sea transportation data lists the ports and their locations and functions. Road transportation information gathered includes highway networks and traffic needs. Problems resulting from road transportation such as the high volume of traffic accidents, pollution, and lack of quality public transportation were gathered, evaluated and addressed.

Rail transportation data were collected including existing railway networks, railway projects under construction, planned railways and future needs. In addition, railway distribution and the pros and cons of rail transportation were assessed. For each set of data, problems and future needs were determined and challenges of solving problems associated with these transportation modes were presented. The results of the data collected regarding these four transportation modes in KSA are summarized in the next section in terms of tables and illustrated using maps of the country. The research methodology used in this study, including data collection and analysis for the four modes of transportation, is presented in Figure 1.

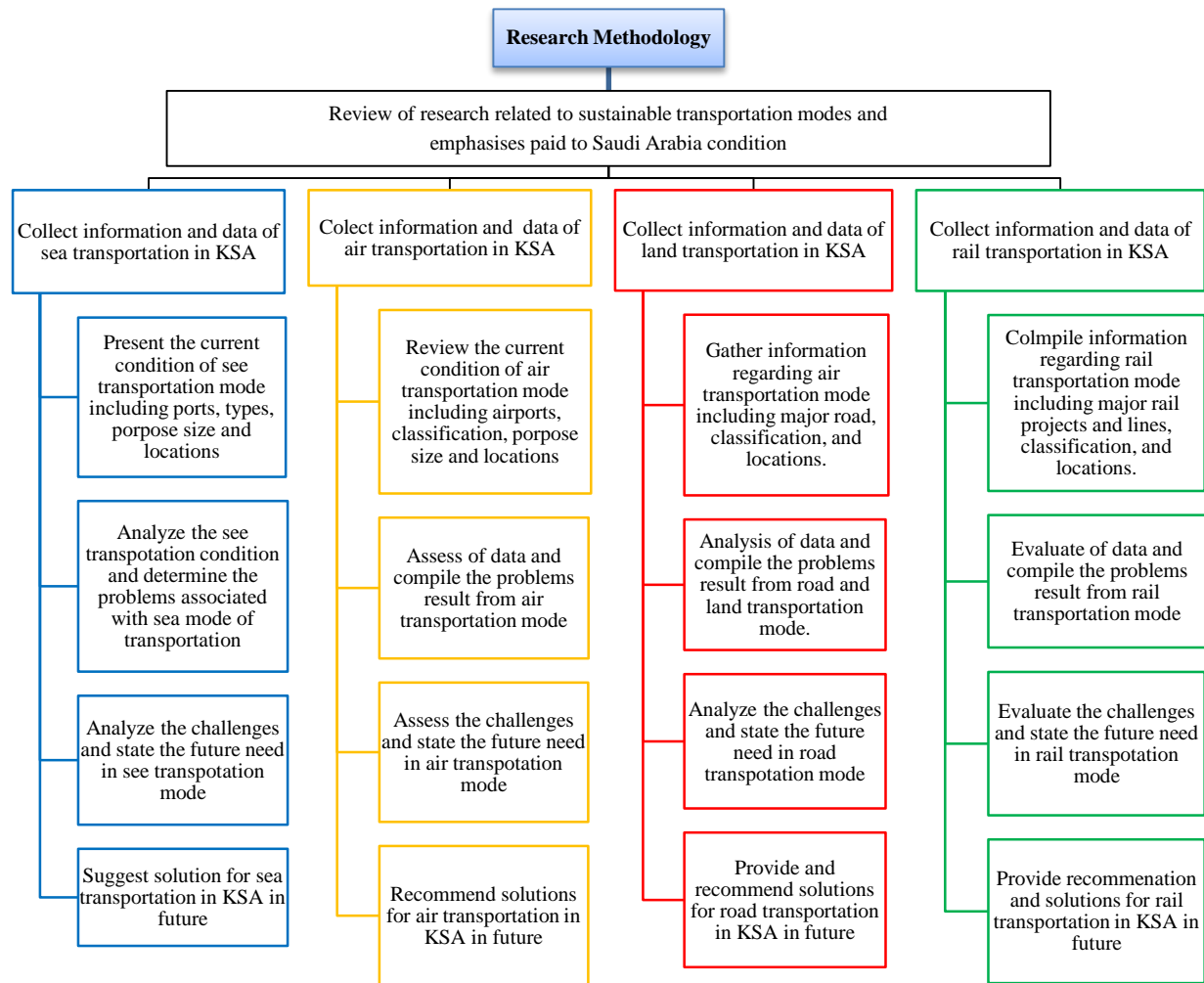


Figure 1. Flowchart of research methodology conducted in this study

3. Mode of Transportation in KSA

The average household expenditures on transportation in KSA equals approximately 20% of the total expenditures, making it the second largest expenditure after housing. This agrees with other studies conducted in USA and Europe which found that transportation accounts for 15% and 25% of total expenditure. Transportation is considered the second source of greenhouse gas emissions and environmental pollution, and is also first cause of death in Saudi Arabia. In the last 20 years, the country has invested a huge amount of capitals into modern transportation projects. These projects cover all mode of transportation via roads, air, sea, and rail. This section reviews the development of these modes of transportation and determines the strength and weakness of each mode, the challenges facing them, their impact on the country’s development plan, and the problems associated with each mode. It goes on to determine the future needs of transportation planning in Saudi Arabia.

3.1. Sea Transportation

Located in west of Asia, KSA forms the greater part of the Arabian Peninsula. KSA is bordered by Jordan and Iraq from the north, Kuwait, Qatar, the United Arab Emirates and Oman from the east, the Red Sea from the west, and Yemen from the south. KSA is a major trading country both regionally and internationally. Sea transportation in KSA was developed to meet the demand of oil and petrochemical transport. This leads to the construction of 10 major ports in the east of the Gulf and to the west on the Red Sea. These ports are pivotal and critical factors in the economic growth and development of the country. Figure 2 shows the locations of KSA’s major ports. Table 1 includes information of the major ports in both the Gulf and Red Sea.

Jeddah Islamic Port located on the Red Sea, is the most crucial port in KSA. The busiest port in the Red Sea, Jeddah handles approximately 70% of the KSA’s import and export goods and materials. It plays a very important role in the storage of gas oil, of which KSA is the world’s biggest exporter. The port has in excess of 1700 pieces of modern handling equipment as well as massive warehouses to handle retention of cargo where applicable, a ship building and repair yard, and 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 tons across the 5 terminals, which are expected to employ automation in the near future. The second most important port is King Abdul Aziz Port in Damman on the Gulf. It is not only considered the second biggest and busiest port in the Gulf, but also in the Middle East and Africa. The port boasts a specialized center for training in marine sciences and technology. Several other activities are conducted here, such as ship repair, and there is a re-export area, warehouses, and yards for transshipments. Sea transportation is excellent for freight transport, but its services to passengers are limited to those in the Gulf region, or in the Red Sea with some African countries.

Table 1. Major ports in KSA and their location on 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 the biggest share of the gas and oil export services. The port is consists of a refrigerated cargo terminal, general cargo terminals for bulk grain, and two terminals for container terminals.
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, on the northern part of the Gulf coast. This location also several other transport facilities such as airport and highway, which help with export and import in the area. Even this port is small but it is designed to manage middle cargo. In addition, several military exercises are conducted in this port.
Khafji	Gulf	Khafji	-
Khobar	Gulf	Khobar	-
Ras Al-Zour	Gulf	Ras Al-Zour	-
Jeddah Islamic port	Red Sea	Jeddah	The biggest and main port in Red Sea in KSA. The location of this port occupies a strategic position of international shipping routes which form an important connection between the West and the countries of the Far East.
King Fahad Industrial Yanbu	Red Sea	Yanbu'	The Yanbu port is the main port handling the export of crude oil in KSA. This port deals with the export 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 northern area of KSA on the Red Sea. It is near to the Suez Canal, and could have good routes to several Europe countries such as Turkey, France, Italy, Spain and Greece. Dupa supports activities such as passengers and cargo services. This port has been upgraded with modern infrastructures to deal with various types of cargo
Rabigh	Red Sea	Rabigh	-

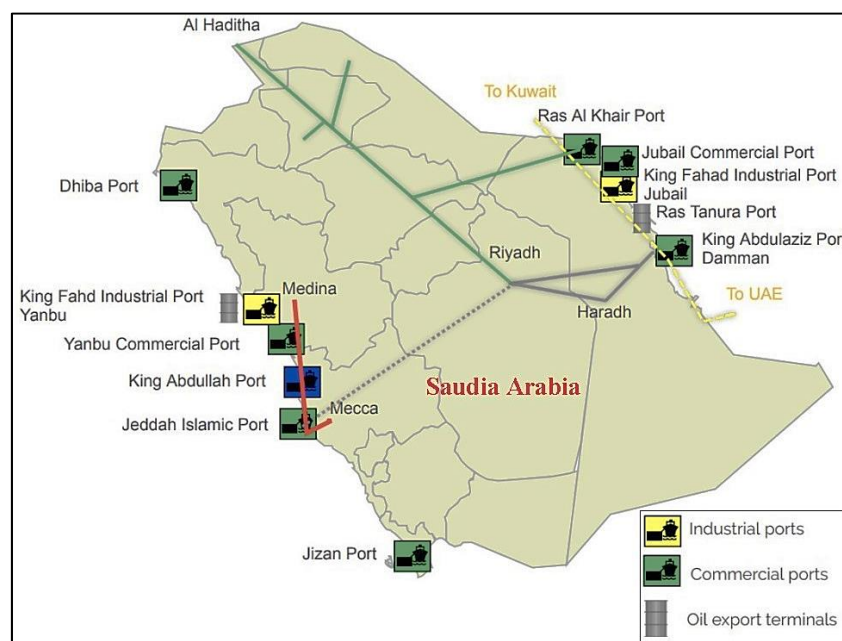


Figure 2. Map of KSA showing the distribution of major ports in the Gulf and Red Sea

3.2. Air Transportation

Saudi Arabia occupies a large area connecting Asia, Africa, and Europe. In the last 30 years, KSA has invested a huge amount of money to build 23 airports to meet the demand posed by a growing number of passengers. The location of these 23 airports are given in Figure 3. In addition, the large area raises the need for several domestic airports to connect different region of the country. In recent years, construction has been underway on another five airports, including Amaala which was completed in 2019, and Neom airport which is expected to be completed in 2023. With these additions, the total number of airports in KSA reaches 28. Where there are formerly four international airports, there are now eight. Five airports are regional airports and the remaining 15 are domestic airports. The details of all airports are listed in Table 2.



Figure 3. KSA’s national and international airports and their locations

Table 2. Lists of airports in KSA and their location according to city and province

International airports			
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
Regional airports			
Airport	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	-
Domestic airports			

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 Borders	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

3.3. Road Transportation

The extent and quality of road and highway networks can be used to determine the level of a country's development. During the last decades, Saudi Arabia has built a vast road network that connects the regions and major cities. The total distance covered by main roads and highways exceeds 700000 km in length and will continue to increase further due to the need of roads to serve new urban areas and the expansion of most cities in the country. These roads and highways ranges from 2 lanes to 8 lanes. Figure 4 shows the map KSA including the major road and highway networks.



Figure 4. Major highway and roads network in KSA

Saudi Arabia currently has a large excellent road network and the focus should be shifted from building new roads to maintaining the existing road network to ensure a good quality. The intensive investment in road network in the country is driven by the high demand in a rapidly growing economic and the fact that most passenger transportation relies on private car ownership. This is because the country has a high income, fuel prices are very low, the culture encourages this, and there are limited other modes of transportation, such as railways. The public bus transportation system is very limited, with only one company. SAPTCO was established in 1979 and has more than 5000 buses. There is a limited acceptable taxi service in most major cities. The increasing use of highway and road transportation in KSA has raised many problems, including air pollution, noise pollution, and a vast number of road traffic accidents. Road traffic accidents, road traffic injuries and resulting deaths have continued to increase in the last 30 years despite all major steps taken to reduce this problem. A new transportation strategic plan was implemented in 2018, and a new vision for KSA for 2030 have both served to reduce the number of road traffic accidents. However, road traffic accidents become the first cause of death in the country with a daily average of 27 deaths per day, as reported by several studies [20-21]. In addition, several researches has been conducted to enhance asphalt pavement using industrial ash waste to reduce the cost of the repair of roads and highways in Saudi Arabia and to recycle these waste materials in a sustainable way [22-31].

3.4. Rail Transportation

The history of railways in KSA dates back to 1900 when work began on a project to connect Damascus to Madina via the Hejaz railway, which has completed in 1908 but later closed in 1920. The main purpose of this rail line was to carry pilgrims on the Hajj. After 50 years, in 1951, a 16 km railway line was constructed to connect the port at the Gulf to Dammam city. This was extended to Riyadh at a distance of 450 km. This first line was used for passengers and a parallel line was subsequently installed to transport freight. A part from the above-mentioned projects, KSA remained without railways until major rail projects started in the 21st century. These major projects came under country's master rail plan. The plan includes several large rail projects such as North-South rail line, Gulf countries line, the linkage line, the Haramain line connecting Madina to Jeddah and Mecca and several other rail projects. The major rail projects in KSA are listed in Table 3.

Major rail transportation in KSA

The major rail plan including the completed rail lines, those under construction, those planned for the future, and other needed rail projects, are summarized in Table 3. The most important rail projects in KSA are also discussed and introduced. Figure 5 shows KSA map and constructed railway projects and indicates that when all current major rail projects are completed and the remaining planned rail projects are constructed, KSA will have an excellent railway transportation system.

Table 3. 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 2,400 km passenger and freight rail line. The 1,418km passenger line runs from Riyadh to Al Haditha close to Jordan border.	Completed
The Haramain Railway	It still planned and under construction.	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 cross-border 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.	

Figure 5 illustrates the necessity for another two railway projects, namely one to connect the other project to the north-south line from Tabuk to Al-baseeta and another project to link Riyadh to the south area to Wadi al-Dawasir (Khamis Mushait) and Najran in the southern region. The completion of these projects will provide KSA with an adequate railway network to connect all regions and major cities in the country [32-33]. Additional, local urban rail networks are needed in KSA to improve public transport inside the major cities and to ease the high volumes of traffic in large cities such as Riyadh, Jeddah, Dammam, Mecca and Madina. KSA has started to work on solving this problem by providing high quality rail transportation systems in major cities. These systems could provide the much-

needed sustainable public transportation systems that induce citizens to forego their customary use of private motor vehicles. Such systems are environmentally friendly and will serve to reduce the existing levels of air and noise pollution resulting from high car traffic volume. Moreover, they could help in reducing KSA’s critical road traffic accident figures. The Riyadh Metro project will be completed in near future. A further three project have been planned and designed and will eventually be constructed in Dammam, Jeddah and Mecca. There is a further need to invest large amounts of capital to develop rail transportation in a few other major cities in KSA, including Madina, Tabuk, Qassim, and Abha. The expectation is that once these railways and public transport systems become fully operational and passengers get used to their tremendous advantages, the roads in most big cities and urban areas such as Riyadh will be markedly safer and less congested. Less people will feel the need to travel by car, realizing that they can make faster journeys, free of the frustrations of traffic congestion [34].

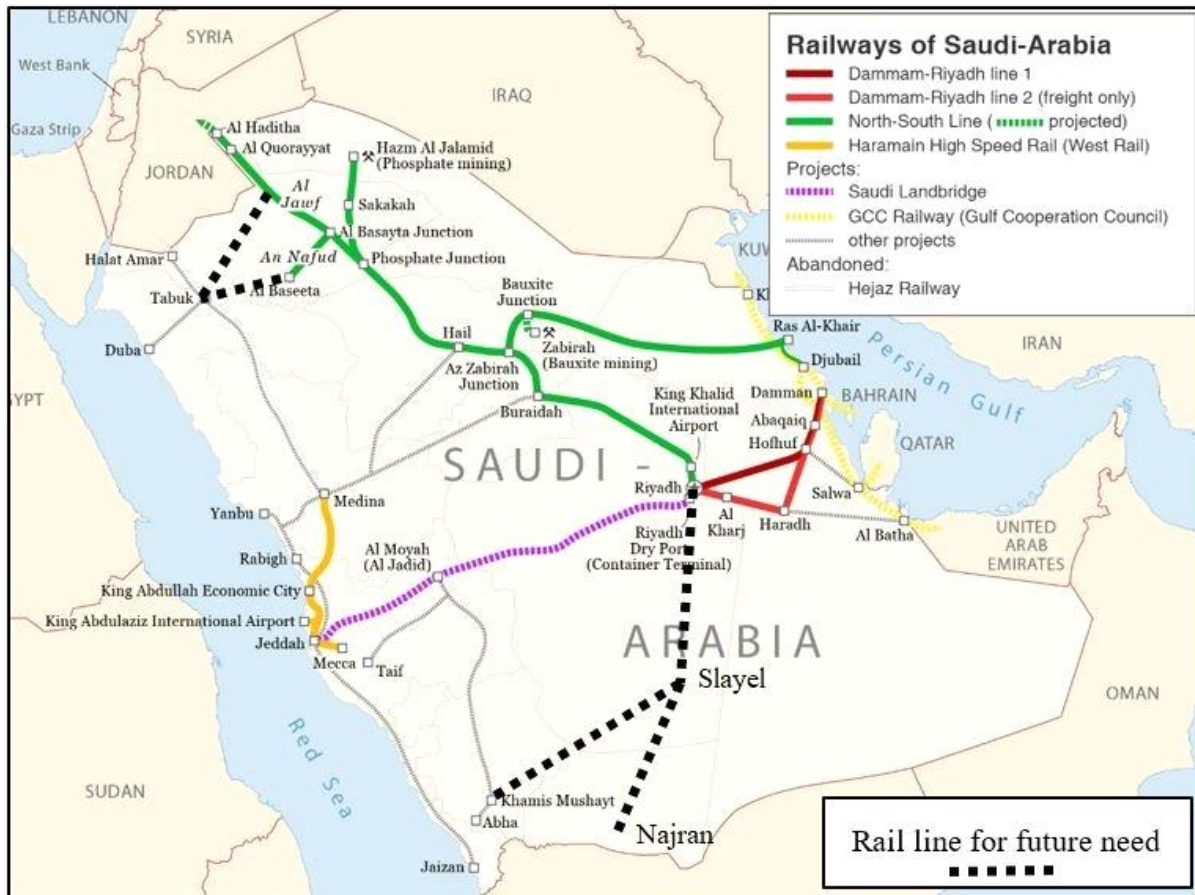


Figure 5. Major rail transportation projects in KSA

Advantages of Rail Transportation

The transportation of passengers and freight can be conducted via four possible modes, namely road, water, air, or rail, each of which has its merits and disadvantages. The merits of an extensive rail transportation system make it the most sustainable mode of transport worldwide. For KSA, the rail transport system could have the following advantages over other modes of transport [35].

- **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 can continue to run through fog, hot temperature, heavy rain, sandstorm, and dust-storm, while other land transportation like trucks are forced to remain stationary until the roads conditions clear [36-37].
- **Environmentally Friendly:** Rail transportation, while reducing road and highway congestion, reduces pollution with less CO₂ emissions. In addition, most modern rail transportation run on electricity which is more environmentally friendly than the fossil fuels used by cars, trucks, and busses.
- **Well Organized System:** Rail transportation is better organized than all other modes of transportation since it has definite and known routes and the schedules are predesigned and planned. The service provided by rail transportation has a uniform and regular quality as compared to all other 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 passengers and freight trains.
- Railway transportation is considered extremely cost effective since trains haul cargo than can be hauled by one truck. Individuals and companies can save on transport costs which is an important factor when conducting business.
- Speed: Railway transportation over long distances is much faster than most other modes of transportation, except air. Therefore, railway could be the best choice for relatively long-distance travel.

Disadvantages of Rail Transportation

It is clear that rail transportation offers a number of excellent advantages in general, and for KSA in particular. However, there are also several disadvantages and challenges. Railways do not provide door to door service like road transport. The construction, maintenance, repair and rehabilitation, operating, and overhead cost of railways are tremendously high compared to road, sea and air transportation modes. Another downside to railway transportation is inflexibility. It cannot serve many outlying areas because of the limited number of secondary routes and a smaller number of stations and substations. Its timing and routes are fixed and cannot be adjusted to serve individual needs.

4. Urban Transportation in Major Cities

Population growth and density have a strong impact on several other sectors such as land use and transportation. Cities such as Riyadh, Jeddah, Mecca, Madina, and Dammam are considered fast-growing cities and the citizens and decision-makers are urging for the development of sustainable urban transportation systems. Saudi Arabia is trying several solutions to overcome transportation problems in these cities but long distance travel, lack of space for parking, noise, pollution, and traffic accidents continue to increase over time [2-3, 19]. Recently, KSA recognized the benefit of rail transportation in urban areas and the major metropolitan project for Riyadh is close to being completed and put into operation. This project could help in solving the problem. Two other projects for Jeddah and Dammam are in the planning phase. It is necessary to speed up the process to implement four major projects in urban rail transportation for Jeddah, Mecca, Madina, and Dammam. These urban transportation projects could reduce the deterioration of existing transportation infrastructure, minimize traffic congestion, solve parking problems, reduce road traffic accidents, and reduce high rates of carbon emissions.

5. Results and Discussion

KSA is rich with distinct topography. It has a harsh climate associated with very high temperatures, rapid weather changes, sandstorms, and low rainfall. Saudi Arabia is one of the wealthiest Arab countries and enjoys high incomes and low fuel prices. There is a need to develop a sustainable public transportation system that takes into account all these factors. This paper presents a review of the four modes of transportation in KSA, discusses the advantages and disadvantages of these modes, and draws conclusions regarding the country's future needs in transportation development.

- The most popular mode of transportation used in KSA is privately owned cars travelling via road and highway. This mode raises several issues and problems including large traffic volume and traffic congestion leading to environmental problems such as air and noise pollution, and vast numbers of road traffic accidents resulting in many deaths. Road traffic accidents are the first cause of death in KSA.
- Sea transportation mode in Saudi Arabia play a vital role in the country's economic development and forms the main mode of the transportation of oil and freight. However, it is of limited for passenger transportation except for a small number of routes between Gulf countries in the east and to other countries on the Red Sea in the west.
- While it was late to pay attention to sustainable rail transportation, KSA has completed several magra rail projects and several others are in the planning and contracting phases. It is also clear that there is a need for two additional rail projects, one to connect the north-south line from Tabuk to Al-baseeta and another project to link Riyadh to Wadi al-Dawasir (Khamis Mushait) and Najran in the southern region.
- Rail transportation promises to be the future dominant mode of transportation in KSA due to several factors. Among these factors, rail transportation is relatively fast, comfortable and suitable for the harsh and hot environment in KSA. In addition, rail transportation is environment-friendly because it produces less air pollution and mostly it is safer and could reduce road traffic accidents and deaths, a problem which has posed a major challenge to Saudi government during the last 30 years.
- Attention should be paid to developing and promoting public bus and taxi transport in KSA. This may help in providing people with a low-cost transportation system and reduce traffic volume the consequent congestion.

- Air transportations has undergone major developments in both international and domestic travels. The number of airports is adequate to cover the needs of the country and link it with the rest of the world. There may be a limited need to improve the service in these airports and upgrade some of the airports to increase their capacity and it may be desirable to change some of the domestic airports to international airports, such as Abha in the south of the country and Tabuk in the north.

The main challenges and opportunities regarding the future of transportation modes in KSA drawn from this study are summarized in Table 6.

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 quite 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.	Developing more passenger cruises in the Gulf and Red Sea will solve problems in travelling to Gulf countries and to several African countries.
Road transportation	Deterioration of roads and highways from passage of heavy trucks and harsh environment in KSA. Lack of quality public bus and taxi transit. A major problem is the high number of road accidents and deaths, in addition to environmental pollution and traffic congestion.	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.

6. Conclusions

Saudi Arabia is among the rich Arab countries with high income and low fuel prices. The country faces several problems and unique factors and conditions in transportation such as high traffic accidents, lack of public transportation, high pollution and CO₂ emissions, high noise, and traffic congestion. Development of a sustainable transportation system to suit all these factors is needed. This case study presents a review and analysis of the data regarding four modes of transportation in KSA, a country experiencing fast economic and social development. The study presents the advantages and disadvantages of these modes of transportation and draws conclusions and recommendations, stating the future needs in transportation to enhance the development of a sustainable transportation system in the country. The following are the main conclusions, recommendations and future needs which could be drawn from this study:

- While KSA was late to pay attention to sustainable rail transportation, it has completed several mega rail projects and several others are in the planning and contracting phases. It is also clear that there is a need for two additional rail projects, one to connect the north-south line from Tabuk to Al-Baseeta and another project to link Riyadh to Wadi al-Dawasir (Khamis Mushait) and Najran in the southern region.
- Attention should be given to developing and promoting public bus and taxi services in KSA. This may help in providing people with a low-cost transportation system and reduce traffic congestion as well as noise pollution and CO₂ emissions.
- Saudi Arabia has an extensive large road network and infrastructure that meets the needs of the Kingdom well, but these roads need maintenance to keep them at a good level of service. The massive use of the road network has resulted in many problems such as accidents and pollution. These problems can be solved by implementing a number of solutions, including the development of environmentally friendly road construction materials and introducing legislation to help shift from the use of private cars to public transportation. The Kingdom should also encourage the use of hybrid and electric cars to solve environmental problems.

- Saudi Arabia needs to capitalize on its unique position at the center between Asia, Europe, and Africa to make it a hub for air travel worldwide. KSA has four international airports in Riyadh, Jeddah, Dammam and Neum. Converting another airport such as Abha or Najran from local and regional services to an international airport could form a good economic investment for the country especially with the Saudia airline acting as a carrier with a large fleet of planes.
- Saudi Arabia should consider sustainable urban transportation, especially in major cities. KSA should conclude work on metro projects as soon as possible for Dammam, Mecca, Madina and Jeddah, similar to the metro project in Riyadh. These future projects could solve many transportation problems in KSA.
- Sea transportation in KSA does not contribute to any environmental problems. Conversely, it plays a vital role in the country's economic development and forms the main mode of transportation of oil and freight. However, its use for passenger services is limited to routes between Gulf countries and other countries on the Red Sea.

7. Declarations

7.1. Author Contributions

Conceptualization, M.D.; methodology, M.D.; formal analysis, M.D.; data curation, M.D.; writing-original draft preparation, M.D.; writing-review and editing, M.D. The author have read and agreed to the published version of the manuscript.

7.2. Data Availability Statement

Data sharing is not applicable to this article.

7.3. Funding

The author received no financial support for the research, authorship, and/or publication of this article.

7.4. Conflicts of Interest

The author declare no conflict of interest.

8. References

- [1] Ogryzek, Marek, Daria Adamska-Kmieć, and Anna Klimach. "Sustainable Transport: An Efficient Transportation Network-Case Study." *Sustainability (Switzerland)* 12, no. 19 (2020). doi:10.3390/su12198274.
- [2] Zohbi, Gaydaa Al. "Sustainable Transport Strategies: A Case Study of Riyadh, Saudi Arabia." In *E3S Web of Conferences*, Vol. 259, (2021). doi:10.1051/e3sconf/202125902007.
- [3] Aljoufie, Mohammed. "Toward an Effective Analysis of Public Transportation Demand Factors in Car-Dependent Cities: Case of Makkah City, Saudi Arabia." *Urban, Planning and Transport Research*, (2021). doi:10.1080/21650020.2021.1933581.
- [4] Al-Habaibeh, Amin, Samer Hamadeh, Khalid Aljahdali, and Shatirah Akib. "Towards Enhancing Sustainability: A Novel Approach for Reducing Carbon Emission during the Transportation of Zamzam Water by Pilgrims during Hajj and Umrah." *Research in Transportation Business and Management* 37 (2020). doi:10.1016/j.rtbm.2020.100523.
- [5] Aluko, Oluwakemi. "Review of Urbanisation and Transport Challenges in Developing Countries." *International Journal for Innovation Education and Research* 7, no. 4 (2019): 315–23. doi:10.31686/ijer.vol7.iss4.1410.
- [6] General Authority for Statistic "Statistical year book 52", 1437H/1438H." (2016).
- [7] Ministry of Interior, "The Statistical Report for the Year of 1431H." General Administration of Traffic, Kingdom of Saudi Arabia, (2010).
- [8] World Bank, 2016. "World Development Indicators. Washington, DC. License: Creative Commons Attribution CC BY 3.0 IGO." (2016).
- [9] Central Department of Statistics, "Information, Initial Population Census for the Year of 1437H." Central Department of Statistics and Information, Kingdom of Saudi Arabia, (2016).
- [10] Poumanyong, Phetkeo, Shinji Kaneko, and Shobhakar Dhakal. "Impacts of Urbanization on National Transport and Road Energy Use: Evidence from Low, Middle and High Income Countries." *Energy Policy* 46 (2012): 268–77. doi:10.1016/j.enpol.2012.03.059.
- [11] Scholl, Lynn, Lee Schipper, and Nancy Kiang. "CO2 Emissions from Passenger Transport: A Comparison of International Trends from 1973 to 1992." *Energy Policy* 24, no. 1 (1996): 17–30. doi:10.1016/0301-4215(95)00148-4.

- [12] Rodrigue, Jean Paul, Claude Comtois, and Brian Slack. "The Geography of Transport Systems." *The Geography of Transport Systems*. New York, 2016. doi:10.4324/9781315618159.
- [13] Schäfer, Andreas. "Long-Term Trends in Global Passenger Mobility." *Frontiers of Engineering: Reports on Leading-Edge Engineering from the 2006 Symposium* 36, no. 4 (2007): 85–98. doi: 10.17226/11827.
- [14] Schafer, Andreas, and David G. Victor. "The Future Mobility of the World Population." *Transportation Research Part A: Policy and Practice* 34, no. 3 (2000): 171–205. doi:10.1016/S0965-8564(98)00071-8.
- [15] Khodeir, Mamdouh, Magdy Shamy, Mansour Alghamdi, Mianhua Zhong, Hong Sun, Max Costa, Lung Chi Chen, and Polina Maciejczyk. "Source Apportionment and Elemental Composition of PM_{2.5} and PM₁₀ in Jeddah City, Saudi Arabia." *Atmospheric Pollution Research* 3, no. 3 (2012): 331–40. doi:10.5094/APR.2012.037.
- [16] Anable, Jillian. "'Complacent Car Addicts'; or 'Aspiring Environmentalists'? Identifying Travel Behaviour Segments Using Attitude Theory." *Transport Policy* 12, no. 1 (2005): 65–78. doi:10.1016/j.tranpol.2004.11.004.
- [17] Aljoufie, Mohammed. "Exploring the Determinants of Public Transport System Planning in Car-Dependent Cities." *Procedia - Social and Behavioral Sciences* 216 (2016): 535–44. doi:10.1016/j.sbspro.2015.12.013.
- [18] Williams, Sarah, Waishan Qiu, Zeyad Al-awwad, and Aljoharah Alfayez. "Commuting for Women in Saudi Arabia: Metro to Driving - Options to Support Women Employment." *Journal of Transport Geography* 77 (2019): 126–38. doi:10.1016/j.jtrangeo.2019.05.002.
- [19] Aljoufie, Mohammed. "The Impact Assessment of Increasing Population Density on Jeddah Road Transportation Using Spatial-Temporal Analysis." *Sustainability (Switzerland)* 13, no. 3 (2021): 1–17. doi:10.3390/su13031455.
- [20] Dahim, Mohammed A.H. "Impact of Vision 2030 on Traffic Safety in Saudi Arabia." *International Journal of Pediatrics and Adolescent Medicine* 5, no. 3 (2018): 103–9. doi:10.1016/j.ijpam.2018.08.002.
- [21] Al-mattarneh, Hashem, and Mohammed Dahim. "Road Traffic Accidents and Traffic Safety in Saudi Arabia: A Review." In *Urban Transition*. Sitges, Barcelona, Spain, (2018).
- [22] Abuaddous, M., M. Dahim, R. Ismail, M. Taamneh, A. H. Alomari, W. Darwish, and H. Al-Mattarneh. "Sustainable Asphalt Concrete for Road Construction and Building Material." *IOP Conference Series: Earth and Environmental Science* 801, no. 1 (2021). doi:10.1088/1755-1315/801/1/012023.
- [23] Dahim, Mohammed. "Crude Oil Fly Ash Waste for Road Pavement Application." *IOP Conference Series: Earth and Environmental Science* 801, no. 1 (2021). doi:10.1088/1755-1315/801/1/012006.
- [24] Dahim, Mohammed, Musab Abuaddous, Hashem Al-Mattarneh, Andan Rawashdeh, and Rabah Ismail. "Enhancement of Road Pavement Material Using Conventional and Nano-Crude Oil Fly Ash." *Applied Nanoscience (Switzerland)* 11, no. 10 (2021): 2517–24. doi:10.1007/s13204-021-02103-z.
- [25] Al-Mattarneh, Hashem, and Mohammed Dahim. "Comparison of Nondestructive Testing Method for Strength Prediction of Asphalt Concrete Material." *Civil Engineering Journal (Iran)* 7, no. 1 (2021): 165–78. doi:10.28991/cej-2021-03091645.
- [26] Malkawi, Ahmad B., Hashem Al-Mattarneh, Bitrus Emmanuel Achara, Bashar S. Muhammed, and Muhd Fadhil Nuruddin. "Dielectric Properties for Characterization of Fly Ash-Based Geopolymer Binders." *Construction and Building Materials*, 2018. doi:10.1016/j.conbuildmat.2018.08.180.
- [27] Shafiq, N., Hussein, A.A.E., Nuruddin, M.F., Al Mattarneh, H. "Effects of sugarcane bagasse ash on the properties of concrete." *Proceedings of the Institution of Civil Engineers: Engineering Sustainability* 171(3), (2021):123–132. doi: 10.1680/jensu.15.00014
- [28] Malkawi, Ahmad B., Muhd Fadhil Nuruddin, Amir Fauzi, Hashem Al-Mattarneh, and Bashar S. Mohammed. "Effect of Plasticizers and Water on Properties of HCFA Geopolymers." *Key Engineering Materials*, 2017. doi:10.4028/www.scientific.net/KEM.733.76.
- [29] Nuruddin, M. F., A. B. Malkawi, A. Fauzi, B. S. Mohammed, and H. M. Almatarrneh. "Geopolymer Concrete for Structural Use: Recent Findings and Limitations." *IOP Conference Series: Materials Science and Engineering* 133, no. 1 (2016). doi:10.1088/1757-899X/133/1/012021.
- [30] Nuruddin, M. F., A. B. Malkawi, A. Fauzi, B. S. Mohammed, and H. M. Almatarrneh. "Evolution of Geopolymer Binders: A Review." *IOP Conference Series: Materials Science and Engineering*. IOP Conference Series: Materials Science and Engineering, (2016). doi:10.1088/1757-899X/133/1/012052.
- [31] Mohammed, Bashar S., M. F. Nuruddin, Muhammad Aswin, Nursyuhada Mahamood, and Hashem Al-Mattarneh. "Structural Behavior of Reinforced Self-Compacted Engineered Cementitious Composite Beams." In *Advances in Materials Science and Engineering*, Vol. 2016, (2016). doi:10.1155/2016/5615124.
- [32] Public Transport Authority (PTA). "Railway Sector in the Kingdom of Saudi Arabia," (July 2017):1-24.

- [33] Dano, Umar Lawal, and Ali Muflah Alqahtany. "Issues Undermining Public Transport Utilization in Dammam City, Saudi Arabia: An Expert-Based Analysis." *Journal of Sustainability Science and Management* 14, no. 2 (2019): 157–71.
- [34] Aldalbahi, Majid, and Guy Walker. "Riyadh Transportation History and Developing Vision." *Procedia - Social and Behavioral Sciences* 216 (2016): 163–71. doi:10.1016/j.sbspro.2015.12.024.
- [35] Saif, M. A., B. A. Ghulman, I. Ahmed, and M. H. Khalil. "Challenges to the Development of Railway Infrastructure in Remote and Formidable Terrain: A Case Study from Saudi Arabia." In *Civil-Comp Proceedings of the Third International Conference on Railway Technology: Research, Development and Maintenance*, Vol. 110. Stirlingshire, Scotland: Civil-Comp Press, 2016. doi:10.4203/ccp.110.13.
- [36] Zhang, Ke cun, Jian jun Qu, Qing he Niu, and Qing jie Han. "Characteristics of Wind-Blown Sand and Dynamic Environment in the Section of Wudaoliang-Tuotuo River along the Qinghai-Tibet Railway." *Environmental Earth Sciences* 64, no. 8 (2011): 2039–46. doi:10.1007/s12665-011-1026-8.
- [37] Yin-Hai, Yang, Zhu Ben-Zhen, Jiang Fu-Qiang, Wang Xi-Lai, and Li Yong. "Prevention and Management of Wind-Blown Sand Damage along Qinghai-Tibet Railway in Cuonahu Lake Area." *Sciences in Cold and Arid Regions* 4, no. 2 (2012): 132. doi:10.3724/sp.j.1226.2012.00132.