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INTRODUCING HIGH SPEED RAIL SYSTEM IN MIDDLE EAST (KINGDOM OF SAUDI ARABIA): A COMPARISON OF PAST, CURRENT AND FUTURE NETWORKS

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ABSTRACT
High-speed rail has flourished in technological development since their first appearance in Japanese Shinkansen line 1960. High speed rail systems are far more developing in developed countries, than the Emerging countries especially Saudi Arabia. The study then applies these two models to an emerging high speed network such as the planned/under construction corridors in Saudi Arabia to assess the extent of applicability and suitability of applying established high speed models to the Haramain high speed rail project network. The focus of the article is on assessing the three keys distinct models emerging from Asia and Europe such as: the French model, the Spanish model, the Japanese model, and Chinese model. This paper details the variation in technological implementations HSR project from Asia, and Europe. The results indicate that an appropriate possibility would be to apply the Europe model for the operational aspects given the similarities in terms of geography, population distribution and distance. Implementing the lessons learned from the Asia model in terms of construction and infrastructure design would be more suitable given the striking similarities in geological characteristics linked to the flat area. Kingdom of Saudi Arabia with limited HSR development stands to benefit from the technological advances of others and learn from the economic impacts of HSR in other countries.

INTRODUCTION
The first High-speed rail (HSR) connection was inaugurated in Japan 1964 between Tokyo to Osaka. In early 2017, there were more than 37,343 kilometers of new HSR lines in operation around the world and about 15,884 kilometers under construction to high speed services [1]. The HSR is a brand new rail technology developed in the 20th century, which consists of a special infrastructure that allows trains running at a speed over 250 km per hour. There is no standard definition of what constitutes HSR. In all cases, high speed is a combination of all the elements that constitute the established system infrastructure. One of the HSR definitions depends on infrastructure comprises with three different types of lines: ‘’ The first one is: New tracks specially constructed for high speeds, allowing a maximum running speed of at least 250 km/h; Second of the HSR definitions is: Existing lines upgraded for high speeds, allowing a maximum running speed of at least 200 km/h, Third of the HSR definitions is: upgraded lines whose speeds are constrained by circumstances such as topography or urban development [1].This definition will be considered for the objective of this paper. In terms of speed, it is widely accepted that speeds of 250km/h or more for new dedicated lines and 200km/h or more for upgraded ones constitute HSR [2]. Many high speed rails are also compatible with the conventional network. The expression of high speed traffic is frequently used to express the movements of this type of trains on conventional lines with lower speeds than permitted on the new high speed infrastructure. There are some obstacles in this application: in very densely populated regions, the speed is restricted to 110 km/h in order to avoid noise and nuisance. And in case of special mountain tunnel or crossing long bridges, the speed is limited to 160 or 180 km/h for obvious reasons associated with capacity or safety [1]. Finally, in these countries where the performance of the conventional rail cannot exceed the speed of 160 km/h, it is considered as a first step towards a future genuinely high speed service.

BACKGROUND
HSRs have experienced fast change in the last decades around the world. In Japan the Shinkansen system is the first dedicated HSR system in the world. The Shinkansen Tokaido line connecting between Tokyo and Osaka was

opened in 1964. It reduced the travel time between the cities to 2.30 hours from six and half hours. The success of HSRs in Japan is attributed by high population densities. There are over 8 million populations in Tokyo locating about 400-700 km from most other major cities, which is an ideal distance for rail [3]. The opening of the Shinkansen in Japan stimulated the developing of high capacity HST as proposed at the International Transport Fair in Munich, Germany; whereas the fully development of Europe's high speed rail service started from 1980s. France is the second country to develop HSR technol- ogy. TGV (Train a Grande Vitesse) was opened in 1981 between Paris and Lyon in a length of 1,896 km. Annual ridership was about 114 million passengers in 2010, including 31 million passengers between Paris and Marseille. The TGV services have generated $1.75 billion in profits [4]. Other countries such as Spain, Italy, Netherlands, Belgium, Taiwan, South Korea and China have since joined the ever growing HSR movement. In 2008 the worldwide HSR network had approximately 20,000 km [1]. By the early of 2017 there were 37,343 km of high speed rail lines operating at 250 km/h or more with a further 15,884 km under construction plus 35,909 km long-term planned [1]. China alone has seen a qualitative leap since the first high- speed rail line was completed on 1st August 2008. In the following two years after that, a significant number of HSR lines have been added to its network e.g. Wuhan-Guangzhou, Zhengzhou-Xi'an, and Shanghai-Nanjing. An ambitious mid- to-long term Railway Network Plan established by the Chinese Ministry of Railway (MOR) in 2008. However, China planned passenger-dedicated HSR network consists of four north-south HSR corridors and four east-west HSR corridors, with a total of 16,000 km of dedicated high-speed rail lines connecting all of China's major cities by 2020 [5]. This planned HSR network is connected within China but isolated from other countries. The designed speed for these new passenger-dedicated HSR lines is 300-350 km/h, but China planned to decrease this speed due to safety concern and energy consideration [6]. Similarly, and in terms of maximum speed, the evolution of HSR has been very significant. The following Tab. 1 shows some speed records since the introduction of HSR, and also the main technical aspects of HSR [1]. These include operational and non-operational records.

Table 1. Technical characteristics of some HSR lines in the world

Country	Japan Tokyo Osaka [515 km]	France Paris-Lyons [427 km]	Germany Hannover-Würzburg [327 km]	Spain Madrid-Barcelona [522 km]	Korea Seoul-Pusan [412 km]
Max. speed (Km/h)	260-300	300	250	300	350
Travel time (hours)	2:3	1: 50	2:00	2: 30	1: 55
Radius curvature	2500	4000	7000	4000	7000
Max. longitudinal gradient (‰)	20	35	12.5	30	5
Distance of axes of two tracks (m)	4.2	4.2	4.5	N.A	5
Superelevation (mm)	200	180	150	N. A	N.A
Dedicated route (km)	3443	2776	1843	4133	777

HIGH SPEED RAIL MAIN MODELS

The limitations and requirements imposed locally have meant that while high speed rail technical and Features aspects are well known and necessary, the process for high speed rail implementation have been different. This has resulted in four distinct models namely: 1) Japanese or Shinkansen model, 2) French or TGV model, 3) Spain or AVE Model, 4) Chinese (CHSR) Model. The Japanese or Shinkansen model has a main characteristic the use of specified lines that are in impact isolated from the rest of the rail network. The geographic and geological constraints in Japan (e.g.frequent earthquakes and mountainous landscape) also mean higher construction costs. On the other hand, the French model is based on an integrated the process between conventional lines and HSR. The geographic characteristics of France with large unpopulated areas and relatively flat means that construction costs are amongst the lowest [7; 8]. The Spain or AVE Model which is characterized by mountainous topography and large distances between the main major cities in relation to European countries, this lead to result of the large travel distance, this lead also to back the air travel as the most appropriate mode of transport in long distance services. In the fourth model the various costs need to be taken into account when considering the additional expenditure incurred from building HST lines. Population density varies significantly between Chinese and Europe countries. So, China is a highly dense populated country with very large cities relatively far from each other. The population of France or Spain is more dispersed.

Asia model

Japanese or Shinkansen Model: The increasing ability constrains during the 1950s in the Tokaido trunk line linking Tokyo and Osaka led to the birth of HSR [9; 10]. It can be noted that, the response to the exceptionally high demand for passenger services to be on this corridor. Immediately after the opening of the Tokaido line in 1964 the popularity gave to law by the then Japanese National Railway (JNR) operated Shinkansen system planners. In many ways the concept was innovative, a new segregated railway built to the standard gauge 1435mm [one of the characteristics in Japans traditional railway network is the narrow gauge, 1067mm].

This regulation of braking capability has been also a major obstacle to increase the maximum speed of trains running on the narrow gauge tracks, because the cast to eliminate existing grade crossings is not negligible. It adopted the international standard l435 mm gauge rather than the traditional narrow gauge so that no compatibility with the traditional rail network was realized. It is dedicated to passenger transportation and no freight trains are allowed to run on the routes. There are other reasons for establishment high speed line in Japan, this result in the problem on the road transport presented by a narrow, mountainous and earthquake. In addition, the Japanese model is also shaped by the geographic and geological characteristics of the country. This mountainous topography, and the high rate of earthquakes experienced and the high population density mean a significant number of tunnelling and technical challenges for the infrastructure construction such as slope protection, erection of avalanche fences and wind barriers, and seismic reinforcement of infrastructure are typically used to reduce the risks of natural disasters [12]. An estimated 30% of the whole Shinkansen network consists of tunnels [13].

The importance of the introduction of the Shinkansen affected the way other railways approached their strategic planning (Smith, 2004). Smith R.A. stresses this point when he highlights the shift in Western European countries which were developing conventional lines while Japan was setting up HSR system. It can be observed that, thereby, this advantage must be disadvantage for high speed rail transport in Japan are to be compared. Due to the special geological and geographical situation in Japan, the high speed services running through this type of terrain requires many long tunnels and bridges designed to withstand earthquakes, as well as countermeasures to earthquakes, floods, and deep snow. Furthermore, pass through densely populated cities, stringent noise and vibration environmental, this leading to the need layout for a high-speed transport, and a very high proportion of the routes over bridges and tunnels. The result of this shift was the launch of commercially successful high speed services in France (TGV) and Germany (ICE).

Chinese (CHSR) Model: China has the world's longest high-speed rail (HSR) network with about 10,730 km of routes in service as of April 2017. Nonetheless, The Beijing-Shanghai High-Speed Rail is 1318 kilometers consider the long HSR line that connects two major economic cities in China, the Beijing-Shanghai HSR line, a passenger-dedicated trunk line opened in June 2011, which reduced the 1,318 km journey between the largest cities in China to under 5 hours. The total construction costs of the Beijing-Shanghai HSR are about $32.48 billion [14].

By far the most extensive high speed rail system is in China. China rail systems are comprised of a variety of different technologies. The Chinese HSR (CHSR) net- works synthesize technology from Japan, Germany, and France, while adding in innovations of the country’s own [15]. The Shanghai Maglev debuted in 2003 and runs on technology from a German company, reaching top speeds of 430 km/h [16]. The principal funding agency comes from only the centre governments and provincial government. Consequently, HSR system in China isolated from other countries, this lead to the principal funding source are by the bond issued by Ministry of Railway. Obstacles China had to overcome in the quest for leading the world in HSR included topography and geology. The extensive networks race over starkly dif- ferent geologic bases and large spans of rivers. Three of the HSR bridges in China hold records for span, width, and capacity [15]. Extreme technological precedents were also set in the tunnel construction and speed (up to 350 km/h) through the tunnels of the trains. The CHSR tracks, unlike others using repurposed tracks, was a ground-up design that allows for top speeds over a range of ob- stacles without having to slow down as repurposed lines require [17]. China uses ballastless tracks that do not use rock material to stabilize them and also has track net- works that are seamless, a feat that required heavy re- search due to varying temperatures across the country [15]. The Chinese rails are nearly all set in concrete slabs of German design, which reduce wear and tear on the wheels and tracks [17]. Chinese-made trains operate worldwide and remain the fastest.

Europe Models

Spain or AVE Model: The first HSR line in Spain was 1992 and named AVE (Alta Velocidad Espanola) between Madrid and Seville. Spain which is characterized by mountainous topography and large distances between the main major cities in relation to European countries, this lead to result of the large travel distance, this lead also to back the air travel as the most appropriate mode of transport in long distance services. Actually, the economic potential in Spain is still less than the average European country; however, there is a strong demand on the national air transport. The railway in this time played the secondary role in the long distance. For the medium distance, it can be used the bus, where is as a cheap alternative to flying. Increasing motorization in the period 1982-1992, and there are no improvement of the train connections for passenger that could be achieved by lack of the train 50% (López Pita, Andrés. 2008). The Spanish government decided in late 1988 for the construction of an entirely a new high speed line Liniea Alta Velocidad (LAV) mainly to ensure the new service was in operation by the Sevilla exposition in 1992 between Madrid and Seville.

Spain has five of the new lines as of 2011, and AVE system is the longest HSR network in Europe and the second in the world. AVE lines have reduced journey times by an average of 60-70%, compared to the conventional rail system. The new AVE service produced a dramatic reduction in journey times and the impact in terms of traffic generation and abstraction from the airlines was large and instantaneous. Therefore, reducing the travel time from 6 ½ to 2 ½ hours and this leads to increase the market share of rail in this ratio from 16% to 51% has more than tripled. At the same time, the market share of air traffic fell from 40% to 13% and thus only slightly more than 1 / 3 of the original value [13]. The traffic growth between 1993 and 2003 increase the total number of travelers on the new line from 3.25 million passenger to 6 million passenger with increasing by 84%, at the same time the number of passenger increased over long distances on the conventional track by 18% from 10.7 million to 12.6 million, also it can be observed that, the volume of traffic in the Nord corridor to fell off again by 75 % [18]. It can be observed that, to make the achievement of modal split in Europe; it will be excellent with travel times on routes with a length about 400 and 800 km. The railway can be attractive almost all the passenger who cannot carry, for practical reasons (luggage, physical disability, etc.), on the motor vehicle, or aircraft, because the rail can carry a connecting flight at their destination. It can be noted that, the increase the total traffic volume of approximately 1/6 to 1/2 from total traffic volume of the proceeds of the track.

AVE carries 29 million passengers per year, including 6 million passengers between Madrid and Bar- celona and 10 million passengers between Madrid and Seville [4].The average construction cost was cheaper than other European countries at $14.6 million per km, compared to over $36.6 million per km in Germany because of low rural population densities, which reduced costs of acquiring land for track construction [19]. The length of track in Spain is about 2,057 km, and the government announced the plan to build a further 9.000 km of HSR by 2020, costing $100 billion. According to [19] Spain's success of HSR system is attributed to two factors: lower travel time between city centers in two and half hours, and lower fares than air that compete well with air transport.

French or TGV Model: France is the second country to develop HSR technology. TGV (Train a Grande Vitesse) was opened in 1981 between Paris and Lyon in a length of 1,896 km. Annual ridership was about 114 million passengers in 2010, including 31 million passengers between Paris and Marseille. The TGV services have generated $1.75 billion in profits [4].

The French Train TGV began operations in 1981 with the opening of the Sud-Est (South-East) line connecting Paris and Lyon. TGV-Atlantic was added in 1989 with operations from Paris to Le Mans, and the TGV-Nord line between Paris and Lille started services in 1993. As of 1996, the TGV route was in service, along lines that primarily radiate out from Paris to other parts of France [20]. Before the construction of TGV, between Paris and

Lyon, this line was most important transport path in France, however, this lines was truly one of saturation and has produced a rail traffic condition for which a separate high speed passenger train line offers the only practical solution. Therefore, the importance of this corridor in France is: There was never any doubt about the genuine necessity for the first TGV line in France. It creates out of the traffic saturation of the Paris-Lyon rail artery. This, make the most important transport path in France, runs from Paris to Marseille via Lyon. Investment in this major French transport corridor, which served about 40% of the French population, was prompted by severe congestion on the existing rail route [21]. The success of TGV Sud-Est led to an early decision to build the TGV Atlantique, which reduced the travelling time from 4h to 3h between Paris and Bordeaux [22; 23]. The topography of France, its population density and the early decision to build the new HSR as compatible with the traditional network meant not only significantly less construction costs but also more operational flexibility. Actually, the ability to operate on the traditional network has allowed accessing to more regions and passengers [11].

Germany or ICE Model: Germany ICE started in 1980 in planning a high speed network with Speed more than 200 km/h. The main axles Hannover- Würzburg and Cologne – Frankfurt were in focus. The old railway axles are satisfied with trains – Passenger and freight-Trains at that time. The successful InterCity-system with max speed up to 200 km/h needs new tracks in those days in the 80s. Also the freight trains want to have new track-capacity. So new lines (NBS) are planed: Hannover –Würzburg up to 250 km/h PV and up to 160 km/h for freight trains at night and Köln – Rhine/Main (Frankfurt) only for passengers caused by the gradients crossing the hills in this area.

A new train comes in service, the ICE and special freight trains, the ICE-G with new cars up to 160 km/h. The ICE was very successful and is now (2017) build in the fourth series as ICE IV, now able to run up to 300 km/h. After some year's successful operation especially in intermodal service between North and south of Germany, the ICE-G went out of operation. Some crashes by unrailing conventional freight cars at the highspeed-lines in the night, the freight service on NBS is stopped. Some trains can run on conventional tracks up to 120 km/h. Another reason to go back in freight was the high cost for energy to run fast. Today more and more new elements are built in the high speed network, like Karlsruhe - Basel (Rhine-corridor) or Nürnberg- Erfurt and some more tracks are planned in upgrading the European highspeed network, but there no plans up to now to make freight trains faster than 120 km/h caused by the high cost or special freight cars and their operation/energy-costs.

HIGH SPEED RAIL IN SAUDI ARABIC (WESTERN RAILWAY)

The railways system in Saudi Arabia

Saudi Arabia is a large country, similar in size to Western Europe, and it is among the 25 largest economies in the world and the largest in the Arab world. But the country has a very small railway network which consists of a 449 kilometre passenger line linking Riyadh with the Gulf port of Dammam, and a 556 kilometre freight line which takes a more circuitous route between these two cities via Harad. The railways remain the least developed means of transportation in the Kingdom. The railways have been only a minor element in the country's transportation system, and were re-established in the early 1950s after a four- decade hiatus. The Ottoman Turks built the first railroad on the peninsula, the Hejaz Railway linking Damascus with Madinah. The Hejaz Railway is considered to be the first railway in the Arabian Peninsula and ran between Damascus and Madinah. It was proposed to continue the railway to Makkah, but this section was never constructed [24].The construction of this railway started in 1900 and the railway reached Madinah in 1908.

The existing railway network

Information from the Saudi Railway Organization (SRO) indicates that the idea of constructing a railway line in Saudi Arabia after the Hejaz Railway was first introduced in the mid-forties, when the need was felt for a port on the eastern sea-shore of the Kingdom to handle goods dispatched to the Aramco Petroleum Company. Such goods had to be conveyed inland from the port to the warehouses of Dhahran. The name of this organization was the Saudi Government Railroad Organization (SRO). In October 1947 the SRO started construction the first rail line in Saudi Arabia and in October 1957 the railway line was officially inaugurated (SRO. 2000). The SRO is responsible for rail transport in the Kingdom and is an autonomous agency headed by a President who is responsible for the policies

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There have been several development projects undertaken by the SRO, some of which are as follows:

- Construction of a direct railway line from Dammam to Riyadh - with a total length of 499 kilometres.
- Construction of 3 modern passenger stations in Dammam, Hofuf and Riyadh.
- Establishment of a fully-equipped central maintenance workshop at Dammam.
- Construction, inauguration and operation of a dry port in Riyadh, which may be regarded as one of the most important achievements of the corporation. The availability of this service in Riyadh has greatly facilitated import of goods from abroad and clearance by customs directly to the importers in Riyadh (see Figure 1) [25].

The expansion projects

Railway networks as is known all over the world are effective in moving large volumes of bulk commodities over long distances and according to regular schedules and when compared to other means of transport can often be cheaper. In addition, there is heavy passenger movement on along between the Holy Cities between Makkah, Madinah with the big commercial traffic. Furthermore, they are safe and efficient in use of fuel and are responsible for less environmental pollution than some other forms of transport. The Saudi Arabia government has long had an ambition to expand its rather modest railway, which currently links Riyadh via two railway lines to the port of Dammam. There are five big projects planned by which the dream finally looks set to become a reality. The Supreme Economic Council has approved the implementation plans for five railway projects, which will be under the direction of the Saudi Railways Organization. The five railway projects are (Figure 1):

Figure 1: The five railway projects by Saudi Railways Organization

1. The Saudi Landbridge: this will involve building a new 950 kilometres line from the capital, Riyadh, west to the Red Sea port of Jeddah, and a 115 kilometre line from Dammam north along the Gulf coast to Jubail; the existing Riyadh-Dammam railway will also be upgraded.
2. The Western Railway: 750 kilometres of new lines from Jeddah southeast to Makkah, and northeast to Madinah and Yanbu. The 444 km Haramain High Speed Rail linking Makkah, Jeddah and Madinah is the part from this line.
3. The North-South Railway: a 1400 kilometre mineral railway running between mines at Al Jalamid and the port of Ras Az Zawr was completed in mid-2013 [27] and

4. GCC railway: A 1 940 km international railway network is proposed to link all the Gulf Co-Operation Council member states. This would connect Saudi Arabia to the Etihad Rail network which is under construction in the UAE and
5. Metros Project Jeddah: Three light metro lines are planned to open in 2020 as part of the urban transport development strategy; Makkah: The 18 km Al Mashaaer Al Mugaddassah metro built to carry pilgrims during the annual Hajj period opened in November 2010 [27]; Madinah: A metro is being planned with opening envisaged by 2021.

REQUIREMENTS FOR CONSTRUCTION A NEW HARAMAIN HIGH SPEED RAIL (HHSR) PROJECT.

The high construction and operation costs for establishing a HSR system, either for construction a new line or upgrade an existing line, cannot be justified unless some factors are realized:

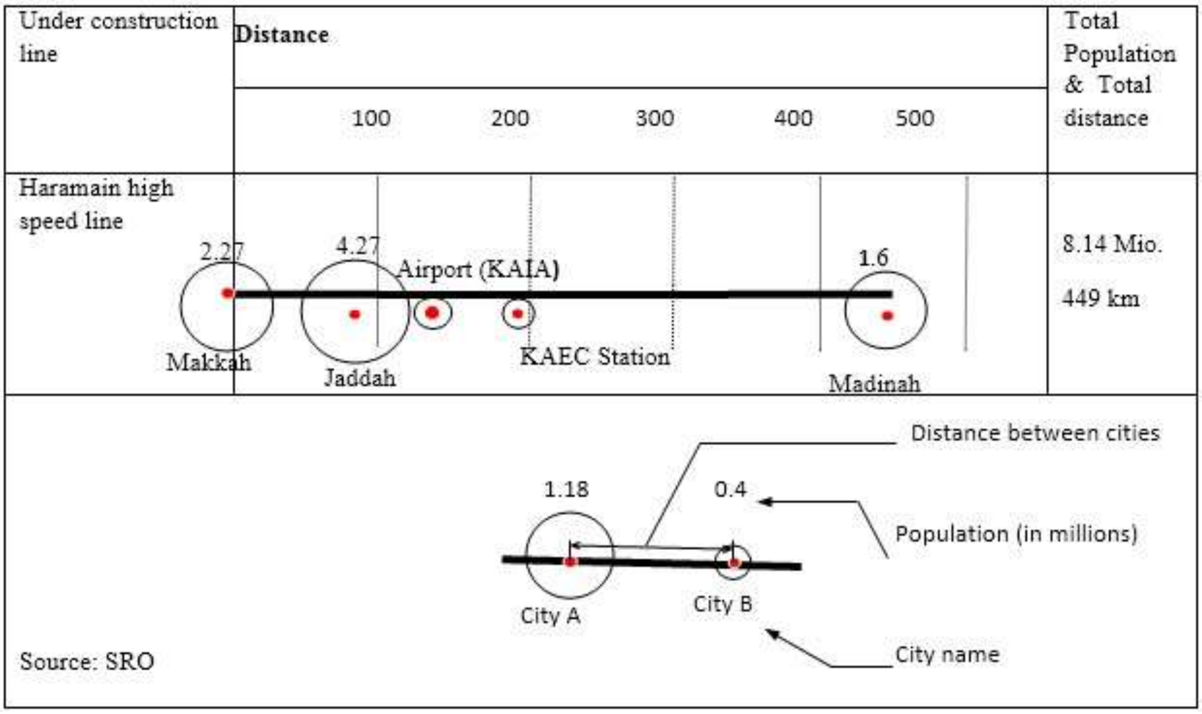
Population concentrations: The first factor of justification of an investment in HSR line would be the required population concentrations on both ends or along the line. For a HSR line to be economically justified, a minimum of ten million people at the one end and four million people at the other may be considered as a rough first criterion [26]. Figure 2 shows the population concentrations along the HHSR project 'Makkah- Madinah' in Saudi Arabia. Travel distance: The suggested distance to ensure the competitiveness of HSR is between 200 and 800 km. Below 200 km, HSR has no competitiveness over the conventional railway. Furthermore, in case of distances greater than 800 km, air travel is faster than HSR [28]. From the experiences in Japan and Europe, it was suggested that HSR could amount up to 80 – 90% of the transport market between 200 and 500 km and 50% between 500 and 800 km. The optimal journey time of HSR is between 2 and 4.5 hour [28]. For the under construction HHSR 'Makkah- Madinah' the suggested route, 450 km, has major competitiveness over other transport modes.

Background

The primary focus of Saudi Arabia's railways has historically been on freight and conventional passenger service. The first Modern railways introduced in Saudi Arabia after World War II in 1951 to facilitate the transport of goods for the Arabian American Oil Company. The Saudi Railways Organization (SRO) operates a network of railways with a total length of about 1,380 kilometers. The network consists of two main lines. The first one about 449 km passenger line that links Dammam with Riyadh, and the second about a 556 km freight line that connects the King Abdul Aziz Port in Dammam with Riyadh connect King Abdul Aziz Port in Dammam with Riyadh, while the other connects the city of Dammam with Riyadh.

Currently there is no railway line connection between Mecca and Medinah, and the same normal bus passenger between Mecca and Medinah would take five hours and a half under normal conditions (not during Ramadan and seasonal holidays). The new high speed railway currently being built between the holy cities of Makkah and Madinah in Saudi Arabia is one of the largest world's most challenging rail projects in Middle East. The city does not offer many public transport options to citizens, as well as pilgrims. The only options available are personal vehicles or private taxis. During the Hajj period pilgrims are transported by a large fleet of buses. The Haramain project was conceived to address the transportation needs of the growing number of pilgrims visiting Mecca, Umrah performers and the people of the city. Once completed, the new HSR project will be reduced the travel time from five hours and a half to two and a half hours and also provide passengers with a view of the monumental architecture of Mecca and Medinah as they travel near the cities.

Figure 2. Population of Cities on the HHSR Line in Saudi Arabia.



Project Description

The Haramain High Speed Rail Project will deliver a new electrified passenger railway line, between Makkah, Madinah approximately 450 km in length with a commercial operating speed of 320km/h. The project aims to provide a fast, comfortable, reliable and safe mode of transport between the Holy Cities utilizing state of the art proven technology. The Haramain High Speed Line is projected within the parameters of a European high speed line. The maximum operational speed will be 300 km/h, with dual track in UIC gauge, 25 kW 60 Hz electrification, and implementation of the European ERTMS level 2 systems, in which Spain is one of the world leaders.

The line has the highest passenger density which anticipates a peak time transport of over 166.000 passengers a day (8000 passenger per hour) during pilgrimage to the holy cities, using the latest technology and keeping environmental impact to a minimum (Loskant, 2014). The line will be used by 35 trains, each with capacity for over 500 passengers. HHSR incorporates one cut-and-cover tunnel, 46 rail bridges, 9 wadi bridges, and 5 rail underpasses. We also designed 53 vehicular overpasses, 30 vehicular underpasses, 12 Camel crossings, 5 stations, and 3 depots to allow the rail to fulfill the needs of its users [29]. HHSR is the first in the Middle East. It provides the fastest and the safest mode of conveyance for the pilgrims, Umra performers, and other passengers. It combines necessary comfort with entertainment and high luxury.

Furthermore, HHR Project will establish five stations one in each of the major cities of Makkah, Madinah, Jeddah and King Abdullah Economic City (KAEC) in addition to King Abdulaziz International Airport (KAIA). Furthermore, in the city of Makkah and Madinah the stations are based on the principles of the terminus while in Jeddah and KAEC the stations are based on the principles of through stations. The stations are modular buildings that retain high quality features and enables speedy delivery and faster construction with an overall emphasize on rewarding passenger experience. The new HSR project in Saudi Arabia is divided into several phases Phase 1 and Phase 2. Phase 1 is divided into two-stage 1) Construction of overall civil works along the railway line, 2) Construction works of 5 high speed train stations with their related car parks and fire station buildings. Phase 2 of the project includes the remaining infrastructure not included in Phase I such as Track, Signaling, Telecommunications, Power, Electrification, etc.

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The HHSR project is to be the first high speed train system implemented in the Saudi Arabia as a Middle East. According to the Saudi Railway Organization, High speed rail service would reduce the current Mecca and to Madinah travel time from nearly five hours and a half to two and a half hours, a speed that is highly competitive with air and much faster than by car and Bus [30]. The system would provide service between Mecca and Medina with frequencies of up to one train per hour. The new HHSR line in the Saudi Arabia will run from Makkah to Madinah on new rail system. The project which includes trains equipped with the state of the art signalling and communications systems, together with high-speed electrified two way lines designed with established UIC – International Union of Railways- wide, for speeds up to 320 km/ The city of Mecca is the birthplace of Prophet Muhammad and is considered to be the holiest place Islam. With a population of 1.7 million, each year the city attracts about 2.5 million Hajj (Hajj is a pilgrimage to Mecca) pilgrims and more than two million Umrah (performing the small Hajj) performers during the month of Ramadan and seasonal holidays [31].

In addition, there is heavy passenger movement on Fridays along with the regular commercial traffic. As mention before, the city of Mecca does not offer many public transport options to citizens, as well as pilgrims. The only options available are personal vehicles or private taxis. During the Hajj period pilgrims are transported by a large fleet of buses. The Haramain project was conceived to address the transportation needs of the growing number of pilgrims visiting Mecca, Umrah performers and the people of the city. According to a study by the Ministry of Haj, in the next 25 years the number of pilgrims is expected to increase to more than three million and Umrah performers to more than 11 million. The annual increase is expected to be 1.4 percent for Haj and 3.14 percent for Umrah and pilgrims [32].

A train service was chosen as the best option to provide safe and comfortable travel for the pilgrims and to relieve the pressure on the roads connecting Mecca and Madinah. The project is expected to link a number of centers, boosting local businesses and tourism. The construction and design of the project will allow it to withstand tough climatic and heavy traffic conditions. Since temperatures in the region range from 0.50°C, the track will be designed to handle the temperature changes. The main barriers to the development of HSR in Saudi Arabia are funding. It takes substantial financial resources to develop a network that is high speed, efficient, and attractive to travelers [33]. If a train system is not cutting travel times between cities sufficiently, it will not be able to attract the ridership it needs. Other issues include the balance of increasing speed with the variety of track uses. The current of the Saudi Arabia tracks are also used by freight systems, which has successfully worked in other countries but does impose some restrictions on speed and safety if proper technology is not used, which can also be financially encumbering. A strong HSR network in the Saudi Arabia will require the construction of more new infrastructures to fit the needs of the technology.

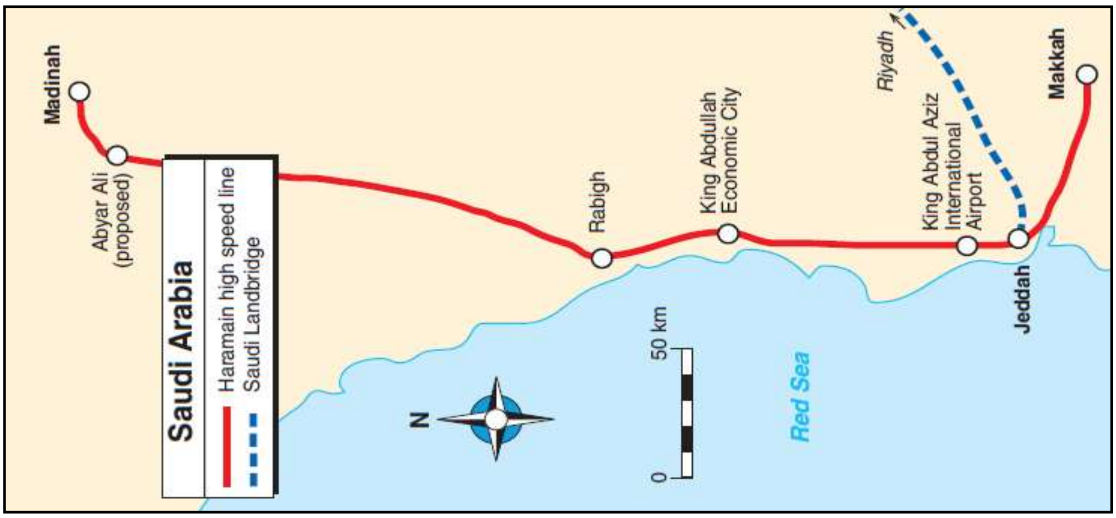

Figure 3: Shows the corridor for an HSR system in the Saudi Arabia

ANALYSIS AND COMPARISONS BETWEEN ASIA AND UROPE HSR LINES

In the worldwide, the train passenger has a very different impact within the transport market. Despite, the ratio between rail and individual transport of passenger traffic in Europe about 1 to 10 the proportion of rail travel in the U.S. is 1/150 of those private individual transport [34]. The international comparison of travel behavior cannot be made between countries without taking into account the specific cultural, population density and geopolitical situation. For examples there are some factors affecting on the average distance traveled based on the volume and population density of the country, the density of motor vehicles of the private transport and historical integration between regions, but also the costs referred to the use and quality of roads. Since Russia and China have a very developed system of cross-subsidization within the railway sector however the considerations on the efficiency of the economy rail transport can be difficult. In addition, the long-distance for public transport is understood by masses in these countries in planning and operation of railway projects, also this from responsibility of state. The general economic benefits, not the economy has in the construction, operation and design of the first fare priority. Therefore, it will be compared between the developments in European countries and Japan, China and Saudi Arabia.

However, significant differences between developing countries such as Saudi Arabia and other countries, such as Japan, Chain, France and Spain, which have developed successful high-speed rail projects. It is still not sure whether high-speed rail will truly allure Egypt citizens to get out of their congestion on the road and choose high speed rail as an alternative. In Saudi Arabia., because of the dominance of the national roadway system, and intercity passenger by air transport is some time neglected. However, with the emergence of problems such as congestion, accidence, environment protection, as well as energy saving, high speed intercity train that has already demonstrated a great success in other countries starts to gain new attention in Saudi Arabia.

Based on the analysis previous section, there are many factors affecting rail ridership, such as population density, levels of private vehicle ownership, trip length, mode choice, topography, service frequency, fares, system reliability, and cleanliness. Studies also show that ridership increases with increased income, whether for business, personal, or leisure travel. The geographic and demographic size of countries is with HSR systems, as well as the population density within the countries and the portion of the population that lives in urban areas. The geographic size of a country is an important consideration with regard to HSR because of the potential land area that must be crossed, or served, by HSR. The benefits of HSR are numerous. Rail stations, as opposed to airports, are located in city centers, which can make travel between cities, up to a certain distance away, much faster once time to get to the airport, security, and boarding time are factored in. Furthermore, high-speed trains travel faster than automobiles and are not subject to traffic congestion. High-speed rail systems lessen the demand on roads and crowded airports, and are statistically safer to ride than automobiles. For example, the French and Japanese high-speed systems have been operational for over 40 years and there have been no passenger deaths as a result of a high-speed crash in either country. Japan Rail East, the largest of the seven companies operating Japan's HSR network, requires no public subsidy because it owns the land around its stations and is able to capture the added value of that land and reinvest it into its system. Nearly one-third of JR East's revenue comes from commercial developments along the railway route. While other countries have invested more than hundred s of billions of dollars to develop strong high speed networks, the Saudi Arabia has pour comparatively little into their networks. This could still result as a benefit to the Saudi Arabia, as future projects will enjoy the well developed technology and expansive research that others have put into their own high speed systems. Table 1 shows comparisons of construction costs for HSR projects in different countries [22.

Table 1. Comparison of construction costs for HSR projects in different countries.

Country	Cost per km (US $) million
Japan	28.92 million to 62.16 million
China	15.17 million to 29.70 million
Europe	25.05 million to 39.01 million
USA	52.07 million
Australia	34.23 million
Malaysi	34.55 million

Saudi Arabia	28.82 million

Overseas HSR construction costs are generally significantly higher per km than estimates contained in Europe and Asia than the HSR in Saudi Arabia. This would imply that there are significant opportunities to leverage on overseas construction methodologies and approaches, potentially resulting in significant savings. Although the costs in the above table are at best approximate, consideration must be given to different factors that may lead to the lower HSR costs as achieved by some of the countries, such as Tunnel construction, Constructing viaducts, labour cost, manufacturing costs, cost of land acquisition and relocation costs.

CONCLUSION

Higher growth of economic and rapid urbanization in developing countries such as Saudi Arabia is likely to result in an unprecedented level of travel demand. This paper has presented an overview of the background, developments and opportunities of high speed rail in Saudi Arabia. The characteristics of HSR, when compared with other competing modes, fit well into the context of Asian developing countries. The relative efficiency of HSR as a transportation investment varies among countries, as its level of usage is likely to depend on the interplay of many factors, including geography, economics, and government policies. As rail systems become more sophisticated and continue to increase in size in Europe and Asia, other countries are set to benefit from the technological improvements and research investments that countries are pouring in to this technology. The suitability of the Europe and Asia models to the plans drawn by the Saudi Railway authorities have been discussed showing that lessons can be more learned. Though Saudi Arabia has not poured substantial resources into creating an HSR system, the country does stand to benefit from technology and successes of other countries. However, travelers and commuters have the most to gain in a time of improved transportation technology with faster travel times, easier mobility, decrease congestion of road, and development of the urban areas of the transportation nodes. All this suggests that high speed rail is the very important to and attractive for transport mode its own right.

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