

Railways in Jordan: Possible Implementation in Public Transportation

Enas Al-Najjar¹, Ahmad Hardan², Adli Balbissi³

¹ School of Civil Engineering, University Science Malaysia, Nibong Tebal, Penang, Malaysia.

² School of Maritime Business and Management, University Malaysia Terengganu, Kuala Terengganu, Malaysia.

³ Department of Civil Engineering, University of Jordan, Amman, Jordan.



Abstract - In the last few years Jordan has witnessed significant economic and social changes that led to serious challenges in the transportation sector. This paper investigates the possibility of recruiting railway services as one of the strategies to improve public transportation and face the ever increasing traffic problems.

A rehabilitation project of existing railways is presented in comprehensive details starting with an evaluation of the current situation and defining the main requirements to implement the project. The project considers both passengers and freight possible improvements can be gained by applying the railway services.

Through the detailed review of the suggested project's benefits, the recommendations came to go for the rehabilitation project, especially under the current budget limitations in Jordan and current political events in the neighbor countries.

Keywords - Railways, Jordan, Al Hejaz Railway, Freight Transport.

I. INTRODUCTION

In the last few years, Jordan has witnessed significant economic and social changes due to the rapid increase in population under the political conditions that affected the Middle East recently. These changes have applied a noticeable pressure on the different economic sectors, especially the transportation system, prompting the Jordanian government to take serious steps toward the transportation development. One of the important strategies that can be applied to face traffic problems is the improvement of the public transportation system. This study investigates the possibility of using railway services to face the increasing demand on both passengers and freight transportation. Railways have proven their efficiency in social and industrial development over the years, and have many advantages over the other modes of land transportation, as it is the safest,

cheapest, and easiest, not to mention the largest carrying capacity of cargo and people.

Over the last decade, many projects have proposed the use of railways in Jordan, such as "Amman-Zarqa Light Rail" project and "National Jordan Railway" project. However, Jordan's limited sources have been an obstacle facing the actual implementation of these projects.

According to Jordan's Third Competitiveness Report 2011, Jordan has a relatively low transit level of service, as it shows a shortage in achieving a satisfactory level of service.

Most of transit users in Jordan are considered "Captive Riders". Despite the low average individual income in Jordan, commuters would rather pay more for a convenient ridership than using the transit system. . This will lead the country to serious traffic problems in the

future (especially with high rates of population growth) unless a radical solution is applied. The most important characteristics should be provided by any solution suggested to face this challenge can be summarized as following:

1. Reliable services.
2. High quality service in terms of travel time and comfort.
3. Sufficient capacity proportionate with demand.
4. Compatibility with environment.
5. Sustainability.
6. Economical and has a reasonable cost.
7. Availability within a reasonable service distances.

This study aims to provide a comprehensive overview of the current status of the railways in Jordan focusing on the main challenges that face the rehabilitation of the existing railway in the country. Since transportation evaluation studies widely ignored the railway service as a good solution for the traffic problems, this study is the first study, based in our best knowledge, which is conducted on the Jordanian railways (Al-Hejaz Railway and Aqaba Railway), and proposes the rehabilitation of the existing Jordanian railways as a possible alternative for constructing a new network in the meantime.

1.1 Railways in Jordan:

The railway system in Jordan is one of the oldest transit systems. Despite the fact that railways in Jordan have been constructed more than one century ago, it has not been used effectively. Railway in Jordan are represented by two main organizations: Al- Hejaz Railway Corporation, and Aqaba Railway Corporation. The existing railway line extends from the Syrian borders in the north, to Aqaba Port in the south. The line is divided according to ownership and operates as follows:

- a) From Syrian borders to Al-Abyad Station: Owned and operated by Jordanian Hejaz Railway (Total length= 213km).
- b) From Al-Abyad Station to Batn Al-Goul Station: Owned by Al-Hejaz Railway, operated by Aqaba Railway Corporation. (Total length= 116km).
- c) From Batn Al-Goul Station to Aqaba old port: Owned and operated by Aqaba Railway Corporation. (Total length= 177km).

1.2 Historical Background:

Hejaz Railway was constructed based on the order of Sultan Abdul Hamid II, who aimed to provide a transfer service for pilgrims. The project was not welcome at first by the Britain who described it with “impossible” dream at that time due to the challenges that faced that idea at the time, such as the limited sources of the Ottoman Empire, the hard land nature, and the length of the proposed line. It was suggested that the line will connect Damascus with Al-Medina Al-Monawwara.

Sultan Abdul Hamid addressed a call for all The Muslims all over the world and succeeded to collect donations for establishing the Hejaz Railway. The 3500 Lira cost project started in 1900 under the supervision and guidance of a German company. After 8 years, the first trip of pilgrims was held. The trip, that uses to take between 4050 days, was accomplished successfully in 72 hours. The Hejaz Railway served other goals of the Ottoman Empire, besides facilitating the transportation of pilgrims. It established a strong connection between the Empire’s countries, especially in the Arab world. After 9 years of working, the Second World War started, and the railway was a strength point of the Ottoman Empire that used to serve military purposes.

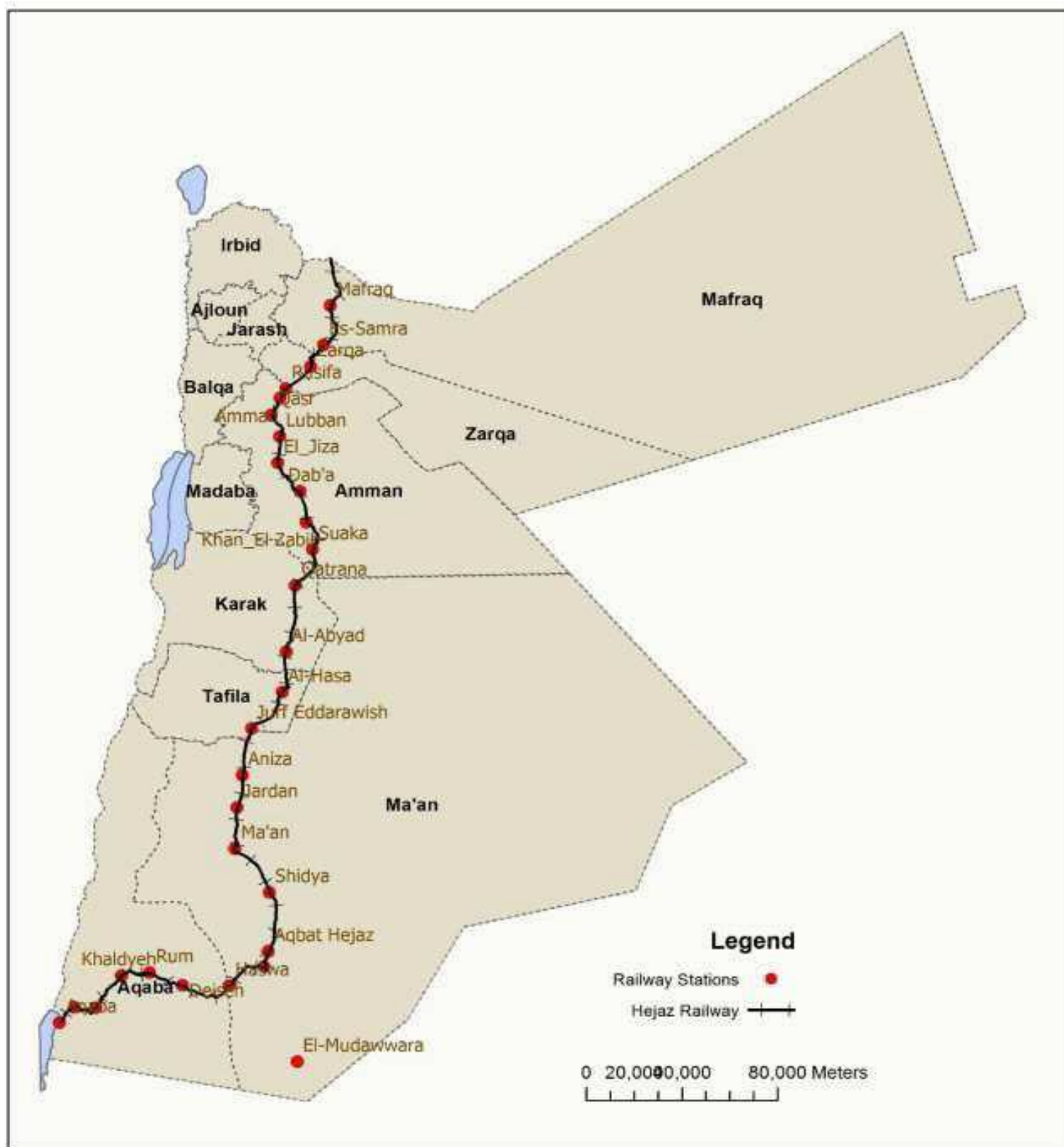


Figure 1.1. Jordan Existing Railway Network and Stations Map
(Source: Ministry of Municipal Affairs, Master Plan, 2016)

The railway was destroyed during the Great Arab Revolt on the Ottoman Empire in 1916 and stopped operating since that time.

Several attempts were made to reactivate the line by the Jordanian government. In the early 1970s, a new trend has spread to use the railway in transporting phosphate

from south rich mines to Aqaba Port. As a result, a new line was constructed to connect Hejaz Railway from Batn Al-Goul Station to Aqaba with new 18 stations during 1975. Aqaba Railway Corporation (ARC) was established to operate the transportation of phosphate. Since that time until now, Hejaz Railway and Aqaba Railway have been contributing in the transport of both freight and passengers.

Railway Passengers' Transport

The rail transit services offered by Hejaz Railway are limited to tourism trips. Many trips that used to be held between Amman and Syria have been cancelled recently, because of the Syrian crises. The only trips for passengers nowadays start from Amman Station to Al-Jiza Station near Queen Alia Airport, passing through a crowded built up area. The trips are held upon requests for tourism purposes, meaning, no regular schedule for the trips is set.

Train wagons are well prepared for passengers' comfort. However, the track deficiencies affect the trips efficiency and the train speed. Despite the efforts of Hejaz Railway Corporation (HRC) of maintaining a healthy condition of the track, the safety of passengers' trips has been threatened in some few cases. The decrease in passengers' trips has affected the income of the HRC, especially in the last three years. Nowadays, the rental fee of facilities (buildings or right of way) forms the only income resource that covers the expenses of the corporation.

Railway Freight Transport

After cancelling HRC freight trips to Syria three years ago, ARC became the only operator of freight trips in Jordan, it operates the phosphate transportation as a main product of Jordan's exports. The total phosphate revenues share in Jordan GDP is 7.7%, while potash and phosphate fertilizers combined contribute a16.3% to national exports. Phosphate is produced in three main mines in the south: Hasa, Al-Abyad, and Shydia mines. ARC is the main transporter for the products of Jordan Phosphate Mines Company (JPMC) to Aqaba port. The last few years witnessed a noticeable decrease in the phosphate production. The number of decreased loaded trains in 2013 was 968 trains. Upon JPMC request, this decrease has affected the total revenues of ARC by 510 thousand JD in 2014. The amount of phosphate production in 2016 was 7,991,157. Only 1,328,000 tones (around 17%) of the produced amount were transported by railroads (Jordan Phosphate Mines Company Annual Report, 2016).

II. OBJECTIVES

The main purpose of this project is to provide an alternative for constructing a new railway network in Jordan in order to enhance the transport system considering limited budget that has stood on the face of the actual implementation of other projects.

The project idea is to provide an assessment for the existing railway (Hejaz Railway and Aqaba Railway) and determine the main requirements for upgrading the services to a satisfying level for both commuters and investors.

Implementing this project should achieve the following goals:

1. Connecting the north and south of Jordan to form a new trading foundation, since the Hejaz Railway extends from the Jordanian-Syrian border in the north to Aqaba port in the south, passing through or nearby major cities of the Kingdom.
2. Providing an improved public transport service for passengers that may attract users of other modes in the future.
3. Reducing costs of providing such services by the rehabilitation instead of establishing a new railway track. This can be shown through the feasibility study of the project.

III. PROJECT DESCRIPTION

Many plans and projects in Jordan were suggested to activate the rail transport in the last decade. Yet, no real implementation of the project has appeared on the surface; some of these plans were rejected owing to the failure appeared in the feasibility studies and the under expectations benefits, while other projects still waiting for proper donation to be transformed from studies into actual implementation.

This study presents a proposed project of rehabilitating the existing railway lines in order to upgrade the level of service and become effective as a means of transport for both passengers and freight in Jordan.

Rehabilitation of railways is expected to give the results that cannot be gained by normal maintenance techniques, as it approaches a minor construction in requirements, costs and expected benefits. This procedure is proposed after conducting an assessment for track general condition.

3.1 Evaluation of the Current Situation of the Jordanian Railway:

An assessment of the current condition is the first stage of determining the need of rehabilitation. Thus, this study proposes a rehabilitating project of the existing railway lines. As the method to get results that cannot be gained by normal maintenance techniques, it approaches a minor construction in requirements, costs and expected benefits. This procedure was recommended after conducting an assessment for track general condition. The main requirements of rehabilitation were determined according to brief field inspection visits, inventory reports and information collected through interviews with Hejaz Railway Corporation (HRC) and Aqaba Railway Corporation (ARC) employees.

The main purpose of the rehabilitating project is to provide an alternative for constructing a new railway network in Jordan in order to enhance the transport system considering limited budget that has stood in front of the actual implementing of other projects. In this paper, we focus on the main challenging and obstacles facing the rehabilitating project of the existing railway (Hejaz Railway and Aqaba Railway).

During evaluation, railways were found to consist of two main parts: Hejaz railway (509km) between the Jordanian-Syrian borders and Al-Mdawara, completed in 1908. In 1972, Aqaba Corporation rented and renewed a part of Al-Hejaz Railway; from Al- Abyad station and Batn Al-Goul station (178km) and constructed a new line between Batn Al-Goul and Aqaba port (116 km). Three inspection visits were conducted to evaluate the current condition of the railway network in Jordan as follows:

- **First visit:** Hejaz Railway southern part (Amman Station-Qatrana Station), surveyed on 29th of January 2015.
- **Second visit:** Hejaz railway –north part (Amman Station- Syrian border): on 5th of February 2015.
- **Third visit:** Aqaba railway (Ma'an Station –Batn A-Goul Station): on 25th of March 2015.

The evaluation focused on two major aspects; the social and economic factors that affect the railway from one side, and the technical and structural characteristics of the railways' different parts.

3.1.1 Socio- Economic Survey Results (Observations):

The railway traverse a variable nature of lands, this could be clearly noticed during the field inspection. Each area or land use applies its own requirements; due to the difference in problems nature. These areas can be classified as follows:

- a) **Urban Areas (built up areas):** During over a century, construction has grown on both sides of Al-Hejaz Railway track. Fortunately, there is no need for acquisitions to reactivate the railway, since the land is owned by HRC. The acquisitions include the track base land and a buffer area of 15m from the center line of the railway on each side, as a required corridor of impact (COI). HRC could keep a clear COI and succeeded to monitor any encroachment of the residential buildings or craft workshops that spread along the track sides. However, the clear corridor (and sometimes the track itself) is used usually as a parking area or shopping display area or even as scrap storage, since no regular train trips or fixed schedule to pass through. Construction debris, trash and industrial garbage have become a normal view in the built up area.

Households have grown at the edge line of COI with entrances facing the railway. This may become an obstacle for implementing the project, unless the corridor of impact is reduced to 10m from the centerline on each side, leaving enough space to be used as corridors (local streets) with keeping the right of acquisition to HRC. Urban sprawl caused more streets to be opened, which intersect with railway track causing more level crossings. Furthermore, building around the railway has changed the drainage requirements, most of culverts within built up areas are either useless (dry or buried) or needed in other locations. The transportation services are available in parallel with the railway existence, such as the bus terminals that have been built in close locations with the railway stations, which can abbreviate many requirements or costs to coordinate between both transports modes. (See appendix, Figure (3-1) and Figure (3-2)).

- b) **Industrial Areas:** the railway approaches some industrial areas that are scattered along the path of the track. Activating the railway can be useful in transporting products and raw materials, since it can

be a focal point between several factories and borders, Queen Alia Airport, Aqaba port and many other terminals (exporting points). In addition, it passes by the custom department. Figure (3-3) shows the industrial areas and factories in Jordan, and the location of the railway with respect to these factories.

- c) **Deserted (Clear) Areas:** through its way, the track passes wide empty and rural area between cities; these parts of railway are mainly ignored since no trips were held for tens of years. This is the reason behind the different kind of troubles it faces, such as:
- Holes have been digged by citizens following rumors and looking for the Turkish gold that was claimed to be buried under the track or stations; this has become a major reason of destroying the infrastructure of the abandoned track and stations in these areas.
 - Some parts of the railway were stolen, until the HRC decided to sell the remaining of the unused parts and kept the acquisition of the land.
 - Some wild animals made holes in the formation layer of the track causing sever damages that affect the stability and safety of the railway. Appendix1, figure (3-4).

3.1.2 Technical and Structural Survey Results (Observations)

First: Track Condition

- **Rails:** the existing Hejaz Railway used a 23 kg section rails. This was designed over one hundred years ago to carry a 10.5 ton axle load train, laid in 9m length bars. Later in the early 1970s, Aqaba Railway was designed and built with different characteristics to meet the industrial needs at that time. The characteristics are: 18m long rails of 49kg section with welded joints used to carry a 21 ton axle load with designed speed of 100 km/h. ARC also renewed the rented part of Hejaz Railway, using different rails sections, such as rails of 30, 34, and 49 kg/m. The renewal process started in 1984 and was completed in 1991.

Over the years, both types of rails have experienced many defects that affected its original characteristics:

- Wearing out of head and rail sides due to weather conditions and wheels interaction and braking. This has applied limitations on train speed, especially on curved portions to

avoid the possible derailment. The train current running speed does not exceed 35 km/h in the best cases; while in other cases may be reduced to 10 km/h.

- Wearing and poor maintenance caused the rails to be vertically bent on sides (Hogging). The hogged parts of rails should be removed or cut immediately.
 - Some adjoining parts of Hejaz Railway rails have slightly moved at joints (kinks) which affect passengers' comfort. This can be clearly noticed in level crossings and curves.
 - Due to the repeated loads and the deserted lands, the southern part of Al- Hejaz Railway and the Aqaba Railway suffers from Corrugation in rails. The corrugation usually occurs where sand or high moisture is available. The surface of rails suffers from verifications in shape and size causing a wavy surface, and an annoying squeak sound that affects the comfort of the ride.
- **Sleepers:** In the 20th century, the steel sleepers were desired for its durability and sustainability. Most of Al- Hejaz Railway steel sleepers are abraded and buried under the ground. However, the sleepers now have a fixed situation that cannot be changed easily. This somehow has increased the track constancy and resisted the lateral movements through years. In some cases, HRC used wooden sleepers to support steel sleepers wherever a collapse under rails has occurred.

Concrete sleepers were adopted in Aqaba Railway as the life span of these sleepers is higher than steel or wooden sleepers. It also keeps a fixed gage. Therefore, wooden sleepers were used in the southern part of the line, where curves are available because of gauge widening on curvatures. Almost 90% of concrete sleepers are in a very good condition, while most of wooden sleepers require change. Mechanical maintenance of the track was provided periodically by ARC.

- **Ballast:** along the Hejaz Railway route, the ballast layer condition varies between good to poor condition. In many cases, the minimum requirements (thickness or quality) of ballast layer are not met. In some cases, the ballast layer is totally eroded, while the minimum required

thickness is 25cm. Aqaba Railway has good ballast condition in general because of the availability of basalt and granite quarries in the southern area and the regular pouring of ballast.

- **Formation:** since the formation layer is responsible for supporting all other track components, the failure in this layer should be seriously considered. Along the Hejaz Railway, in several locations, where formations consists of embankment, have suffered from erosion of formation surface, either because of the saturation in soil during rainy seasons or because of the low bearing capacity of soil. In case of the cut section formation, land sliding causes a very dangerous threat to train and passengers' safety. These cases were treated as high emergencies by HRC.

Despite the intensive monitoring and the continuous filling back of holes by HRC, formation stability has been affected by the holes digged by gold seekers. The formation of Aqaba railway and the Hejaz line under ARC authority is in a good condition, since it was changed during the renewal of the line in the 1980s, in addition to the daily use and maintenance of the line that have moved people away.

Second: Stations Condition

The total number of stations along Al-Hejaz Railway in Jordan is 26 stations. However, only 8 of those stations are hosted by managers, the effective stations are in fair conditions and need some rehabilitation. The stations are: Mafraq, Al-Samra, Zarqa, Amman, Um Al-Hiran, Al-Jiza, Qatraneh and Batn Al-Goul. Generally, these stations are situated in useful central locations, so that they are close to traffic generators, terminals and other transit services. ARC is responsible of a number of Al-Hejaz stations and has succeeded to maintain these stations in a good condition, in addition to their own stations that were constructed with Aqaba Railway line.

Third: Bridges, Tunnels and Culverts Condition

In some parts, bridges were damaged due to floods in winter time, which required HRC to rebuild those bridges. Only few tunnels along the Hejaz Railway were built during the earlier construction of the railway. The tunnels require lighting features, otherwise they are generally in a good condition. Since all culverts were built during the construction stage and the change in land nature over hundreds of years, culverts in built up and

industrial areas need to be reassessed according to their function. In addition, some culverts should be added wherever drainage for the track is needed. Total number of bridges and culverts of Aqaba railway is 1044 with a total length of 4422 km.

Fourth: Level Crossings Condition

The number of level crossings has significantly increased due to the increased number of streets and intersections. For instance, there are 17 level crossings only inside Amman urban area. This has led to more interruptions on the train way. The greater the distance from built up area, the less level crossings were found. However, some of these crossings are in a bad condition because of the poor maintenance. The absence of signaling has made the crossings even more annoying and dangerous.

Fifth: Rolling Stocks

HRC has two locomotives that were repaired in 2012 and currently in use. 15 passenger coaches (saloons) are available with capacity of 20-30 passenger/saloon, these are used in transporting passengers in tourism trips. 49 wagons used to transport freight before the Syrian crises. ARC has more rolling stocks in service, total number of locomotives is 23 and 187 wagons are used in transporting phosphate as a main product. Daily maintenance for rolling stocks is conducted by qualified technicians in ARC to ensure its efficiency.

3.2 Project Requirements:

This section describes the technical and practical details of the work in order to achieve the goals of the proposed project. The rehabilitation of the existing railway (both Hejaz and Aqaba lines) requires several remedial actions differs along the path. The project is to be divided into stages according to priority. Each stage is to be divided into sections with specific length depending on the needs and deficiencies of each section.

The proposed stages are as following:

Stage I (Amman – Ma'an Line):

The main objective of the project is to connect the north and the south of the Kingdom services and trade markets. Along this line, different nature of deficiencies have applied different correcting actions. Therefore the line is divided into the following sections:

- **Section (1-1):** Starts from Amman Station toward the south until Umm Al-Hiran Station, between

(223-234), the total length of this section is about 11 km. However, it can be considered one of the hardest sections since the line traverses a crowded built-up area. The work also includes signaling and maintenance of 17 crossings and rehabilitation of the two stations.

- **Section (1-2):** extends between Um Al-Hiran and Al-Abyad Station (234-353) with a total length of 119km. The section contains level crossings and different levels of rehabilitation for four stations (Al-Jiza, Kan Zabib, Qatranah and Al-Abyad).
- **Section (1-3):** between Al-Abyad Station and Ma'an Station (353-459), this includes a rehabilitation of a 101 km length of railway. Ma'an Station is in a very good condition and may need minor maintenance.

Stage II (Ma'an – Aqaba Line):

This stage is a complement for the first stage. However, it was given less priority due to its good condition comparatively. It can be divided into the following sections:

- **Section (2-1):** Ma'an Station to Rum Station (459-607)
- **Section (2-2):** Rum Station to Aqaba Station (607-661).

Stage III (Aqaba New Line):

Aqaba Station and Aqaba new port, with a total length of 15 km for this stage. Since this section is a construction not rehabilitation, the design and cost estimation of National Railway Project (Ministry of Transport, Jordan) is to be adopted.

Stage IV (Amman –Jaber Line):

- **Section (4-1):** from Amman Station to Mafraq Station passing by Zarqa Station (223-162) with a total length of 61km.
- **Section (4-2):** from Mafraq to Jaber borders (borders with Syria) total length of around 40km. This section is postponed under the current circumstances of the Syrian war. Until the political events are settled down, there is no need to start working on this section.

3.2.1 Track Requirements:

- **Rails:** In general all rails along the existing railways (Hejaz and Aqaba) are to be replaced according to the proposed project, in order to use a heavier section that will upgrade the level of service. Generally, the age of these rails ranges between (30-100) years old. The selected rails section is 52kg/m laid in 18m length bars. This section is adequate to carry an expected axle load of 25 ton and a speed of 100km/h. All joints are to be connected by welding to ensure a smooth and comfortable ride for passengers and to reduce the maintenance cost of joints in the future. Fastening costs will be added as a percentage of 10% to rails total cost.

Rails specifications and prices:

The selected rail section (UI52) standard specifications are shown in figure (3-5):

Top: 67mm

Length: 18m

Bottom: 136mm

Weight: 52.08kg/m, or 105lb/yd.

Height: 156mm

Price: 700JD/ton.

- **Sleepers:** Along the existing railway route three types of sleepers were used: steel, wooden and concrete. Both steel and wooden sleepers are to be replaced by new wooden sleepers. Concrete sleepers are generally in a good condition, only few sleepers need to be changed using new concrete sleepers.

- **Sleepers' specifications and prices:** "Kempas" Malaysian medium hardwood sleepers are to be used, with a density of 770-1,120 kg/m³ air dry and 60cm center-to-center spacing is adopted. Sleepers should be treated with the appropriate wood preservatives to resist fungus and insects, it is necessary to get durable sleepers even under exposed condition.

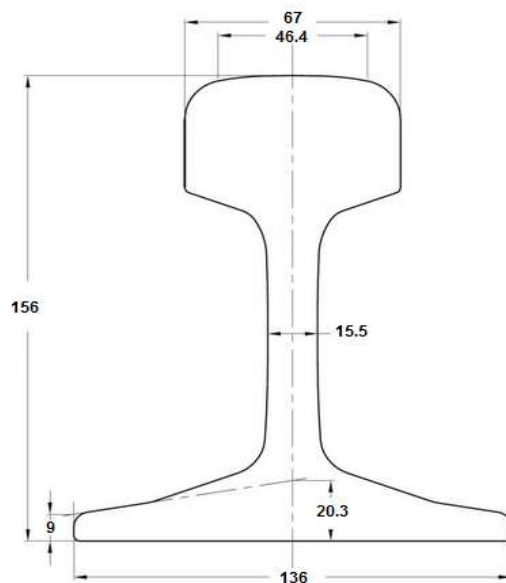


Figure 3.5. Typical Section in the Selected Rail (UI52)

Expected quantities and prices of required rails can be shown in table (3-1):

Table 3.1. Quantities and Cost Estimate of Required Rails (52 kg/m)

RAILS REQUIRED QUANTITIES AND PRICES					
Stage	Sec.	Leng.(km)	Wt. (ton)	Unit Price (JD)*	Total Price (JD)
Stage I	1-1	11	572	700	400400
	1-2	119	6188	700	4331600
	1-3	104	5408	700	3785600
Stage II	2-1	148	7696	700	5387200
	2-2	54	2808	700	1965600
Stage IV	4-1	61	3172	700	2220400
	4-2	Excluded			0
Total					19,899,880

* Unit Price was adopted according to recent prices of 2016 tenders

Strength properties are shown in the following table:

Table 3.2. Strength Properties of Kempas Wooden Sleepers

Test Condition	Modulus of Elasticity(MPa)	Modulus of Rupture(MPa)	Compression parallel to grain (MPa)	Compression perpendicular to grain (MPa)	Shear strength(MPa)
Green	16,600	100	55	6	10
Air dry	18,600	122	66	8	12

Required specifications in sleepers can be summarized as following:

Width: 24cm. Length: 210 cm
Height: 14 cm Price: 55 JD/ piece.

Concrete sleepers are pre-stressed concrete of the same dimensions but the price is around 80JD/piece. Total required quantities and prices of sleepers for the proposed project as follows:

Table 3.3. Quantities and Cost Estimate of Required Sleepers

SLEEPERS REQUIRED QUANTITIES AND PRICES						
Stage	Sec.	Existing	Proposed	Qnt.(No.)	Unit Price (JD)*	Total Price (JD)
Stage I	1-1	Steel	wooden	18,333	55	1,008,333
	1-2	Steel	wooden	198,333	55	10,908,333
	1-3	conc.+ wood	concrete	173,333	80	13,866,667
Stage II	2-1	Wooden	wooden	246,667	55	13,566,667
	2-2	conc.+ wood	wooden	90,000	55	4,950,000
Stage IV	4-1	Concrete	concrete	101,667	80	8,133,333
	4-2	Excluded				0
Total						52,433,333

* Unit Price was adopted according to recent prices of 2016 tenders

• **Ballast:** The depth of ballast layer is usually between (10-30)cm. For this project a layer of 30cm depth is to be laid under sleepers, and the required quantity of ballast is about (810 m^3/km).therefore the quantities required for this project can be determined in table (3-4).

Price of ballast is governed by the required properties and the availability of materials. In Jordan, both Basalt and Granite are used for ballast in percentages of 28% and 72% respectively, because of its quarries availability. For ballast particle size that varies between (12-60)mm, the price of one cubic meter is around 25JD.

Table 3.4. Quantities and Cost Estimate of Required Ballast

BALLAST REQUIRED QUANTITIES AND PRICES				
Stage	Sec.	Qnt.(m3)	Unit Price (JD)*	Total Price (JD)
Stage I	1-1	8910	25	222750
	1-2	96390	25	2409750
	1-3	84240	25	2106000
Stage II	2-1	119880	25	2997000
	2-2	43740	25	1093500
Stage IV	4-1	49410	25	1235250
	4-2	32400	25	810000
Total				10,874,250
* Unit Price was adopted according to recent prices of 2016 tenders				

• **Formation:** since the formation section varies between embankment and cut, an average formation depth of 2m is adopted where formation is required to be replaced. Compaction is to be applied on layers of 30cm thick at

optimum moisture level to get 90% of dry density. The minimum width of formation required for 1.05m gauge is 4.88m. For this project a 5m of formation width is to be

adopted, drain sides should be considered in case of cut sections.

The price of one cubic meter of formation (including excavation, moving old materials and fill) is around 10JD.

Formation needed to be removed and totally replaced along the sections between Mafraq to Al-Byad with a total length of 188km. The total quantity and prices of required formation can be calculated as the following:

$$\text{Length} \times \text{Depth} \times \text{Width} = 188 \times 1000 \times 2.0 \times 5 = 1,880,000 \text{ m}^3.$$

$$\text{Total price} = \text{Quantity} \times \text{Unit price} = 1880000 \times 10 = 18,800,000 \text{ JD}$$

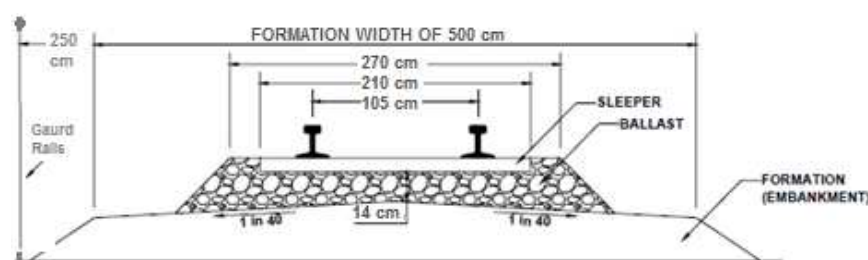


Figure 3.6. Typical Section of Rehabilitated Railway.

3.2.2 Stations Requirements:

The stations along the route are in different condition, thus, three levels of rehabilitation were adopted as following:

- Minor rehabilitation: this includes painting, fixing, lighting features, drainage pipes, doors and windows with simple maintenance.
- Moderate rehabilitation: this includes plaster fixing, painting, changing some or all parts for windows and doors and tiling.

- Major rehabilitation: it includes minor construction works, such as repairing some parts, remodeling, adding partitions or adding new latrines.

Each level of rehabilitation is given a price per square meter. The total cost depends on station area and current condition. No furniture or landscaping costs were considered in the requirements. Table (3-5) shows the required level of rehabilitation and costs for each station.

Table 3.5. Cost Estimate of Stations Required Rehabilitation.

REQUIRED REHABILITATION LEVEL AND PRICES FOR STATIONS						
Station	Owner	Sec.	Area (m2)**	Required Level	Unit Price (JD/m2)*	Total Price (JD)
Mafraq	HRC	4-1	332	Minor	25	8299
Zarqa	HRC	4-1	415	Minor	25	10367
Amman	HRC	1-1	2615	Minor	25	65363
Um Al-Hiran	HRC	1-1	283	Moderate	60	17009
Al-Jiza	HRC	1-2	467	Minor	15	6999
Kan Al-Zbib	HRC	1-2	193	Major	110	21220
Qatrana	HRC	1-2	615	Moderate	60	36901
Al-Abyad	ARC	1-3	511	Minor	25	12775
Al-Hasa	HRC	1-3	308	Moderate	60	18501
Al-Jarf	HRC	1-3	518	Moderate	60	31084

Ma'an	ARC + HRC	1-3	2121	Minor	15	31815
Al-Shidya	HRC	2-1	117	Minor	25	2925
Oqbat Hijaz	HRC	2-1	117	Minor	25	2925
Batn Al-Goul	ARC	2-1	208	Minor	15	3120
Haswa	ARC	2-2	118	Minor	25	2950
Deiseh	ARC	2-1	118	Minor	25	2950
Rum	ARC	2-3	198	Minor	25	4950
Amran	ARC	2-3	84	Minor	25	2100
Wadi Al-Yutm	ARC	2-3	84	Minor	25	2100
Aqaba	ARC	2-3	84	Minor	25	2100
Total						286,453
* Unit Price was adopted according to recent prices of 2016 tenders						
** Area counted for residence and offices only.						

3.2.3 Bridges and Culverts Requirements:

A percentage of 5% will be added to the total cost to cover required rehabilitation costs of bridges and culverts.

3.2.4 Level Crossings Requirements:

Generally, level crossings between railway and roads are considered the most dangerous points of any railway; it should be given an attention during design and maintenance stages to decrease accidents possibility. Despite the regular maintenance of existing level crossings, it still in fair condition. This project, level crossings require moderate level of maintenance, in addition to the necessary signaling. These requirements cost will be added as another 5% on the total cost of the project.

3.2.5 Operation and Maintenance Costs (O&M):

The major components of the railway operation and maintenance costs are: fuel consumption, locomotive and rolling stock maintenance, fixed and variable track maintenance, and stations' maintenance costs. Through the review of a similar project study (Cambodia Railway Rehabilitation Project), the Asian Development Bank

estimated O&M costs (in US\$/km) for 30 years starting in 2013. Since both projects treat narrow gauge rehabilitation, the same prices (exchanged into JD/km) will be adopted in this project, and can be shown in table (3-6).

3.2.5 Rolling Stock Costs:

Required rolling stock fleet for the project was assumed to grow gradually through years to accommodate the traffic growth. In this study the number of required locomotives and wagons is to be adopted from the ADB report of Cambodia as well, due to the lack of data on passengers' demand and rolling stocks prices. Table (3-7) shows the estimated required rolling stocks within the project's lifetime.

Table 3.6. Estimated Operation and Maintenance Costs.

OPERATION & MAINTENANCE ESTIMATED COSTS*				
Years	2010-2015	2015-2020	2020-2030	2030-2050
Railway Operation Costs (JD/km)	0.0624	0.0622	0.0573	0.0523
Railway Maintenance Costs (JD/km)	0.00653	0.00419	0.00383	0.00355
Total	0.0689	0.0664	0.06113	0.0559

* Source: ADB Final Report, 2013. (Rehabilitation of Cambodia Railway).

Table 3.7. Estimation of Required Rolling Stocks (Cumulative)

REQUIRED ROLLING STOCKS AND PRICES				
Year	Locomotives.	Freight Wagons	Passenger Cars	Price (million JD)
2016	4	0	0	5.32
2030	20	480	6	60.02
2050	30	720	10	104.46

Total cost of suggested railway rehabilitation is the summation of all previous detailed requirements:

Total Estimate Cost = 245.40 million JOD

3.3 General Considerations for Implementation:

1. The project is assumed to need three years duration of construction starting from 2018. It will start operating in 2020, and, benefits were considered after 30 years of operations (until the year 2050).
2. Disposed materials (removed rails, sleepers ...etc.) should be kept safely in a storage area to be sold as scrap.
3. All sections should be divided into work zones, each zone does not exceed 1 km length.
4. Railway line passes built-up areas should be protected by guard rails on both sides on a distance of 10m from the center of the track.
5. Stage III (Aqaba branch) and Section 4-2 (from Mafrq Station to Syrian borders) are excluded from the requirements study and cost analysis.
6. The cost analysis is based on the pricing of major items in the project, minor works cost is expressed as a percentage of the total project cost.
7. Some stations along the path were ignored from the rehabilitation, since there is no need to activate these locations.

3.4 Expected Benefits of The Project:

Several benefits are expected to be gained by the implementation of the railways rehabilitation project by reducing number of vehicles on roads. For example, reduction in road maintenance costs, reduction of vehicles operating and maintenance costs, reduction in accidents rates, travel time savings, reducing gas emissions and reduction of fuel consumption. These benefits are associated to the expected shifting of freight and passengers from other modes to railways.

In this study only three main benefits were considered in the economic analysis of the project as follows:

a. **Travel Time Savings:** shifting from bus transit to rail transit is expected to save time for passengers who travel between Amman, Zarqa and Mafrq. Since the trains' expected speed is 100km/h. Railways will be competitive to bus lines between these cities, where the average speed of buses is 70km/h, besides the interrupted trips due to irregular stops of buses, which will save around 18.4min/trip for Amman-Mafrq trips, 13min/trip for Zarqa-Mafrq trips, and 8min/trip for Amman-Zarqa trips. Referring to site survey, average number of bus trips between those cities is:

Amman-Zarqa: average number of trips = 200/day, total daily saved time = 26.67 hr/day

Amman-Mafrq: average number of trips = 80/day, total saved time = 24.53 hr/day

Zarqa-Mafrq: average number of trips = 110/day, total saved time = 23.83hr/day

The roadway between Amman and Aqaba (passing Ma'an) has almost the same speed of the train. Therefore, it was not considered in the travel time saving calculations. However, it is expected to witness an increase in the passengers' demand due to other factors, such as: reliability, safety and comfort. Freight transport by railway is not expected to save more time than trucks as well, since both modes use almost the same route length with same speeds. The difference in loading capacity per trip will be an attractive reason to shift modes, besides reducing the fuel consumption costs.

The travel time savings should be given a financial value to use it in the economic analysis. To estimate the value of time (VOT) in Jordan, Jordan Gross Domestic Product (GDP) is to be converted into an annual

individual income, which the value of working hour is derived from as follows:

According to World Bank statistics in 2016, Jordan has a GDP of 38.655 billion USD and a total population of 9.456 million.

Annual average income = $(38.655 \times 1000) / 9.456 = 4,088$ USD

Assuming 8 working hours in five days a week, VOT = 1.97 USD/hr, which equals 1.395JD/hr.

In order to estimate this value for the project life time (30years), an average growth rate of population of 3.94% and average GDP growth of 4.79% (Source: World Bank Statistics).

Table 3.8. Estimated Value of Time for Project Duration

ESTIMATED VOT AND TRAVEL TIME SAVINGS					
Year	Population (million)	GDP (billion USD)	VOT (JD/hr)	Travel Time Savings (JD/day)	Travel Time Savings (JD/year)
2016	9.456	38.655	1.395	104.67	27,214.2
2025	13.917	61.72	1.514	113.59	29,534.81
2050	36.568	198.79	1.856	129.98	33,793.68
Total savings along project duration (JD)					376,371.10

b. Reduction in Fuel Consumption: Railway transport decreases the amount of consumed fuel in the transportation process. An average tonnage per gallon of trucks is 249.45 ton-km, where the average load shipped by a train is around 659.83 ton-km per gallon.

In order to analyze the fuel consumption savings for the proposed project, the estimation of freight demand was prepared by BNP PARISBAS Company in 2010 to study the benefits of Jordan National Railway Project, the same estimations will be adopted in this study as well.

Table 3.9. Estimated Rail Freight Demand

Freight Traffic	2015 Tonnage (000s tons)	2016 Tonnage (000s tons)	2017 Tonnage (000s tons)
Phosphate/Sulfur/Phosphatic Acid	6,430	7,600	11,000
Cereals	1,490	1,700	2,300
Crude Oil and products	4,000	4,600	6,000
Containers	3,150	7,300	17,000
Cement and Cement Feedstock	2,250	6,500	6,500
Other	600	800	1,700
Total	17,920	28,500	44,500

(Source: BNP PARIBAS, 2010)

The fuel price average increasing rate due to the last five years observation is 2.8%. The fuel consumption savings for the project can be calculated by finding the difference in required fuel (per gallon) for both trucks and train to carry the expected freight loading. The results are summarized in the following table:

Table 3.10. Fuel Consumption Savings.

ESTIMATED FUEL CONSUMPTION SAVINGS						
Year	GDP (billion JD)	Freight (1000 ton)	FP(JD/Liter)*	Truck Fuel Cost (JD)	Train Fuel Cost (JD)	Fuel Consumption Savings (JD/year)
2016	33.68	17920	0.455	61487.69	23245.54	38242.15
2030	56.34	28500	0.748	160762.67	60776.64	99986.04
2050	99.79	44500	1.299	435921.14	164800.82	271120.31

*Fuel price average increasing rate due to the last five years observation is 2.8%

** Gallon = 3.785 Liter

c. Reduction in road accidents costs: Increasing accident rates in Jordan were being noticed in last few years. Crashes cost countries about 1%-2% of its GDP. The reduction in number of vehicles using the roads is a major reason of decreasing the possibility of car accidents, thus, saving costs associated to these accidents. The methodology in estimating accidents cost savings is by

finding the difference between trains accident rates and other modes (buses) accident rates in veh-km.

In Land Transport Accident Statistics report, 2010 (OGP), tables of fatality and injury accidents rates were prepared for several countries, as shown in table (3-11).

They developed a procedure by which the number of accidents due each mode can be estimated.

Table 3.11. Road Fatality and Injury Rates in Selected Countries.

Country Asia/Middle East	Year	Traffic Volume (10 ⁶ Veh- km)	Frequency of Injury Accidents (10 ⁶ Veh-km)	Injury Rate (10 ⁶ Veh-km)	Fatality Rate (10 ⁶ Veh-km)
Armenia	2005	0.4	2978.4	4027.2	703.7
Bahrain	2002	5.3	308.9	540.0	15.2
China	2005	10.8	1392.8	1763.3	14.0
Israel	2005	41.1	413.5	863.5	10.9
Japan	2004	781.7	1218.1	-	10.9
Korea, Rep.	2005	314.9	680.1	1086.8	20.2
Kyrgyz Republic	2005	10.2	365.4	449.3	87.8
Mongolia	2002	2.3	2897.3	2148.8*	178.8
Singapore	2005	13.8	486.6	596.8	12.6
Ukraine	2005	14.0	3319.7	3999.1	516.3

* These appear to be incorrect values as the injury rate should be higher than injury accident rate in previous column.

(Source: RADD – Land transport accident statistics, 2010)

In Jordan, the fatality accident rate in veh-km is to say 20.1 billion veh-km according to The World Health Organization report in 2010 for middle income countries. In order to find the accident costs for bus and rail transit, table (3-12) was used. The following results were found:

Table 3.12. Accident Rates by Road User Type (billion veh-km)

Road User	Urban roads		Rural Roads		Motorways		All Roads	
	Death	Serious Injury	Death	Serious Injury	Death	Serious Injury	Death	Serious Injury
Pedal Cycle	24	490	58	520	-	-	32	500
Motor Cycle	65	1220	200	1220	51	300	120	1140
Car	2	28	7	44	2	9	4	31
Bus or Coach	4	110	3	29	4	11	4	75
LGV	1	6	1	11	1	5	1	8
HGV	1	11	2	17	1	7	1	12
All vehicles	3	51	8	52	2	10	5	44

(Source: RADD – Land transport accident statistics, 2010)

Table 3.13. Accident Rates for Railways (billion veh-km)

Vehicle Type	Death	Injury
Rail	0.4	15

(Source: RADD – Land transport accident statistics, 2010)

Bus accidents rate is 4 billion veh-km in UK. This value should be adjusted according to Jordan's accident rate, which is about 3.14 times of UK rates. The total distance of the project (Mafrq-Aqaba) is around 475km long, so the total bus accidents in veh-km for buses and rails can be calculated as following:

Bus accident rates = $4 \times 10 \times 475 \times 3.14 = 59660$ billion veh-km.

Rails accident rates = $0.3 \times 10 \times 475 \times 3.14 = 4474.5$ billion veh-km.

The reduction in accidents due to shifting modes can be expressed as the difference between both modes, which equals 55185.5 billion veh-km.

Federal Highway studied the external costs of accidents through a case study in 1997. In this study, the cost of fatal accidents was determined for passenger cars and heavy vehicles as \$12.8 and \$19.9 per1000 km respectively.

Depending on the same study, the cost of fatal accidents in Jordan can be estimated as 9.56 JD/1000km. Thus, the total accident cost savings, over the project lifetime, can be estimated as:

$$(9.56 \quad 55185.5)/1000 = 527.5 \text{ million JD.}$$

IV. CONCLUSION

This paper investigates the current situation of the railways in Jordan. The financial situation in Jordan is the main obstacle facing either rehabilitation of the current railway (Al-Hejaz Railway and Aqaba Railway) or constructing new railway.

In this study several aspects related to railway design, maintenance and implementation were presented and the following points were found:

- 1- Importance of railway system, as in any society, the application of railways reflects many benefits on the social and economic levels.
- 2- The study proposed Al-Hejaz Railway rehabilitation as an alternative option to implement railways in public transport.
- 3- The estimate cost of the suggested rehabilitation project is around 245.4 million, which is relatively acceptable for donors, compared to railway

construction projects which cost billions of Jordan dinars (Ministry of Transport, 2014).

- 4- Recruiting railways in serving public transportation will improve transit services for both freight and passengers by saving travel time, reducing fuel consumption and accidents cost, beside many other benefits.

V. RECOMMENDATIONS:

Like most of the infrastructure projects, and with the high estimated cost of the project it was recommended to use a private partnership with the government to finance and execute this project. a Build- Transfer- Operate (BOT) model is suggested for operating the project, a 30 years contract is suggested in this study.

Other recommendations, to ensure viability of the suggested project, are listed below:

1. A comprehensive survey of public transportation in Jordan is to assess the general situation of transit services and to reflect the daily demand on all routes and terminals. It should also reflect traffic generators, origin- destination data, travel times, reliability of transit modes and other characteristics.
2. For the suggested project (Rehabilitation of Hejaz Railway), a test for bearing capacity of the soil is to be conducted on several locations to reflect the ability of carrying loads of 25ton/axle.
3. Since the project is suggesting a complete renewal of the track, applying a standard gauge instead of the narrow gauge can be done, with an expected increase in cost estimation for widening the track.
4. To mitigate the effect of the project on the near households, it is recommended to reduce the COI to 10m, (to leave a 5m as a corridor or entrance way for close households and shops) with keeping the acquisition right.
5. In order to get the optimum benefits of the project, an upgrading of service level of adjacent terminals and bus stops is to be considered.
6. For both proposed projects, a complementary study for Aqaba city should be prepared in details to demonstrate the connection between the new port location and the best alignment of the proposed railway line.

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Appendix 1



Figure (3-1): Railway Condition in Built-up Areas.

(Source: Author, 2015)



Figure (3-2): Households Facing Railway Corridor.
(Source: Author, 2015)

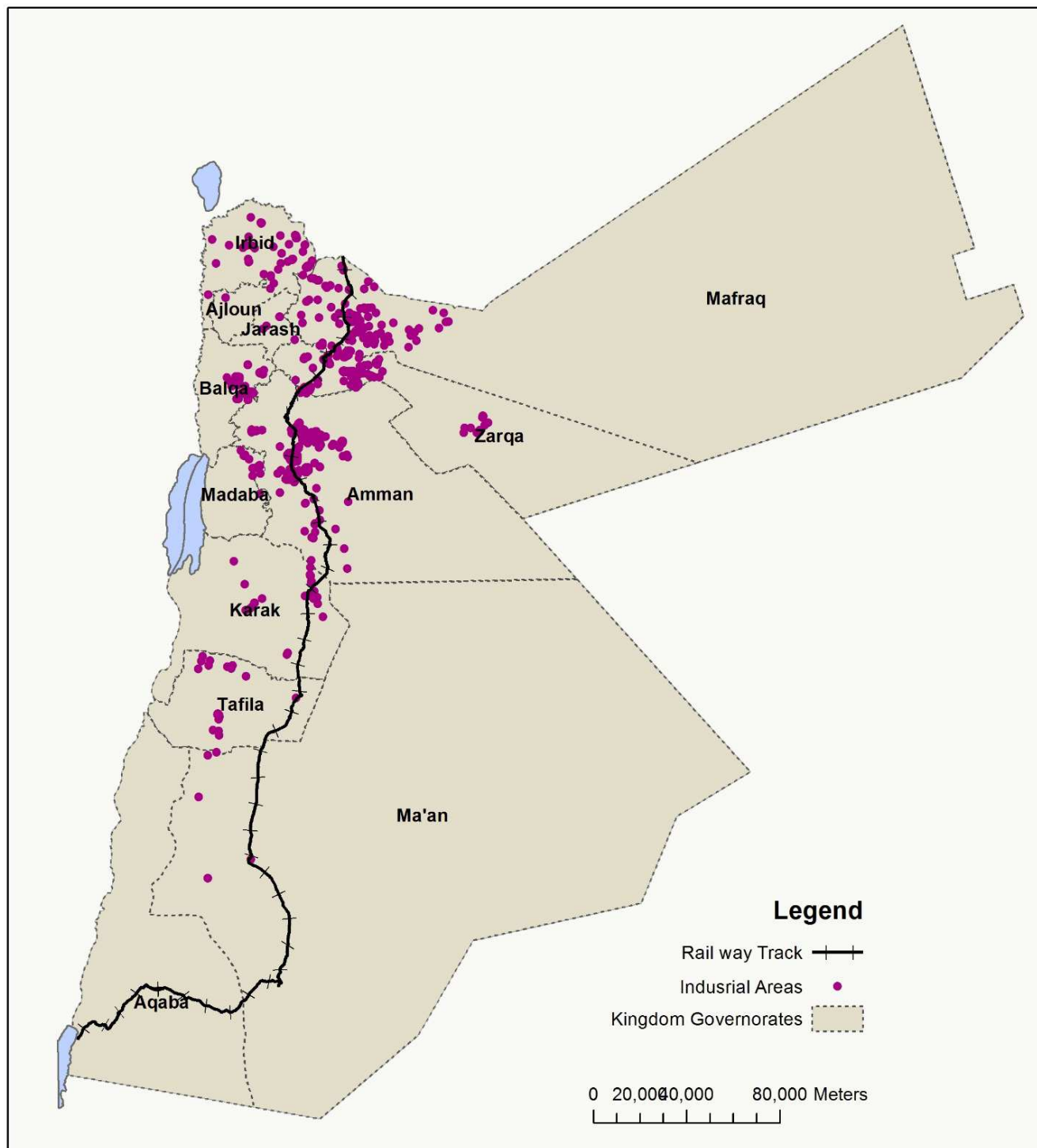


Figure (3-3): Factories and Industrial Area Map
(Source: Ministry of Municipal Affairs, 2016).



Figure (3-4): Damages in Stations and Track
(Source: Author, 2015)