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Traffic Solution and Improvement for the Area Surrounding Shubra Museum in Taif City, KSA

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Abstract - *Planning and designing of road infrastructure are based on the determination of traffic flow parameters and their distribution in the observed area in terms of space and time. To select the optimal solution for the planned period, it is necessary to research relevant traffic flow parameters in characteristic conditions of the observed road network. Taif city is located in the western zone of the Kingdom of Saudi Arabia where it is the eastern port of the Holly Capital, Makkah. In addition, it is a major touristic destination for citizens throughout the year. Due to this importance, Taif city needs to develop traffic flow, especially downtown because of high traffic congestion, traffic accidents, location of the city, and the increasing population annually. This paper shows the solution of traffic systems and improvement of the area surrounding of Shubra museum in Taif City. The engineering calculations such as the peak hour factor, peak hour volume and engineering designs of the roads, pedestrians, and design of the parking to achieve the KSA vision 2030 taking into consideration national and global codes within the realistic constraints and reduce the cost as much as possible. The alternatives proposed were studied within the current road networks surrounding the Shubra Museum in downtown Taif to obtain the optimized alternative, in order to find a sustainable future traffic flow. The proposed alternatives are based upon international and national standards for highway design, AASHTO, Highway Capacity Manual (HCM), American Society for Testing and Materials (ASTM), and Specifications of Saudi Ministry of Transportation. Results revealed that the proposed alternatives achieved better performance in terms of traffic regulation in downtown Taif city. Also, the wide-area obtained around the museum showed a better performance in terms of organizing the pedestrian movement and the comfort of visitors as well as achieving goals of the museum very efficiently in the future. Moreover, the construction of a tunnel reduces the traffic congestions in the future and increases the area in front of the museum by 60 %. Although of the high cost of constructing a concrete tunnel in the front area of the museum which needs extensive geotechnical and structural studies, the positive environmental impacts give this alternative more advantages as a viable and sustainable alternative.*

Keywords *–Taif, Traffic, Congestion, Roads, Shubra, Museum, Engineering, Tunnel*
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1. Introduction

In this paper, a review of the literature about traffic congestion, traffic systems improvement, and different previous researches related to traffic solutions were carried out. Their definition and distribution were presented; the origin, the engineering properties, and identification of traffic solutions were discussed. Also, a summary of parking and tunnels from this study is presented. Traffic congestion is one of the major global and local problems that negatively affect people's health, as it is dangerous in emergencies, as well as environmental pollution resulting from vehicle exhausts and other negative effects. Traffic congestion affects the environment directly and indirectly vehicles and road infrastructure [4]. Parking is one of the major problems that arise from increased road traffic. It is the influence of transport development. The availability of less space in urban areas led to an increased demand for private parking spaces and vehicles, especially in areas such as the central business district and in the city center as general in most countries of the world.

The development of highways or bypass roads, especially within and in the middle of cities, may include the construction of tunnels to organize and develop the traffic system and to reduce the impact of the highway upon the

community. The development of highways or bypass roads, especially within and in the middle of cities, may include the construction of tunnels to organize and develop the traffic system and to reduce the impact of the highway on society. A proposal to construct a tunnel in the area surrounded by the Shubra Museum played a major role in this scientific paper by organizing the traffic system and creating a wide area for pedestrians.

Several investigations were carried out [8 - 13] to study the traffic solutions and improvements. HetalB Patel and Bhasker Vijaykumar Bhatt 2018 [18] studied the critical study of road intersections in the southeast part of surat city. Their Suggested treatments to overcome traffic congestion problems including improving the design of the intersection design. Providing parking spaces as well as providing a traffic control device such as traffic channelize to direct traffic and reduce conflict points. Many researchers have performed [14 - 17] similar studies related to traffic delay causes and characteristics at urban road intersections worldwide and are accounted for in the literature. Geethu Lal, Divya L 2016 [7] examined traffic problems, and various sustainable remedial measures such as intersection signalization, parking proper road markings, and signs were suggested for intersection improvement (Geethu Lal 2016 [7]).

Roads in the Kingdom of Saudi Arabia are divided into highways and secondary roads in all cities of the Kingdom; serve the transportation traffic sector between them. In addition to the internal and branch roads of each administrative region, whose role is to regulate traffic in the governorates and the centers that it covers. Figure 1 shows the road map in the Kingdom of Saudi Arabia, which includes all regions of the Kingdom of Saudi Arabia [1, 2]. Taif is one of the cities of the Kingdom attracting residents because of its moderate climate most of the days of the year and its geographical location in the western region of Saudi Arabia. It is also considered the eastern port of the holy capital of Makkah, besides it is a major tourist destination for citizens, residents, and visitors from outside the Kingdom throughout the year. The geographical location, the high traffic congestion, and the increasing population annually in the city of Taif are the main causes of traffic accidents. For all these reasons, Taif city needs intensive traffic studies that will develop traffic flow and transportation systems, especially in its downtown [1, 2].

Traffic density is expected to increase in the soon future according to the development of the Shubra Palace to become a major museum in Taif city. A large number of visitors and tourists will come to the museum from inside and outside the Kingdom of Saudi Arabia. The development of Shubra palace into a museum consider one of the main factors for the growth of traffic in the area, surrounded Shubra Museum, which results in high traffic congestion. Consequently, this study was issued to develop roads and traffic systems through the area surrounded Shubra Museum. Roads in the Kingdom of Saudi Arabia differ in terms of traffic capacity and paths, including two-lane roads, three-lane, and four-lane highways. Maintenance of highways inside cities and other major highways is well and continuously maintained by the competent authorities represented in the Saudi Ministry of Transport. The roads were constructed with high-temperature resistance in mind and always taken into consideration in accordance with national and international specifications. The government is now rebuilding and maintaining some internal, express, and other access roads periodically throughout the Kingdom of Saudi Arabia (Figure 1) [1-2].

Figure 1. Map of roads in Saudi Arabia

By reference to many scientific studies such as published papers, conferences, and international seminars, it shows the scarcity of published scientific research that focuses on developing the traffic system in the Kingdom of Saudi Arabia, especially in the city of Taif. Most of the published scientific research focuses on engineering issues related to traffic and vehicle safety [3-5]. Also, few scientific studies have discussed the required controls regarding road user's behavior and traffic awareness issues to achieve traffic safety [6, 7]. Therefore, the research problem of this study evaluates the traffic congestions, traffic systems, and roads in the area surrounding Shubra Palace which is connected by the major roads such as Abu Bakr Road, Shubra Road, and the main intersection of Al- Sail Road with Al-Jaish. The development of roads and traffic systems in the area surrounding Shubra Museum plays a major role in traffic safety and sustainable traffic flow, as well as the museum's visitors and tourists, are highly encouraged.

2. Study Program and Results

2.1 Location of the study

Figure 2 shows the main location of the study area that includes the major roads surrounding the palace such as Abu Bakr Road and Shubra Road beside the secondary roads and the main intersection of Al-Sail Road with the Al- Jaish Road. Intensive academic studies of these roads and traffic are required here in the mentioned area, considering the lowest costs, road quality, comfortable and sustainable traffic flow to achieve the continuity of the Shubra Museum for bringing visitors and tourists with high efficiency.

Figure 2. Location of the study

2.2 Research Objectives

This study aims to improve the traffic systems in the area surrounding the Shubra Museum, that due to the conversion of the palace into a museum, where the traffic is expected to increase significantly in the future by increasing visitors and tourists to the museum from inside and outside the Kingdom of Saudi Arabia. Therefore, the objectives of this study can be summarized as follows:

- To conduct the necessary surveys to benefit from the improvement of the traffic flow
- To select and design the optimal alternative within realistic constraints according to national and global standards.
- To conduct a traffic systems development for the area surrounding Shubra Museum.
- To obtain more area for pedestrians and parking through the improvement of the area surrounding Shubra Museum.

2.3 Methodology of the study

The methodology of this study focuses on the data collected from previous scientific researches related to traffic congestions, traffic solutions, and traffic system development. The second stage included the general field works, traffic surveys and surveying works for the area study. Figure 3 shows the Apps used in vehicle traffic surveys and for field surveying works.

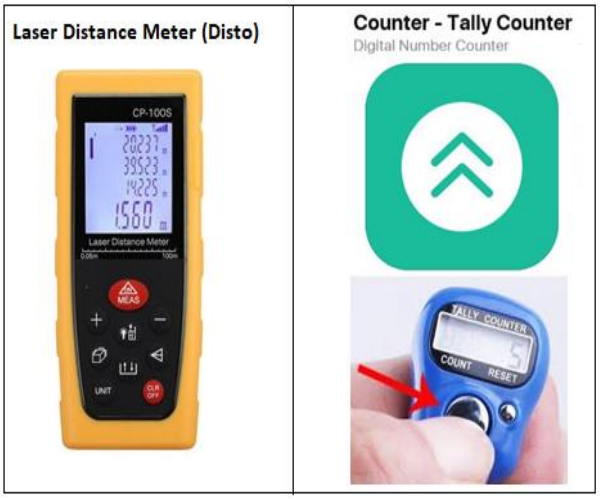

Figure 3. Apps used in traffic surveys and field surveying works

2.4 Traffic surveys results

The project team conducted the traffic counting works during three days of the week and throughout the whole month. The days that were chosen are the first days of the week, medium days, and the end of the weekends to know the traffic volume during the whole week. Table 1 shows the selected days and times, while Table 2 illustrates the coordinates and monitoring points.

Table 1. The selected days and times

Days	Time (hour)
Thursday	8:00 – 10:00 PM
Friday	4:00 – 6:00 PM
Tuesday	6:30 – 8:30 AM

Table 2. The coordinates and monitoring points

Location	Coordinates
1-infront of the Shubra palace	21° 17'47.0 "N 40° 25'35.5" E
2-infront of Aswaq Sara	21° 17'54.0 "N 40° 25'35.7" E
3- before the traffic light of Jaish st	21° 17'46.4 "N 40° 25'35.6" E

Through the initial survey of the location of the study, the traffic restriction places were identified taking into consideration the peak hours time. Figure 4 and Table (2.1) show the five points that were agreed as the main points of the traffic inventory. Table 3 shows the starting and ending points of the main roads surrounding the museum, Abu Bakr road, and Shubra road. The traffic survey results for all points (Point A, B, C, D, and E) are summarized in Tables 4 to 12.

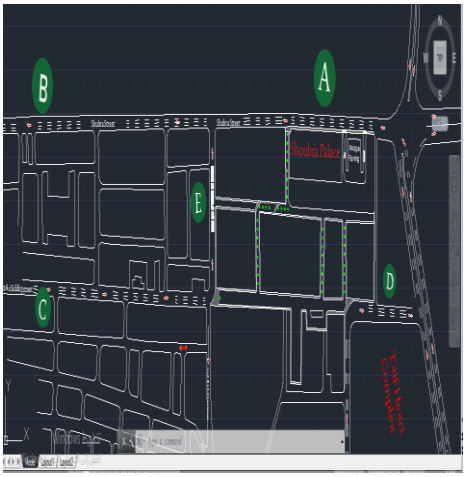

Figure 4. The main points of the traffic inventory

Table 3. main points of the traffic inventory

Point	A	B	C	D	E
Road name	Shubra Street	Shubra	Abu Bakr	Abu Bakr	Abdulaziz Al Saud
Description	Start	End	Start	End	At intersection

Table 4. Results of point A1(start of shubra street)

Period	Number of vehicles
8:00 – 8:15	669
8:15 – 8:30	668
8:30 – 8:45	649
8:45 – 9:00	608
Total vehicles 8:00 – 9:00 PM	2594
9:00 – 9:15	622
9:15 – 9:30	568
9:30 – 9:45	589
9:45 – 10:00	483
Total vehicles 9:00 -10:00PM	2262

Table 5. Results of point A2(start of shubra street)

Period	Number of vehicles
4:00 – 4:15	775
4:15 – 4:30	686
4:30 – 4:45	645
4:45 – 5:00	492
Total vehicles 4:00 – 5:00 PM	2598
5:00 – 5:15	452
5:15 – 5:30	470
5:30 – 5:45	435
5:45 – 6:00	460
Total vehicles 5:00 – 6:00 PM	1825

Table 6. Results of point A3 (start of shubra street)

Period	Number of vehicles
6:30 – 6:45	471
6:45 – 7:00	701
7:00 – 7:15	721
7:15 – 7:30	700
Total vehicles 6:30 – 7:30 PM	2593
7:30 – 7:45	724
7:45 – 8:00	663
8:00 – 8:15	661
8:15 – 8:30	620
Total vehicles 7:30 – 8:30 PM	2668

Table 7. Results of point B1 (At Aswaq Sara)

Period	Number of vehicles
8:00 – 8:15	470
8:15 – 8:30	487
8:30 – 8:45	503
8:45 – 9:00	520
Total vehicles 8:00 – 9:00 PM	1980
9:00 – 9:15	511
9:15 – 9:30	490
9:30 – 9:45	476
9:45 – 10:00	457
Total vehicles 9:00 - 10:00PM	1934

Table 8. Results of point B2 (At Aswaq Sara)

Period	Number of vehicles
4:00 – 4:15	354
4:15 – 4:30	512
4:30 – 4:45	448
4:45 – 5:00	387
Total vehicles 4:00 – 5:00 PM	1701
5:00 – 5:15	351
5:15 – 5:30	323
5:30 – 5:45	331
5:45 – 6:00	305
Total vehicles 5:00 – 6:00 PM	1310

Table 9. Results of point B1 (At Aswaq Sara)

Period	Number of vehicles
6:30 – 6:45	289
6:45 – 7:00	469
7:00 – 7:15	331
7:15 – 7:30	236
Total vehicles 6:30 – 7:30 PM	1325
7:30 – 7:45	289
7:45 – 8:00	257
8:00 – 8:15	243
8:15 – 8:30	236
Total vehicles 7:30 – 8:30 PM	1025

Table 10. Results of point C1 (before the traffic light of Jaish Street)

Period	Number of vehicles
8:00 – 8:15	230
8:15 – 8:30	310
8:30 – 8:45	318
8:45 – 9:00	363
Total vehicles 8:00 – 9:00 PM	1221
9:00 – 9:15	340
9:15 – 9:30	298
9:30 – 9:45	285
9:45 – 10:00	246
Total vehicles 9:00 - 10:00PM	1169

Table 11. Results of point C2 (before the traffic light of Jaish Street)

Period	Number of vehicles
4:00 – 4:15	460
4:15 – 4:30	589
4:30 – 4:45	640
4:45 – 5:00	684
Total vehicles 4:00 – 5:00 PM	2373
5:00 – 5:15	625
5:15 – 5:30	635
5:30 – 5:45	644
5:45 – 6:00	658
Total vehicles 5:00 – 6:00 PM	2562

Table 12. Results of point C3 (before the traffic light of Jaish Street)

Period	Number of vehicles
6:30 – 6:45	294
6:45 – 7:00	451
7:00 – 7:15	478
7:15 – 7:30	417
Total vehicles 6:30 - 7:30 PM	1640
7:30 – 7:45	415
7:45 – 8:00	343
8:00 – 8:15	336
8:15 – 8:30	280
Total vehicles 7:30 - 8:30 PM	1374

2.5 Future traffic estimation

One of the most important uses of AADT is for determining funds for the maintenance and improvement of highways. Calculate the average annual daily traffic volume (AADT) which is the daily average annual traffic, which is one of the main indicators for determining volume Traffic on the road is calculated using Equation 1. AADTF is calculated based on current, generated, attracted, and developed traffic [13].

$$AADT_F = AADT_P(1+i)^n \quad \text{Equation (1)}$$

Where:

AADTF: The daily traffic volume for a specific year in the future
AADTP: The daily traffic volume for the current year
i: Annual rate of increase in traffic
n: number of years

The increase of future traffic volume assumed 4%, 5%, and 6% for every ten years increment. This percent based on many previous traffic studies conducted in the Kingdom of Saudi Arabia and according to the publications of the Saudi Ministry of Transport in 2019 through its main site [1]. Figure 5 shows an increase in traffic rates every ten consecutive years.

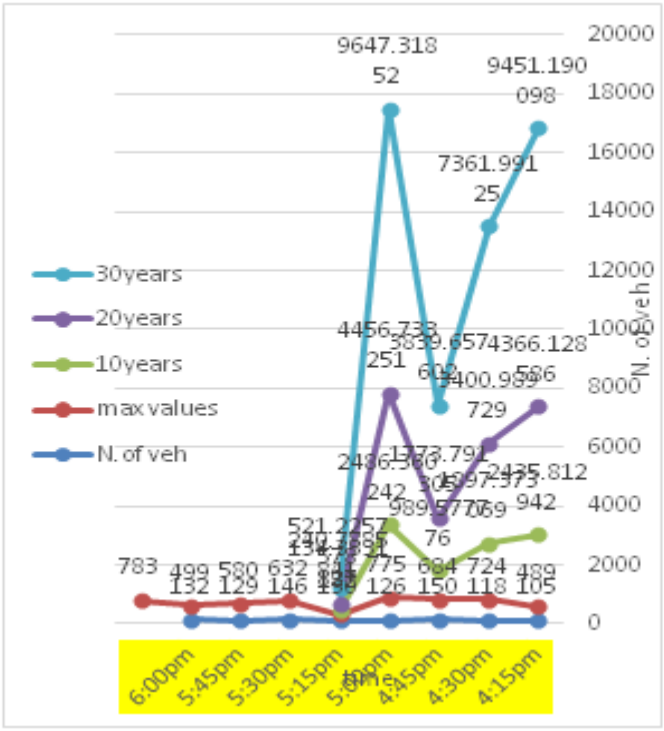

Figure 5. Future traffic volumes 10, 20, and 30 years

3. Discussion of the results

The Peak hour factors calculations for all project points shown in tables 4 to 12 indicate that the values are range from 0.8 to 0.98 according to the specifications. These values classify that, the traffic is high volume and a greater traffic volume is expected in the future when the museum becomes ready to receive visitors from inside and outside of the Kingdom of Saudi Arabia.

According to the specifications and values of the service levels and taking into consideration the highest rate of traffic volume and the current design speed of (80 km/hour), the level of service for the project is obtained as (level D). This indicates that the flow approaching unstable. Therefore, this level of service indicates the necessity of traffic solutions and

enhancing the area surrounding the museum to improve the level of service, especially in the future.

3.1 Initial proposed alternatives solutions

Five alternatives proposed solutions were studied at the first stage. These alternatives proposed solutions are shown in Figures 6, 7, 8, 9, and 10 for the first, second, third, fourth, and fifth proposal respectively.

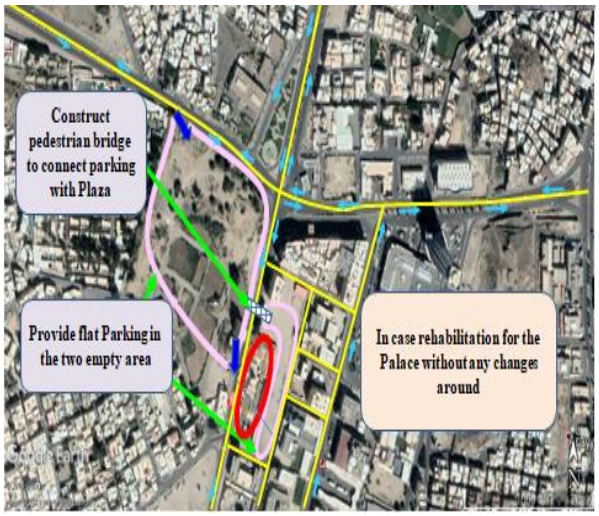

Figure 6. First Proposal Solution

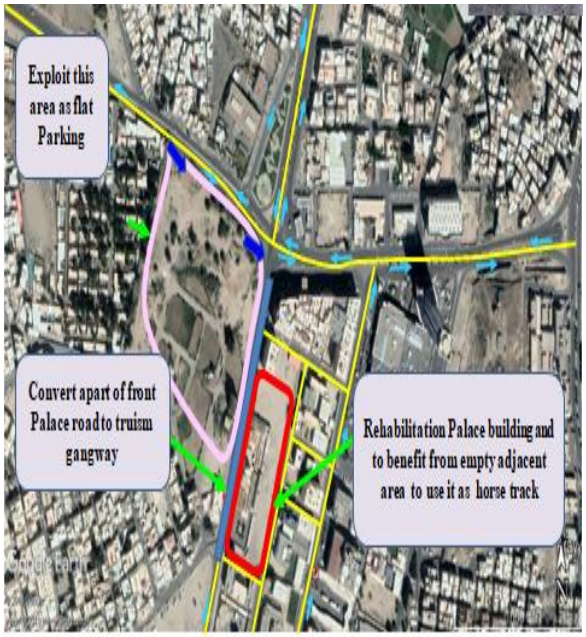

Figure 7. Second Proposal Solution

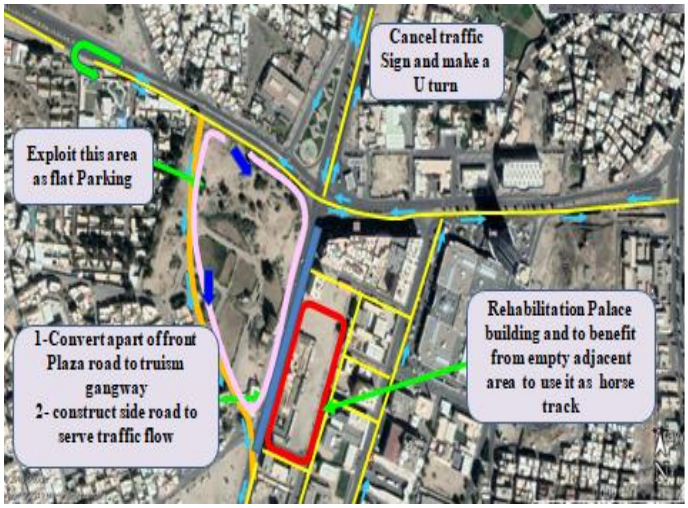

Figure 8. Third Proposal Solution

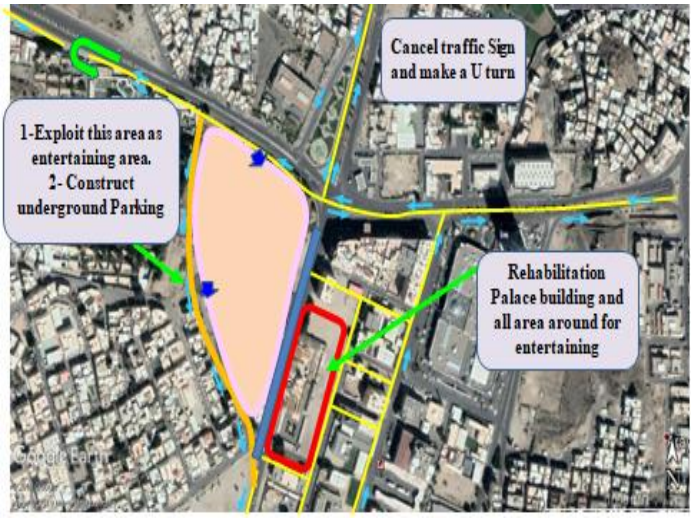

Figure 9. Fourth Proposal Solution

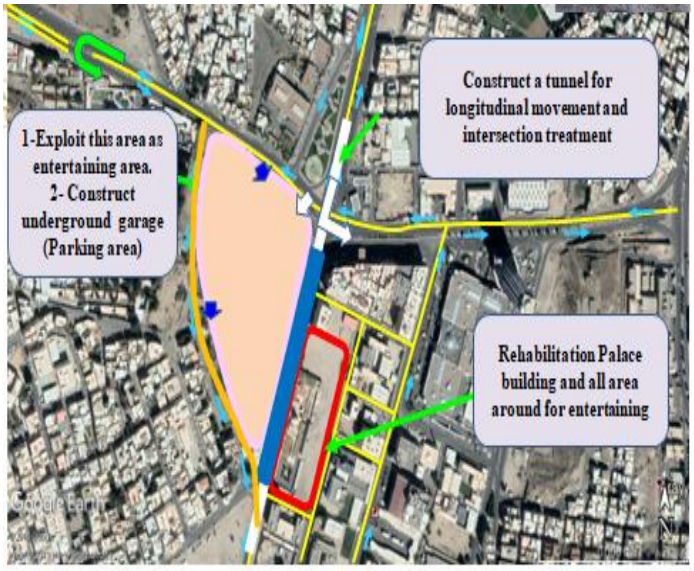

Figure 10. Five Proposal Solution

3.2 Final proposed alternatives selected

Two proposed alternatives solutions were studied. The first proposal is the schematic solution showed in Figure 11, which aims to close the main road (Abu Bakr Road), from the gas station until the intersection of the Taif heart complex. The main objective of closing the main road is to obtain a safe pedestrian area without any delay during museum visits and to avoid traffic congestions surrounding the museum.

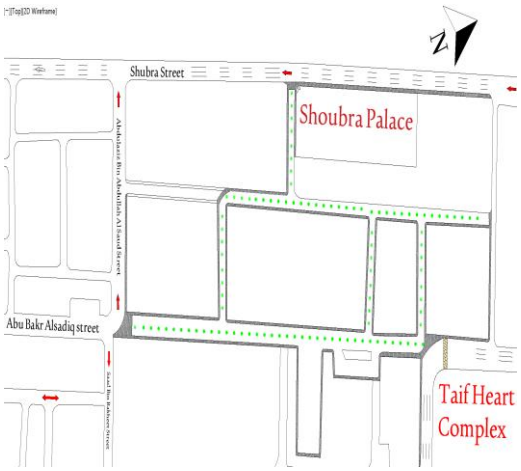

Figure 11. Schematic solution proposal

Figure 12 shows a structural design proposed, that includes the design of a tunnel with four lanes toward Shubra Street. This proposal is comfortable for the movement of all vehicles along the Shubra road and creates a large area for pedestrian traffic in the front of the main entrance of the museum as well as its great importance in developing the traffic systems at downtown Taif city.

Figure 12. Structural design proposal (location of tunnel proposal)

Through the above-mentioned proposals, the proposed schematic and structural design of the tunnel showed a significant reduction in conflict points compared to the existing roads and magnificent improvement for the current area study. Figure 13 illustrates the general alternatives solutions, schematic and structural design. Proposals of the suggested tunnel, recreation area, basement parking's, pedestrian area, and rehabilitation of fully museum building and area surrounded showed in Figure 13.

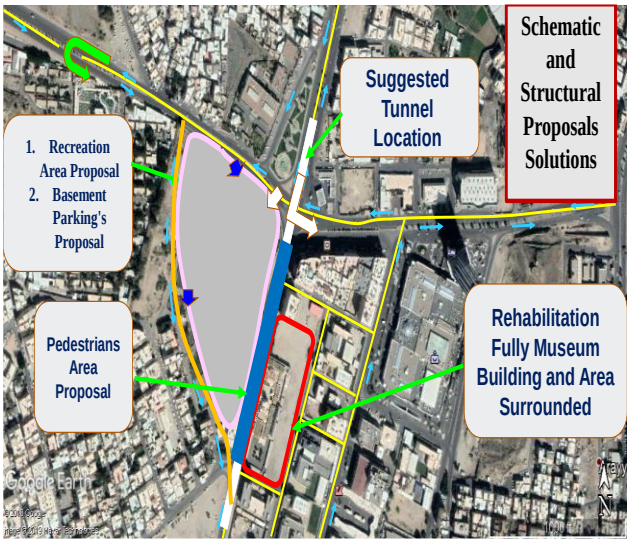

Figure 13. General view of Schematic and structural proposals solutions

The tunnel proposed structural material is the pre-stressed concrete. This type of concretes is widely used in the construction of tunnels and bridges because of its high strength to resist high loads. In this research, a traffic tunnel design is investigated. This traffic design includes the tunnel dimensions, lanes, height, markings, and general traffic considerations according to the types of vehicles and the national and global specifications. Table 13 shows the different design vehicle dimensions for passenger cars, buses, and trucks.

Table 13. Design Vehicle Dimensions according to AASHTO guide

Category	Symbol	Average Dimension (m)	Projected rectangular area (m^2)
Car	P	5.79x2.43	14.07
Bus	Bus-40	12.19x2.59	31.5
Trucks	WB-50	16.76x2.6	43.57

The Tunnel classification is a one-way tunnel with four lanes along the Shubra road. The total of the tunnel is about 412 m; the width is 20 m including the shoulders, the total height is 5.5 m and the design speed is 80 km / h based on national and global specifications.

4. Conclusions

A direct field survey was carried out, and the data of traffic volume, road signals were collected. Five of the engineering solutions for traffic solutions were studied to obtain the improvement for the area surrounding Shubra Museum in Taif City, KSA in the preliminary stage of this

study. In the final stage of the study, two proposed alternatives solutions were studied as per the final stage, schematic proposal and structural design proposal by applying traffic specifications, national and international. From the results of this study, the following conclusions have been drawn:

- Improvement in the planning of the current area surrounded Shubra museum within the proposed planning solution (close the main road (Abu Bakr Road), from the gas station until the intersection of Taif heart complex); to obtain a large area for the pedestrians around the museum. This is a schematic solution, considered an economical and ideal solution as it achieves a safe pedestrian area around the museum only.
- A structural design solution was proposed with the design of one way tunnel with four lanes in the front area of the museum to improve the future traffic system. This proposal is an integrated solution that provides a safe pedestrian area around the museum also organizing and improving the traffic system through the area surrounding Shubra Museum in Taif City, KSA.
- Adequate road signals and markings should be provided to inform and guide the road users in advance;
- More traffic studies, geotechnical and structural are required for the proposed structural alternative solution of this study.
- All the proposed improvements are expected to provide adequate capacity for the near future.

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