

PLANNING AND DESIGN OF THE FIRST TRAMWAY SYSTEM IN THE WEST BANK, NABLUS CITY

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Abstract— The public transportation systems in the Palestinian cities face numerous challenges and limitations. This paper aims to address some of these issues by introducing a new mode of public transportation which is the tram. To conduct this study, relevant data were collected to determine the current demand for public transportation in Nablus. Subsequently, a questionnaire was distributed to assess whether travelers' preferences for public transportation would change with the introduction of a new and efficient system. The results indicated that 30% of travelers who currently use private vehicles would switch to the tram. The study analyzed the current state of Nablus's public transportation system, highlighting the need for improvement. Mass transportation options were examined, and the tram was identified to be one of the most suitable solutions. The study presents the general standards for designing the tramway, along with the basic routes and a plan for the horizontal alignment to serve the majority of demand in Nablus. The tramway system was designed and scheduled to integrate with existing public transportation modes. Basic plans for project development and implementation were included. The assessment of the tramway system's efficiency shows that the Level of Service (LOS) at key locations of the network would be improved. Finally, the total project cost is estimated to be approximately 82 million dollars for the overall length of the tramway routes of about 11.4 km.

Keywords: Nablus City, Palestine, public transportation system, mass transportation, tramway.

I. INTRODUCTION

Nablus is considered the heart of Palestine. It connects the north with the center, the south, and the east with the west of the West Bank. It is about 69 km north of Jerusalem, the capital city of Palestine, and 42 km east of the Mediterranean coast. In the last century, it accommodated the Al-Hijaz Railway that led to Damascus and Istanbul to the north and Al-Medina Al-Monawara to the south. Nablus Governorate contains 64 villages. It also includes three refugee camps: Al-Ain, Balata, and Askar. The population of Nablus Governorate is 439,900 (2024), with 168,000 living in the city, 32,000 in

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the refugee camps, and the rest living in the surrounding villages (PCBS, 2024). The city also contains many higher education institutions, including the largest university in the West Bank, An-Najah National University, specialized hospitals and advanced medical centers, as well as commercial and industrial areas.

The city has a relatively high share of travelers who use public transportation modes on a daily basis. The city's nature forces traffic to use the main East-West spine, creating many bottlenecks and traffic congestion along key intersections.

This has motivated the search for a more efficient transportation system and could help to improve the traffic conditions and achieve a sustainable transportation.

II. LITERATURE REVIEW

The effectiveness of tram systems in urban transportation has been widely studied, with numerous cities adopting trams to combat traffic congestion and reduce environmental impact. Tramways are considered more sustainable than buses and cars due to their ability to carry higher passenger volumes and reduced carbon emissions when powered by electricity (Fang & Yancai, 2016). Compared to metro systems, trams are less expensive to implement and can be integrated into existing road networks, making them an ideal choice for cities with moderate to high transport demand, like Nablus (Bozzo et al., 2010).

Studies on global tram implementations, such as in Istanbul and Portland, highlight the benefits of trams in reducing congestion and improving accessibility to key urban areas like business districts and universities (Guerrieri, 2023). Furthermore, trams offer greater flexibility and comfort than bus rapid transit (BRT) systems, making them more suitable for dense urban environments (Bhatti, 2014).

However, challenges such as high initial costs and public acceptance remain important considerations in tramway implementation (Boyan, 2007). Kalbouneh et al. (2017) emphasized that the success of mass transportation systems depends on factors such as convenience, cost, and integration with existing transport modes. In Nablus, where private car usage is high, ensuring the proposed transportation mode's efficiency and public acceptance will be key to its success.

III. METHODOLOGY

The methodology involves collecting data and representing relevant institutions, such as the Nablus Municipality and the operators of the public transportation system. It includes field surveys at intersections and terminals, preparing and distributing a questionnaire to investigate the willingness to use the tram once put in operation. Several studies were conducted, including travelers' preferences, public transportation frequency, travel forecasting, vehicle occupancy rate, traffic counting at critical intersections, and dwell/headway time study. Proper programs and software were used for analysis and design, such as Synchro and Civil 3D.

The proposed solution focuses on the highest-priority corridors due to their significance and the high demand and traffic along them. These corridors are intended to serve the new Eastern and Western Terminals, which are included city's Master Plan to relocate the existing terminal away from the city center. However, the main challenge in implementing this lies in ensuring efficient passenger transportation between these planned public transportation terminals and key destinations such as the city center (CBD) and An-Najah National University.

The analysis was subsequently conducted, and the mass public transportation systems were discussed as a suggested solution. After that, the tramway was chosen as a solution according to the expected daily demand for the Nablus City public transportation system, depending on the results of the questionnaire.

The proposed tramway path and facilities were designed in terms of the key geometric design features, as well as the scheduling of the tramway service. The estimated cost was calculated considering experiences of implementing tramway projects in other cities around the world, similar to Nablus.

At the end, the before and after studies for the level of service LOS at three key intersections along the proposed tramway route were conducted, depending on the existing traffic volumes and the expected traffic volumes at these intersections, to assess the effect of the proposed tramway on the transportation system.

IV. DATA ANALYSIS AND RESULTS

Considering the questionnaire replies of the sample of 50 individuals, 52% of the sample used the public transportation system before improving it. The questionnaire results show that 82% of the respondents would be willing to use the public transportation system after improving it through the establishment and operation of the tramway.

The total number of passenger trips served daily by the Nablus public transportation system is currently 103,073 trips per day. This number is found by collecting the number of trips (arriving or departing) through public vehicles (service taxis, shared taxis, mini-buses, and buses) to/from the public transportation terminals through interviews with the operators. The average number of trips of each public vehicle during the

day is multiplied by the number of seats to find the overall number of passengers arriving and departing from each public transportation terminal, where the results are tabulated in Table I.

TABLE I. TOTAL NUMBER OF PASSENGERS/ DAY

Terminal	Number of passenger trips served/day
Internal Terminal	63,134
External Western Terminal	18,765
External Eastern Terminal	21,154
Total	103,073

(Source: Nablus Public Transportation Terminals)

Taking 30 years as a design period, as the railway projects are considered a large-cost project (Boyana, 2007), the estimated design demand is 255,568 passengers/day, considering an average annual growth rate of 2.8% (Nablus Municipality).

Calculations for the morning and afternoon peak and off-peak hours were conducted by assuming that the demand in the peak hours equals 25% of the total daily public transportation demand (TRB, 2013).

To search for the optimal future public transportation mode or mode combination, several options were investigated (Bozzo, R, et al., 2010, Bhatti. M, 2014, & Sharma, N, et al., 2013). The summary of the comparison is presented in Table II.

TABLE II. SUMMARY OF THE ALTERNATIVE MASS PUBLIC TRANSPORTATION MODES

Item	Metro	Monorail	Tram	Bus Rapid Transit
Design Speed (Km/hr)	80	90	40-70	50-70
Financial costs (million dollars/ Km)	Tunnel	30	Tunnel	2.5
	Upper		Upper	
	Level		Level	
Capacity/ day	1-1.5 (million)	150,000	400,000	180,000
Distance between stations (Km)	0.8-1.2	1.0-2.5	0.4-1.0	0.3-0.8
Places of implementation	High population density	Mid-high population density	Connect between close spaces in mid-density population cities	In the streets that the R.O.W allows to be made from the specified stations
Implementation method	Tunnel-Upper-Superficial	Upper	Tunnel-Upper-Superficial	Upper-Superficial

(Source: Bozzo. R, et al., 2010, Bhatti. M, 2014, & Sharma. N, et al., 2013)

The Tramway is chosen as a solution due to its daily capacity; the tram can serve up to about 400,000 passengers per day, and the future daily demand for Nablus' public transportation system is close to this range, as it exceeds the other modes' capacities, except the tramway and the metro. However, the metro is excluded due to its very high capacity and cost.

Tramway is regarded as a sustainable and green mode, due to reducing congestion and environmental impacts. The width of

the tramway track is lesser than that for bus and other existing modes in Nablus City. Tramway vehicles offer greater per-trip capacity than buses and shared taxis, enhancing their ability to accommodate high passenger volumes along major corridors. Tramway routes are more flexible compared to other rail systems, because of moderate operating speed and narrow working tracks, and low noise of the tramway.

The tram will integrate with other public transportation modes of the current transportation system that are expected to be used in the future as well, but in smaller numbers and through a more flexible manner.

The stations are found to be optimally distributed along the tramway with spacings between 500 to 1000 meters. Stations are identified based on key major trip generators and intersection locations.

The scheduling of service included considering dwell time, time headway, number of trolleys, the number of doors per trolley, and number of trams for the peak periods and off-peak hour period note that the number of trolleys per tram vehicle can be reduced during the off-peak hours, to be suitable to the expected passenger load during the off-peak hours.

Tram dimensions and design criteria are illustrated in Table III. These are based on the standard gauge dimensions (Yangka and Newman, 2019).

TABLE III. TOTAL NUMBER OF PASSENGERS/ DAY

Tram Vehicle Standards and Dimensions for (standard gauge 1435mm)	
Width (m)	2.4
Height (m)	3.5
Design Speed (Km/hr)	50
Maximum Grade	8
*Length per trolley (m)	20
Number of Passengers per Trolley	150
Weight (ton)	51 (9 per axle)
Minimum Turning Radius (m)	15

* The length depends on the number of passengers per trolley (Source: Yangka and Newman, 2019)

Figure 1 shows the proposed routes for the tram with a total length of 11.4 km, and the suggested area for the tram depot. These routes will connect the Eastern Terminal with the Western Terminal, crossing the city center. In addition, it will connect the An-Najah National University New Campus with the city center.

The overhead catenary system (OCS) is proposed as a power system because this system is more efficient than the other systems, and safer than the other type, especially in urban and congested cities.

The turnout is an important element in the tramway that allows the tram to change direction after reaching the destination point, or in case of emergencies, when the tram vehicle can't continue on the track due to an urgent issue.

A railway depot is a facility where trains are parked, serviced, maintained, and sometimes assembled or disassembled. It's selected to be a basement floor under the future Western Terminal.

Intersection LOS analysis was conducted for the years 2023 and 2030, using peak hour demand data at three key intersections (Balata, Al-Salam, and Ma'zouz intersections) located along the tramway corridor. The results show that LOS will be improved at the key intersections after the establishment of the tramway, as presented in Table IV.

TABLE IV. THE VALUES OF LOS AND ICU% FOR EACH INTERSECTION BEFORE AND AFTER ADDING THE TRAMWAY SYSTEM IN 2030 USING SYNCHRO

Intersection	Morning Peak Hour				Afternoon Peak Hour			
	Before Tram		After Tram		Before Tram		After Tram	
	ICU %	LOS	ICU %	LOS	ICU %	LOS	ICU %	LOS
Al-Quds-Balata	119	H	65	C	115	H	66	C
Mazouz	136	H	100	G	106	G	84	E
Al-Salam	151	H	78	D	154	H	80	E

The estimated cost of the tramway project is calculated to be about 82 million dollars, and Table V illustrates the cost estimation.

TABLE V. COST ESTIMATION FOR TRAMWAY SYSTEM

ID	Item	Unit	Measured Quantity	Unit Cost (\$/Unit)	Total Cost (\$)
1	Infrastructure				
1.1	Curbstone	m	11,400	30	342,000
1.2	Milling	m ²	277,300	2	554,600
1.3	Asphalt	m ²	277,300	15	4,159,500
1.4	Traffic Signal	No.	2	40,000	80,000
1.5	Marking	m	11,400	2	7,800
1.6	Traffic Signs	No.	65	120	7,800
1.7	Power System	m	11,400	2,200	25,080,000
2	Facilities for the tram system				
2.1	Tram Trolley	No.	40	220,000	8,800,000
2.2	Tram Station	No.	16	10,000	160,000
2.3	Tram Depot	m ²	10,000	2,000	20,000,000
2.4	Tram Rail	Km	11,400	2,000,000	22,800,000
Total Cost (\$)				81,979,340	

(Source: CAF Company for Railway Systems, 2024)

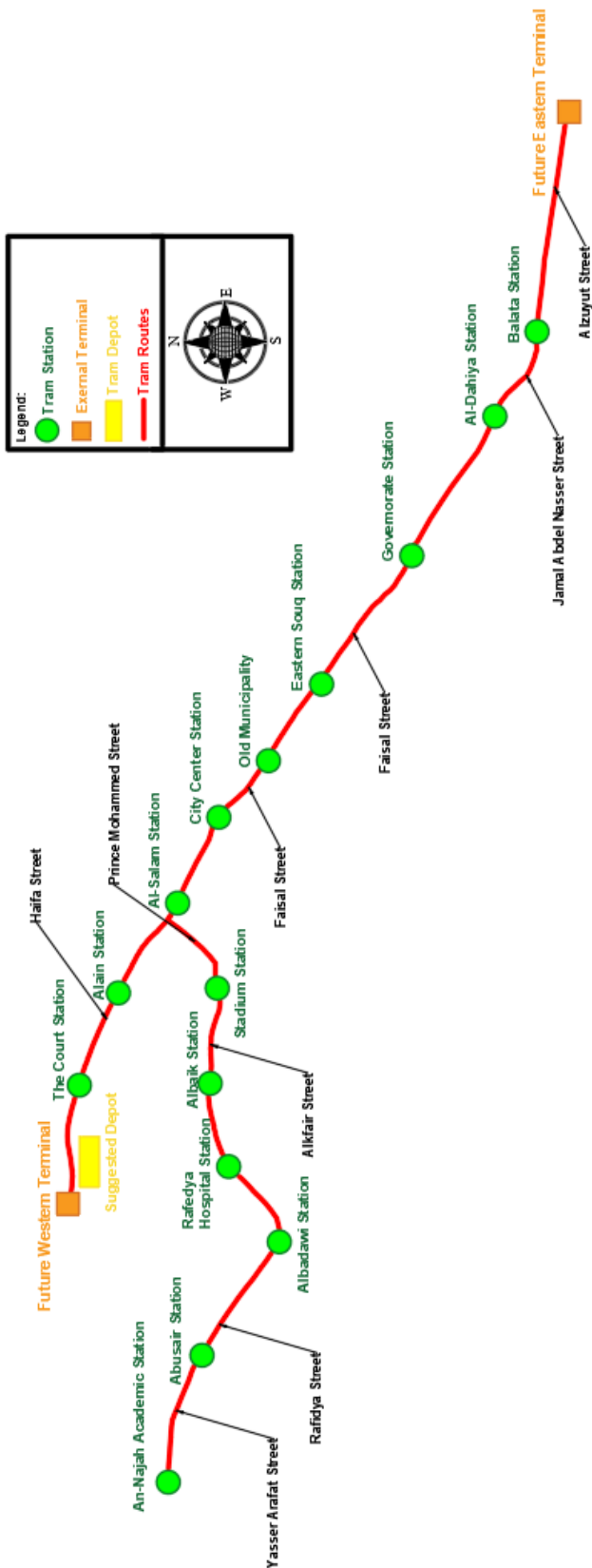


Figure 1. Single Line Diagram for Nablus Tramway

V. CONCLUSIONS AND RECOMMENDATIONS

• Conclusions

Based on the outcome of the study, the following can be concluded:

- The tramway system is one of the modes that could be more efficient and more environmentally friendly than other existing public transportation modes. This will also be the case for Nablus City, due to its potential to accommodate large numbers of passengers, and therefore will reduce the number of daily and hourly vehicles due to the potential diversion of traffic to the tramway. Moreover, the tram will be operating in an electric-powered mode.
- This study aimed to develop the public transportation system in Nablus City, considering the tram. It is to be stated that there are previous studies that were conducted to solve the traffic system problems, such as the BRT study (Kalbouneh et al., 2017). This study will help the decision maker to choose the most appropriate solution.
- The current traffic congestion problems in Nablus are increasing considerably with time. Most of the links and key intersections suffer from the inability to accommodate the large traffic volumes, and traffic congestion is therefore getting worse, especially along the main east-west corridor.
- The public vehicles that serve the passengers traveling between the cities and villages and the city of Nablus form a considerable share of traffic, thus transferring these to the designated new terminals in the east and west of the city, and connecting them with proper transportation modes will improve the operations of the links and intersection along the main east-west corridor at specific, and the city in general. This is because these vehicles form a major reason that causes increasing traffic congestion on the corridor.
- A large number of passengers use the terminals of the city during the morning and afternoon peak periods, which makes it a necessity to provide an effective way to transport them from the terminals to their major destinations in the city, and vice versa.
- The proposed tram will enhance the public transportation system and improve its efficiency with high efficiency to meet the current and future demand, especially serving the major trip generators, including An-Najah University's new campus, together with the CBD area.
- The results show that the implementation of the tramway system would enhance the LOS at the intersections of the main corridor.

• Limitations

Throughout the various stages of the study, several challenges and limitations were encountered, including:

- Collecting the necessary information for critical intersections. Due to the political situation, it was difficult to gather representative data on the normal demand and volume in Nablus City. Consequently, previous data and studies were utilized, and a growth rate was applied to estimate the volumes that represent normal conditions.
- The percentages of travelers that were interviewed using the questionnaire was limited. It could be more accurate if there was a larger and more comprehensive survey, but this would require more effort and cost.

• Recommendations

Based on the outcome of this paper, the following recommendations are proposed for future studies:

- To conduct a more detailed and comprehensive field-based data collection to obtain more accurate data.
- To consider expanding the routes of the tramway system to serve additional key districts in the city in the future, based on detailed studies.
- To use the current transportation modes (buses and service taxis) as feeders to the new tram system, transferring passengers from tram stations to other districts that are not served by the tram.
- To conduct a comparative feasibility study to compare the benefits and costs of implementing the BRT or tramway to facilitate reaching the proper decision on the mass transit mode to be adopted.
- Reuse part of the area of the current terminals for parking spaces.
- Conduct specialized studies to determine the proper fare for riding the tram.
- The railways were considered mega projects, which were delivered by the build-operate-transfer (BOT) method, where public-private partnerships would be appropriate to construct such projects.

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