Kerbala Journal for Engineering Science
https://kjes.uokerbala.edu.iq

Framework for the Tram Service Criteria in The Urban City

Huda Al-yasery, *[1], Hamid Athab Eedan Al-Jameel, [2], Raid R. Almuhanna [1]
[1]Department of Civil Engineering, University of Kerbala, Karbala, Iraq
Email: huda.hafodh@s.uokerbala.edu.iq
Email: raidr@uokerbala.edu.iq

[2] Department of Civil Engineering, University of Kufa, Kufa, Iraq
Email: hamid.aljameel@uokufa.edu.iq

Received: 21 February 2025; Revised: 03 March 2025; Accepted: 28 March 2025.

Abstract

Several municipalities adopt sustainable public transit mobility as a strategic approach to increasing passenger flow, reducing overload, and mitigating the negative environmental effects of congestion. These municipalities are facing growing traffic volume and negative environmental impacts. Tram systems, which have the advantages of reliable operation, comfort, low emissions, and moderate capacity, have been quite popular in recent years. Public network site selection primarily aims to find the best public network that meets the predetermined criteria, thereby allowing this network to serve the largest volume of passengers, realize the attraction–generation trip zone, and achieve sustainability objectives. This research presents a critical review of the related literature to select the evaluation criteria of the best site selection process for tramways and other public transportation. This study’s primary goal is to identify the most crucial factors that should be considered when determining the ideal location for public transportation routes and stations, particularly tram routes and stations, to ensure that the network of public transportation meets the needs of people and reduces urban congestion while adhering to sustainability principles. The previous studies show that the most crucial factors in selecting the best locations for public transportation networks are engineering, economics, environment, social issues, accessibility, and traffic demand.

Keywords: Public transport, Criteria, Tramway, Best locations.

1-Introduction:

The growth and success of cities and cultures have historically depended heavily on roads and transportation. The transportation networks connecting cities to the outside world were a key indicator of their development and prosperity; land roads provided the greatest obstacles to local communities. The transportation industry has grown to play a crucial role in daily living over time. The problems caused by transportation, such as the extensive negative effects it has on the communities it serves in terms of the environment, the economy, and society, have, nevertheless, collided with this contribution to the growth of cities. Because of this, it is now essential to address environmental issues like climate change by making transportation, particularly public transportation [1]. The hub of economic activity in every urban region on the planet is the urban transportation system. It consequently guarantees the people's survival there. The main means of transportation in cities include roads, railroads, rivers, and airplanes. In most urban areas, the road transportation network is crucial to economic activity [2]. The goal of transportation networks is to move people and things in a timely, safe, and economical manner. In addition to taxis, trams, trolleys, metros, and "para-transport" vehicles like rickshaws, bicycles, and motorcycle taxis, land-based public transportation options include trains, buses, and minibuses. Any system's ability to function more effectively and efficiently depends on its modes and infrastructure. Within the project's framework, public transportation was described as services that include both official and informal modes (vehicles) and require a passenger to pay a fee [3].

A city's social and economic growth is largely dependent on its transportation system. In acknowledgment of their vital function, transportation networks have been called the "lifeblood" of cities [3]. Growing transportation networks in the 20th century not only aided urban growth but also presented several obstacles to sustainability.

Transportation is the most active sector in the city and contributes significantly to pollution, accounting for over 65% of all pollutants in the city. It also negatively impacts on the health of individuals, communities, and other organisms. Furthermore, it degrades, distorts, and eventually eliminates urban interfaces, particularly historic and archaeological buildings [4]. Fuel consumption rises in response to traffic congestion, which raises vehicle emissions of CO, CO2, and NOx as well as noise pollution, which is defined as any uncomfortable or undesired sound that degrades urban quality of life [4]. The primary strategy to solve this issue is to offer environmentally friendly, high-carrying capacity, and sustainable public transportation options like tramways. Any public transportation infrastructure project should begin with identifying and analyzing potential locations for certain routes and geographic areas to accommodate the demand that is current and will only increase in the future [5]. This study mainly aims to identify the most important criteria that should be considered when determining the ideal location for public transportation routes and stations based on previous study findings to ensure that the public transportation network satisfies people’s needs and reduces urban congestion while adhering to sustainability principles.

2- Sustainable Transportation

Sustainability is commonly explored in terms of the theories of sustainable development. A commonly used definition of sustainability comes from the Brundtland Commission’s report, Our Common Future: “Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs” [6]. Transportation and sustainable development are closely related. For instance, cities all over the world have clogged roads because of people's reliance on cars, which results in emissions and societal costs, such as accidents [7]. Thus, transportation networks play a contradictory role: they stimulate urban growth while posing several obstacles. The effects on the economy, society, and environment are among these challenges [8]. The challenges of these three categories' are collectively referred to as "sustainability challenges." Investing in public transportation is frequently presented as a vital tool for decreasing reliance on personal vehicles. As a result, the negative effects of transportation networks on the environment and society are mitigated, and transportation's vital role in sustainable development is preserved.

The triple bottom line is a key concept in applying sustainability to transport. Theis [9], Black [10], Jeon [11], Kennedy et al. [12], and Banister [8] considered sustainable development issues by using three dimensions: environment, economy, and society. These three dimensions are commonly referred to as the "triple bottom line" [13]. They are defined as follows [13]:

- Environment: The ecological or environmental component considers how changes in local and global surroundings are impacted by human activity and developments.
- Economy: It includes the process of a community's growth or progress toward economic goals, such as increased wealth, employment, productivity, or ultimately welfare.
- Social: The social dimension of sustainability is frequently defined as addressing issues of equity and inclusion.

Aspirational definitions include those written by Black [10]. According to Black [10], the "transportation that satisfies the current transportation and mobility needs without compromising the ability of future generations to meet those needs" is the Brundtland definition of a sustainable transportation system. [10]. This definition locks sustainable transport in line with broad research on sustainability.

The "center for sustainable transportation definition" is a goal-oriented term that is frequently mentioned in various works. It elaborates on alternative meanings and lists the following three crucial components of sustainable transportation: (1) provides for the safe and equitable fulfillment of the basic needs of individuals and communities in a way that is respectful to the health of people and ecosystems, as well as equity within and between generations; (2) is reasonably priced, runs smoothly, presents various transportation options, and fosters a thriving economy; (3) limits emissions and waste within the planet's capacity to absorb them, minimizes the use of nonrenewable resources, restricts the use of renewable resources to the level of sustainable yield, reuses and recycles its constituent parts, and reduces the amount of land and noise it produces [8].

Banister [8] outlined a sustainable transportation paradigm composed of four aspects: (1) actions to reduce the need to travel, (2) encouragement of modal shift, (3) short trip lengths, and (4) increased efficiency [8].

2.1- Transportation Sustainability Challenges

The environment and many facets of society are intersected by transportation, which has several positive effects on human wellbeing. It may link people with essential services and promote economic growth. It may, nonetheless, also provide some challenges. As seen in Table 1, which is derived from [14], an increasing amount of research indicates that the present trends in automobile-oriented transportation are unsustainable due to significant implications across environmental, economic, and social concerns.

Congestion is a major problem in auto-dependent cities that has a significant influence on their sustainability. Congestion is a major problem associated with vehicle reliance and is characterized by poor traffic flow rates and excessive vehicle densities. It has been determined that the growing number of automobiles is the global source of congestion. Growing reliance on automobiles has been identified as the global source of congestion [15]. Negative effects include those on the environment (increased pollution), the economy (loss of production), and society (effects on human health and equity). Other than energy production and industrial processing, transportation is the main source of pollution, particularly air pollution [16]. Bannister [8] examined the economic effects of congestion and contends that a system is deemed unsustainable from an economic perspective if it is unable to offer sufficient levels of mobility for various reasons and modalities. Table (1) below shows the transportation impacts adapted from [14].

Table (1): Transportation impacts [14].

Environmental	Economic	Social
Air pollution	Accessibility quality	Equity/fairness
Climate change	Traffic congestion	Impacts on mobility disadvantaged
Noise pollution	Infrastructure costs	Affordability
Water pollution	Consumer costs	Human health impacts
Hydrologic impacts	Mobility Barriers	Community cohesion
Habitat and ecological degradation	Accident Damages	Community livability
Depletion of non-renewable resources	Depletion of non-renewable resources	Aesthetics

2.2-Sustainable Public Transport Infrastructure

Public transportation infrastructure is essential in providing services that support economic development. Yang et al. [17] implied that improvements in transport infrastructure services are projected to minimize transport costs, with low congestion, short distances, and high speeds, to achieve the goal of lowering fuel consumption and capital costs. The feasibility study of technical engineering for transport infrastructure ignores this issue when evaluating the economics and concurrently raising the awareness of environmental sustainability and natural resource protection, even though congestion reduces the operational efficiency of the transportation system and increases air pollution [17]. According to Yang et al. [17], public transportation projects should strive to incorporate sustainability considerations by evaluating potential designs' transport performances and the design's effects on the environment, society, and economy over the course of the infrastructure projects' lifetime.

3-Public Transportation Modes

Public transportation, often known as mass transit or public transport, refers to a range of services that offer public transportation, such as shared taxis, buses, trains, ferry lines, and their derivatives. It can play significant and distinctive roles in an efficient and equitable transportation system by offering inexpensive basic mobility for nondrivers, presenting economical urban travel, and providing motivation for more efficient urban planning [18]. As a result, it may have various effects (costs and advantages), many of which are external and indirect (affecting those who do not currently utilize transit). Some come from the fact that the service is available, some from people using it, some from a reduction in operating a vehicle, and some from the way transportation can influence how land is developed [18]. The advantages and cost categories for public transportation are compiled in Table 2.

Table (2): Public Transport benefits [18].

Category	Improved transit service	Increased transit travel	Reduced automobile travel	Transit-oriented development
Indicators	Service quality (speed, reliability, comfort, safety, etc.)	Transit ridership (passenger-miles or mode share)	Mode shifts or automobile travel reductions	Portion of development with TOD design features
Benefits	• Improved convenience and comfort for existing users. • Equity benefits (since existing users tend to be disadvantaged). • Option value (the value of having an option for possible future use). • Improved operating efficiency (if service speed increases). • Improved security (reduced crime risk)	•Mobility benefits to new users. Increased fare revenue. • Increased public fitness and health (If transit travel stimulates more walking or cycling trips). • Increased security as more non criminal’s ride transit and wait at stops and stations.	• Reduced traffic congestion. • Road and parking facility cost savings. • Consumer savings. • Reduced chauffeuring burdens. • Increased traffic safety. • Energy conservation. • Air and noise pollution reductions.	• Additional vehicle travel reductions. (“leverage effects”). • Improved accessibility, particularly for non drivers. • Reduced crime risk. • More efficient development (reduced infrastructure costs). • Farmland and habitat preservation.
Costs	• Increased capital and operating costs, and therefore subsidies. • Land and road space. • Traffic congestion and accident risk imposed. by transit vehicles.	• Transit vehicle crowding.	• Reduced automobile business activity.	• Various problems associated with more compact development.

Vehicle use (automobiles, light trucks, minivans, SUVs, and motorcycles) increased for the majority of the 20th century. At the same time, public transportation suffered from a decline in ridership, investment, and service quality. Moreover, land use development focusing on automobiles increased. Opponents contend that increasing transit service or promoting transit use outside of a few major metropolitan areas has no justification. [19], [20]. However, current changes make public transportation increasingly important, as illustrated by Litman [4]. These changes are as follows:

- The demand for travel shifts away from automobiles and toward alternatives because of factors such as the elderly, increasing costs of fuel, urbanization, traffic jams, rising expenses associated with expanding roadways, altering consumer preferences, and growing welfare and environmental issues.
- As a result, a growing number of cities, including many formerly suburban areas that are becoming increasingly urbanized—have grown to the size and level of traffic demand that justifies relying more heavily on transit. These cities also face issues with parking, land values, increased traffic jams, and commercial accumulating that make transit economical.
- Transportation experts and a large portion of the public are beginning to see the benefits of providing an improved transit system.

Litman [18] stated that the primary transportation issues that transit can address include the following:

1. Traffic congestion
2. Parking congestion
3. Traffic accidents
4. Road and parking infrastructure costs; automobile costs to consumers
5. Inadequate mobility for nondrivers
6. Excessive energy consumption
7. Pollution emissions

3.1- Main Types of Public Transportation Modes

Public transportation modes are divided into five groups: paratransit, bus transit, light rail transit (LRT), suburban rail, and rapid rail transit (RRT) [21].

Paratransit

An example of this service is a taxi, which is considered a vehicle that transports a small number of passengers. It has become increasingly popular because of the lack of other public transport. It meets the increasing needs of transport. Unlike users of other public transport services that are restricted by a specific timetable and route, taxi users are free to choose their route, schedule, and working hours. Paratransit also provides a home delivery service, indicating that it has highly accessible services. Its speed ranges from 12 km/h to 20 km/h.

Bus transit

Bus service is the most widespread service in cities and developing areas. This service operates on a schedule and has a special track. It also has the advantage of fixed passenger transport fees regardless of the different distances within the region. Bus speed ranges from 10 km/hr to 12 km/hr and reaches up to 25 km/hr in low-density areas.

LRT

It is known as the electric power rail system and is characterized by the following:

1. Passengers are transported from the street surface or from a low station.
2. These systems generally run as short trains (three coaches) or single vehicles.
3. They run on the B or C right-of-way category.

The LRT has three categories: tramways, LRT, and LRT metro.

Tramway

A tramway is made up of a basic streetcar that travels on the rail in a fixed, single unit while dealing with mixed street traffic. It has a 100–200 passenger capacity range. Approximately 12 km/h is the operational speed.

Light rapid transit (LRT)

LRT normally consists of two or three coaches, which are linked together in one unite as a train. It runs on a separate right-of-way, and its route is limited. The train passenger capacity ranges from 700 to 900 passengers. The total capacity is approximately 20000 passengers/hr. The operating speed is 15 km/hr, with a capacity of 36000 passengers/hr.

Suburban rail

Suburban rail runs on the same routes as those of intercity passenger and truck trains. The trains consist of 10, 12, and 14 coaches. The capacity of 12 coaches is 2750 passengers. Moreover, the capacity for the lane is 55000 passengers/hr. The operating speed is between 45 and 55 km/h, and the range of distance between stations is from 2 km to 3 km.

Rail Rapid Transit (RRT)

This system runs on rights-of-way that are in cutting or elevated tunnels. The path of such trains is fixed and limited. This system achieves a high level of reliability and safety. An underground system is not influenced by weather changes. The operating speed is approximately 100 km/hr. It carries 80000 passengers/hr at an operating speed of 30–35 km/h. This system has a high capital cost of approximately US$40–20 million per km of the route. This cost depends on whether it runs through a tunnel (underground) or without a tunnel (elevated) because the cost of constructing the tunnel is high. As shown in Table (3), Willer [22] summarized the most important characteristics of different types of public transportation.

TABLE (3): Important Characteristics of Different Types of Public Transportation [22].

properties	**Public transportation types**				
	BRT	Bus transit	Tramway	Suburban rail	Metro
capacity (p/hr/dir)	4000-12000	1200	6000-15000	55000	80000
Operating speed (km/hr.)	20-40	15-20	15-45	45 -55	100
Stop space (m)	300-2000	200-500	200-600	2000-5000	400-3000
Headway (min)	13 s	5	6	2.5	1.5
Path away characteristic	The users are free to choose their route and are not restricted.	The path is fixed and restricted.	It runs on rail within a fixed and single unit in the mixed traffic on the street.	It runs on the same routes as those of the truck train.	It runs on the right-of-way that is in a cutting or elevated tunnel. The path of such trains is fixed

					and limited.

3.3- Rail as Opposed to Bus Transportation

Table (4) provides a summary of the main distinctions between rail and bus transportation. Instead of discussing, which is generally better between the two, considering which of them is highly suitable for a given circumstance is usually preferable. Buses function best in locations with low demand or dispersed destinations. Rail works well in corridors with dense ridership and destinations, such as urban towns and major commercial areas [18]. Although buses can travel far and serve most of the city areas, rail generally draws great ridership within a given area; therefore, overall ridership impacts depend on various factors. When accompanied by policies that enhance service quality, foster highly favorable land use patterns, and promote ridership, both become highly effective and successful in accomplishing planning goals. Table (4) displays the major variations.

Taple (4): Key Differences Between Bus and Rail Transit [18].

Bus	Rail
• Adaptability. Bus routes are flexible and may expand as required. For instance, the routes may alter if a road is closed or if the demand or destinations vary. • Does not need any unique facilities. Existing bus routes can be used by buses, and busways can be created by converting ordinary traffic lanes. • Highly appropriate for distributed land use. This feature allows buses to service a large riding catchment area. • Minimized transfers when multiple routes merge onto a single busway. For instance, buses that originate from various suburban areas can utilize a busway to travel to the city center. • Minimal cost for capital. • Numerous equality benefits of bus service enhancements. This advantage results from the frequent use of individuals who rely on public transportation.	• Increase attraction of passengers. Rail usually draws more affluent passengers than buses. • Increased comfort because of roomy seats, increased legroom, and calm ride. • Increased upper limit of capacity. Rail is highly economical and space-efficient on high-traffic routes. • High dependability and speed of travel for grade-separated rail service. • More advantageous effects of land use. Many approachable development patterns are often generated by rail. • Elevated property values in the vicinity of transit hubs. Noise and air pollution are reduced, particularly when electric power is used. • Aesthetically pleasing. When a large number of transit vehicles are gathered, rail is preferred over bus stations because the former is typically more aesthetically pleasing than the latter.

4. Tram Characteristics:

According to [23] and [24], rail transportation, such as subways, trams, and monorails, is a more appropriate means of mass transit and is more punctual than other public transportation systems. Increased public transit accessibility, reduced automobile congestion, and decreased wait times increase the likelihood that a passenger car user may switch to public transportation [25]. According to the American Public Transportation Association (APTA), a tramway is an electric railway system that can operate one or more cars. It can be found along exclusive rights-of-way at the ground level, on aerial structures, in streets, or on subways. It can pick up and drop off passengers at station platforms, streets, tracks, or car-floor levels. It is typically powered by overhead electrical wires. According to this description, a tramway is a system of electrically powered passenger cars with steel wheels that travel on a track made of steel rails. The cars, the tracks, and the streets themselves must be able to accommodate people and vehicles with rubber tires. According to [5], the track system may also be built inside exclusive rights-of-way.

Kaewunruen et al. [26] stated that trams have positive environmental effects, including low carbon emissions and minimal traffic. According to [27], trams combine routes with existing roadways and have a lower construction cost per mile than light rail or subways. Prud'homme et al. [28] contended that "road diets" can discourage the use of passenger automobiles by lowering carbon emissions through the integration of existing roads and tram routes [24].

McGreevy [29] stated that the two-way laying of tram rails reduces the number of traffic lanes available to cars and that increasing the inconvenience of vehicle drivers can stimulate the conversion of private cars to public transport. Buehler and Pucher [30] noted that the transition from passenger cars to public transport can help alleviate environmental and social problems by reducing energy consumption and CO_2 emissions. Börjesson et al. [31] noted that trams are less expensive to build and operate than subways, which require many structures for construction because the former can be used only by laying rails using existing roads. Tramway is a commonly used public transport system in cities. It consists of one to four wagons that move along a railway by electricity. As a result, it is light, short, and flexible. The width of each wagon ranges from 2.3 m to 2.9 m, whereas its length ranges from 14 m to 40 m. Its operation speed is 50 km/h along the streets and can reach up to 80 km/h along dedicated lines out of residential districts. Its capacities range from 120 to 280 passengers on each trip or 10,000 to 28,000 passengers per hour [32].

4.1-Tram History:

The first mass transit system is the tramway. In Swansea, Wales, the first horsecar tramway system debuted in 1807. Cities around Europe and North America began to employ tram transportation extensively with the invention of the electric engine in Berlin, Germany, in 1880. "Cable cars," a type of transportation, have been specially created in cities with mountainous topography [33]. Although these cities mostly use land-based tracks and light rolling stock, some cities in Europe, Canada, and the United States have developed new tramway systems that are more efficient than metro (subway) systems. LRT is the modern version of the traditional tramway. As a result, new tramway lines and systems are built worldwide as a process of renewal and activation [33]. Tramway renaissance is depicted in Fig. (1), showing the number of newly created tramway systems per world regionfrom 1978 to 2019 [33].

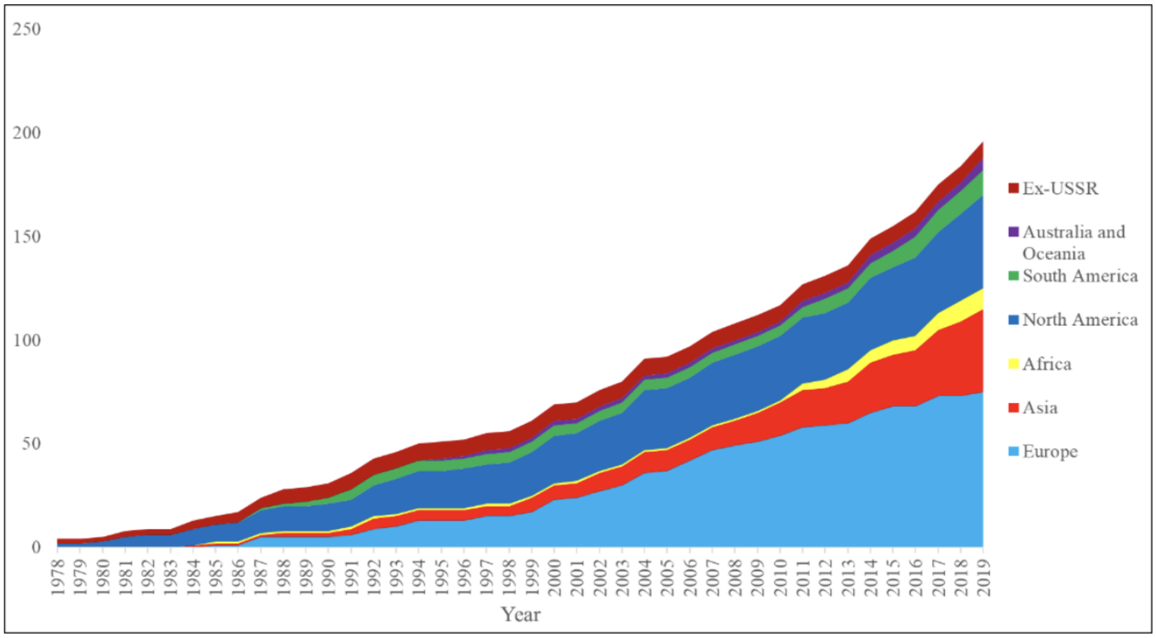

Figure 1: Number of newly established tramway systems by world regions in 1978 to 2019, source: [33].

4.2-Tram Benefits:

Reduction of pollution

Given that most tram lines are entirely powered by electricity, trams are environmentally benign. In particular, trams help to keep the city's pollution levels lower by reducing carbon emissions [34].

Metal shavings produced by the friction of the wheels and rails are the only waste that results directly from tram operation. In addition, the rubber tire exhaust from the trolleybus has negative effects on the air and land. Asynchronous motors, which enable braking while recovering a portion of the electricity back into the grid, are the norm in modern tram cars. Furthermore, trams use less electricity to run than trolleybuses or electric buses because rubber sticks to asphalt more firmly than metal wheels because of the rail. These scenarios are tolerated at the expense of safety because trams have a more sophisticated braking system than the trolleybus and the bus, with their independent brakes being four, three, and two, respectively [33]. The tendency in Europe and North America is to plant lawns or grass on the land between the rails to make tramway lines aesthetically pleasing. The reason is that tramway lines have a consistent trajectory and the lowest potential transport emissions. Asphalt has an albedo indicator of 11%–15%, open soil of 16%–20%, and grass cover of 21%–25%, indicating that it repels solar heat the best. The urban heat island effect is diminished by using the empty area between the trains. Furthermore, the repulsion of increased solar heat prevents tramway rail overheating and related issues such as “rail ejection” [35], [33].

High passenger capacity

According to [36], one of the most significant aspects of tramways is their capability to move large numbers of passengers, which helps to relieve traffic congestion on city streets [5].

Economy and saving

The public transportation that uses the least amount of energy is the tramway. In addition to the previously discussed aspect of electric recuperation, the tram uses less energy than a metro (because passenger and technical facilities do not need to be maintained at stations) and a trolleybus (because wheels slide on rails easily) [37], [33].

Reduction of noise level

The tram is generally quieter than the bus. The tram is slightly noisier than the bus when traveling at high speeds because of the rail–wheel contact; however, the bus is noisier than the tram overall because of its peak engine noise. According to noise impact research conducted by Loughborough University, the maximum bus noise measured at 7.5 m is 93 dB, whereas the maximum tram noise is 87 dB [38].

Increased comfort

A tram offers more comfort to its riders than an underground system or train travel [38]. It is also simple for elderly or disabled individuals to utilize (low floor rolling stock, easy access to the platform from ground level) [33].

Reliable due to the timetable

Timetabling is an important stage of movement planning. The timetable itself is the main document for every transport company because it declares the number of races to be paid from a city budget. Thus, it is the main document for transport companies and is the main document for passengers who plan transfers from one place to another. This scenario explains the relevance of timetabling [39].

Low infrastructure cost

The tramway network requires infrastructure (tracks, overhead lines, and stops), but it is cheaper than the infrastructure for a railway or an underground “metro” [5].

Provide business chance

The business tends to concentrate along the tramway corridors because of the accessibility for large numbers of customers. In contrast to the centralized location of primarily large businesses and network services around metro stations (due to the polarization of rental rates), tramway corridors are characterized by equal business opportunities at different levels [33].

4.3-Tram Disadvantages:

High initial cost

A tram or streetcar project is always substantially more expensive up front than a bus project [36]. According to APTA’s 2016 fact book, an average streetcar or light rail project costs US$123.3

million, whereas a bus project typically costs US$4 million. Railwaygazette.com reports that the building expenses of metro lines that opened in 2019–2020 range from US$29 million per kilometer in Barcelona, Spain, to US$110 million per kilometer in Hohhot, China. In London, United Kingdom, certain projects have a cost per kilometer exceeding US$500 million [33]. Savchuk and Nahornyi (2020) found that the cost per kilometer of the newly constructed tramway lines varies between US$5 million in Daugavpils, Latvia, and US$40 million in Utrecht, Netherlands.

Low flexibility of its network

In addition, the transit agency can easily reroute buses if the serving area shows a decrease in ridership, whereas trams are rather permanent, indicating that the only option is to keep the line running or shut down the station. The nonflexibility of trams can serve as an advantage and disadvantage [33].

Limited maneuverability

Reliance on railroads limits traffic maneuverability and raises the expense of rail and wagon infrastructure [40]. The main characteristic of trams and the difference between trams, bus rapid transit (BRT), and subway according to Wang [41] are presented in Table (5). The tram is less expensive to build than the light rail and metro. The tram can offer more capacity and lower energy consumption, pollution, and emissions than BRT systems. Its constructed cycle is only one-third of that of subways, and the cost per kilometer of its construction is a tenth of that of subways. Table (5) displays a full comparison of the subway, BRT, and tram.

Abdi Kordani (2020) investigated the users' preferences by comparing different effective indices, such as benefit-to-cost analysis, passenger satisfaction, traffic congestion, environmental emissions, operational costs, and time-wasting, to evaluate BRT and light rail, particularly monorail and tramway prioritized in Tehran City. Consequently, they are compared and analyzed by using the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method on SPSS. Each index is investigated through a question in a questionnaire to obtain an accurate comparison. They are carefully responded to by 30 experienced public transport experts. The results show that the questionnaire is of high validity. The experts' judgment indicates that the monorail is superior to the tramway, whereas the tramway is superior to BRT.

Table (5): Comparisons between BRT, Tram, and Subway.

Item	BRT	Tram	Subway
Vehicle Length (m)	18-25	15-40	90-140
Vehicle width (m)	2.0-2.5	2.1-2.7	2.5-3.2
Floor Height (m)	0.3-0.6	0.3-0.5	0.4-1.1
Vehicle Capacity (person)	80-120	120-300	800-1500
One-way capacity(person/hour)	4000-12000	5000-15000	30000-60000
Maximum speed (km/hour)	100	70-80	80-100
Average traveling speed (km/hour)	15-30	15-30	25-40
The minimum curve radius(m)	15	15-25	125
Construction cost (million / km)	20-50	40-90	300-800
Vehicle costs (million yuan / vehicle)	1-3	25-30	40-70
emission/person·km）NOx, CO2	83-125/0.79-1.12	48/0.2	
Relative construction cycle	shorter	longer	long

vehicle depreciation rate	higher	low	low
Road right	Partly or exclusive	Partly or exclusive	exclusive

Data Source: Shenyang Urban Planning Design & Research Institute, [42]; [43].

In [44], the passenger flow impacts of 49 tram lines in China and other countries were examined by using an indicator called passenger flow intensity. The findings indicate that, overall, the passenger flow effects of tram lines in other countries are far better than those in China. The effects of adjacent regions' land exploitative intensity, the average distance between stations, and the traffic conditions of the same corridor on the influence of passenger flow are evaluated based on circumstances to determine the major causes and countermeasures. These analyses demonstrate that the effective ways of improving the passenger flow effect of tram lines include shortening the average station spacing, increasing the intensity of land development along the tram line, and placing the tram line in a corridor with high traffic volume and no other parallel rail transit lines.

In [24], the authors aimed to analyze how the conversion of modes to public transportation caused by tram construction can affect the atmosphere. They also aimed to study how much the increase in physical activity caused by the increase in public transportation affects the reduction of disease. Dongtan New Town in Korea, where trams are scheduled to be introduced, was set as the study area. Moreover, the effect of the conversion of modes of transportation resulting from tram construction was analyzed through the modal split process of the four-stage transportation demand prediction model. Their analysis showed that trams can generate 54,700 trips/d conversion to public transportation within the affected area. The benefit from air pollution reduction is 25.13 × 108 KRW/y. Finally, the benefit of reducing diseases caused by increased physical activity owing to the use of public transportation was predicted to be 65.63.5 × 108 KRW/y.

5-Routes and Stations Selection Criteria:

The main objectives and related criteria have been defined by [45], [46] as follows:

According to [46], the site selection process aims to identify the best and most suitable future rail corridor that can serve the people. It also aims to meet the social, economic, institutional, environment, and engineering objectives and promote the use of public transportation systems.

El-Yazory [47] defined the criteria as a set of guidelines or requirements that are used as the basis of decision-making (a choice between alternatives). Supporting the evaluation of public networks can be achieved by breaking down the main objectives into specific objectives or criteria. These criteria are used to evaluate the performance of each alternative option on each main objective [45]. Fig. 2 represents the hierarchical structure of objectives and criteria [46].

Economic objective

The economic objective seeks to maximize the feasible economic return on investment from the system. Several criteria are used to measure how well an option performs on each indicator (e.g., benefit/cost ratio, first-year return, internal rate of return, net present value, construction cost, and operation cost). The economic objective also aims to minimize land estate acquisition (expropriation of property), intensify existing land use, and maximize the potential of the location.

Engineering objective

This objective looks at three main concerns regarding the efficiency of the system.

A transit option contributes to a reduction in travel time compared with time spent on the roads. It also provides a close-to-optimal convenience for pedestrian access and links to other local and commuter transportation modes. Moreover, an effective connection of housing jobs, retail centers, and recreation areas is beneficial and can obtain a high score.

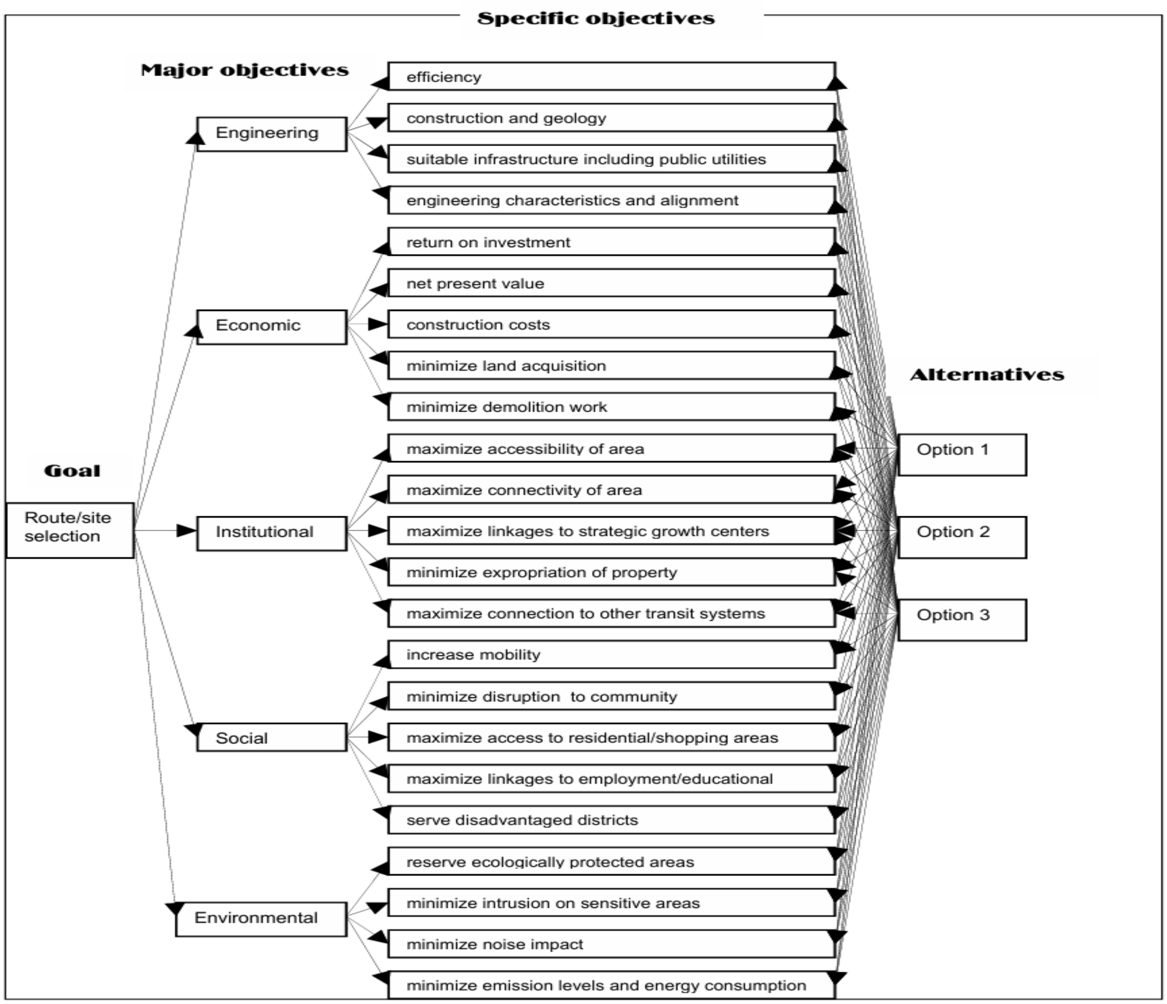

Figure (2): The hierarchical structure of objectives and criteria [46].

From the construction aspect, passing through high-demand areas, such as high-density built-up areas, commercial areas, industrial areas, and institutional areas, can obtain a high score for this criterion. Engineering characteristics are evaluated by measuring the attributes related to the geological environment, hydrogeological conditions, and geotechnics.

Institutional objective

This objective measures the compatibility between the transit system and the spatial policies of the government/urban municipality to maximize the interconnectivity in the existing public transport systems, maximize linkages to strategic growth centers (as designated/proposed in local plans), provide good linkages among urban centers and suburban railway networks, airports, long-distance bus stations, park, and ride lots, and minimize land acquisition.

Social objective

The establishment of a transit system should increase social mobility via easy access to existing and future settlements. Social mobility can be measured by forecasting the passenger/km reduction from residential areas to employment areas and from residential areas to educational institutions.

Environmental objective

The proposed transit system should have minimal damage to the environment, including minimal energy consumption, minimal emissions of toxic gases, and minimal sound and noise impact on sensible land use such as residential places, schools, and hospitals.

Accessibility

Accessibility can be defined as the relative ease of reaching particular locations or areas. It includes two important sub criteria: travel time and land use. Accessibility-oriented public transportation planning can improve the operational efficiency of public transportation, guide orderly urban development, and alleviate issues such as traffic congestion, environmental pollution, and resource consumption in large cities [48].

Safety and reliability

Safety is a top concern for those who utilize public transportation. Thus, improvements in raising consumer satisfaction with public bus services are required. Negative events that damage public transportation’s reputation include delayed service or inaccurate information about bus and rail routes and schedules [49], [50]. Ensuring the provision of safe and comfortable bus stops and pedestrian walkways is crucial for users; additionally, factors such as bus cleanliness, safety, punctuality, and other amenities play a vital role in the overall service quality [51]. Moreover, improvements in the quality of public services, coupled with ongoing efforts to encourage their use, result in passengers feeling unthreatened but comfortable and confident in continuing to utilize the services provided. This positive shift is expected to lead to an increase in the number of passengers and a subsequent reduction in the number of cars on the road. Consequently, the reliability of public transportation can reduce traffic congestion, which affects elderly mobility as stated in [52].

6. Studies of Sites Evaluation Criteria:

Farak [45] explained how a geographic information system (GIS) with the value-focused approach of multicriteria decision-making (MCDM) supports decision-makers in the design, implementation, and evaluation of spatial decision-making processes to determine the suitable metro line locations in Cochabamba City in the Andean region of Bolivia depending on engineering characteristics and geological soil structure, ecological suitability, population density, and projected construction costs criteria.

Jakimavičius and Burinskiene [53] evaluated the technological advancement of an extra tram network for public transportation in Vilnius City. The optimal transport development alternative was found by comparing two methods: Simple Additive Weighting and TOPSIS.

Alkubaisi [5] adopted a methodology of using MCDM with GIS to find the best route for the tram in Al-Ramadi City based on the main criteria (accessibility, safety, environment, economic, and security). The study showed that proposing tram routes based on traffic demand data (traffic flow, speed, and level of service [LOS]) is more efficient than using land use criteria only.

Ghani Ahmed and Moutaz Asmael [21] selected the Baghdad metro route using a multicriteria evaluation based on three primary criteria: the environment, the economy, and engineering. Data preparation and analysis were conducted using a GIS in this process. Analytic hierarchy process (AHP) and TOPSIS were employed in a two-stage MCDM model for data analysis. Additionally, several route options were investigated using GIS. Each option was assessed in relation to the chosen criteria to determine the best one. In addition to expert judgments, the weighting system incorporates a set of measurements derived from the actual data.

Shafik [54] identified the optimal metro locations for stations and routes in the Gaza Strip based on MCDM. The criteria that have been relied upon in choosing the best site include population density, vital places, important intersections, suitable land, soil type, ground water, slope, and land use. For the weighting criteria, a simple linear combination method was used.

El-Hallaq and Khalid [55] evaluated a case study in Gaza City to select the metro site route by using spatial multicriteria decision analysis. The criteria used include population density, vital places, available parking, the area of the intersection, traffic importance of the intersection, and land use. Each of the previous criteria has a weight confirmed by experts.

Awasthi et al. [56] investigated how to evaluate the sustainability of the three environmentally friendly transportation projects by using Fuzzy TOPSIS depending on MCDM. The installation of a car-sharing terminal for electric cars, the construction of an extra tramway in Luxembourg’s city center, and the restructuring of the city’s bus routes offer the best possible service. The review process relied on economic, environmental, social, and technical factors. A new tramway in Luxembourg City’s downtown was determined to be the best option for the implementation based on the results of the assessment.

Al-Yasery H. et al. [57] aimed to identify the optimal locations for metro stations in Karbala City based on various factors (population, land use trip attraction zone, and distances of critical places) to serve the greatest number of passengers and connect important destinations with densely inhabited areas. GIS, a potent tool for spatial analysis, was used in this investigation. The criteria were given a weight and a chosen scale for importance by using AHP. According to the findings, 31 station locations can be chosen as the ideal locations for metro stations.

Farooq et al. [58] concentrated on creating a transportation model that can improve connectivity, decrease travel time, and maximize transfer capacity between the Beijing and Xiong An hubs. A network capable of meeting future demand was suggested after analyzing the current transportation system between the two cities. Several options were investigated in the first step by employing a GIS. A mass transportation system’s planning and implementation requires decision-making between many possibilities, including a new high-speed rail line, an existing intercity railway line, and/or choices for motorways. The researchers analyzed these possibilities by considering certain criteria and using AHP in their second phase of the study. The alternatives were assessed based on several factors that were used to determine which alternative would be best. The results showed that the most important factors are journey time, cost, safety, dependability, accessibility, and environment. According to the multicriteria analysis and GIS, the optimum option for action is to construct a new high-speed train route.

Tubis [59] presented the findings of a study by evaluating the stop zones' degree of safety for the chosen tram lines in Wroclaw. This evaluation enables the establishment of appropriate corrective measures. The safety assessment of the stop zones is based on an indicator that includes three parameters: the location and infrastructure of the stop, its accessibility, and the volume of traffic in the stop zone. These parameters are the most important ones from the point of view of the safety of stops.

Yildirim and Bediroglu [60] utilized network analysis based on GIS and AHP to determine the best routes for a high-speed railway (HSR) project on the Erzincan–Trabzon leg of the Turkish railway network. Slope, geology, soil quality, rivers, protected areas, highways, land cover, and lakes are the eight elements that make up the route-generating study. Approximately 12% less money was spent on building the new hybrid route, and its environmental efficiency was verified by the least-cost path study.

Zak and Kurek [61] used the MCDM, and multiple criteria decision aiding (MCDA) methodologies based on universal and standard sustainable parameters to evaluate and present the study of tram specifications in several countries, such as the Czech Republic, France, Germany, Hungary, Poland, and Turkey. The primary evaluative variables are travel comfort, dependability, longevity, safety, traction-operational features, cost of operations, utility, environmental friendliness, and functionality.

Ghorbanzadeh et al. [62] proposed five subway stations along the suggested subway line for a planned future mass transportation system in Rasht City, Iran, based on a range of parameters connected to the population, their socioeconomic features, and the large surroundings. The Traffic and Transportation Agency of Rasht recommended several potential locations for subway stations. The researchers aimed to use geospatial analysis to determine the best locations. A GIS-based multicriteria decision approach along with the implementation of the AHP was used to select the best subway station locations.

Görçün [63] presented a multicriteria decision-making model to evaluate the selection of the urban rail vehicles operated in the public transport systems in Turkey, which were metro and tram, based on 22 factors (commercial speed, design speed, passenger capacity, length, width, height, max tractive force, emission [CO_2], noise [dB], seat number, purchase cost, maintenance cost, maintenance, vehicle weight, energy consumption, max braking force, max grade slope, accelerate, min radius, wheelbase, life span, and axle load). The results showed that the tram rail is the best and proper rail vehicle.

Sawicki and Sawick [64] studied the location of a new tram depot among the existing facilities of this type. The selection is preceded by the evaluation of the alternatives. Economic, technological, environmental, and organizational factors should be considered while evaluating new tram depot locations. The authors suggested a methodology that combines optimization and multiple evaluation techniques to address such a complicated decision problem. The established methodology was used experimentally to choose one of the five locations for tram depots in the public transportation system in Poznan, Poland. All the computational experiments were performed by using optimization and MCDA methods and tools, i.e., a linear optimization engine called the Solver Premium Platform and the AHP method with its application AHORN simple. The calculations are the basis for the recommendation of the location of a new depot in the central part of the transport network. This approach is a reasonable solution considering the proximity of the main railway line and the possibility of the triple distribution of the transport means from the depot.

Balket and Asmael [65] aimed to propose and determine the routes of a new means of public transport in the city of Kut, namely, BRT. Their study mainly aimed to encourage citizens to leave their private cars. This approach can alleviate traffic congestion by refining the LOS and performance of the public transport system in the city and can enhance the citizen's comfort as a final outcome by delivering citizens to their place of residence or their place of work as soon as possible and at the lowest cost. The application of the AHP program to compute criteria weights and the processing and analysis of data involve the adoption of GIS. The main criteria used are population, land use, government sites, health sites, education sites, and bus stops.

Harkat et al. **[66]** used MCDM to investigate and evaluate the effects of the Constantine tramway line in Algeria. Their methodology involves conducting investigations, interviews, and on-site surveys with a population composed of individuals who utilize various transportation options. The results confirm the following:

1. The tramway line has a strong effect on ridership by providing comfort for passengers, particularly the elderly, students, and the disabled.
2. The reliability of the tramway line is higher than that of the buses with respect to the timetable.
3. Compared with the time spent on the bus, that on the tramway is reduced by half.
4. The tramway line can reduce the use of different travel modes.

The main parameters used include the social, economic, reliability, comfort, and time-saving ones.

Djouani et al. [67] assessed the tram track's effectiveness in an Algerian city by integrating the GIS methodology with AHP. Several predetermined criteria were arranged and analyzed in AHP to identify the primary weights for each predetermined criterion, which included traffic safety, security, accessibility, economic, practicality, exploitation by citizens preservation, and the environment. The results demonstrated that the city's tramway track selection is unsuccessful in terms of the selected location and that the efficiency and quality criteria relevant to urban transportation were not considered throughout the selection process.

The study of **Vilke, Petrović, and Tadić [68]** is primarily concerned with the evaluation and selection of an optimal railroad route between Rijeka and Zagreb as part of the Mediterranean Corridor. The large number of criteria used to analyze solutions, including economic, transport, constructional–technical, urban planning, and ecological–sociological considerations, complicates the decision-making. The optimization method of multicriteria analysis was used to analyze the alternative railroad route. A model comprising the defined criteria and subcriteria, including their weighting coefficients, was also set. The authors applied the defined model for the evaluation and selection of a railway route between Rijeka and Zagreb by using the PROMETHEE II method for the multicriteria ranking of alternatives and the computer software "Visual PROMETHEE" to perform the analysis. The criteria employed include trip distance, trip time, and travel speed.

De Ridder and Farah [69] detailed the development of a multiobjective model for optimizing stop locations within an urban tram network while considering multiple-transit objectives. The detailed socioeconomic data of zones were used in the model, alongside the current travel behavior, to estimate transit demand precisely. Additionally, the effects of stop relocation on operations were estimated using running time data. As a result, the optimal stop locations for an entire transit system can be determined. The results of a case study of the tram system of The Hague indicate that in areas where trip distances are short and near the end of a tram line, stop spacing should be denser than the other parts of the system. Moreover, stops are not always optimal where two transit lines intersect. A stop should be located irrespective of the other factors only in the case of a high share of transfer passengers. Finally, the potential speed on the line section does not significantly affect the optimal stop spacing.

Nsaif et al. [70] combined AHP with GIS modeling to produce a strategy for building the greatest potential BRT system in Kirkuk City, Iraq, according to traffic volume, travel time, land use, and vital places.

Zhao et al. [71] suggested a cooperative optimization approach for reducing carbon emissions in the built environment and public transportation system. Enhancing public transportation's service capability and potential for emission reduction with limited resources is the goal. The many-objective optimization model was constructed by considering six factors: governmental subsidies, energy consumption, carbon emissions, time and economic expenses, and resource occupation of the road network. Data from the built environment and many multimode travel sources, such as vehicle order data, vehicle global positioning system trajectory data, and intelligent card data, were used to compute the model's parameters.

Table 6 summarizes the above studies.

Table (6.A): previous studies of evaluation criteria.

Authors	Aim and result	Criteria
Farak, 2009	Determining the suitable metro line locations in Cochabamba City	Engineering, geological soil structure, ecological suitability, population density, and projected construction costs criteria
Jakimavičius & Burinskiene, 2013	Evaluating the technological advancement of an extra tram network for public transportation in Vilnius City	Trip distance, trip duration, and flow speed
Alkubaisi, 2014	Finding the best route of tram in Ramadi City	Accessibility, safety, environment, economics, and security
Ghani Ahmed and Moutaz Asmael, 2015	Finding metro routes in Baghdad	Environmental, economic, and engineering criteria

Table (6.B): previous studies of evaluation criteria.

Authors	Aim and result	Criteria
Shafik, 2016	Identifying the optimal metro locations for stations and routes in Gaza	Population density, vital places, important intersections, suitable land, soil type, ground water, slope, and land use
El-Hallaq and Khalid, 2017	Finding metro site route in Gaza	Population density, vital places, available parking, intersection area, traffic importance of the intersection, and land use
Awasthi et al., 2018	Three sustainable mobility initiatives were evaluated: the establishment of a car-sharing terminal for electric cars, the construction of an extra tramway in Luxembourg's city center, and the restructuring of the city's bus routes to offer the best possible service.	Economic, environmental, social, and technical criteria
Al-Yasery H., et al, 2018	Identifying the optimal locations for metro stations in Karbala City	Population density, land use trip attraction zone, and distances of vital places
Farooq et al., 2018	Making decisions between a new high-speed rail line, an existing intercity railway line, and/or choices for motorways. The optimum option was a new high-speed rail line.	Travel time, cost of travel, safety, reliability, accessibility, and environment
Tubis, Rydlewski and Budzyński, 2019	Evaluating the stop zones' degree of safety for the chosen tram lines	Location and infrastructure of the stop zone, its accessibility, and the volume of traffic in the stop zone
Yildirim and Bediroglu, 2019	Determining the best routes for an HSR project	Slope, geology, soil quality, rivers, protected areas, roads, land cover, and lakes.
Zak & Kurek, 2020	Evaluating and presenting the study of tram specifications in several countries in the Erzincan–Trabzon leg of the Turkish railway network	Comfort of travel, reliability, durability, safety, traction-operational characteristics, price of operational costs, utility of environmental friendliness, and functionality
Ghorbanzadeh et al., 2020	Proposing five subway stations along the suggested subway line in Rasht	Population, socioeconomic characteristics, and the broader environment
Görçün, 2021	Evaluating the selection of the urban rail vehicles operated in the public transport systems in Turkey, namely, metro and tram. They were the best alternative.	Commercial speed, design speed, passenger capacity, length, width, height, max tractive force, emission (CO_2), noise (dB), seat number, purchase cost, maintenance cost, vehicle weight, energy consumption, max braking force, max grade slope, acceleration, min radius, wheelbase, life span, and axle load
Sawicki and Sawicka, 2021	Finding the best tram line in Poznan	Economical, technical, environmental, and organizational
Balket and Asmael, 2021	Determining the routes of BRT in Kut.	Population, land use, health sites, education sites, government sites, bus stops

Table (5.C): previous studies of evaluation criteria.

Authors	Aim and result	Criteria
Harkat et al., 2022	Evaluating the tram lines in Algeria	Social, economic, reliability, comfort, and time saving
Djouani et al., 2022	Assessing the tram track's effectiveness in Algeria	Traffic safety, security, accessibility, economic, feasibility, exploitation by citizens preservation, and the environment
Vilke, Petrović and Tadić, 2022	Finding an optimal railroad between Rijeka and Zagreb as part of the Mediterranean Corridor	Economic, transport, constructional–technical, urban planning, ecological–sociological considerations
De Ridder and Farah (2023)	Developing a multiobjective model for optimizing stop locations within an urban tram network in The Hague	Land uses, building densities, and sociodemographic characteristics of the areas around a stop zone
Nsaif et al., (2024)	Determining the routes of BRT in Kirkuk City, Iraq	Traffic volume, travel time, land use, and vital places
Zhao et al., (2024)	Suggesting a cooperative optimization approach for reducing carbon emissions in the built environment and public transportation system	Governmental subsidies, energy consumption, carbon emissions, time and economic expenses, and resource occupation of the road network

7. Discussion:

According to review papers related to finding the optimal site locations of public transits, the majority presented the criteria related to the transport infrastructure projects within the sustainability/sustainable development framework. Then, the site that meets the criteria, which are a set of guidelines or requirements, was used as the basis of decision-making and defined as the optimal one [47].

The social, environmental, and economic criteria (the three pillars of sustainability) were presented in most of the papers. The definition of the most important site location criteria and their purposes is included in [21], [45], [46], and [47]. These purposes include the following: economic objective (seeks to maximize feasible economic return on investment from the system), engineering objective (related to geological environment, hydrogeological conditions, geotechnics, and the corridor alternative that passes through high-demand areas, such as high-density built-up areas, commercial areas, industrial areas, and institutional areas), institutional objective (to provide good linkages among urban centers and suburban railway networks, airports, long-distance bus stations, park, and ride lots, as well as to minimize land acquisition), social objective (establishment of a transit system should increase social mobility by way of easy access to existing and future settlements), environmental objective (to have minimum damage on environment), and accessibility (to make reaching particular locations or areas easy). It has been selected to include two important sub criteria: travel time and land use.

Out of 23 papers, 11 or 54% of the papers use the environmental criteria in their evaluation. Moreover, 10 out of 23 papers, which is equal to 50% of the papers, used the social criteria.

Accessibility takes 47%, and the economic criteria take 40%, which comprised 8 out of 23 papers. The weaker criteria were engineering criteria, which take 22% percent. This finding indicates that this criterion is of little importance because it varies from one region to another according to terrain and the presence of rivers. It is also of little importance in terms of meeting people's transportation needs.

The best criteria that meet the needs of people and passengers and aim to achieve sustainability objectives are mainly environmental, accessibility, and social criteria.

Considerable research used reliability, safety, and security criteria in their evaluation. These criteria are useful if used in their study to evaluate and compare trams with other types of transportation modes, such as bus or car sharing. However, they are not useful in our study, which is related to finding the best tram routes because the tram itself has high reliability due to the timetable and has high safety, security, and comfort for passengers.

All the studies focusing on finding the best route did not consider the traffic criterion. However, this criterion was recommended only by [5] because the LOS of the network was assessed to choose the weakest network and feed it with public transport and to reduce traffic congestion. As a result, pollution and noise can be reduced, and a large number of passengers can be served. For the purpose of criteria analysis, 7 out of 23 papers, which is equal to 36%, used the combination of AHP and MCDA methods to obtain the best alternative. Moreover, 2 out of 23 papers used the TOPSIS method and one of the papers used the PROMETHEE II method for the multicriteria ranking of alternatives. Other papers (8/23) used MCDM for analysis. Fig. 3 represents the percentage of the criteria used in previous studies.

8. Conclusion:

This paper provides a critical literature review of the key topics to understand the state of research and scope of public transit, particularly tramways. First, a conceptual base was discussed by reviewing comparative definitions of sustainable transportation and key sustainability impacts of transport networks.

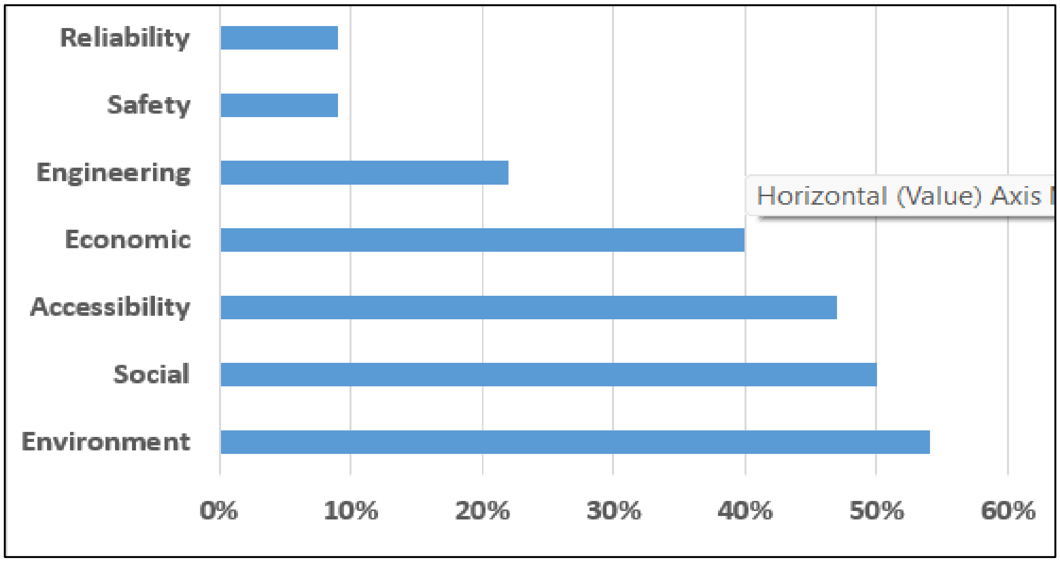

Figure (3): Percentage of criteria, used in previous studies.

Second, a review was presented. This review includes a definition of public transportation and an overview of its main advantages over private vehicles on the road network, such as reduced travel times, pollution, and traffic congestion. It also covers economic benefits. The most significant forms of public transit and the characteristics of each kind were addressed.

Third, the key characteristics of the tram and its advantages for the road system and passengers were discussed. These features include its ability to transport large numbers of passengers, which significantly reduces congestion on the road network. This outcome contributes significantly to the reduction of noise and pollution and indicates a high level of reliability.

Fourth, the most crucial objectives and criteria for determining the ideal site for public transit, particularly the tram's route and stations, as well as other transit options, were reviewed. These objectives and criteria include engineering, economics, environment, and social considerations.

7-References:

1. A.lami, and A.Torok, (2023) 'Sustainability Indicators of Surface Public Transportation', Sustainability (Switzerland). Multidisciplinary Digital Publishing Institute (MDPI). Available at: https://doi.org/10.3390/su152115289.
2. D. AL-Khazali, H. Al-Jameel, R. Almuhanna, (2022). "Classifying and Evaluating Urban Streets in Karbala City."
3. P. Miller, (2016). Public transportation and sustainability: A review, Wirasinghe SKSCE Journal of Civil Engineering (2016) 20(3) 1076-1083.
4. N.Theyab, H. Al-Jameel, R. Almuhanna, (2021), "Impact of Traffic Flow on Pollution at Urban Intersections". Journal of Physics: Conference Series 1973(1).
5. M.I.T. Alkubaisi, (2014) 'Predefined Evaluating Criteria to Select the Best Tramway Route', Journal of Traffic and Logistics Engineering, 2(3). Available at: https://doi.org/10.12720/jtle.2.3.211-217

6. World Commission on Environment and Development (1987). Our common future, Oxford University press, Oxford, UK.
7. F. Moavenzadeh, K. Hanaki, and P. Baccini, (2002). Future cities: Dyanmics and sustainabilit, Kluwer Academic Publishers, Norwell, MA.
8. D. Banister, (2005). Unsustainable transport: City transport in the new century, Routledge, New York, NY.
9. T. Theis, (2012). What is Sustainability? In T. Theis, & J. Tompkins, Sustainability: A Comprehensive Foundation, Houston: Connexions. Retrieved October 1, 2012, from http://cnx.org/content/m41188/1.7/.
10. W. Black, (2010). Sustainable transportation: problems and solutions, guildford, New York, NY.
11. C. M. Jeon, (2007). Incorporating sustainability into transportation planning and decision making: Definitions, performance meaures, and evaluation (Dissertation), Retrieved from https://smartech. gatech.edu/xmlui/bitstream/handle/1853/19782/jeon_mihyeon_c_ 200712_phd.pdf.
12. C. Kennedy, E. Miller, A. Shalaby, H. Maclean, J. and Coleman, (2005). “The four pillars of sustainable urban transportation.” Transport Reviews, Vol. 25, No. 4, pp. 393-414, DOI: 10.1080/01441640500115835.
13. N. Low, (2003). Is Urban Transport Sustainable? In Making Urban Transport Sustainable, pp. 1-22, Palgrave Macmillian, New York, NY.
14. T. Litman, and D. Burwell, (2006). “Issues in sustainable transportation.” International Journal Global Environmental Issues, pp. 331-347, DOI: 10.1504/IJGENVI.2006.010889.
15. F. Moavenzadeh, and M. Markow, (2007). Moving millions: Transport strategies for sustainable development in megacities, Springer, Dordrecht, Netherlands.
16. A. Dobranskyte-Niskota, A. Perujo, M. and Pregl, (2007). Indicators to assess sustainability of transportation activities, Ispra: European Commission Joint Research Centre Institute for Environment and Sustainability.
17. C.H. Yang, Lee, K.C. and H.C. Chen, (2016) ‘Incorporating carbon footprint with activity-based costing constraints into sustainable public transport infrastructure project decisions’, Journal of Cleaner Production, 133, pp. 1154–1166. Available at: https://doi.org/10.1016/j.jclepro.2016.06.014.
18. T. Litman, (2016) ‘Evaluating Public Transit Benefits and Costs’, pp. 1–143. Available at: http://www.vtpi.org/tranben.pdf.
19. K. Orski, (2000), “Can Alternatives to Driving Reduce Auto Use?” Innovation Briefs, Vol. 11, No. 1, Jan/Feb.
20. T. Balaker, (2004), Past Performance Vs. Future Hopes: Will Urban Rail Improve Mobility In North Carolina, Policy Study 321, Reason Public Policy Foundation (www.rppi.org/ps321.pdf).The Centre for Sustainable Transportation (2005, March 31). Defining Sustainable Transportation, Retrieved June 23, 2011, from http:// cst.uwinnipeg.ca/documents/Defining_Sustainable_2005.pdf.
21. N. Ghani Ahmed, and N. Moutaz Asmael, (2015) making a gis-assisted optimal baghdad

metro route selection based on multi criteria decision, Journal of Engineering and Development. Available at: www.jead.org.

22. S.Willer, Sander, Tram-rain: when is it a suitable mode, Development of model to determine applicability of tram-train, Mott MacDonald, 2019.
23. M.Song, G. Zhang, W. Zeng, J. Liu, K. Fang, 2016, Railway transportation and environmental efficiency in China, Transportation Research Part D: Transport and Environment, 48, 488–498.
24. M. Choi, D. Ku, S. Lee, 2021, Environmental Impact of Personal Mobility in Road Managements. Chemical Engineering Transactions, 89, 331–336.
25. L. Redman, M. Friman, T. Gärling, T. Hartig, 2013, Quality attributes of public transport that attract car users: A research review, Transport Policy, 25, 119–127.
26. S.Kaewunruen, J.Sussman, M. Einstein, 2015, Strategic framework to achieve carbon-efficient construction and maintenance of railway infrastructure systems, Frontiers in Environmental Science, 3(FEB), 6.
27. D. K. Zielinski, A. Advisor, B. Fisher, 2020, Cost-Benefit Analysis of Constructing and Operating a Streetcar Cost-Benefit Analysis of Constructing and Operating a Streetcar System in Buffalo, NY, Applied Economics Theses, 43.
28. R. Prud'homme, M. Koning, P. Kopp, 2011, Substituting a tramway to a bus line in Paris: Costs and benefits. Transport Policy, 18(4), 563–572.
29. M. McGreevy, 2021, Cost, reliability, convenience, equity, or image? The cases for and against the introduction of light rail and bus rapid transit in inners suburban Adelaide, South Australia. Case Studies on Transport Policy, 9(1), 271–279.
30. R. Buehler, J. Pucher, 2011, Making public transport financially sustainable. Transport Policy, 18(1), 126–138.
31. M.Börjesson, R. D. Jonsson, M. Lundberg, 2014, An ex-post CBA for the Stockholm Metro, Transportation Research Part A: Policy and Practice, 70, 135–148.
32. V. Phillipe, Trams and Rubber - tyred Guided Vehicle, SaviorFaire,volume, 2001.
33. I. Savchuk, T. Nahornyi, Tramway as an indicator of the realisation of Smart City concept, E3S Web of Conferences (2020) 159.
34. Xu.Yan, "Network Development of Modern Trams." Icte 2015, 2015,
35. R. Zelezny. Tramway-oriented development: what results in what context? Comparative approach between France and the Czech Republic. Transportation Research Arena (TRA) 2014, Paris – La Défense, France (2014).
36. A. Abdi Kordani, S. M. Boroomandrad, & M. Rooyintan, (2020). Preference Analysis of Light-Rail and BRT using TOPSIS Method and Delphi Analysis, Tehran Case Study. International Journal of Railway Research, 7(2), 61-71.
37. O. Dronova, S.D. Brunn. How neoliberal globalization processes are transforming Kyiv's nodal areas. Urbani izziv, Volume 29, No. 2, 96-110 (2018).
38. A. Hensher, David, and Corinne Mulley. "Modal Image: Candidate Drivers of Preference Differences for BRT and LRT." Transportation, vol. 42, no. 1, 2014, pp. 7–23.,

39. A. Gorbachev, (2020, September). Model of Hybrid Timetables for High-Speed Urban Tramway Movement. In 2020 IEEE East-West Design & Test Symposium (EWDTS) (pp. 1-7). IEEE.
40. T. A. Garrett, Light -Rail Transit in America Light -Rail Transit in America Policy Issues and Prospects for Economic Development. Federal Reserve Bank of St Louis. 2004.
41. S. Wang, (2023) ‘A flexible model-free tram signal priority method with a large coordination scope in China’, Transportation Safety and Environment [Preprint]. Available at: https://doi.org/10.1093/tse/tdad027.
42. L. Dongping, 2006. Tram Line Network Planning and Outlines in Suzhou New District [J]. Urban Transportation Planning, 2, 30-38.
43. L. Cuiyan, L. Fang, G. Zhifang, 2000. Factors Considered in makings of Metro Ticket Price Policy [J]. Urban Mass Transit, (1): 17.
44. Z. Xu, and L. He, (2020) ‘Analysis of the Causes and Countermeasures of Low Passenger Flow Effect of Tram Lines in China’, in IOP Conference Series: Earth and Environmental Science. IOP Publishing Ltd. Available at: https://doi.org/10.1088/1755-1315/587/1/012122.
45. A. Farkas, (2009). "Route/site selection of urban transportation facilities: an integrated GIS/MCDM approach". 7th International Conference on Management, Enterprise, and Benchmarking June.
46. M. Sharifi, L. Boerboom, K. Shamsudin, and L.Veeramuthu, (2006). "Spatial multiple criteria decision analysis in integrated planning for public transport and land use development study in Klang Valley, Malaysia". ISPRS Technical Commission II Symposium.
47. K. El-Yazory, (2013). "A Proposal to Select." Metro" Route as a Public Transportation Mode in Gaza City Using (GIS) and Spatial Multi Criteria Decision Analysis (SMCDA)".
48. H. Su, (2023) ‘Estimating Public Transportation Accessibility in Metropolitan Areas: A Case Study and Comparative Analysis’, Sustainability (Switzerland), 15(17). Available at: https://doi.org/10.3390/su151712873.
49. A. Bakar, S. Norhisham, N. H. Z. I. A. Abudeyab, N. M. Saad, N. N. I. M. Azlan, N. S. M. Shkuri, & A. M. Mohamad, (2022). Evaluating the Quality of Service of Bus Performance in Johor Bahru. IOP Conference Series: Earth and Environmental Science, 971(1). https://doi.org/10.1088/1755-1315/971/1/012016.

50. A.M. Zakaria, et al. (2024) ‘Age-Inclusive Transit Environments: An Exploration of Public Transportation Systems for Elderly’, Environment-Behaviour Proceedings Journal, 9(28), pp. 149–158. Available at: https://doi.org/10.21834/e-bpj.v9i28.5906.
51. J. Md Diah, N. Akhirruddin, R. A. Rahman, & S. Alam, (2022). An Evaluation of Smart Selangor Bus Service Efficacy. In Journal of Sustainable Civil Engineering and Technology (Vol. 1, Issue 1).
52. S. Jahangir, A. Bailey, M. U. Hasan, S. Hossain, M.Helbich, & M. Hyde, (2022). “When I Need to Travel, I Feel Feverish”: Everyday Experiences of Transport Inequalities Among Older Adults in Dhaka, Bangladesh. Gerontologist, 62(4), 493–503. https://doi.org/10.1093/geront/gnab103

53. M. Jakimavičius, and M. Burinskiene, (2013) ‘Multiple criteria assessment of a new tram line development scenario in Vilnius City public transport system’, Transport, 28(4), pp. 431–437. Available at: https://doi.org/10.3846/16484142.2013.869253.
54. M. Skaik, (2016). "Gaza Metro Network-Route Site Selection." Journal of Engineering Research and Technology **3**(1).
55. M. A. El-Hallaq, and D. Khalid, (2017). "Metro Route Site Selection in Gaza City Using GIS and Spatial Multi Criteria Evaluation."
56. A. Awasthi, H. Omrani, Gerber., (2018). Investigating ideal solution based multicriteria decision making techniques for sustainability evaluation of urban mobility projects. PTransportation Research Part A: Policy and Practice (2018) 116 247-259 of Traffic and Logistics Engineering 2(3).
57. H. Al-Yasery, R.R.A. Almuhanna, and Z. Al-Jawahery, (2018) ‘Metro stations site selection in Karbala city using (GIS)’, in IOP Conference Series: Materials Science and Engineering. Institute of Physics Publishing. Available at: https://doi.org/10.1088/1757-899X/433/1/012036.
58. A. Farooq, et al. (2018) ‘Transportation planning through GIS and multicriteria analysis: Case study of Beijing and XiongAn’, Journal of Advanced Transportation, 2018. Available at: https://doi.org/10.1155/2018/2696037.
59. Tubis, A., Rydlewski, M. and Budzyński, M. (2019) ‘Safety Assessment of Tram Stops’, Journal of Konbin, 49(2), pp. 431–458. Available at: https://doi.org/10.2478/jok-2019-0044.
60. V.Yildirim, and S. Bediroglu, (2019) ‘A geographic information system-based model for economical and eco-friendly high-speed railway route determination using analytic hierarchy process and least-cost-path analysis’, Expert Systems, 36(3). Available at: https://doi.org/10.1111/exsy.12376.
61. J. Zak, D. Kurek, (2020). Multiple Criteria Evaluation of Trams based on Customers' Specifications (Expectations) in Selected Countries. Transportation Research Procedia (2020) 47 696-703
62. M. Ghorbanzadeh, et al. (2020) ‘Subway Station Site Selection Using GIS-Based Multi-Criteria Decision-Making: A Case Study in a Developing Country’, Computational Research Progress in Applied Science & Engineering CRPASE, 06(02), pp. 60–69.
63. Ö.F. Görçün, (2021) ‘Evaluation of the selection of proper metro and tram vehicle for urban transportation by using a novel integrated MCDM approach’, Science Progress, 104(1). Available at: https://doi.org/10.1177/0036850420950120.
64. P. Sawicki, H. Sawicka, (2021). Combined optimisation and MCDA based solution of the tram depot location problem. Archives of Transport, 60(4).
65. S. F. Balket, & N. M. Asmael, (2021, May). Selecting the best route location for bus rapid transit using geographic information system (gis): kut city is a case study. In Journal of Physics: Conference Series (Vol. 1895, No. 1, p. 012029). IOP Publishing.
66. I. Harkat, et al. (2022) ‘Evaluation of socio-economic variables for the constantine tramway line’, transport problems, 17(3), pp. 173–186. Available at: https://doi.org/10.20858/tp.2022.17.3.15.

67. I. Djouani, S. Dehimi, (2022). evaluation of the efficiency and quality of the tram route of setif city, algeria: combining ahp and gis approaches. Redjem ajournal of the Geographical Institute Jovan Cvijic SASA (2022) 72(1) 85-102.
68. S.Vilke, I. Petrović, and F.Tadić, (2022) 'Evaluation and Selection of the Railroad Route between Rijeka and Zagreb', Applied Sciences (Switzerland), 12(3). Available at: https://doi.org/10.3390/app12031306.
69. T.H.A. De Ridder, and H. Farah, (2023) Multi-Objective Stop Location Optimisation Model for Minimising Social, User, and Operator Costs in Urban Tram Systems.
70. B.S. Nsaif, N.D. Hassan, and Q.F Hasan, (2024) 'Optimal design of public transport networks (lines) in Kirkuk City using GIS-based AHP', in, p. 050002. Available at: https://doi.org/10.1063/5.0238436
71. C. Zhao, J. Tang,W. Gao, Y. Zeng, & Z. Li, (2024). Many-objective optimization of multi-mode public transportation under carbon emission reduction. Energy, 286, 129627.

إطار عمل معايير خدمة الترام في المدينة الحضرية

الخلاصة: *تتبنى العديد من البلديات التنقل المستدام في وسائل النقل العامة كنهج استراتيجي لزيادة تدفق الركاب، وتقليل الازدحام، والتخفيف من الآثار البيئية السلبية للازدحام المروري. تواجه هذه البلديات زيادة في حجم الحركة المرورية وآثار بيئية سلبية. أصبحت أنظمة الترام، التي تتميز بمزايا مثل التشغيل الموثوق، والراحة، والانبعاثات المنخفضة، والسعة المعتدلة، شائعة جدًا في السنوات الأخيرة. يهدف اختيار مواقع الشبكة العامة بشكل أساسي إلى إيجاد أفضل شبكة عامة تلبي المعايير المحددة مسبقًا، مما يسمح لهذه الشبكة بخدمة أكبر عدد من الركاب، وتحقيق منطقة جذب-توليد الرحلات، وتحقيق أهداف الاستدامة. يقدم هذا البحث مراجعة نقدية للأدبيات المتعلقة لاختيار معايير أفضل عملية لاختيار مواقع الترام ووسائل النقل العامة الأخرى. الهدف الرئيسي من هذه الدراسة هو تحديد أهم العوامل التي يجب مراعاتها عند تحديد الموقع المثالي لخطوط ومحطات وسائل النقل العامة، وبخاصة خطوط ومحطات الترام، لضمان أن شبكة النقل العامة تلبي احتياجات الناس وتقلل من الازدحام الحضري مع الالتزام بمبادئ الاستدامة. تُظهر الدراسات السابقة أن أهم العوامل في اختيار أفضل المواقع لشبكات النقل العامة هي الهندسة، والاقتصاد، والبيئة، والقضايا الاجتماعية، والوصولية، والطلب على الحركة المرورية.*

الكلمات المفتاحية: *النقل العام, المعايير, الترام, اختيار افضل موقع.*