The Feasibility Assessment of Railway Public Transportation Systems in Sakarya

[1]Hakan Aslan

[1] Department of Civil Engineering, Division of Transportation, Sakarya University, Turkey

*Corresponding author: Hakan ASLAN Address: Department of Civil Engineering, Division of Transportation, Sakarya University, Turkey. E-mail address: haslan@sakarya.edu.tr, Phone: +902642955752

Abstract

Comprehensive sustainable development ensures the provision of economic, social and environmental sustainability as far as the transportation facilities are concerned. This development is also of importance as it has visible and measurable essence. The common feature of the objectives of sustainable development set out in the transportation sector is to enhance the life quality of the people living in the cities. Reliable, environmentally friendly and sustainable investments in the rail systems are supported in today`s cities in order to provide satisfactory public transportation services. This system consists of a main backbone of a rail system running on the main line with the integrating feeder wheeled systems. This paper investigates the evaluation of high-density public transport routes to suggest the feasible urban rail systems and their routes in the Sakarya Metropolitan Municipality.

Key words: Urban Public Transportation Systems, Railway Systems, Sustainable Transportation

1. Introduction

The railway systems, as well known, are high cost of long term investments. Therefore, the need for the provision of an integrated short and medium term wheel system infrastructure is quite important. After establishing the integrated wheel route systems, the rail infrastructure should be implemented in the long term.

The most important factors in choosing a route for the users are to minimise travel time and costs. The main rail route system with supporting wheeled public transportation systems appears to be sensitive to the environment, provides safe and reliable service, has the minimum adverse effects of the roadway traffic and reduces the operating costs. The resulting reduced operating costs will delay the increase in fares of public transport in the future. As a result, the system users and operators are mutually motivated by the benefits of the system. For these reasons, these transportation systems are supported and encouraged not only by local governments but also by the central governments.

2. Study Area

The total area of city of Sakarya has a size of 4,817 km2 with total 16 available provinces. The city of Sakarya is located on the east of Marmara region and has a 60 km long cost line extending along the borders of Duzce and Kocaeli. The location of the study area is illustrated by Figure 1 below.

Doi: 10.5505/apjes.2013.88597

Figure 1. The Location of City of Sakarya

According to the data available for the year 2011, the total population in the city is 888,556. 75 per cent of this population lives the city and district centres. The number of inhabitants per square kilometre is given as 184 people by the same data.

The table below summarises the basic demographic and geographic information about the city.

Table 1. Administrative Information of the City of Sakarya

Population (Total)	**888,556**
Urban Population Ratio (%)	75
Rural Population Ratio (%)	25
The Annual Population Growth Rate (‰)	18
The Area (km^2)	4,817
Order in terms of surface area of the cities in Turkey	66
Population Density (people / km^2)	184
Number of Districts	16
Number of Municipalities	29
Number of Villages	426

The study area is devised into three different Traffic Analysis Zones (planning regions) as a whole. However, this paper is mainly focused on proposed transportation projects for the Region 1 as it has the highest population and traffic density. Although the solution of the transportation related problems for the remaining regions require being paid attention, the scope of this paper is not in that field.
Figure 2 below illustrates the planning regions.

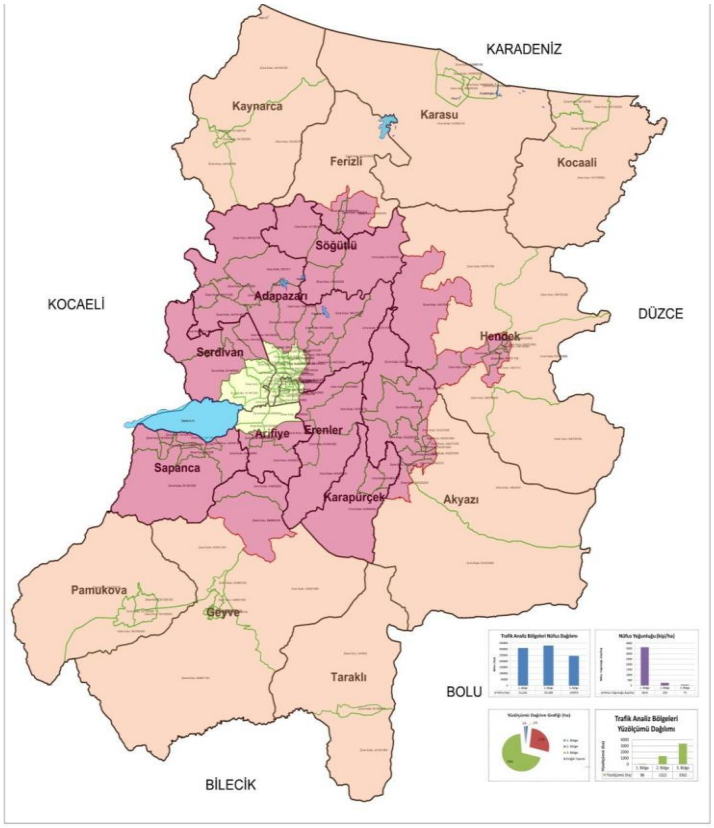

Figure 2. Traffic Analysis Zones

3. Recommended System Projects

This section discusses the system projects planned and proposed for the routes within the scope of the solution of transportation problems arose in Region 1. These projects might be grouped within two main categories, i.e., Road and Rail system pre-projects.

3.1. Road System Pre-Projects

Road System pre-projects carried out within the framework of the general planning process are among the most important aspects. The projects recommended create investment alternatives for the existing and future road network traffic problems affected by urban development trends. The main tool used to determine the trip rates on the links of the road network and the potential problems is a calibrated transport demand model. Through the results obtained from this model, three priority stages are defined for the suggestion of road system pre-projects. The highest priority was given to those network sections on which volume-capacity ratio is over 0.75 both currently and in the future. Second priority roads are regarded as those having volume-capacity ratio less than 0.75 presently but expected to experience this ratio more than 0.75 in a short period of time. The third priority roads are regarded as the roads having the ratio value over 0.75 neither now nor in the future. Depending on the priority rates, the proposed costs of initial investments are summarized in Table 2.

Table 2. Roadway Proposals Project Costs Based on the Priorities

	Expropriation Cost	Construction Cost	TOTAL
1.Priority	306,558,436.00	26,915,289.00	333,473,725.00
2.Priority	226,159,369.00	46,577,919.00	272,737,288.00
3.Priority	115,462,511.00	23,861,456.00	139,323,967.00

By considering the general problems of the city, 50 at-grade, 8 grade-separated intersections and a number of new roadway routes were planned and proposed within the concept of integrated projects.
As the figures imply, the first priority road system projects require the highest amount of investment to lessen the current and expected future problems. Failure doing so will result in more complicated and chaotic traffic environment especially at the central parts of the city.

3.2. Railway System Pre-Projects

The proposed projects are all at-grade rail line routes and planned separately from the vehicle traffic routes to ensure that service speed is not affected adversely. However, the priorities at level crossing points are provided through signaling. The suggested rail routes have transfer stations at the beginning and end of the routes to make the integration with other forms of public transportation modes available.
It is aimed that recommended urban rail systems would play an important role to relieve traffic, reduce the use of cars, provide comfortable and fast public transportation facilities, and in particular bring out the functionality of the city center.
This section of the paper mainly discusses the necessity of the rail systems as a part of the public transportation in Sakarya by examining the administrative, financial, operational and technical feasibility of the projected investments. Urban mass transit rail systems are of important place for metropolitan cities and their importance is increasing every year within the public transportation. There are 11 metropolitan municipalities in Turkey out of 16 having rail systems for the use of public transportation services. Table 3 below shows the rail systems available in the cities in Turkey.

Table 3. Urban Rail Systems in Turkey

City	Population	Rail System	Length of the System (km)	The Number of Passengers Carried per day	The Number of Vehicle
Istanbul	13,710,512	M2 Sishane-Haciosman	18.6	233,333	124
		M1 Aksaray-Airport	19.6	213,888	89
		T1 Bagcilar-Kabatas	19.8	319,444	92
		T4 Topkapi-Habipler	15.3	91,666	85
		M4 Kadikoy-Kartal	21.7	145,000	144
		TOTAL	**95**	**1,003.331**	**534**
Ankara	4,630,735	Ankaray	8.7	105,173	33
		Ankara Metro	14.6	157,310	108
		TOTAL	**23.3**	**262,483**	**141**
Izmir	3,401,994	Izmir Metro	14.7	145,120	77
		IZBAN	80.0	139,926	99
		TOTAL	**94.7**	**285,046**	**176**
Bursa	1,983,880	Burulas	31	144,129	78
Adana	1,636,229	Adana Metro	13.5	23,836	36
Kocaeli	1,527,407				
Gaziantep	1,438,000	Antep	9.7	15,000	15
Konya	1,107,886	Konya Ray	22.0	76,494	60
Antalya	1,073,794	AntRay	11.1	41,258	14
Kayseri	1,004,276	KayseRay	17.5	71,837	38
Diyarbakır	892,713				
Eskisehir	659,924	ESTRAM	16.0	95,317	23
Samsun	547,778	Samsun	15.6	45,572	16
SAKARYA	643,201				

A large number of new projects and constructions are also underway along with the rail systems already in operation in Istanbul, Ankara, Izmir, Bursa, Kayseri. Public transport rail systems become a more popular, as mentioned earlier in brief, form of transportation due to the following advantageous.

- Energy and labour costs are lower than wheeled modes of transportation,
- Construction activities are largely carried out by local contractor firms,
- Domestic firms play important role in manufacturing the electro-mechanical equipment along with rail and cars (vehicles),
- Reduction in the cost of construction and electro-mechanical equipment led the possibility of lower budget rail system investments compare to the past practice.

Rail systems become much more advantageous than the bus systems in terms of operating costs if a certain value of number of trips is reached. Konya public transport system is a good example in this regard. Table 4 below represents the related figures.

Table 4. Comparison of Operating Costs of City of Konya with Regard to Bus and Rail Systems

	Bus System	***Rail System***
Daily Number of Passengers	122,078	76,494
Total Income	41,670,936	25,890,320
Total Expenditure	97,514,998	17,393,332
The Difference of Revenue-Expenses (TL)	**-55,844,062**	**+8,496,988**
The ratio of Total Income and Expenses	0.43	1.48
Operating cost per kilometre (TL)	4.43	3.96
Energy cost per kilometre (TL)	1.63	0.97
The cost per passenger (TL)	2.22	0.63
The number of passengers per kilometre	2	6.27

As can be seen from the table above unit cost of bus public transportation system trips is 3.5 times higher than rail system in Konya. The situation in question is not specific only to Konya. The same situation can quite likely be seen in many metropolitan cities in Turkey.

While the ratio of annual revenues and expenses is less than 0.5 per cent for the public bus companies, the same ratio is over 1.0 for many of the enterprises in the urban rail system operation.

Sakarya is among those five metropolitan municipalities in Turkey not having rail system for their public transportation.

The important district areas in Sakarya in terms of the feasibility of rail systems to be implemented can be summarized as below along with their analytic parameters.

Table 5. The Present and Target Population and Density Values of the Districts in Sakarya

Districts	**The Size of District Areas (km^2)**	**Year 2011**		**Year 2023**	
		Population	***Density (person / hectare)***	***Population***	***Density (person / hectare)***
ADAPAZARI	315.23	251,680	798.40	295,406	937.11
AKYAZI	637.78	83,497	130.92	111,260	174.45
ARIFIYE	70.05	37,889	540.89	56,791	810.72
ERENLER	131.39	75,682	576.01	96,667	735.73
FERIZLI	177.48	23,654	133.28	32,805	184.84
GEYVE	655.19	46,892	71.57	62,131	94.83
HENDEK	660.93	73,918	111.84	98,050	148.35
KARAPURCEK	104.22	12,311	118.13	18,336	175.94
KARASU	410.98	53,928	131.22	64,496	156.93
KAYNARCA	336.70	23,290	69.17	24,276	72.10
KOCAALI	261.81	22,203	84.81	23,524	89.85
PAMUKOVA	301.27	26,978	89.55	39,623	131.52
SAPANCA	150.32	38,089	253.39	50,485	335.85
SERDIVAN	124.85	97,044	777.28	152,603	1222.29
SOGUTLU	137.13	14,229	103.76	18,252	133.10
TARAKLI	293.40	7,272	24.79	11,521	39.27

Traffic household surveys with 26,291 people representing 3 % of the population of the city have been conducted in order to predict the future travel demand framework. The data for transport model obtained through this survey are summarized in the table below.

Table 6. Urban Transportation Model Data for Sakarya

	2011	2018	2023
Population	643,201	760,247	843,852
Population Mobility	1,383,319	1,642,069	1,900,818
Journey Factor	2.15	2.16	2.25
Car Ownership (car / 1000 people)	135	143.5	152
The Ratio of Public Transportation	18.4%	20.2%	22%
Average Travel Time (travels with vehicles)	26 minutes	25 minutes	24 minutes
Daily Travel Capacity of the Transportation Modes			
Private Car	291,839	329,865	367,890
Public Transportation	311,597	363,065	414,532
Services	117,264	123,748	130,231

4. Evaluation of Rail Systems Proposed for Sakarya

At this point of the paper it is required to investigate the feasibility of Sakarya rail systems in terms of administrative, financial and technical point of view.

4.1. Administrative Feasibility

Solving the problems of urban public transportation is left to the responsibility of local governments. The relevant institutions at the national level provide treasury guarantee for foreign loans for the projects financially beyond the capacities of the local governments. Apart from this, the central government establishments play a role as approval authority and produce urban transport related policies and strategies.

The cost of the light rail and metro projects generally exceed the investment budgets available, and the minimum number of travels and depending income levels in feasibility reports may not be achieved straightforwardly. As a result, the return of urban rail project expenditures is not at a satisfactory level. The financial responsibility of the required cost of initial investment remains a duty for the Treasury.

Therefore, the problem was discussed by the central government and some criteria have been set up for the rail system projects to be proposed for the first time. In this way, high-cost railway system projects were taken under serious control in terms of the financial ability of the municipalities along with cost effectiveness of the projects. In addition, the practical problems of public transportation have been suggested to be primarily solved by improving the bus operation services available. The railway projects have been limited to those corridors having inadequate alternative public transportation systems and peak hour demand on one direction at the level of minimum 15,000 passengers / hour. This obviously resulted in a strict restriction of the projects by relating the investments to the financial power of the municipalities.

However, the number of passengers set up as a criterion by the Council of Ministers is under 15,000 passengers per hour in one direction for the majority of the rail systems in operation in Turkey.

Table 7 below illustrates this fact. The figures included in the table reflect those busiest corridors in Turkey.

Table 7. The Number of Passengers for One Way at Peak Hours for Some of The Rail Systems in Turkey

City	Railway System	Total Number of Passengers for the year 2012	The Average Number of Passengers per day	Number of Passengers for one way at peak hours
ISTANBUL	M1	77,000,000	213,888	12,833
	M2	84,000,000	233,333	14,000
	M4	52,200,000	145,000	8,700
	T1	115,000,000	319,444	19,166
	T4	33,000,000	91,666	5,500
ANKARA	Ankaray	3,786,214	105,173	6,310
	Ankara Metro	56,631,842	157,310	9,438
IZMIR	Metro A.S	52,243,350	145,120	8,707
	IZBAN	50,373,487	139,926	8,395
BURSA	Burulas	51,886,289	144,129	8,647
ESKISEHIR	ESTRAM	34,314,453	95,317	5,719

As can be seen from Table 7 only M2 (Sishane-Hacıosman) and T1 (Bagcilar-Kabatas) corridors meet the criterion of number of peak-hour passengers. Other lines including those not been presented in the table; Adana, Konya, Kayseri, Antalya, Gaziantep and Samsun stay far away from the required number of passengers to ensure that the system is feasible enough. In other words, rail system investments remain impossible in all major cities outside of Istanbul. This situation has been recognized by the Ministry of Development and figures have been revised to 7,000 passengers / h for trams (streetcars), 10,000 passengers / h for light-rail systems and 15,000 passengers / h for metro systems.

The transportation corridors have been investigated at this point of the study in Sakarya Metropolitan Municipality having the limits of the peak hour travel demand of 7,000 passengers in one direction at peak hours.

According to the analysis of the existing transportation corridors in Sakarya connecting Ring Road and D-100 highway along with transport corridor of Ataturk and Karaagac Avenue, Inonu and Karasu Street seem to be the most appropriate routes for rail systems in terms of the number of passengers and physical features available.

The proposed route starts from the Et-Balik junction the connection point of the city with D100 highway and progresses along Ataturk Avenue and terminates at the North Terminal. The data related the number of passengers for this route is given by table below.

Table 8. The Mass Transit Passenger Figures for the route of Et Balik-North Terminal

Routes	Daily Number of Passengers
Karasu	10,785
Kaynarca	4,658
Kocaali	4,440
Sogutlu	4,560
Ferizli	3,960
Ikizce and Kuzey	2,220
Subtotal 1	**30,623**
Akyazı	4.080
Hendek	5,200
Nehirkent	1,800
Karapurcek-Kucucek	9,920
Subtotal 2	**21,000**

Et Balık - Tekeler	15,000
Unkapanı-Dagdibi	1,560
Et Balık	7,200
Taskisigi	480
ENKA	960
Subtotal	**25,200**
TOTAL	**76,823**

To determine the number of passengers likely to use the rail system it is assumed that 80 per cent of the passengers would use rail system mode for their mobility requirements for this route. The remaining 20 per cent is expected to use other modes of transportation systems, including walking. The following table illustrates the prediction of the present and future passenger numbers.

Table 9. Future Passenger Projection for Proposed Railway System (Et Balik- North Terminal)

	2011	**2018**	**2023**
Population	643,201	760,247	843,852
Potential Number of Passengers	76,823	91,229	105,481
Number of Passengers for Proposed Railway System	61,458	72,983	84,384
Number of Passengers for Peak Hours	5,223	6,203	7,172

As can be seen from the table above, the number of peak hour passengers reaches the acceptable one way potential in year 2023 for the proposed project to be feasible with regard to the criterion set up by the central government.

The line connects north and south part of the city by passing through the city centre. The distance from the city centre to the North terminal and last southern station is 3.2 and 4.5 km, respectively. It is not an easy task to maintain competition with other forms of public transportation due to the difficulty in changing travellers` habits together with political and social pressures of the existing operators. Hence, it would be one of the main tasks for the railway system operators to ensure that the system is protected against other public transportation modes serving in the same area in order to maintain the productivity and number of passengers required.

4.2. Pricing Policy

As the commercial speed of street tram proposed ranges between 12 to 20 km/h and the centre is located only a few kilometres away from either end of the line, there may not be a remarkable travel time savings especially for the transit travellers. Low-fare policies are therefore needed to attract the transferring journeys passing through city centre. The determination of the exact figures of these fares for different types of the system users require another detailed study which is beyond the scope of this paper. The main point, however, to be paid attention should be the balance between the reduced revenues and the operating costs of the system at a certain level of service.

4.3. Financial Feasiblity

The investment cost of the proposed rail system was evaluated in terms of investment financing, operating expenses and income. Expropriation, Infrastructure and Multi-vehicle (car) expenses are the main items to investigate the initial investment cost.

Average commercial speeds of paratransit minibus and dolmush systems providing public transportation services in Sakarya are 24.9 km / h and 20.32 km / h, respectively. Hence, it is proposed that the railway system should have its own separated routes apart from those inevitable grade junction locations so that a competitive operating speed of 20-25km/ h is achieved. Some expropriation and demolishing is necessary due to insufficient width of right-of-way to achieve this objective. The required number of business and residential buildings to be demolished is 101 and 600, respectively. There is also a need for 25 acres of land for workshop facilities, vehicle storage

and transfer centre. Table 10 below clarifies the total amount of the cost of expropriation.

Table 10. The Cost of Expropriation

Type	Number - Size	Cost (TL)
Residential, Business building	600	90,000,000
Land	25 Acres	23,000,000
Re-arrangement of the place of demolition	-	10,000,000
TOTAL		***123,000,000***

In addition to this cost, the infrastructure cost is estimated as 56,000,000 TL and the fleet cost is calculated as 90,750,000 TL. Thus, the total initial investment cost resulting from all the analysis and calculations is 269,750,000 TL. Considering the total income of Sakarya Municipality being 120,713,002 TL and the necessity that 59 per cent of the project cost must be covered from the equities of the Municipality, this size of investment in rail system will create a huge strain on the financial structure of Sakarya Metropolitan Municipality.

The estimated total annual operating cost consisting of maintenance, repair, administrative personnel, labour, energy and unforeseen expenses is estimated as 7,956,846,000.000 TL.

As mentioned earlier, the ticket prices determined to maximise the number of users for the rail system is estimated as 1.04 TL for the whole route passengers and 0.40 TL for the transferring passengers. Based on these figures, the total annual income is computed as 19,928,124.00 TL.

The income and expense analysis results in the fact that the difference between total income and expenditure of the system is + 6,661,612.00 TL in favour of income.

Table 11 below demonstrates the analysis of income and expenses of the proposed project for the target year 2023.

Table 11. Income and Expense Analysis

Annual Operating Cost	**7,956,846.00 TL**
Annual Depreciation Cost	5,309,666.00 TL
Total Expense	13,266,512.00 TL
Total Income	19,928,124.00 TL
Difference Between Total Income and Expense	+ 6,661,612.00 TL
Total Investment	269,750,000.00 TL

5. Conclusion

This study mainly focused on the economic and constructional assessment of the potential railway systems in Sakarya Municipality in general. Following, Etbalık-North Terminal rail line system was proposed as the main route to be constructed. The evaluation of this line was based upon the vehicle operating - travel time, fuel consumption, car emission, car ownership, noise level, accident and water pollution cost elements. The obtained results by the transportation model to compare the benefits and costs of the proposed railway project resulted in a feasible solution on condition that the project is carried out in accordance with land use acquisitions. The internal rate return (IRR) computed as 12.4 is higher than the decision value 12.0. This means that although the proposed project is economically feasible, the IRR value is quite close to the acceptable level. The detailed construction projects, which are not investigated in this study, must take into account of the fact that the project area is 1st degree earthquake zone and the city is constructed on a thick layer of silt. For this reason, the cost of initial investment may increase as a result of detailed soil surveys. The biggest challenge in implementing the

urban railway projects, however, in Sakarya is the high cost of expropriation due to insufficient land available in the city centre along with the huge amount of buildings to be acquired and demolished.

References

[1] Guidelines for Traffic Impact Assessment. Published by The Institution of Highways and Transportation 1994; London.

[2] Kerner, B. S. (2009). Introduction to modern traffic flow theory and control: the long road to three-phase traffic theory. Springer.

[3] de Dios Ortúzar, J., & Willumsen, L. G. (2001). Modelling transport (Vol. 7). Chichester:: Wiley.

[4] Post, R. C. (2007). Urban mass transit: the life story of a technology. Greenwood Publishing Group.

[5] Transport in the Urban Environment ", 1997, Published by The Institution of Highways and Transportation, London