EFFICIENCY ANALYSIS OF CARGO TRAM FOR CITY LOGISTICS COMPARED TO ROAD FREIGHT TRANSPORTATION: A CASE STUDY OF ISTANBUL CITY

Prof. Omer Faruk Gorçun, PhD
Kadir Has University
Campus of Kadir Has University, Selimpasa / Siliviri – Istanbul, Turkey
Phone: +90 212 731 9001; Fax: +90 212 731 5737
E-mail: omer.gorcun@khas.edu.tr

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Abstract

In recent years, changes relating to logistics approaches have been observed. Logistics activities at a micro level have begun to gain an importance compared to logistics activities at the macro level although global logistics are still important. Urban logistics, also known as city logistics, has come to gain an importance for regional and global actors of logistics and supply chains. While the economic costs were the most important concept in the past, nowadays, external costs have become an important factor in addition to the economic cost of logistics. Not only improved logistics operations but also environmentally-friendly logistics activities are promoted by local authorities, international institutions and governments. Regulations related to green logistics are being put into effect by these actors. Logistics operators and actors are seeking new operation alternatives for more effective, productive and environmentally-friendly logistics and transportation operations.

Cargo trams can provide effective solutions for urban logistics problems. Cargo trams which use urban passenger transportation tram lines can be beneficial and important instruments to solve urban logistics problems. Road transportation plays a key role in causing city logistics problems. When traffic congestion, environmental and air pollution, casualties and injuries caused by road accidents are considered, we see there are significant detrimental results to road transportation. If the share of road transportation can be reduced, these detrimental results can be reduced. One of the beneficial ways of solving this problem is to reduce the number of road vehicles entering the center of the city. In order to reduce road transportation in urban areas, the use of cargo trams can provide numerous advantages in urban freight transportation. During the day, cargoes can be carried with these vehicles as one or more cargo wagons added to the passenger tram. At night, when it is not used for passenger transportation, it can be used more intensively. When cargo trams' use is increased in urban areas, emissions, accidents, loss of life and other detrimental results can be reduced. In this study, impacts of cargo trams on urban logistics system are evaluated in terms of costs and benefits. Furthermore, reduction in the external costs of transportation are described in the use of cargo trams in urban areas. In this paper, urban logistics activities in Istanbul city were selected as a case study. Attainable potential advantages of using cargo trams on available passenger tram lines are defined in comparison with road transportation.

Key words: Urban Logistics, Cargo Tram, Freight Transportation, Cost-Benefits Analysis

1. INTRODUCTION

City logistics has gained an importance in recent years. Reducing the external costs such as environmental and air pollution, noise, accident and losses is an important factor as is increasing the operational efficiency and productivity of city logistics operations. Transportation plays a key role in urban areas and a functional logistics system depends on reliable, systematic and sustainable freight flow. The main purpose of urban logistics systems is to respond to the needs of the city. However, the costs and benefits of the logistics system needs to be taken into account. While the economic benefits increase as a result of improving of logistics activities, the living conditions of inhabitants can be adversely affected by logistics and transportation operations. Urban freight transportation causes a great number of problems such as congestion, air and environmental pollution, noise, emission and accidents, etc. The costs which affect the citizens directly are the sanitary costs due to the noxious emissions of the vehicles, the noise costs caused by the necessity of reducing the noise in the streets having a high daily average intensity, the congestion costs which mainly cause losses of time both to the users of the roadway and to the drivers of vehicles, and the costs of injury or death due to accidents amongst the urban circulation of goods vehicles.[18]On the other hand, the effect levels of these problems is not constant, they can change depending on many factors. If population, income level of habitants are increased in a city, volume of the

[18] Barceloa I. F., Campos-Cachedaa J. M. (2012). Estimate of social and environmental costs for the urban distribution of goods. *Practical case for the city of Barcelona The Seventh International Conference on City Logistics, Procedia - Social and Behavioral Sciences 39*, p: 821.

logistics and transportation activities may increase simultaneously. Problems and the impacts caused by logistics and transportation activities may increase. International and domestic trading has been showing an upward trend. This situation suggests that the volume of logistics and transportation activities will gradually increase as it depends on the volume of trade. If this continues in the same way and something is not done as a precaution, problems will be intolerable in the near future.

New transportation alternatives should be sought in order to solve the urban logistics problems because reducing the freight flow is not possible. However, local authorities and governments have not created an effective and sustainable solution for solving urban logistics problems. The solutions that are created by policy makers should be imaginative and innovative. When the logistics potentials of urban areas are evaluated carefully, logistics opportunities which have been ignored previously can be seen more clearly. In order to reduce the economic and external costs of urban freight transportation, one of the best ways is to increase the level of use of the rail system rather than road transportation. In a city, if light rail systems which can be used for passenger transportation are available, these light rail lines can be used for urban freight transportation without new railway infrastructure costs.

Light freight rail systems can provide systematic and regular freight flows in urban areas, they can also reduce the energy consumption, congestion, noise, emissions and other negative results that road transportation greatly contributes to. This system can also be integrated with the urban logistics system, and furthermore it may become part of an intermodal and combined transportation chain as an instrument which is used in the collection and distribution process. Collected cargo from different point on the light rail line can be transported by cargo trams to intermodal freight terminals. In addition, cargoes can be distributed from intermodal freight terminals to the delivery points by cargo trams.

There are extremely few studies related to the use of light rail systems for freight transportation in urban areas. Furthermore, there is no study on this topic in Turkey. The main purpose of this study is to indicate the potential of light rail systems. In this study, the environmental and economic impacts of light rail systems used in urban areas are analyzed. The results of this study may provide guidance for decision-makers and help fill an important gap. In this study, two main functions, namely distribution and collection, using light freight rail systems is evaluated in the light of concepts such as productivity and efficiency. In addition to passenger transportation, use of light rail systems for urban freight transportation can provide a more effective and productive logistics system configuration.

2. TRANSPORTATION SYSTEMS IN ISTANBUL CITY

Istanbul is one of the busiest cities in the world. Because of the fairly dense population living in Istanbul city, the volume of road traffic and density is extremely high. On the other hand, this city is dependent on other inland and overseas regions to meet its needs for products, semi-products and raw materials etc. For example, the amount of agricultural products produced in the urban area is not sufficient to meet the needs of the city, and its dependence is more apparent for food products, especially fresh fruits and vegetables., Large amounts of raw materials and semi-finished goods are daily brought to Istanbul, while large amounts of cargo is sent out.

There are many logistics nodes in Istanbul city. Although logistics activities and urban freight transportation are carried out and road freight transportation is mostly preferred between these logistics nodes freight flow is not systematic and orderly. It is common in urban distribution networks for suppliers to distribute only their own goods to retail outlets. This involves each supplier operating vehicles to carry each retailer's goods and vehicles must visit each retail outlet regularly from the supplier's warehouse[19]. When considering the environmental pollution, noise, accidents, congestion and energy cost the external costs which result from road transportation is very high and it is not tolerable. Air quality of Istanbul city is very poor and it is causing adverse living conditions for inhabitants. Traffic volume can reach a peak in the center of this city. According to statistics issued by the general directorate of highways of the republic of Turkey, the total number of vehicles that pass across the two bridges in istanbul city has reached 353,475, the number of heavy freight vehicles which operate along the same route was also recorded as 62,879[20]. Urban transportation is provided by two main roads which are the D-100 and E-80 highways. But road use is not balanced for either of these highways. The share of heavy freight vehicles in total traffic reaches 40% at night[21]Whereas, it was observed that the share of automobiles is lowest at the same hours. More importantly, the traffic is concentrated in the city center, and traffic density falls very sharply from the city center to the outskirts of the city. Although the number of vehicles passing across the bridges of Istanbul is very high, it has been observed that the number of these vehicles greatly decreases at the next observation point. In recent years, the number of vehicles passing through the center of town was recorded

[19]Thompson R. G., Hassall K. P. 2012. A collaborative urban distribution network, *Procedia - Social and Behavioral Sciences 39*, p: 215.
[20]General Directorate of Highways of Turkey (GDH), 2012. Statistics of Transport and Traffic, Ankara, p: 34.
[21]General Directorate of Highways of Turkey (GDH), 2011.Specifications and Trends in Heavy Freight Transport on Highways, Ankara, p: 35.

as 353.475. In contrast, the number of vehicles observed in the next observation point was recorded as 219,761[22]. As a result, 133,714 vehicles are used within the city. The distance of routes located between observation points is 82.8 km. and the average number of vehicles that use these routes is calculated at 1615 per kilometer. More importantly, it was seen that, the total number of heavy freight vehicles was observed as 62,872 daily. Approximately 33,763 heavy freight vehicles reach the next observation points. However, 29,129 heavy freight vehicles were used in the center of the city. This figure is not appropriate for sustainable urban transportation. Even worse, creation of a systematic, sustainable and environmentally-friendly urban logistics system cannot be possible with such negative conditions.

Figure 1 Urban Transportation Networks and Traffic Indicators in Istanbul City

On the other hand, changes related to trading and shopping habits have been observed, in the past, people did their shopping from small-scale shops located on both sides of the wide streets. Nowadays, people prefer large scale shopping malls to meet their different needs for things such as shopping, entertainment and socializing. Unlike the examples seen in European countries and the United States, shopping malls are located mostly in the center of Istanbul city. Shopping malls, which are located in the center of the city causes high levels of traffic congestion because of the use of freight vehicles which supply products and transport the waste together with road traffic caused by customers' private cars. Nowadays, 91 shopping malls are located in Istanbul city and the number of stores located in these shopping malls vary between 12 and 470. The average number of stores is 101 per shopping mall. Approximately 68% of these stores are supplied daily and the number of road freight vehicles used to supply the stores may reach 6256 daily.

As a result, shopping malls cause intensive logistics operations in a city. Because road freight transport is the most preferred transportation mode, costs of urban logistic activities is very high. External and economic costs of these operations are not tolerable. On the other hand, the number of shopping malls has been showing an upward trend in the center of the city. According to Reports of European Commission[23], when the external costs of road transportation such as congestion, environmental and air pollution, accidents, fatalities and economic losses are taken in to consideration, it is seen that, the threshold related to creating a solution for the urban logistics problems has already been exceeded. If it continues in this way, neither logistics activities nor urban transportation can be carried out in the near future. Therefore, new and untried freight transportation alternatives should be considered by policy makers and researchers.

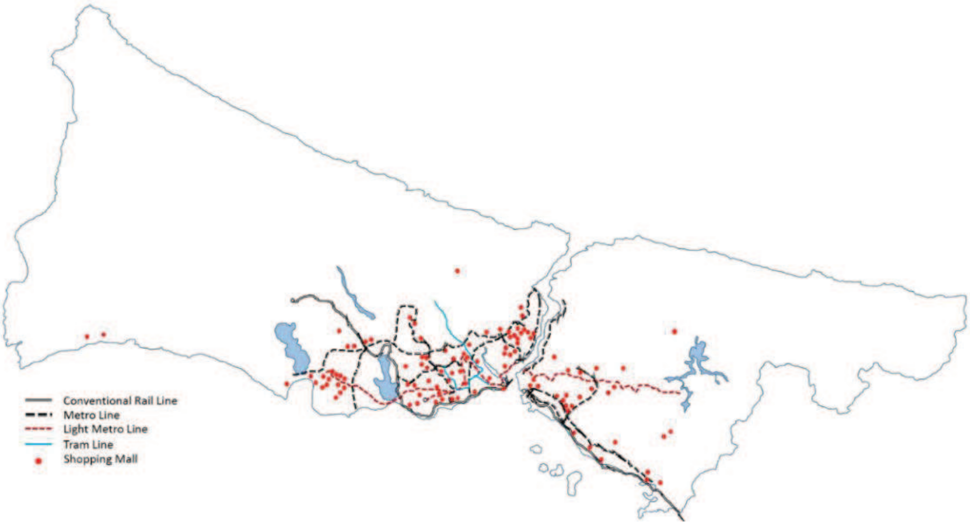
[22]General Directorate of Highways of Turkey (GDH), 2012. Statistics of Transport and Traffic, Ankara, p: 34.

[23] European Commission, An inventory of measures for internalizing external costs in transport, Directorate-General for Mobility and Transport, DM 28 - 0/110 – Archives, B-1049 Brussels, Belgium, November 2012 FINAL,p: 107-109.

3. LIGHT RAIL SYSTEMS IN ISTANBUL CITY AND ITS POTENTIALS FOR CARGO TRAM OPERATIONS

Urban light rail systems may be an effective solution to the problems related to urban logistics systems. These systems can provide the opportunities to reduce the external costs of urban logistics operations carried out by road freight transportation and can especially help to reduce the emissions, economic costs, accidents etc.

Figure 2 Urban Rail Systems and Shopping Malls in Istanbul City



Nowadays, four different urban rail systems are operated in Istanbul city. These are conventional trains, metro rail system, light rail system and trams. Except for conventional rail transportation, they are used only for urban passenger transportation and using these transportation systems for freight transportation was not taken into consideration in Turkey until today. In Istanbul, urban rail systems intersect in the city center and they pass near all of these shopping malls. As a result, they can provide opportunities for freight transportation.

In both of sides of Istanbul city, urban rail systems are available and connections between urban and sub-urban areas of this city are provided by these systems. Usage rates of the urban rail systems are increasing in the city center compared to sub-urban areas. The starting point of the tram line is the Beşiktaş tram station and it is divided into two main routes in Topkapi tram station and the first tram line runs between Topkapi and Bağcılar stations. On the tram line, trams are run between Zeytinburnu and Habibler tram stations.

The second urban transportation type is conventional trains. They can provide an opportunity to link east and west of Istanbul city. On the other hand, conventional rail lines have been uninterrupted by the Marmaray project that provides passage under the Istanbul Strait. In this rail system transportation between Gebze and Halkalı rail stations can be provided continuously. This rail line is mostly parallel to the shores of Istanbul, many shopping centers and shops are located near conventional railway lines. Nowadays, 42 railway stations are present on the conventional rail line. More importantly, improvement practices on the conventional railways lines have been carried out by policy makers recently. Particularly infrastructure rehabilitation works were carried out by the government at great speed.

The third urban transportation system is the subway. In Istanbul, the subway construction begun in 1992 and it was opened on 16 September 2000. In the past, it operated between Haciosman and Şişhane subway stations and carried an average 285.000 passenger per day. They were not extensive and they serviced an extremely limited area. The subway operated between Hacıosman and Taksim subway stations only, and the distance of this line was eight kilometers until recently. But this line was expanded to the Yenikapı subway station. In spite of the subway system giving transport service to a limited area, there are many shopping malls in this area and they are mostly located near this line.. Nowadays, 21 shopping malls and 312 stores are located around this subway line. In addition the number of visitors which come to these centers daily is very high and these shopping malls can g respond to intensive customers' demands. As a result of this, logistics material flows should be fast and faultless, on the other hand, excellent planned and organized logistics operations are needed for these shopping malls. The length of this subway line is 19.5 km at present.

Another urban rail transportation type is light rail systems. In Istanbul city, there are two main light rail lines: (M1) Aksaray - Istanbul Ataturk Airport light rail line and (M3) Basaksehir light rail line. These lines intersect at Kirazlı light rail station. Since 1989, the light rail lines carry to 320.000 passengers daily. The length of this line is 24, 77 kilometers and 22 rail stations are located on this line. 330 transportation operations are performed daily in both directions of this line. Light rail trains are run every three minutes. Another light railway line is Başakşehir light rail line. Its length is 16 kilometers and the number of station is eleven on this line. It was opened on 22 November 2013. Its capacity is 70.000 passengers/hour. 18 shopping malls are located near the two light rail lines.

Secondly, in order to have successful logistics and freight transportation operations, another requirement is the presence of logistics freight terminals and freight transfer points which should be located at the right places. These places should provide opportunities to reduce the logistics costs as well as improving the logistics freight flows. On the other hand, they must help to provide the integration between all the urban transportation systems and other logistics nodes. The new logistics terminals and freight transfer points located at appropriate locations is required in order to increase the urban logistics speed to an optimum level and to more effectively use these urban rail systems. Nowadays, shopping malls, trade centers and stores are clustered in certain regions. In the European side of Istanbul city, a large number of malls and shopping centers are mostly located between Maslak and Şişli regions. Seventeen malls are present in this area. Another region with many shopping malls is the Bayrampaşa - Topkapı region. Eight malls are located in this area, and the third important region is Yenibosna - Zeytinburnu region and it hosts fourteen shopping centers. Finally the fourth and last region is Beylikdüzü – Avcılar region, where approximately fifteen shopping centers are present.

Figure 3 Logistics Nodes and Network of Urban Rail Systems in Istanbul City

- *First Region* : Maslak–Şişli Region (17 shopping centers, subway line)
- *Second Region* : Bayrampaşa–Topkapı Region (8 shopping centers, tram and light rail line)
- *Third Region* : Yenibosna–Zeytinburnu Region (14 malls, tram, conv and light rail line)
- *Fourth Region* : Beylikdüzü – Avcılar Region (15 shopping centers, conventional line)

In the Anatolian side of Istanbul city, 27 shopping malls are located and most of them are near the urban rail systems. But connection between malls and urban rail system is not available because the rail systems are only used in passenger transportation. Two urban rail transportation lines, a conventional rail line and a subway are present in the Anatolian side of Istanbul city. At the same time a new subway line which will be located between Sancaktepe and Üsküdar subway stations is under construction. Completion and opening of this line is expected at the end of 2014. The conventional railway line works between Gebze and Haydarpaşa rail stations. The conventional trains carry freight as well as passengers in this line. The length of this line is 44.1 kilometers and the number of railway stations is 27.

On the other hand, the large number of organized industrial zones, solid waste collection centers, and fresh food and sea food terminals, small-medium scale industrial zones and explosive – flammable freight terminals are located around these lines. They can be defined as logistics nodes in Istanbul city.

They are not correctly positioned as appropriate to logistics needs of the city. Freight flows occur from these logistics nodes to shopping malls and stores, so these nodes are defined as suppliers for the urban logistics system. As they are not connected with the shopping malls and stores at the required level and road transportation is mostly preferred for transportation between logistics nodes and suppliers. All the logistics nodes that are located in Istanbul city are listed as below.

- *Organized Industrial Zones :* Beylikdüzü, Bahçeşehir, Tuzla and Umraniye regions
- *Fresh Food Terminals :* Bayrampasa and Kadıköy regions
- *Sea Food Terminals :* Yenikapi regions
- *Explosive Mat.Terminals :* Avcılar and Kadıköy regions
- *Solid Waste Terminals :* Bakırköy, Çatalca, Bağcilar, Besiktas, Umraniye and Maltepe regions

Currently, links provided by railway lines are not available between these logistics nodes in this city. Logistics activities are carried out by road freight transportation because of the lack of railway transportation alternatives. On the other hand, Istanbul city does not have specific logistics infrastructures such as freight transfer points and centers, urban intermodal freight terminals, cross-docking areas and consolidation centers.

The use of the urban passenger rail transportation systems for urban freight operations and the construction of logistics infrastructure in appropriate places can be one of the best ways for solving urban logistics problems. On the other hand, these logistics facilities should be connected with road and rail freight transportation modes, including maritime transportation. Four scenarios are proposed drawing on specific conditions and existing resources with urban rail systems in Istanbul city.

Use of the urban rail systems for distributing the products from suppliers to shopping malls and stores. The use of one or two wagons which will be added to the passenger wagons may be possible for deliveries of goods in the daytime. At the same time, urban rail lines are not used for passenger transportation at night, so it can be used more intensively. On the other hand, trip frequency and the number of trips are very high in all urban rail lines. As shown in Table 1, minimum number of trips is 165, minimum frequency of trips is two minutes. When all the urban rail system is taken into consideration, the number of trips was recorded as 1336 daily.

Table 1 Urban Rail Lines and Trip Specifications

Urban Rail Lines and Trip Specifications			
No	Name of the Line	Number of Trips	Frequency
M1	Aksaray - Atatürk Airport	165	3
M2	Yenikapi - Haciosman	225	9
M3	Başakşehir - Olimpiyatköy	216	6
M4	Kadıköy - Kartal	270	4
T1	Kabataş - Bağcılar	295	2
T4	Topkapi-Habibler	165	5

Freight trams can be used for distributing the goods from suppliers to shopping malls. They can also carry the solid waste from shopping centers to the solid waste terminals. If it can be applied, the reduction of economic and environmental costs of urban transportation may be possible because of an increase in the share of railway transportation.

4. METHODOLOGY

Cost benefit analysis (CBA) is the most preferred methodology for evaluating a project that is defined in monetary terms. The main aim of CBA is defining the pros and cons of a project. In this evaluation process, benefits which will be obtained are compared to the costs of projects. If the benefits of a project are higher than the costs of this projects, this project may be preferred and implemented by decision makers. Otherwise, it may be ignored.

CBA methodology can help to evaluate the applicability of a project. Because public resources are limited, sometimes decision makers may have to choose between projects. CBA methodology can provide an effective solution for the decision-making processes. It can eliminate the uncertainty or it may reduce the uncertainty to a reasonable level. This methodology consists of a number of sub-processes and techniques. Initially, possible alternatives should be determined and appropriate and fair ways to examine their costs and benefits should be determined. Secondly all the costs and benefits should be defined within the framework of constant and quantitative values. For each project which is evaluated, costs and benefits should be compared with each other. After definition of the costs and benefits of the selected project, a systematic framework in the next process should be determined.

Cost benefit analysis consists of eight stages. In the first stage, a needs analysis, defining the limitations and describing the targets of the project is necessary. Secondly, to make a successful comparison among all the possible options, defining all options has great importance. As a result, all options should be defined by researchers. Third stage is data collection. In this process all datasets are collected and they are grouped and classified. In this study, the costs of the existing urban rail systems in Istanbul city were compared with their benefits and obtained results were analyzed. Costs of urban rail systems consist of economic costs such as energy consumption cost, purchasing costs of freight trains, maintenance-repair costs, logistics infrastructure installation costs and operation costs, including external costs such as costs of environmental pollution, costs of accidents and losses of life and economic assets.

Key factors in costs and benefits of transit include length of directional route miles, load factors, and the proportion of vehicles operating at road grade[24]. Energy costs are important in determining operation expenditures, and there is interaction among these factors as well[25]. In this paper, only economic costs and environmental costs were taken into consideration and other costs were excluded from the scope of this study.

5. ANALYSIS

One of the best ways to determine the optimum transport system is an evaluation of the economic costs of these transport alternatives. The costs of a transport system can be considered as unit costs per load-kilometer. Therefore, the specific cost calculation methodology focused to a fixed value is necessary to the definition of all the costs of transportation systems. Most appropriate cost evaluation methodology to obtain a successful result is the levelized cost methodology. In order to define total transportation costs more comprehensively, technical, economical and operational parameters for the transportation modes, such as road, rail and sea routes, should be set clearly as well as the effects of external costs, such as the costs of the accidents, emissions and noise[26]. In this study, all the costs of the selected two transportation alternatives of road transportation and urban rail freight transportation for logistics operation in urban area were defined in a framework of a fixed value as load-kilometer. This generalized cost evaluation methodology can be applied for both transport alternatives. According to this methodology, the costs of the transport system consists of investment costs (C_{in}), energy consumption cost (C_{ec}) and environmental costs (C_{em}) and it excludes other costs such as noise, accidents, maintenance and repair costs, operation costs, etc. d represents the distance between two points. Total costs (C_t) of transport system can be calculated as below;

$$C_t = uC_{in} + uC_{ec} + uC_{ex} \quad (1)$$

$$uC_{in} = \frac{\left(\left(\frac{C_{in} . n_{vec}}{v_{el} . a_{ot} . d_{ot} . m}\right) . [uo_t + (n_s . wt_s)]\right)}{v_k . d} \quad (2)$$

$$uC_{ec} = \frac{\left(C_{ec} . u_{ep} . d_{po}\right)}{v_k . d} \quad (3)$$

$$uC_{em} = \frac{\left(\frac{(e_{co} . d . n_{vec})}{v_{tk}}\right) . m_{ec}}{v_k . d} \quad (4)$$

5.1. Cost of road transportation

In this study, cost analysis of road transportation is realized in terms of four routes to compare with costs of urban freight rail systems. Urban rail lines are available on selected routes as well as road transportation alternatives. Cost calculation depends on monetary terms and can be calculated in terms of unit ton-km.

Each route was analyzed due to their different characteristics. On the other hand, all the factors which are affect transportation costs were described in similar terms. In this model, road freight vehicles will stop at all the shopping malls located in a defined distribution zone. The first distribution zone (Z1) is the region between Hacıosman and Yenikapı. 18 shopping malls are located in this region.

When a road freight vehicle stops at all the malls, the length of the route is 107.5 km per trip. Capacity of each road freight vehicle is 3.5 ton. A distribution operation can be completed in 168 minutes from starting point to end point. Average waiting time is ten minutes per stop. Extraordinary circumstances such as accidents and traffic congestion, were not included in the evaluation. The second distribution zone (Z2) is the region between Aksaray and Bağcılar. The number of malls is 30 in this region and the total operation time is 164 minutes per distribution operation and the length of the route is 100.2 km.

The third distribution zone (Z3) is the Anatolian region starting at Pendik and ending at Kadıköy. Total distance between the two points is 122 km and a distribution operation is completed in 178 minutes. 21 malls are located in this region. The fourth distribution zone (Z4) is the region located between Bağcılar and Bahçeşehir.

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[24]Lane B. W., Sherman C. P. 2013. Using the Kaldor–Hicks Tableau to assess sustainability in cost–benefit analysis in transport: An example framework for rail transit, *Research in Transportation Business & Management 7*,p: 93.

[25]Savage, I. 1997. Scale economies in United States rail transit systems. Transportation Research Part A: Policy and Practice, 31(6), 459–473.

[26]Sahin B., Yilmaz H., Usta Y., Guneri A. F., Gulsun B. 2009. An approach for analyzing transportation costs and a case study European Journal of Operational Research 193, p: 1–11

5 malls are located in this region and the length of this route is 49.7 km. The distribution operation is completed in 72 minutes. All of variables and symbols can be seen in Table 2 for road transportation related to each lines. All of the variables are obtained from official source. In Istanbul metropolitan area, using road vehicles types are limited. In general, a road freight vehicle can be entered to center of city if its capacity is under 3.5 tones.

Table 2 Urban Distribution Specifications by Road Freight Transportation

	Unit	Symbol	Z1	Z2	Z3	Z4
Investment Cost of Vehicle	C_{in}	€	23.500	23.500	23.500	23.500
Number of Vehicles	n_{vec}	Number	15	1	1	1
Unit Vehicle Capacity	v_k	tons	3,5	3,5	3,5	3,5
Economic Life of Vehicle	v_{el}	Year	25	25	25	25
Annual Operation Time	a_{ot}	Day	365	365	365	365
Daily Operation Time	d_{ot}	Hour	24	24	24	24
Unit time	m	Min	60	60	60	60
Time per Operation	uo_t	Min	168	164	178	72
Number of Stations	n_s	Number	18	30	21	5
Waiting time per Station	wt_s	Min	10	10	10	10
Unit Energy Price	u_{ep}	€	1,5	1,5	1,5	1,5
Unit Energy Consumption	C_{ec}	Lt/100 km	30%	30%	30%	30%
Distance per operation	d_{po}	Km	107,5	100,2	122	49,7
Emission coefficient	m_{ec}	gr	175	175	175	175
Emission Marginal Cost	m_{ec}	€	75.66	75.66	75.66	75.66
coefficient Gram to ton	v_{tk}	ton	1.000.000	1.000.000	1.000.000	1.000.000

For each route, when the determined values are considered, total costs of road transportation can be calculated. Total and unit costs can be seen below; while unit cost of road freight transportation is calculated as 0.411 € / ton$x$km as below in Table 3.

Table 3 Road freight transportation costs

	Z1	Z2	Z3	Z4	Total
Cost of Investment (€)	0,00165	0,00237	0,00163	0,00125	0,00690
Cost of Energy Consumption (€)	0,12857	0,00378	0,12857	0,12857	0,38950
Cost of Emission (€)	0,00378	0,00378	0,00378	0,00378	0,01513
Total Costs (€)	0,13401	0,00993	0,13398	0,13361	0,41153

5. 2. Cost of urban rail system

Total costs of urban rail systems show similar characteristics to road freight transportation. Whereas, these transport systems cannot provide optimum solutions related to door to door transport operations. Cargoes may be distributed to malls located near the urban rail lines. If the shopping center is located at a point far from the railway lines, short-distance road transportation can be used to solve distribution problems. On the other hand urban freight rail vehicles can carry 15 tons of cargo per operation. These vehicles can run on a single line and cargoes can be distributed to malls in one direction. On the other hand, solid waste can be collected from shopping centers while returning to the starting point. When the cost evaluation methodology is applied to road freight transportation in urban areas, cost analysis should be done for each urban freight rail alternative because six urban rail lines are available in this city. On the other hand, each rail system has different characteristics and unique conditions. All of the urban freight rail lines and their specifications are shown in Table 4.

Table 4 Urban Rail Lines and Trip Specifications

Description of Vehicles	Sym	Unit	M1	M2	M3	M4	T1	T4
Invest. Cost of Vehicle	C_{in}	€	1,800,185	1,800,185	1,800,185	1,800,185	1,800,185	1,800,185
Number of Vehicle	n_{vec}	Num.	1	1	1	1	1	1
Unit Vehicle Capacity	v_k	tons	15	15	15	15	15	15
Economic Life of Vehicle	v_{el}	Year	25	25	25	25	25	25
Annuel Operation Time	a_{ot}	Day	365	365	365	365	365	365
Daily Operation Time	d_{ot}	Hour	24	24	24	24	24	24
Unit time	m	Min	60	60	60	60	60	60
Time per Operation	uo_t	Min	52	27	20	32	65	42
Number of Station	n_s	Num.	22	16	11	16	31	22
Waiting time per Station	wt_s	Min	5	5	5	5	5	5
Unit Energy Price	u_{ep}	€	1,5	1,5	1,5	1,5	1,5	1,5
Unit Energy Consumption	C_{ec}	liter	0,04	0,04	0,04	0,04	0,17	0,17
Distance per operation	d_{po}	Km	49,54	39	31,8	43,32	37	30,6
Emission coefficient	m_{ec}	gr	2,7	2,7	2,7	2,7	2,7	2,7
Emission Marginal Cost	m_{ec}	€	75.66	75.66	75.66	75.66	75.66	75.66
coefficient Gram to ton	v_{tk}	Ton	1.000.000	1.000.000	1.000.000	1.000.000	1.000.000	1.000.000

When all the zones are considered, M2 subway line is located in zone Z1, M1, T1 and T4 are located in Z2, zone of M4 are run in zone of Z3 and M3 subway line can provide a service in Z4. From table 5, transportation costs for each zone can be calculated as below;

Table 5 Urban Rail freight transportation costs

	Z1	Z2	Z3	Z4	Total
Cost of Investment (€)	0,02506	0,12954	0,02361	0,02154	0,19975
Cost of Energy Consumption (€)	0,00400	0,03800	0,00400	0,00400	0,05000
Cost of Emission (€)	0,00001	0,00004	0,00001	0,00001	0,00008
Total Costs (€)	0,02907	0,16758	0,02764	0,02557	0,24986

As seen in table 4, unit energy consumption is converted from mega joule (MJ) to one liter of diesel. Average energy consumption of trams is 5.5 MJ per kilometer and energy use of subways is 1.3 MJ per kilometer.[27] When one liter diesel is equal to 32.2 MJ energy, unit energy consumption of trams is equal to 0.04 liter diesel per kilometer, and energy consumption is equal to 0.17 liters in trams. At the same time, unit emission values of trams and subways is equal to 2.7 gr CO_2/kilometer. CO_2 emissions have not been part of Euro emission standards to date[28]. However this is about to change with the European Commission planning to impose limits on the amount of CO_2 emitted by new vans, restricting it to 175 g/km CO_2 by 2012 and 160 g/km CO_2 by 2015 (European Commission, 2008). The calculated emission value caused by heavy road vehicles is very high. According to an important scientific study realized by the Research Center of Marine and Climate at the University of Hamburg, the marginal cost of emission is calculated as 104 dollars per ton[29]. Unit energy cost is 1.5 € currently in Turkey. Unit transportation cost including the investment, energy consumption and external cost can be calculated as 0.249 €/tonxkm. When this figure is compared to road transportation costs, it is seen to be almost half the road transportation cost.

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4. CONCLUSION

If road freight transportation cost is compared to urban rail transportation costs, the urban rail transportation cost is almost half the road transportation cost in urban areas. Furthermore urban rail systems can provide better environmental conditions and more reduced external costs as well as economic advantages compared to road transportation. Urban rail systems can affect the environment at almost half the rate of road transport. Consequently, the usage rates of urban rail freight systems can be increased, and obtained benefits may be increased in urban logistics operations. Finally, the benefits provided by more effective logistics activities may affect all the parties of logistics, such as companies, governments, local authorities, users and inhabitants.

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