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Environmental development model of bus rapid transit (BRT) system in term of reduced environmental degradation

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Considerable economic and environmental advantages of using Bus Rapid Transit (BRT) introduced it as a managerial preference for improved transportation in Tehran and metropolises. The purpose of the present research is to study the effect of air pollutants and particulate matter on BRT routes as well as the role of this system in reducing fuel consumption and air pollution optimal management. In this regard, air pollutants and particulate matters were measured in 14 stations of Tehran BRT, line 1 using specialized instruments and compared with national and international environmental standards. The results of this study showed that the most significant effect of BRT is to decline social costs of consuming less fuel. In addition, direct measurement results of pollutants demonstrated that despite increased traffic volume, air pollution reduced in understudied routes following launching BRT line. Finally, the results revealed the proper performance and efficiency of BRT in metropolises, in particular, Tehran, comparing former conventional bus system. However, achieving optimal transportation system in Tehran focused on developing public transportation, particularly BRT, it is necessary to prioritize environmental concerns in development planning.

Keywords: Bus rapid transit (BRT), air pollution, environmental pollutants, particulate matters, fuel consumption

In 2003, about 38% of Asian population (almost 1.2 billion people) lived in cities; by 2020, according to the estimation, the ratio of urban population shows 50% increase which will be raised to 2 billion urban people [1]. Given that urban areas serve citizens' social and economic requirements, transportation is one of the most critical issues.

Transportation is the major issue of sustained cities, as it consumes over 20% of total energy and plays the main role in air pollution around the world. Since people are increasingly dependent on private cars, it is expected that transportation energy consumption and greenhouse gas emissions are doubled by 2025 comparing 2000 [2].

Of these, Tehran with an area over 700 km^2, as Iran's main metropolis, contains the largest urban population. Clearly, regarding the distance between various centers, vehicle-less daily movement is impossible; therefore, policy-making in order to provide a comprehensive traffic and transportation system is regarded as of the critical challenges in Tehran. Considering the increasingly growing of urban vehicles and increased pollution and fuel consumption, on the other side, urban air quality underwent a crisis.

Indeed, air pollution in Tehran is such that the *fourth Plan codified reduced air pollution plan for* Tehran as well as technology transferring in 9 implementation lines. Data analysis methodology was in accordance with Japan experiences in compliance with Tehran's conditions. Objectives of this comprehensive plan include optimal environment management and countermeasures to control air pollutants.

On the other hand, to remove the existing problems and create an efficient transportation, transportation sector of environment program of the United Nations offers a sustained development-based strategy concentrating on demand on the contrary to the conventional approach. Conventional approach dealt with increased transportation demand, extending of the existing roads and or construction of new roads. This supply-oriented approach not only met the expected positive results, but also intensified traffic, burdened heavy weights on roads and released greenhouse gases and other damages. To achieve this object, the United Nations Environment Plan proposed ASL strategy (Avoid, Shift, and Improve) for developing countries. The purpose of this approach is to significantly reduce greenhouse gas emissions, decrease energy consumption, less traffic, and finally to construct cities worth living [3].

ASL strategy consists of the three following main components:

1. Avoid
2. Shift
3. Improve

Avoid refers to the need for improving transport system efficiency i.e. avoid travel or reduce number of trips, which are made possible through integrated transportation and land use planning, designing denser and higher settlements, remote communication technologies such as teleconference

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and localized production and consumption leading to lower travel demand and reduced distances.

Shift seeks for increasing travel efficiency. It focuses on changing current transportation models with high energy consumption (like automobile) toward environment-friendly patterns. Non-motorized transportation (like walking and bicycling) and public transportation (bus, subway) are more considered. Meeting these models usually requires fundamental investments on infrastructures.

Improve concentrates on vehicle efficiency, transportation infrastructures as well as fuel optimization. The purpose is to improve transportation pattern efficiency in term of energy and vehicle technology for reducing environmental degradation effects such as pollution and resource depletion. Enhancing fuel economy of conventional engines, lighter vehicles, and developing alternatives such as electric and hybrid automobiles, biofuels, and hydrogen fuel technologies are all examples of this strategy. This sector seeks for higher productivity through improving the rate of car ownership and enhancing environmental compatibility of vehicles [4].

Considering large differences of public transportation systems throughout the worlds, it is necessary to employ this strategy in accordance to the major difficulties of each area. Many developing countries largely depend on non-motorized transportation. Thus, more sustained public transportation system in developing countries requires more focusing on shift strategies and avoiding higher improvement.

Regarding limited development of green transportation technologies in addition to expensive existing technologies, shift and avoid, to some extent, are highly prioritized for implementation. In this regard, executive polices concentrate on reforming transportation demand management, high-quality public transportation development and providing walking and bicycling infrastructures. Finally, studies of major difficulties of Tehran as a metropolis also indicate that adopting some measures to achieve shift not only solve traffic problems in short-term, but also provides the opportunity of new green transportation technologies, in long-term, and implementing improvement and avoiding alternatives; and finally, it furnishes sustained transportation [5].

Thus, developing public transportation along quality management and traffic volume in urban passages and consequent reduction of environmental pollutants using different means of public transportation is inevitable. Public transportation is of critical place regarding their unique properties and merits. In general, high security, passengers' convenience, reduced air pollution, adequate speed, relatively cheap in comparison to other private transportation means make developing public transportation a necessity (requirement).

Of various public transportation systems, bus rapid transit system (BRT) is known as one of the most economical way of public transportation offering safe, rapid and convenient moving of passengers prioritizing bus to other vehicles. In addition, high speed operation, marketing and service delivery are other positive characteristics of this system [6]. This system is comparable to rail transportation system in term of efficiency and customer satisfaction properties [7]. Significant time and cost saving of Tehran citizens, which was about 50 billion in 2009 for line 1 BRT, are of other advantages of BRT system launched in 2003 in Tehran metropolitan [8]. All these features are introduced where all system costs are lower than other systems such that organizations and institutions can afford [9]. Moreover, according to case studies, fewer development costs and more flexibility of BRT system in implementation in comparison to other public transportation turned it into a comprehensive system over the world in public transportations system [10]

Jeram, L. and Vincent, W, in a study, published in 2006, entitling "The potential for Bus Rapid Transit to reduce transportation- related CO2 emissions", introduced BRT system as a short-term strategy of reducing CO_2 emissions of urban transportation. Scholars, in this paper, comparing three transport systems relying upon private cars, LRT and BRT concluded that BRT shows higher potential in decreasing greenhouse gas emissions.

All the aforementioned shows that BRT transportation system has the potential of reducing air pollution and greenhouse gas emissions comparing other former bus systems in Tehran.

However, air pollution diagnosis and monitoring management as the most significant subclass of air pollution management requires investigating the ratio of pollutants in air pollution to enable any resource adjusting leads to predictable effects on air pollution diagnosis and monitoring.

Thus, the purpose of the present research is to measure air pollutants and particulates in BRT stations, particularly in term of reduced fuel consumption in Tehran in comparison to national and international standards in order to study BRT system expected potential realization level in reducing air pollution and to offer an optimal model for system efficiency along air pollution comprehensive management.

METHODOLOGY

Air pollutants and particulates were investigated in BRT route through field study. Thus, BRT line 1 was initially selected; next, 14 stations were determined by field studying method. Totally, 14 sampling stations were from Jomhuri Square to Parkway Bridge, and from Parkway Bridge to Tajrish square.

Measurement points included the following stations: 1. Tajrish square, 2. On the corner of Major General Fallahi street, 3. Baghe Ferdows gas station, 4. On the corner of Amir Ashrafi street, 5. Valiasr-Parkway intersection, 6. Chamran highway-Velenjak gas station, 7. Chamran highway- Evin Hotel, 8. Chamran highway-Management bridge, 9. Chamran highway- Nasr Bridge, 10. Chamran highway- Tohid square,11. Chamran highway- Nejat dead end corner, 12. Chamran intersection-Enghelab, 13. Chamran intersection- Uremia, 14. Chamran highway- Jomhouri square

In order to study air quality parameters in understudied area, carbon monoxide parameters, nitrogen dioxide, sulfur dioxide parameters as well as quantity of air pollutants ($PM_{10,}$ $PM_{2.5}$, PM_1) were measured by weight through following instruments.

Air pollutants measurement devices

a. Air quality parameter measurement device (LSI): this device equipped with electrochemical sensors allows measuring NH_3, CH_4, NO, NO_2, SO_2, CO metrological parameters.
b. Particulates weight measurement device (TSI):

This device gauges particulates in three areas of PM_{10} ‹$PM_{2.5}$ ‹ PM_1 by weight and direct reading based on laser beam scattering. This study determined environment PM_{10} through using TSI device.

Solomat 5102

Solomat 510e is a device capable of measuring CO, CO_2, temperature, relative humidity, wind speed and direction. This study applied this device to estimate wind speed.

Particulate quantity measurement device (MetOne)

This device measures particulates quantity per a cubic meter of air.

Sampling, lasted for seven days, initiated from December 25, 2012 and ended in December 31, 2012. Sampling was daily conducted for SO_2, NO_x, NO and CO pollutants from 6 a.m. to 6 p.m. However, SPM pollutant was measured for 24 hours to be compared with national and international standards.

FINDINGS

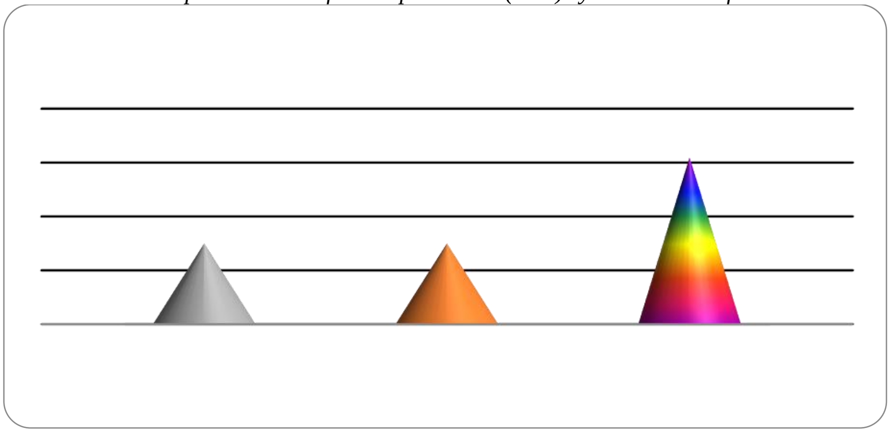
Table 1 represents measurement results of air pollution parameters in BRT lines comparing standards of Iran and Environment Protection Agency.

Comparing pollutants and particulates' measurement results with national standard demonstrates that the obtained statistics is almost two times more the standard limit, which is 5 times comparing EPA standard. Carbon monoxide is less than national and EPA standards. NO (about 5 times) exceeded EPA and national annual quantity. However, annual figures are disregarded in this study; the comparison was performed in the absence of one-hour standard. NO_x and SO_2 were 10 and 3 times more than EPA, respectively. Air pollutant parameters and particulates were precisely compared with existing standards, which is illustrated in graphs 1-6.

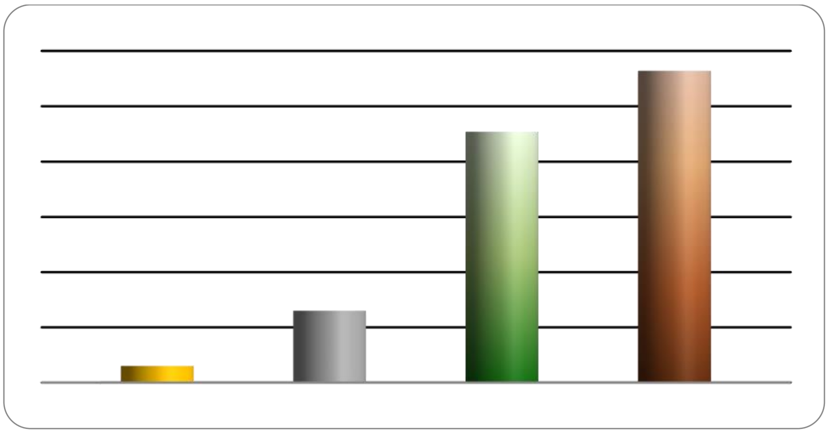
Table 1. Comparing air pollution measurement with environmental protection organization standards

Mean hour		PM (μg/m^3)			Ppm			
		PM_1	$PM_{2.5}$	PM_{10}	CO	NO	NOx	SO_2
Mean of 6 working day		227	282	310	5.02	0.17	0.23	0.08
Friday		29	38	52	3.21	0.14	0.19	0.03
Clean air standard	One hour				35			
	3 hours							0.5
	8 hours				9			
	24 hours	150						0.1
	Annual	60				0.05		0.02
EPA standard	One hour				35	0.03	0.02	0.03
	3 hours							
	8 hours				9	0.01		
	24 hours	15	65	150				0.14
	Annual	15	15	50			0.05	0.05

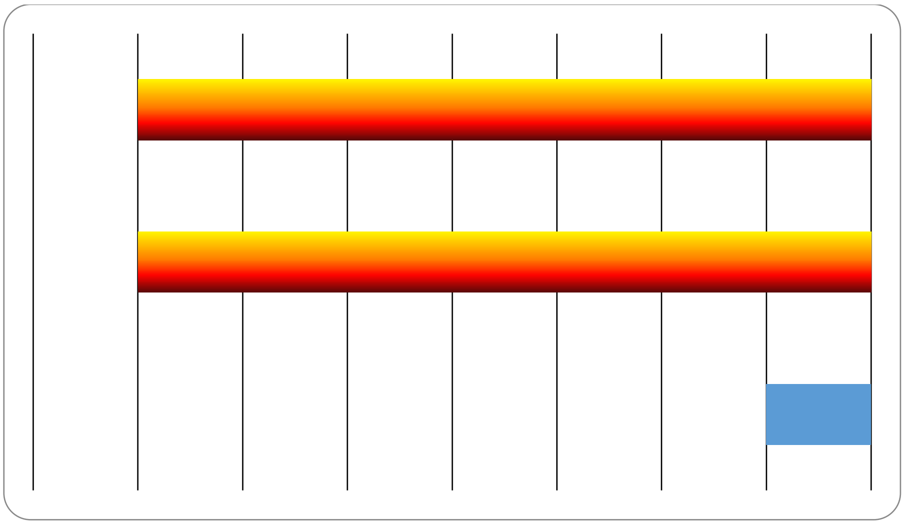
*One hour mean (excluding PM that is 24-hour mean)



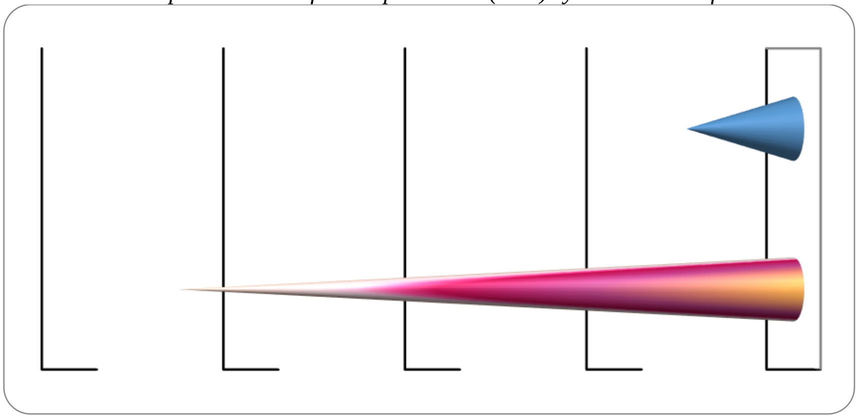
Graph 1: Comparing PM10 concentration with Iran and EPA standards (μg/m^3)



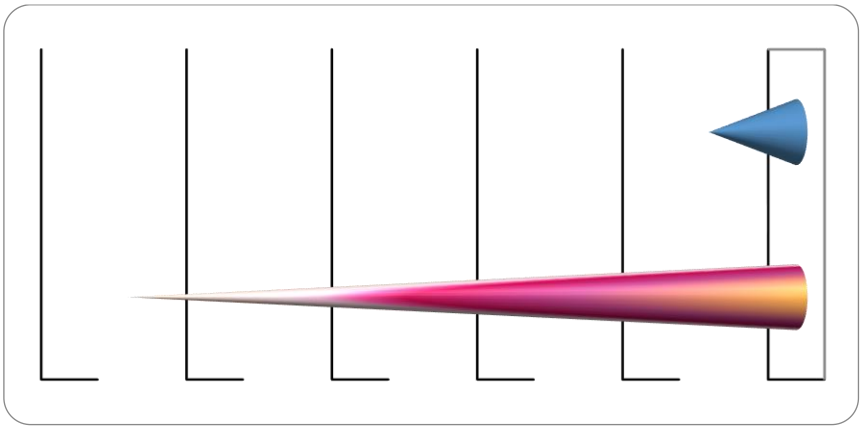
Graph 2: Concentration of PM 2.5 and PM1 in given routes based on EPA standard (μg/m^3)



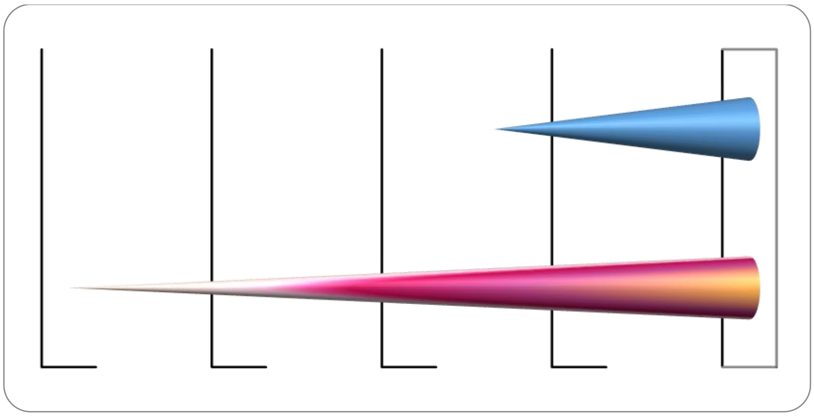
Graph 3: Comparing carbon monoxide concentration in the given routes with Iran and EPA standards (ppm)



Graph 4: Comparing NO concentration in given routes with EPA standard (ppm)



Graph 5: Comparing NOx concentration in given routes with EPA standard (ppm)



Graph 6: Comparing SO_2 concentration with EPA standard in given routes (ppm)

Though, comparison of air pollutants was after BRT launching, the results are obvious. However, no significant difference is seen. According to increased volume of PCU, it may be expressed that air pollution decreased after BRT launching. Almost 8 million PCU increased annual traffic was seen prior and following BRT that may be attributed to new cars supply. In addition, measurements were performed at activity time of schools and educational centers that may cause higher traffic. According to calculating volumes, around 40480690 PCU of total cars have round trip over one year. New private cars are of other effective factors of increasing PCU (Table 2).

Table 2: PCU fuel consumption in the given routes in 2013

PCU	Distance travelled per car (km)	Total distance over year (km)	Fuel consumption per 100 km (Lit)	Total fuel over year (Lit)
31490375	13.07	411579201	13.6	55974771

According to Table 2 and using energy and environment software, emissions and its associated social costs (according to EPA coefficients) are represented in Table 3 and 4.

Table 3: Air pollution emission resulted from traffic (of passenger cars) in the given routes in term of ton in 2013

NO_x	SO_2	CO_2	SO_3	CO	CH	SPM
756	84	130030	0	19591	3526	73

Table 4: Social costs of traffic in the given routes (in term of million Rial) in 2013

NO_x	SO_2	CO_2	Total
58455	890	37449	96794

According to obtained results, the positive significant effect of BRT lines is declining fuel consumption social costs. Based on US EPA coefficients, total reduced social costs in the given routes equal 10349 million Rials shown in Table 5.

Table 5: Decrease of social-environmental costs of BRT line in the given routes

Cost/pollutant	NOx	SO2	CO2	Total
Million Rial	7135	609	2605	10349

Results of measuring pollutants also revealed that air pollution decreased following BRT line launching in the given routes. Table 6 summarizes the results of pollutant concentration after launching BRT.

Table 6: Air pollution at BRT launching in the given route

PM (μg/m^3)			Ppm			
PM_1	$PM_{2.5}$	PM_{10}	CO	NO	NOx	SO_2
230	280	320	5.12	0.16	0.21	0.08

In general, research results showed that in spite of increased traffic and annual traffic estimation, air pollution negligibly (insignificantly) decreases. This is also true for particulates PM_1, $PM_{2.5}$ and CO. Fuel saving is another positive dimension of this plan. Energy saving in a year equals 3.9 million liters (15.6 billion Rials/ 4000 Rials per Liters). Estimations of reduced air pollution resulted from not using private cars over the whole routes are presented in Table 7.

Table 7: Air pollutant reduction resulted from fuel saving (in the given route)

Description	NO_x	OC	SO_2	SPM	THC
Air pollutant reduction (ton/year) resulted from fuel saving of 3.9 million liter per year	45	1151	4.5	4.6	207

DISCUSSION AND CONCLUSION

The object of sustained urban traffic in Tehran is to improve urban life quality and to achieve suitable communities and healthy economy. A sustained transportation system requires activities more than air pollution, traffic or fuel consumption monitoring. Sustained development management of urban transportation may aid in decreasing environmental effects, increasing transportation system efficiency as well as improving social life status that may not be met without reorganizing the strategies, policies and plans.

The present research studied BRT contribution in decreasing air pollutants and particulates, particularly from reduced fuel consumption view. Research results demonstrate that the significant social effect of implementing BRT system associates with reduced social costs resulting from fewer pollutants emissions. Such decrease has come from two sources of less fuel consumption, which is ranked the first; and less air pollution despite higher traffic. Indeed, regarding the significant status of Iran in Middle East in addition to the global significance of Iran in Hydrocarbon resources, it is necessary to maximally optimize fuel consumption in transportation sector. The results show that fuel optimization through reduced fuel consumption is one of BRT line achievement in Tehran.

The aforementioned reveal the acceptable performance and efficiency of BRT transportation system in Tehran metropolitan, especially in comparison to former general bus system. However, BRT system has some disadvantages and deficiencies need to be dealt with in order to significantly improve system efficiency and passengers' satisfaction.

BRT system merits are generally reduced local pollution and greenhouse gases through substituting old polluting buses and fewer noises. On the other hand, unfortunately, developing this system was along with cutting the trees and pollutant emissions during construction, which may be considered as system disadvantage. Finally, improved fuel qualities for buses as well as enhanced technology of these buses are of the opportunities provided to improve environmental condition in the future.

At the end, to achieve optimized transportation system in Tehran focused on public transportation system, and in particular, BRT system, it is necessary to observe environmental concerns in development planning.

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