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ORIGINAL RESEARCH PAPER

Environmental impact assessment of bus rapid transit (BRT) in Tehran Metropolitan City

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ABSTRACT: Bus rapid transit is an innovative, high capacity, lower cost public transit solution in metropolitan cities. Idea is to dedicate Lanes for quick and efficient transport of passengers to their destinations. In the present investigation the environmental impact assessment of bus rapid transit in Tehran metropolitan city is brought out. For this purpose bus rapid transit Lane No. 10 is investigated. The bus rapid transit Lane No.10 is about 10 km in distance that moves up and down between Azadi and Simon Bolivar Squares. About 77500 passengers using 50 buses are transited per day in Lane No. 10. These 50 buses cover a distance of 9600 km/day. The results of present study showed that about 6.5 million liters of fuel is saved annually. It should be pointed out that environmental costs are also reduced for about US$ 1.7 million/yr. The overall score of environmental impact assessment stands at +10 that is indicative of Lane No. 10 compatibility with the environmental considerations.

KEYWORDS: *Air quality; Bus rapid transit (BRT); Environmental impact assessment (EIA); Noise pollution; Urban traffic*

INTRODUCTION

One of the major environmental degradation in Iran is inefficiency of energy uses in various sectors (Karbassi *et al.*, 2007a; Karbassi *et al.*, 2007b; Abbaspour *et al.*, 2013; Alipour *et al.*, 2011). The main reason for higher use of energy might be due to inefficient home appliances. Some of the researchers opine that there are many areas to save energy within the metropolitan of Tehran (Rashidi *et al.*, 2012; Tehrani *et al.*, 2010; Tehrani *et al.*, 2009; Abbaspour *et al.*, 2006) Fortunately in the recent years more attention has been paid to various environmental aspects of urban areas including agricultural sectors by developing pollution index (Mohammadpour Roudposhti *et al.*, 2016). Such pollution dispersion has also been of interest by researchers in the vicinity of urban areas located near industrial zone (Ghaemi *et al.*, 2015). Post-earthquake in Tehran under various earthquake scenarios has been studied for the better management of debris (Askarizadeh *et al.*, 2016; Rafee *et al.*, 2008). These debris can be efficiently handled in-situ and the remains can be transported to the nearest areas for temporary disposal. An overview of the spatial distribution and chemical properties of heavy metals through dust fall out in urban area is investigated. It is found out that about 70% of metals in the deposited particulate matter were from external origin during dust fall (Tabatabaei *et al.*, 2015; Tabatabaei *et al.*, 2014). In the recent years more attention has been paid to the external costs of various civil activities and even some models are developed for computations (Tajziehchi *et al.*, 2014a,b; Tajziehchi *et al.*, 2013, Tajziehchi *et al.*, 2012). There are many other studies on the Tehran's landfill as well as

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wastewater purification techniques (Pazoki *et al.*, 2014). The average concentration of total tri-halo-methane (THM) in different districts of Tehran city ranges from 0.81 to 9.0 μg/L, and the highest concentrations were detected in district 2 at 19.5 μg/L. The highest risk from THMs seems to be from the inhalation route followed by ingestion and dermal contacts (Pardakhti *et al*., 2011). Higher concentration of metals are found in soils of Aradkuh landfill that requires further remediation (Salehi *et al*., 2014). These studies reveal that new technologies must be used in Tehran metropolitan city to promote the environmental conditions of capital city of Iran.

The main objective of present study is to find out the environmental impact assessment (EIA) of Bus Rapid Transit (BRT) in Tehran. It is also vital to know about the amount of energy saving and its positive consequences such as reduction in external costs. We have selected Lane No. 10 as a case study of BRT to show its positive and negative effects on environment of Tehran. However, it should be pointed out that the results of Lane No. 10 cannot be the same for other BRT's Lane within Tehran since there are many technical factors as well as environmental conditions in each area.

MATERIALS AND METHODS

The overall BRT rout and terminals within Tehran is shown in Fig. 1. About 24 stations along Lane No. 10 were selected for air quality as well as noise

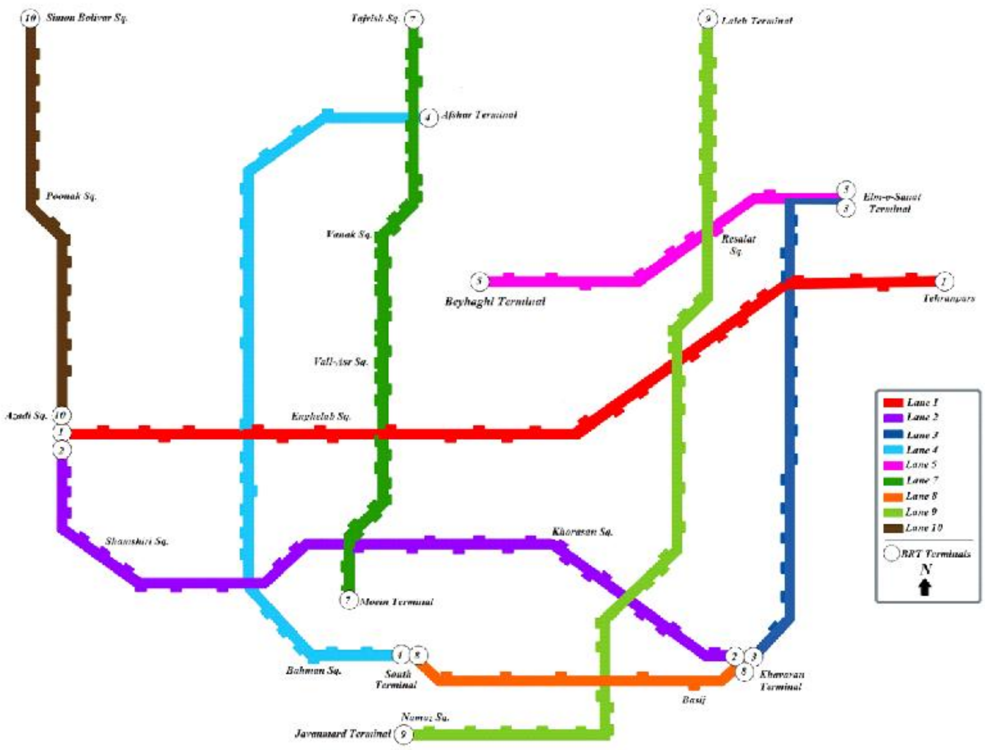

Fig.1: Overall BRT route and terminals in Tehran metropolitan city

measurement in the year 2011. For the measurement of PM_1, $PM_{2.5}$ and PM_{10}, a Metone equipment (model Metone-228) was used. Other air quality parameters such as CO, NO, NO_x and SO_2 were measured by Solomat equipment (model Solomat 510e). Noise level was measured in accordance with ISO method. Fig. 1 shows the sampling locations along BRT Lane No. 10.

It should be pointed out that all measurements (air quality as well as noise level) was carried out on hourly basis and diurnally for a week. The mean values of collected data are used in the present investigation (Fig. 2).

RESULTS AND DISCUSSION

The type numbers of activities are very important in traffic view. Table 1 depicts the commercial activities in BRT Lane No. 10. Among the activities that are listed in Table 1, educational centers (universities, schools, etc.) can create more trips into the area of study. For instance about four universities containing over 40 thousand students and employees are located along BRT Lane No. 10.

Subsequently, air quality measurements were carried out prior and after BRT initiation (Table 2). It is evident from Table 2 that various air pollutants are reduced between 4 to 13% after initiation of BRT Lane No. 10. Figs. 3 to 9 depict the concentration of various air pollutants after and before BRT initiation.

The obtained results showed a slight increase in noise level after initiation of BRT in Lane No. 10. Figs. 10 and 11 compare the noise levels with national standards of Iran. It should be pointed out that the

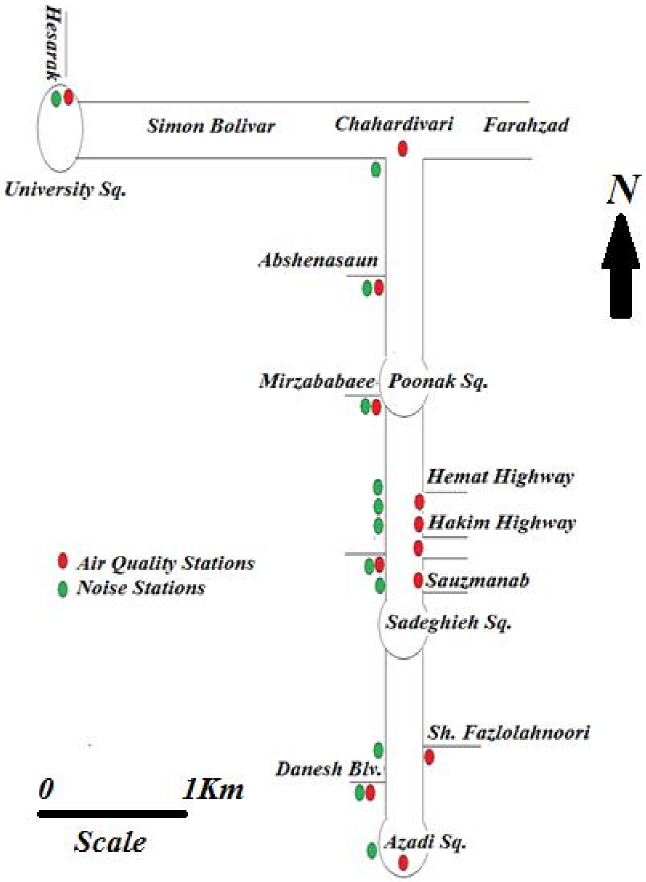

Fig. 2: Air quality and noise level stations along BRT Lane No. 10 in Tehran

noise level even in the absence of BRT Lane stands at higher level than national standards. The noise level under normal conditions somehow resembles the industrial zones.

There is not any doubt that civil works can leave adverse environmental impacts on urban areas. Sometimes, it would be inevitable to avoid civil works especially in urban areas. Table 3 shows the negative and positive environmental impacts of BRT along Lane No. 10. Physical environment receives about -10 points along the BRT route (sum of -15 points for noise/groundwater deterioration and +5 points for promotion in air quality). It should be pointed out that initiation of BRT in Lane No. 10 possess adverse biological environmental impacts for about -5 points. However, BRT has many positive effects on socio-economic environment that gains about +25 points. Thus, the overall score would be +10 that implies suitability of BRT project between Azadi and Simon Bolivar squares.

Table 1: Type and percentile of commercial and educational activities along BRT Lane No. 10 in Tehran

Type of activity	Share (%)*	Type of activity	Share (%)
Civil shops	15.4	Beauty parlor	3.5
Real states	13.6	Gazette office	3.3
Glossary shops	10.6	Educational centers	3.3
Clinical centers	9.9	Home appliances	2.4
Restaurants	8.9	Main commercial complex	1.3
Car repairs	7.9	Travelling agencies	1.3
Banks	4.4	Administrative offices	0.9
Insurance offices	4.4	Others	8.0

*share percent when compared with total number of activities along BRT route.

Table 2: Comparison of air pollution prior and after initiation of BRT along Lane No. 10 between Simon Bolivar and Azadi square

Phases of investigation	PM (μg/m^3)			ppm			
	PM_{10}	$PM_{2.5}$	PM_1	CO	NO	NO_x	SO_2
Before BRT initiation	121	87	74	15	0.51	0.45	0.08
After BRT initiation	114	79	71	14	0.50	0.42	0.07
% of changes*	**-4**	**-9**	**-6**	**-5**	**-5**	**-7**	**-13**

*negative sign denotes reduction in air pollutants

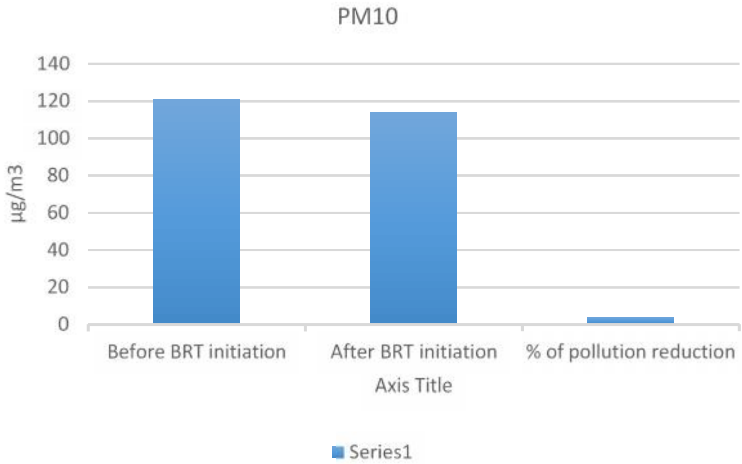

Fig. 3: Concentration of PM_{10} before and after BRT initiation along Lane No. 10

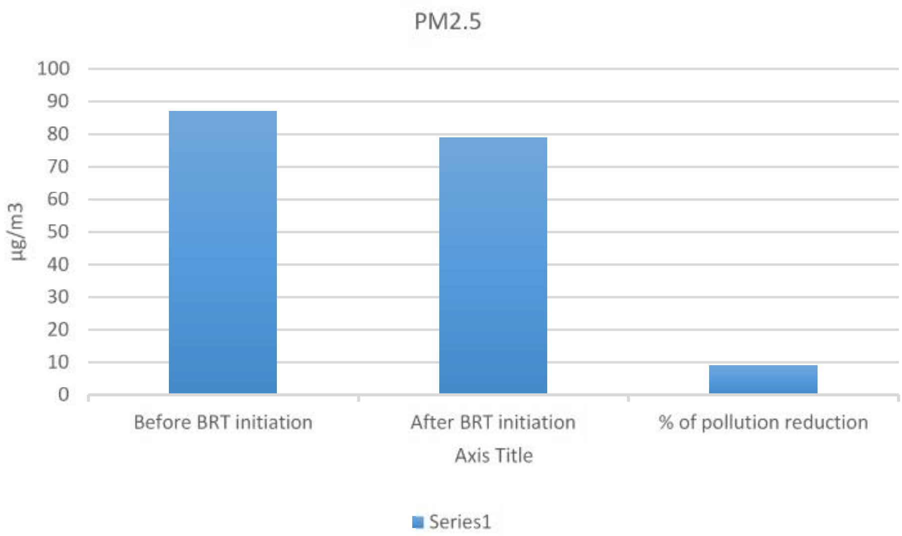

Fig. 4: Concentration of $PM_{2.5}$ before and after BRT initiation along Lane No. 10

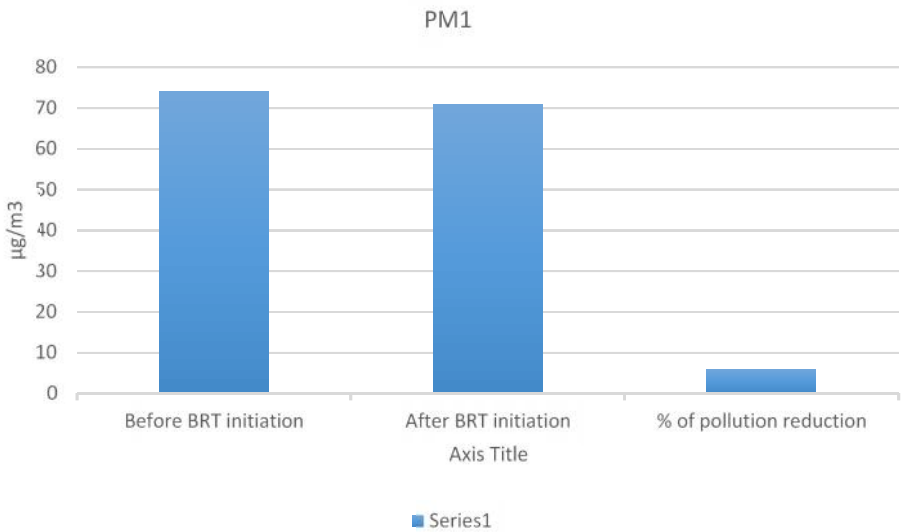

Fig. 5: Concentration of PM_1 before and after BRT initiation along Lane No. 10

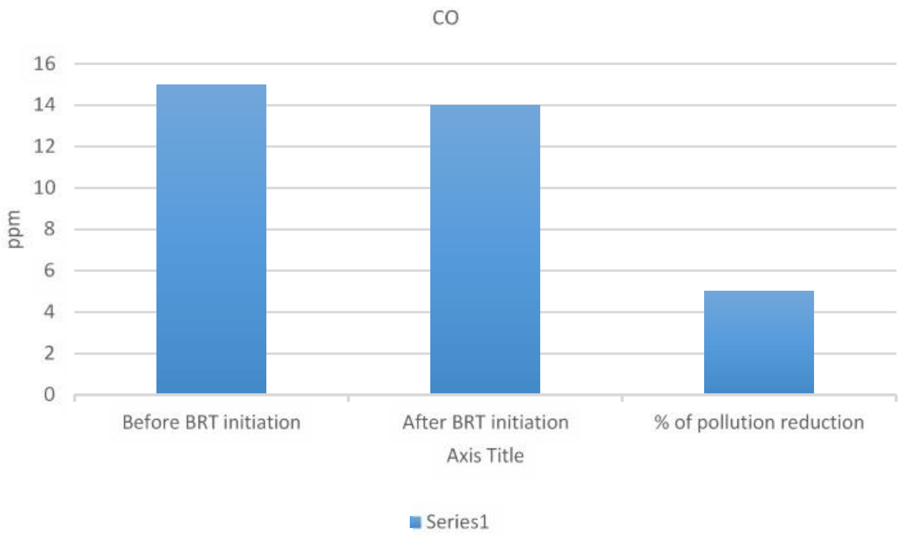

Fig. 6: Concentration of CO before and after BRT initiation along Lane No. 10

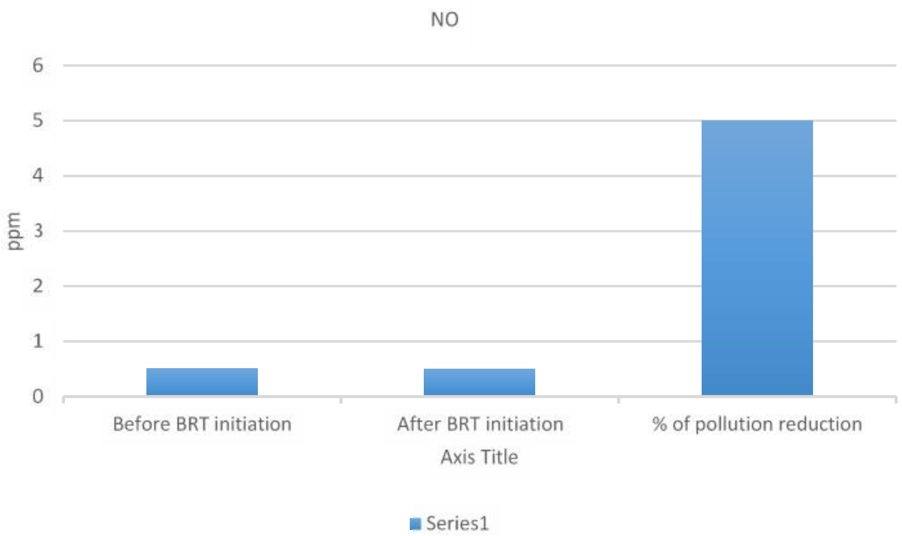

Fig. 7: Concentration of NO before and after BRT initiation along Lane No. 10

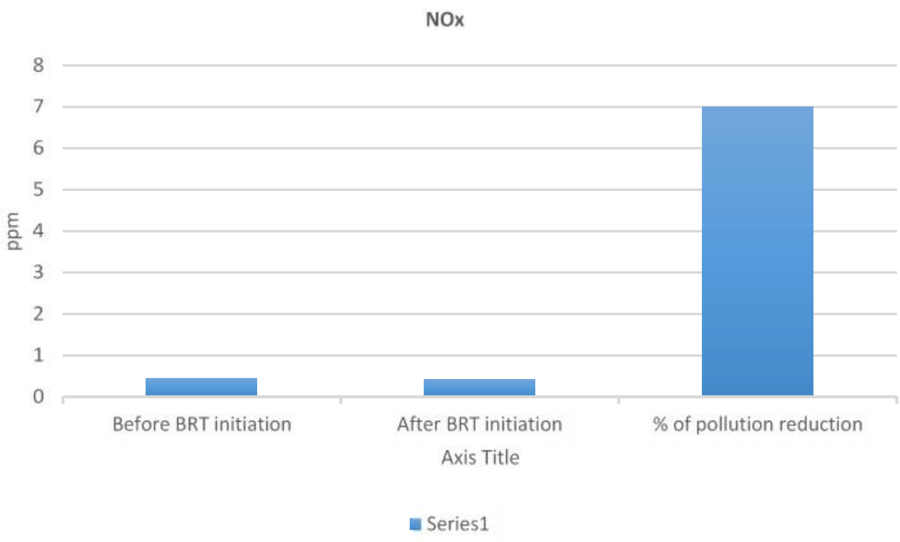

Fig. 8: Concentration of NO_x before and after BRT initiation along Lane No. 10

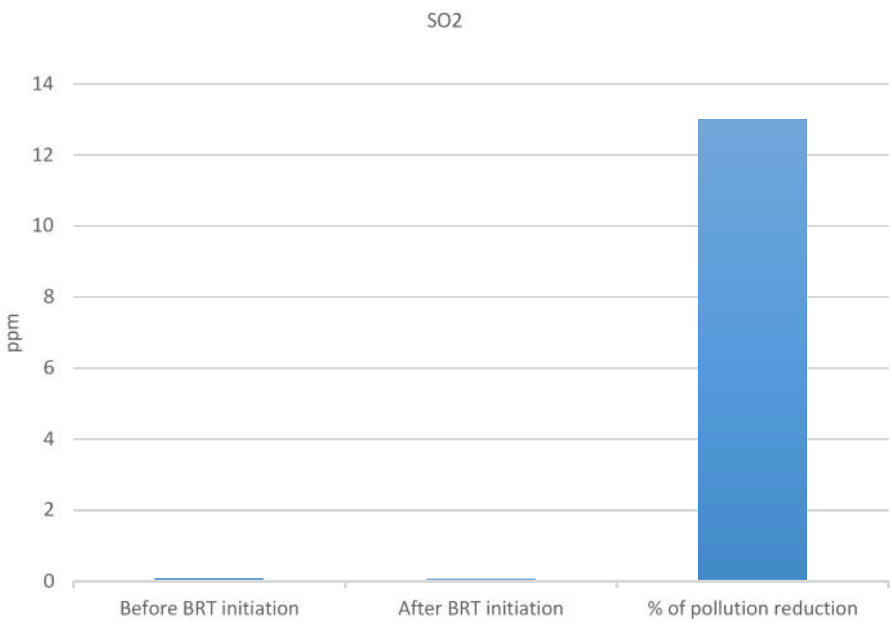

Fig. 9: Concentration of SO_2 before and after BRT initiation along Lane No. 10

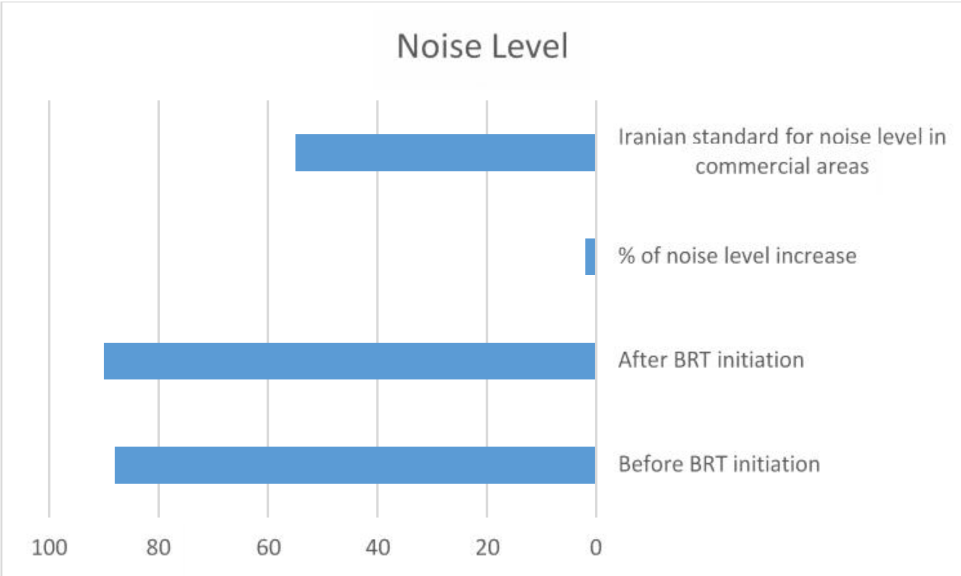

Fig. 10: Noise level in dB (day time) after BRT initiation along Lane No. 10

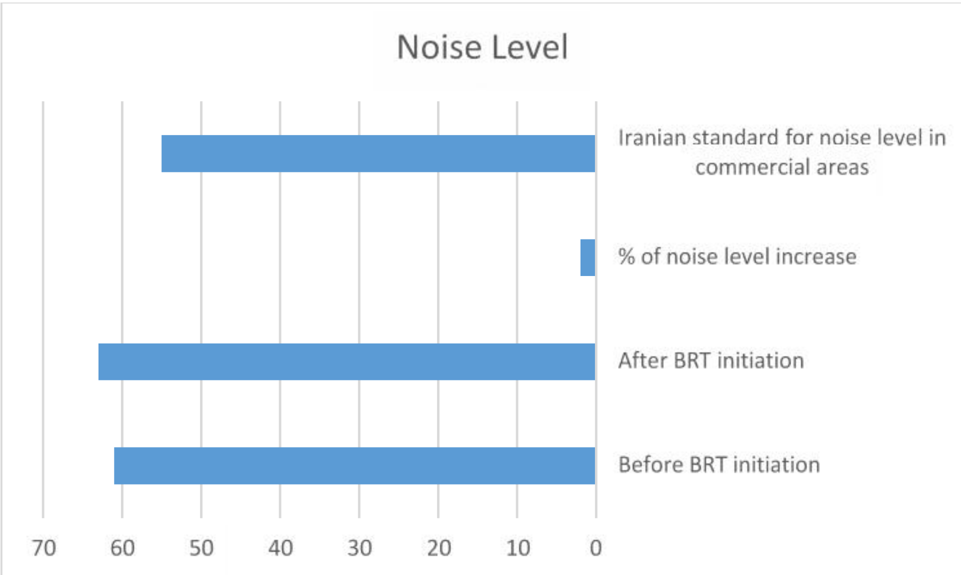

Fig. 11: Noise level in dB (night time) after BRT initiation along Lane No. 10

Table 3. Environmental impact assessment of BRT on various media along Lane No. 10

Media	Sub-media	Rate	Rank	Rate x Rank	Notes
Physical Environment	Surface water	5	0	0	Absence of surface waters; no groundwater supply; land use already shaped; no solid waste production, increase in noise level
	Ground water	2	-1	-2	
	Land use	3	-1	-3	
	Air quality	5	+1	+5	
	Solid wastes	2	0	0	
	Noise	5	-2	-10	
Sub-total	-10				
Biological Environment	Flora	2	-2	-4	Rather suitable flora; absence of fauna
	Fauna	1	-1	-1	
Sub-total	-5				
Social & Economic Environment	Health	5	+1	+5	Increase in health, safety & welfare; deterioration of landscape; no employment; opposition by shop keepers; passengers comfort
	Welfare	5	+3	+15	
	Landscape	5	-2	-10	
	Employment	5	+1	+5	
	Earnings	5	+1	+5	
	Expenditures	5	+1	+5	
	Historical	8	0	0	
	Educational	8	0	0	
Sub-total	+25				
Total Environmental Scores			+10		

Table 4: Reduction in air pollutants along BRT route No. 10 (ton/yr.)

Fuel consumption	NOx	CO	SO_2	SPM	THC
Emission by 29450 private cars: 20.4 million liters of benzene usage in 300 working days	276	7140	30	26	1284
Emission by BRT: Transit of 8893125 passengers/yr.	13	357	2	2	64
Reduction in air pollution during 300 working days	263	6783	28	24	1220

CONCLUSION

The fuel consumption before and after initiation of BRT between Azadi and Simon Bolivar squares is reduced by about 6.5 million liters per year. Considering average international price of benzene at about US$ 1.2/L, the total earning in the view of national economy would be around US$ 7800000/yr. It is also concluded that after initiation of BRT Lane No. 10 about 29450 taxi have left the route and subsequently cleaner air quality is achieved. It is also found out that about 38% of passenger have kept aside their private cars as a result of initiation of BRT Lane No. 10. Table 4 depicts the reduction in air pollutants along BRT route. It is evident that over 8 thousand tons of variety of air pollutants are reduce after the initiation of BRT between Azadi and Simon Bolivar routes. Table 5 shows the reduction in externalities (mainly environmental and social costs).

The data generated in the present investigation clearly show the positive environmental effects of BRTs. However, it should be pointed out that many shopkeepers lose their income since BRT routes set out restrictions for car parking aside the roads. To reduce the noise pollution, buses should use soft tires and also even asphalt should be used throughout the route. It is also suggested that municipality of Tehran build up more parking lots along the BRT route.

Table 5: Comparison amongst external costs before and after initiation of BRT (US$/yr.)

Phase	Route	NOx	SO_2	CO_2	Total
Before initiation of BRT	Azadi square to Simon Bolivar Square	94000	14400	600000	708400
After initiation of BRT		71500	10900	460000	542400
Reduction		22500	3500	140000	166000

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

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