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CHALLENGES AND SOLUTIONS

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A LONGITUDINAL ANALYSIS OF DENSITIES WITHIN THE PEDESTRIAN SHEDS AROUND METRO STATIONS

THE CASE OF TEHRAN

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ABSTRACT

Evaluation of spatial accessibility to public transportation has a weak background in many emerging countries, including Iran. Transit-Oriented Development is of great interest among Iranian planners and academics, but little is known about transit orientation provided by major public transport systems exemplified by the Tehran Metro. Statistical difference tests and polynomial regression done in this study show how residential densities within walking distances of metro stations established at different times after 1998 are significantly different. Both population and employment densities have decreased in more recent stations compared to those opened between 2005 and 2010. Moreover, one-way T-Tests comparing the population and densities of older lines with those of newer lines reveal that, in most cases, densities within walking distances of stations of older lines are higher. The paper concludes that lack of proper site selection and failing to locate new stations near job centers and highly populated areas threatens the transit-friendliness that emerged in the early years after establishing the first metro station in 1998.

KEYWORDS
Transit-Oriented Development, urban development, population density, employment density, walking distance, accessibility, public transportation, Tehran

1 INTRODUCTION

Urban density is an essential part of Transit-Oriented Development (TOD). Its role in integrating urban development and urban transportation planning has been emphasized in a considerable part of the fundamental literature describing the basic approach of TOD (i.e. Calthorpe, 1993; Bernick & Cervero, 1997). The idea is supported by a large body of literature mostly dating back to 1990s that confirm higher residential (Pushkarev & Zupan, 1977; Newman & Kenworthy, 1989, Parsons et al. 1995; Cervero, 1998; Spillar & Rutherford, 1998; Banerjee et al. 2005) and employment (Frank & Pivo, 1994; Nelson & Nygaard, 1995; Transit Cooperative Research Program, 1996) densities generate higher transit ridership. More recent studies confirm that commute travels, trips made around the work place, and travel modes to work are in need of further attention in TOD (Reconnecting America's Center for Transit-Oriented Development, 2008).

This study targets the Tehran Metro system as a public transport system in a less studied context. The problem motivating this research is the lack of evaluations on the efficiency and consumer-orientation of this metro system, especially in case of integration of land use. Since the land use and transportation approaches were not so much included in urban transport planning of Iran back in the 1980s and 1990s, during which the development plans were initiated, it is important to be informed how these old approaches to mass urban rail transport work with the new perspectives of accessibility to public transport, walking, and in general sustainable mobility.

As a rapid transit system, the Tehran Metro serves 94 stations spread along five lines. The system currently carries more than 3 million passengers a day. In 2014, 815 million trips were made within Tehran Metro, which had fewer stations then than today. As of 2015, the total system was 170 kilometers long, 127 kilometers of which are metro-grade rail. It is planned to have a length of 430 kilometers with 9 lines once the whole construction is complete by 2028. The initial plans of the Tehran Metro, which was to be Iran's first metro system, were laid out in the 1970s before the 1979 revolution. In 1976, metro construction studies and executive administration were begun. However, this development was short-lived with the advent of the Iranian revolution and Iran–Iraq war in 1979 and 1980 respectively. In 1985, the "Tehran Metro Execution Plan" was re-approved by the Iranian parliament. Work proceeded slowly due to the continuing Iran–Iraq war and often ground to a halt. Line 5 of the Tehran metro began operations in 1999 and was Iran's first metro system (Tehran Urban and Suburban Railway Operation Co.).

Having in mind the conditions under which the Tehran Metro was planned or implemented, including the war conditions, lack of proper land use and transport knowledge, the harsh influence of transportation engineering leading to lack of interdisciplinary plans, etc., to compensate for the possible deficiencies resulting from the above, assessments on the Tehran Metro with special emphasis on spatial considerations, e.g. TOD evaluations, seem necessary. It is intriguing to know whether there has been any change in the attitudes of decision makers and planners of Tehran Metro regarding the use of urban density in site selection of the stations. Also the differences between the approach to residential and employment densities can be appealing.

The paper seeks to analyze the changes in population and employment density around metro stations of Tehran during the past 18 years, as a determinant of the ideology of urban planners and transport planners to TOD. The pre-assumption is that if planners and decision makers select the site of metro stations in denser city districts with proximity to more residential units and employment centers, they have deliberately provided higher transit-friendly urban developments. The questions that this study is going to answer include (1) Are there any significant differences in population and employment density in the vicinity of the metro stations opened in Tehran between 1998 and 2016? (2) If the differences in density within the walking distance of the stations are found significant, how can this be interpreted?

The core concept of TOD concerns density, which is also dealt with in this study. Other influential attributes providing a transit-oriented environment are beautiful, vital, and walkable neighborhoods (City and County of Denver, 2006), employment in activity sites together with public spaces (Cervero, 1998; Curtis et al., 2009), mix of land uses (Loo et al., 2010), and the like. However, this paper only focuses on the density of the station areas, which is considered basic and the starting point of implementation of TOD. One of the most prominent steps for integrating transit and urban land use is to "develop transit systems to connect existing and planned concentrations of development" (Curtis et al., 2009, 3). Setting this as the main focus of this study, it is assumed that planning other characteristics of a successful TOD can be carried out after or in parallel with densification of the vicinity of the transit stations and stops. It should be mentioned that this study considers only the metro network, so support given by the metro system for creating a TOD is examined. Other modes like buses, taxis, or even paratransit can separately be researched.

The paper continues with an explanation of the methodology, including the data, and the methods applied for hypothesis testing and regression analyses. Section three presents the research findings including the results of the T-Tests and the polynomial regression analysis based on the time periods of opening the stations and also based on lines. This part is followed by a discussion to increase the level of physical understanding of readers concerning the site selection and location of stations, explained by means of examples of stations in central Tehran. A short summary of the findings and discussion ends this contribution.

2 METHODOLOGY

To analyze the longitudinal changes in density within the walking distances around metro stations of Tehran, a sample of stations was selected in a way that they are launched or planned in residential and urban quarters of Tehran. Stations located in the non-urban areas or with little density around them were considered outliers and were omitted from the sample. The sample consists of 84 stations, 73 of which were established between 1998 and 2015 and the remaining 11 are being planned or constructed. Two of three major density types, namely population and employment densities are targeted in the study, the data of which were obtained from the 2011 Tehran Census of the Statistical Center of Iran. The data were provided in the form of statistical blocks that surround the metro stations. The summary of the collected data can be observed in Table 1, the details of which are presented in Table 2 (in the annex) based on stations. The selected stations are surrounded by a minimum of 3 and maximum of 318 statistical blocks as seen in this table. All statistical blocks were arranged to be located in a walking distance of 800 meters on an aerial pedestrian shed basis. The average population and employment density around the stations accounts for 152.1 inhab./ha and 55.2 jobs/ha respectively. Fig. 1 illustrates the geographical location of the stations addressing the years of establishment. Fig. 2 and 3 depict the distribution of population and employment density within the walkable distances from stations.

Part of the analysis done in this study is based on a T-Test analysis between three periods of time consisting of 1998-2003 and 2005-2015 periods as well as post-2015, which includes 12 stations that have not yet been launched. 29 and 44 of the stations established during the first and the second periods were observes. These time intervals were selected in order to find a significant turning point, so that the behavior of the Iranian planning system regarding TOD is examined. It should also be mentioned that between 2003 and 2005 no stations were established. So it is hypothesized that around the years 2004 and 2015 a change in the attitude of urban transport planners occurred, and the result of the designing and planning metro network altered.

The T-Tests taken in this part of the study are one-tailed because, as seen in Table 3, the variances of the above three time categories differ in both population density (1998-2003: 11095.8, 2005-2015: 11219.7,

and after 2015: 5305.1) and employment densities (1998-20013: 1803.6, 2005-2015: 1004.7, and after 2015: 421.1). Thus, the T-Test between different samples with different variances is taken.

	POPULATION DENSITY Σpop/Σarea (inhab./ha)			**EMPLOYMENT DENSITY Σemp/Σarea (jobs/ha)**		
	1998-2003	2005-2015	Still not Opened	1998-2003	2005-2015	Still not Opened
No. of Stations	29	44	11	29	44	11
Standard Deviation	105.3	105.9	73.4	42.5	31.7	20.5
Min	5	14.2	20.8	4.5	6.8	8.4
Max	362.9	557.3	230.3	201	149.6	66.7
Mean Density (inhab./ha for population density and jobs/ha for employment density)	131.2	174	119.6	66.7	52.1	37.2

Tab. 1 Summary of descriptive statistics of the sample stations

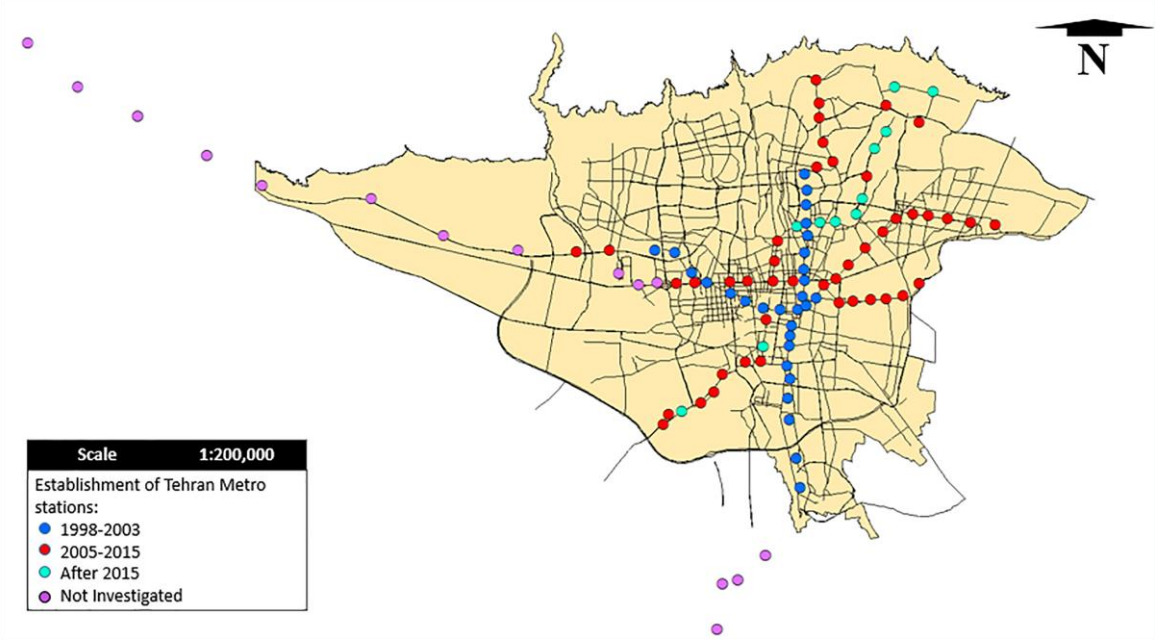

Fig. 1 Location of Tehran Metro stations.

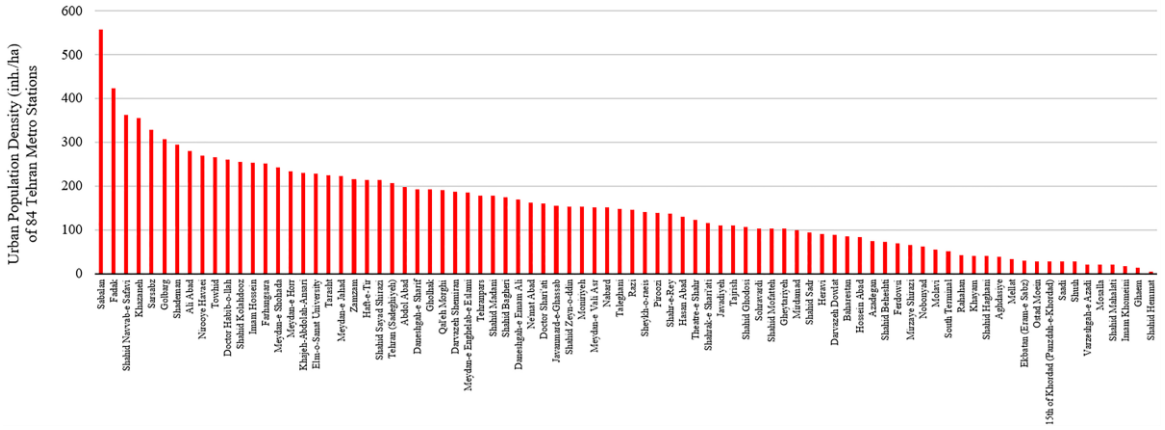

Fig. 2 Urban population density around the 84 observed metro stations of the study

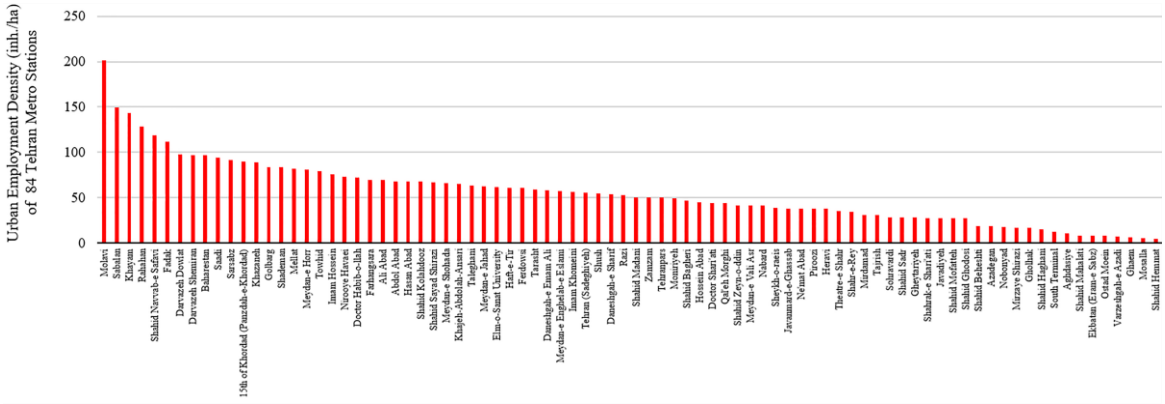

Fig. 3 Employment density around the 84 observed metro stations of the study

To avoid methodological biases related to the time and location of stations, the hypothetical comparisons are conducted also based on lines. As observed in Table 2, lines 1, 2, and 5 are the oldest lines launched. Line 5 is more or less suburban and some of its stations are located in less populous areas. The purpose of opening this line was to connect the city of Karaj west of Tehran to the capital. Thus, the one-way T-Tests were done between older urban lines, namely lines 1 and 2 and more recent lines, which are lines 3 and 4. The Tests were done assuming that the variances were different. Again, the comparisons were undertaken for population and employment densities. In this study, Line 3 includes 25 stations, 23 of which were launched in 2013 or after. The two stations opened before 2013 are Theatr-e Shahr and Shahid Beheshti that were basically stations located on the older lines of 1 and 4. Line 4 includes 15 stations, 12 of which were developed in 2007 and after.

The remaining three stations were common with the older lines of 1 and 2, developed in 1999, 2001, and 2006. The hypothesis of these T-Tests is that the current population and employment densities around the stations of older lines (1 and 2) are higher than those of newer lines (3 and 4).

Finally, in order to investigate the changes in site selection of metro stations and integrating public transit and density, polynomial regression analysis is employed to depict non-linear trends. Polynomial regression taken here follows the general equation of $y = a_3x^3 + a_2x^2 + a_1x + a_0$. Here the regression analysis was performed with two degrees, so only a_3x^3 and a_2x^2 are shown in the formulations.

3 FINDINGS

Significant differences between two different densities and three time periods were sought by doing four sets of T-Test analyses. The results of the analysis are illustrated in Table 3, where the differences between time classes were observed to be significant or marginally significant. In this study, the differences are treated as marginally significant when the one-tailed p-values fall between 0.05 and 0.10, as one observed p-value out of four proved to be so. Table 3 shows the results of the four comparisons conducted.

The population densities of the observed metro stations significantly increased between 2005 and 2015 compared to 1998 and 2003 (p-value: 0.0479). However, the population densities significantly dropped after 2015 (p-value: 0.0288). The status of employment densities around metro stations is different; job densities around stations established between 2005 and 2015 are lower than those of 1998 and 2003. Similarly, the job densities of the new stations yet to be established are even lower than in the period of 2005-2015. Job densities decreased from 66.7 jobs/ha to 52.1 and then to 37.2 during the mentioned three eras. The above indicates that the mean population and employment densities were treated differently.

	POPULATION DENSITY AROUND STATIONS				**EMPLOYMENT DENSITY AROUND STATIONS**			
	Population Density 1998-2003 and 2005-2015 (Inhab./ha)		Population Density 2005-2015 and after 2015 (Inhab./ha)		Employment Density 1998-2003 and 2005-2015 (Jobs/ha)		Employment Density 2005-2015 and after 2015 (Jobs/ha)	
Time Period	1998-2003	2005-2015	2005-2015	After 2015	1998-2003	2005-2015	2005-2015	After 2015
Mean	131.2	174	174	119.6	66.7	52.1	52.1	37.2
Variance	11095.8	11219.7	11219.7	5305.1	1803.6	1004.7	1004.7	421.1
No. of Stations	29	44	44	11	29	44	44	11
df	60		22		48		24	
t Stat	-1.69		2		1.58		1.9	
P-Value (one-tailed)	**0.0479**		**0.0288**		**0.0603**		**0.0344**	
T Critical (one-tailed)	1.6706		1.7171		1.6772		1.7108	

Tab.3 Results of T-Test of mean difference analysis on population and employment densities of 84 metro stations of Tehran

The T Critical values presented in the last row of Table 3 are calculated by means of degrees of freedom (df) and the upper-tail probability, which is 0.05 here. In three comparisons out of four the T Stat is more extreme than the T Critical, which indicates rejection of the null hypothesis of no difference (p-values of less than 0.05). The remaining one case with lower T Stat value is related to employment density 1998-2003 and 2005-2015, which is marginally significant (p-value between 0.05 and 0.10). The slight change in the value of T Stat and T Critical does not reflect any physical meaning for our longitudinal analysis, since only checking the significance of mean differences of job and employment densities is important for this study.

The above indicates that the mean population and employment densities were treated differently in different times. Fig. 4 indicates these differences based on the year of establishment of stations. Each column of this graph includes the average densities of a couple of stations established in that year. The annual number of stations established differs from 1 to 17 (2001).

The same difference is observed between population densities (40 to 346 inhab./ha) and employment densities (19 to 104 jobs/ha). The density analysis is largely inconsistent and does not reflect any continuous policy or intention behind the selection of metro station sites, i.e. in 2006, five stations were established, which provided a prominent population density of 346 inhab./ha and a job density of 104 jobs/ha. This year produced the most transit-friendly developments, while the three stations launched the next year only had a population density of 40 inhab./ha. In 2013, the average employment density became only 19 jobs/ha.

As explained in the methodology section, the comparisons of population and employment densities were repeated based on lines, assuming that lines 1 and 2 are older and lines 3 and 4 are more recent, while Line 5 is suburban and/or intercity and stays out of analysis. The findings are presented in Table 4, where the results of 5 out of 8 T-Tests show that the densities around stations of older lines are more than those of newer lines. Only 1 out of 8 tests reflects more densities in a newer line (population density of Line 4). In this comparison, the status of employment density is worse, because 3 out of 4 comparisons show lower employment densities in lines 3 and 4. The remaining test shows statistically equal densities. Hence, the hypothesis of higher densities around stations of older lines compared to those of newer lines can be accepted.

POPULATION DENSITY (INHAB./HA)

Lines	Line 1	Line 3	Line 1	Line 4	Line 2	Line 3	Line 2	Line 4
Mean	104.9	125.6	104.9	163.9	227	125,6	227	163,9
Variance	7810.1	3902.6	7810.1	7579	15637,6	3902,6	15637,6	7579
No. of Stations	24	25	24	15	21	25	21	15
df	41		30		28		34	
T Stat	-0.94		-2.047		3.3797		1.7855	
P-Value (one-tailed)	**0.1758**		**0.0248**		**0.0011**		**0.0416**	
T Critical (one-tailed)	1.6829		1.6973		1.7011		1.6909	
Result	Line 1 = Line 2		Line 1 < Line 4**		Line 2 > Line 3***		Line 2 > Line 4**	

EMPLOYMENT DENSITY (JOBS/HA)

Lines	Line 1	Line 3	Line 1	Line 4	Line 2	Line 3	Line 2	Line 4
Mean	55.2	41.1	55.2	56.8	77,8	41,1	77,8	56,8
Variance	2162.1	639.7	2162.1	797.5	708,8	639,7	708,8	797,5
No. of Stations	24	25	24	15	21	25	21	15
df	35		37		42		29	
T Stat	1.3163		-0.1303		4.7658		2.2521	
P-Value (one-tailed)	**0.0983**		**0.4485**		**<0.0001**		**0.016**	
T Critical (one-tailed)	1.6896		1.687		1.682		1.6991	
Result	Line 1 > Line 3*		Line 1 = Line 4		Line 2 > Line 3***		Line 2 > Line 4**	

***Marginally significant at 0.10 level**

****Significant at 0.05 level**

*****Highly significant at 0.01 level**

Tab. 4 T-Test results for comparison of population and employment densities based on lines

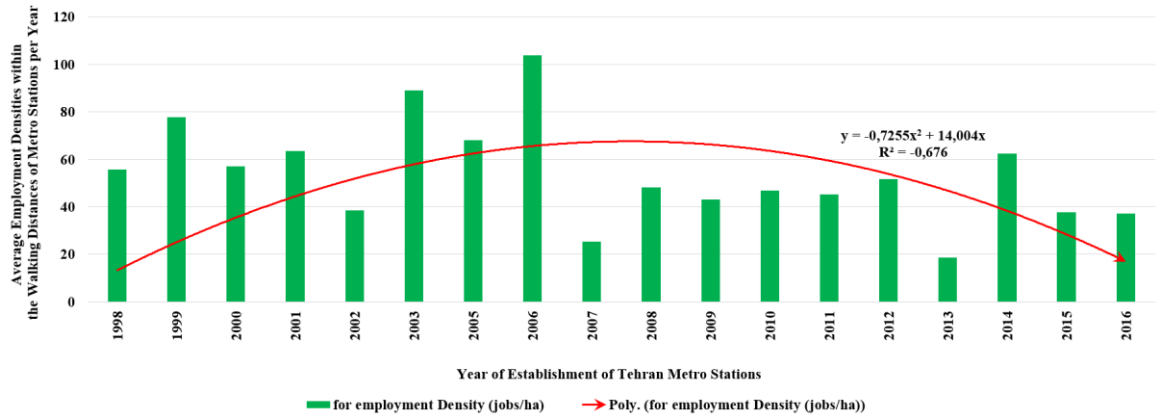

Fig. 4 Average annual population densities around Tehran metro stations since 1998

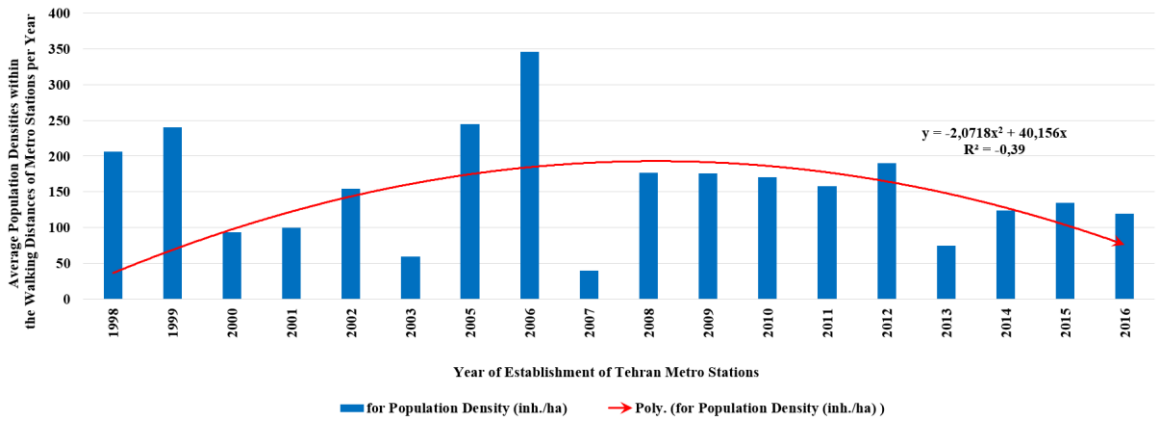

Fig. 5 Average annual employment densities around Tehran metro stations since 1998

The densities are also analyzed based on time on an annual basis of station development by means of polynomial regression analysis. Fig. 5 depicts these differences and highlights how a better approach to integrating urban rail systems was taken for ten years after 2005 and then this attention to connecting public transport to residential functions weakened again after 2015. Fig. 5 shows the same pattern for opening stations around employment centers such as retail centers, shops, offices, commercial areas, entertainment centers, malls, etc. between 1998 and now. The figures reflect the results of regression analysis for both density types. Both population and employment densities in 2016 exceed those in 1998, thus a_2 has a positive sign for both. However, the patterns and curves of the trend-lines are exactly the same. In both figures, it is assumed that those stations that had not been opened until the end of 2015 (11 stations) were open to operation in 2016. The R-squared value of Fig. 4 is 0.676, which means 67.6 percent of variability of population density around the observed stations is explained by the regression model. This value is considered to be an acceptable amount. Likewise, 39 percent of variability of employment density is explained by the model depicted in Fig. 5, which reflects a weaker model.

4 DISCUSSION

This study addresses the basic need for stronger integration of transit with dense land use in Tehran, Iran, as a first step accompanied by other necessary factors including implementation of pedestrian-friendly environments, mixed land uses, beautiful and vital neighborhoods, compact housing, and finally presence of public spaces, employment and working opportunities in the vicinity of transit. To set a clear target for the study, only two types of density, population and employment, were examined. Nevertheless, a complete

integration has to cover all the above aspects of transit-friendliness that have been frequently recommended by transport scholars and practitioners, some of which were addressed in the introduction of this paper.

The results of this research are comparable to a handful of international studies that have tried to evaluate TOD, an example of which is a recent working paper reflecting the work of Schuetz et al. (2016), who did not find any change in employment density, housing sales volume, or new housing development within five years after the stations of Los Angeles metropolitan area were opened.

However, the findings of this study show significant changes in population and employment densities. One point that should be noted is that the longitudinal changes in density targeted in this paper are not an impact of investment in public transportation as has been found in a wide range of studies that examined the impacts of land use, urban form, and housing (for instance Cervero & Landis, 1997; Debrezion et al. 2008; Mathur & Ferrell, 2009; Bowes & Ihlanfeldt, 2011; Kheyroddin et al. 2014 (Tehran case)), but they reflect the planning attitudes of urban and transport planners in selecting the metro station sites. The station site selection process in Tehran is the result of a complicated procedure studying very different factors for selecting the best line choices (direction and location) such as geo-technique, underground barriers, surface barriers, slope, etc. Moreover, the city is much denser than its western counterparts, so finding appropriate plots for new stations has been a severe challenge, particularly in the central parts. The above may have caused trade-offs between selecting sites providing the highest densities on the one side, and a broad range of difficulties in implementing and executing the plan. In the case of cities like Tehran, a public transport network is implemented in a highly-dense city with a majority of already established quarters. Having in mind that mobility-related decisions regarding commute urban trips have a very limited influence on residential location choices in Tehran compared to Western cities (Masoumi, 2013), one can conclude that TOD in Tehran may play a very weak role in changing the densities. This assumption is in line with Kolko's findings (2011), who found no significant change in employment density around the majority of transit stations in California opened between 1992 and 2006.

Here, it is worth adding that redistribution of population and relocation after the opening of new stations have not been subject of studies in Iran so far. The above study about self-selection (Masoumi, 2013) only seeks individual preferences for buying or renting residential location based on transportation priorities in general, but it does not consider decisions for choosing a place for living after a metro station has been recently opened. Such studies can contribute interesting inputs to the subject, if reliable disaggregate data are collected from individuals. It is clear that secondary data cannot be helpful for such purposes. In addition to the above, the interaction of stations with one another on the same line or on other lines was not covered by this study. Again, to clarify this issue, individual and household data need to be collected. Furthermore, between the time the stations were planned and the time they were actually opened to operation, population or employment dynamics may well have changed. This can also be a subject for further research.

The findings of this study show a significant (or in one case marginally significant) change in the residential and employment densities within walking distance of the metro stations. Although the stations that were opened between 2005 and 2015 enjoy higher population densities than those opened in the 1998-2003 period, the densities around stations to be opened in the near future will drop again. Thus, relatively good planning of stations in high-density areas has reversed previous low-residential densities before 2003. The same pattern is observed about employment densities. The above is the response of the authors to the question one of this paper.

In response to the second research question of this study, it is worth mentioning that accessibility to public transportation as well as integrating density concerns and mass urban rail transport have not been a priority in site selection of the metro stations in Tehran. Perhaps accessibility has been traded off in favor of

technical issues or lack of state-of-the-art knowledge of land use-transport integration. Moreover, the attention of Iranian planners to different densities around stations has been different: residential density has received relatively more attention, while employment density has been neglected. As Kolko (2011) concludes, "employment density is more strongly associated with transit ridership than residential density is". The findings of the T-Tests in this study show that the attention of transport planners has intentionally or unintentionally been on population densities, which can address trip origins, while destinations such as job locations, employment centers, etc. have gained less attention. Neglecting employment centers as well as a lack of attention to locating metro stations near the main street nodes such as the main squares and intersections are obvious in site selection of the first generation of the stations. Neglecting or disregarding employment in public transport planning runs contrary to the findings of a number of studies like Belzer et al. who recommend planners "to focus on employment patterns, clusters outside of CBDs incorporate transit, and new fixed-guideway investments". In a more detailed regression analysis of the average densities around stations, it became clear that the general pattern of population and employment densities are the same. However, with a larger-scale look at the findings of all the tests and regression analyses, a general pattern can be concluded concerning population and employment densities.

To clarify the situation, some examples of different station generations are described here. The first example is Shahid Haghani station, which was established in 2001 to serve Vanak square in spite of a long distance of one kilometer to the square (Fig. 6). Passengers who intend to reach Vanak Square have to take a taxi or bus after they get off the metro to reach their destination. The station was opened north of the Abbas Abad hills that accommodate city-level non-residential functions, which limits the proximity of the station to residential use. As seen in Table 2, there are 39.8 inhab./ha of population density and 15.2 jobs/ha within linear walking distance of 800 meters of the station (see no. 60 in the table). These densities provide limited accessibility to the station as an origin of trips. Furthermore, the location of the station offers weak connection to the main destinations in the region exemplified by Vanak Square.

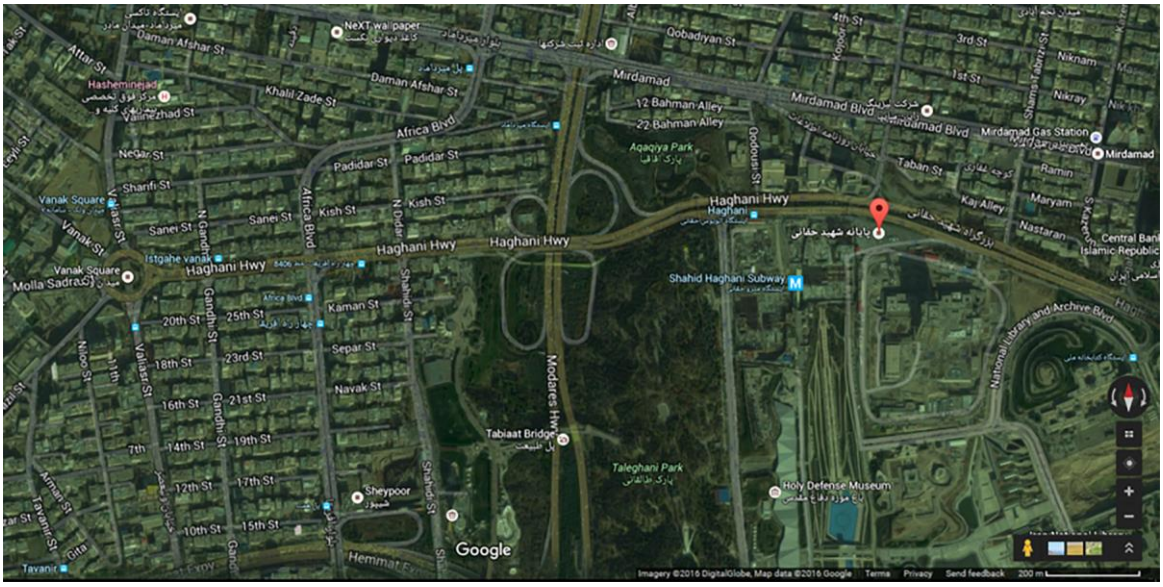

Fig. 6 Haghani metro station (on the right side) and Vanak Square (the left side of the map)

Fig. 7 Enghelab Square is one of the main nodes of Tehran, under which a metro station was established in 2009

Enghelab Square is an example of a more successful station opened between 2005 and 2015. The station is located under a main node called Enghelab Square (Fig. 7), which is surrounded by 185.1 inhab./ha of population density and 56.9 jobs/ha of employment density as shown in Table 2 (station no. 41). These figures are considerably higher than those of Haghani station in terms of connectivity to street nodes and the main intersections. Thus people can more easily reach their destinations in the city center. Nevertheless, the good attributes of Enghelab station are not inherited by many other stations, particularly the new generation of stations yet to be opened in the future.

More recent stations to get opened to operations soon are four stations, namely Shahid Mahalati, Aghdasiye, Hossein Abad, and Heravi (all located in the north and northeast of the city as seen in Fig. 1), none of which are located near major local or regional employment centers. The job densities of the above are between 8.4 to 37.8 jobs/ha, which are similar to the below-average population densities of between 20.8 and 90 inhab./ha (Table 2). Such decreasing levels of density within walking distance of stations can make the patterns seen in figures 4 and 5 more extreme, and worsen the walkability around stations.

It may be claimed that, during the first years of establishment, stations in the metro network were constructed in central areas with higher densities, followed by less dense areas closer to the periphery of the city. Two responses can be imagined for this assumption; firstly, the whole network was planned once by French consultants in the 1970s and later revised by Iranian planners. Thus, the mid-city stations were not the first planning outputs, but the stations were all planned together.

Secondly, still large areas with high residential and employment densities in the central city are not covered by the network. Therefore, there is still capacity to add stations to high-density quarters, especially those near the central business district. This is important because the city is relatively monocentric compared to several other megacities.

5 CONCLUSION

This study found significant differences in the densities within the walking distances of metro stations in Tehran. This longitudinal investigation of densities asserts neglecting the widely accepted and practiced principles of transit-friendly development. Locating new metro stations in the vicinity of populous or, even more importantly, areas with a high number of jobs is recommended. In other words, technical challenges should not be envisaged as the only planning priorities, but spatial determinants should also be a part of planning norms. This recommendation becomes more decisive when we consider that the present 170 kilometer network will extend to 430 kilometers and the current 5 lines will increase to 9 by 2028. Hence there are still quite a large number of stations to be added to the system.

There may be different reasons for the drop of densities around stations. One can be that many potential places in the central areas for planning new stations have already been taken for older stations. However, overpopulation of the city accommodating millions of people in only 730 Km² necessitates a tightly-weaved network of lines in the central areas. In other words, there is a potential for planning new stations in the very dense areas of the center.

This shortcoming raised here is in association with poor site-selection for new stations. It is also shown by this paper that the attitude of planners and decision makers has relatively leaned towards residential densities, while the new literature supports proximity of stations to job centers. This aspect of transportation planning in Tehran, namely locating stations near employment-based destinations, is a dark point.

In conducting this study it was assumed that no changes have occurred in the residential and employment density of the areas surrounding metro stations, motivated by opening the new stations. Further study is needed to prove this hypothesis with the context of Iran. As mentioned in previous sections, the effects of mobility decisions regarding commute travels on residential self-selections in Iran are weak.

ANNEX

No.	Station Name	No. of Statistical Blocks Around Stations	Date Established	Line No.	Population Density ∑pop/∑area (inhab./ha)	Employment Density ∑emp/∑area (Jobs./ha)
1	Shahid Mahalati	47	Still not opened	3	20,8	8,4
2	Aghdasiye	58	Still not opened	3	38,0	11,0
3	Hossein Abad	35	Still not opened	3	83,7	44,6
4	Heravi	90	Still not opened	3	90,0	37,8
5	Khajeh-Abdolah-Ansari	177	Still not opened	3	230,3	65,1
6	Shahid Sayad Shirazi	143	Still not opened	3	213,8	66,7
7	Shahid Ghodosi	95	Still not opened	3	107,5	27,1
8	Sohravardi	147	Still not opened	3	103,7	28,7
9	Mirzaye Shirazi	131	Still not opened	3	65,8	17,1
10	Razi	266	Still not opened	3	145,2	53,0
11	Zamzam	127	Still not opened	3	216,5	50,0
12	Ne'mat Abad	91	2015	3	161,7	38,0
13	Ghaem	16	2015	3	14,2	6,8
14	Nobonyad	64	2015	3	62,9	17,4
15	Shahid Zeyn-o-ddin	169	2015	3	152,7	41,2

16	Meydan-e Jahad	219	2015	3	222,7	62,3
17	Meydan-e Vali Asr	165	2015	3	151,1	41,2
18	Abdol Abad	179	2015	3	198,3	68,2
19	Shahrak-e Shari'ati	181	2015	3	115,0	27,6
20	Qal'eh Morghi	278	2014	3	190,1	44,1
21	Moniriyeh	172	2014	3	152,5	49,6
22	Rahahan	165	2014	3	42,6	128,5
23	Javadiyeh	280	2014	3	111,0	27,5
24	Azadegan	20	2013	3	74,6	18,5
25	Nirooye Havaei	186	2012	4	268,8	73,0
26	Tajrish	110	2012	1	110,6	30,6
27	Sheykh-o-raeis	308	2011	4	140,4	38,7
28	Doctor Habib-o-llah	136	2011	4	259,7	72,0
29	Ostad Moein	100	2011	4	28,9	7,8
30	Shahid Sadr	139	2011	1	93,5	28,5
31	Towhid	183	2011	4	266,7	79,7
32	Piroozi	259	2010	4	138,2	38,0
33	Shahid Kolahdooz	118	2010	4	254,4	67,5
34	Nabard	243	2010	4	150,9	41,2
35	Farhangsara	3	2010	2	251,0	69,9
36	Gheytariyeh	120	2010	1	103,0	28,4
37	Theatre-e Shahr	134	2010	3 & 4	123,0	35,5
38	Meydan-e Shohada	225	2009	4	242,2	66,4
39	Gholhak	167	2009	1	192,7	16,8
40	Doctor Shari'ati	159	2009	1	160,5	44,5
41	Meydan-e Enghelab-e Eslami	192	2009	4	185,1	56,9
42	Mirdamad	120	2009	1	99,0	31,0
43	Shahid Bagheri	133	2008	2	174,5	46,4
44	Tehranpars	124	2008	2	178,7	49,9
45	Ferdowsi	132	2007	4	68,6	60,9
46	Ekbatan (Eram-e Sabz)	40	2007	4	30,4	8,2
47	Varzeshgah-e Azadi	34	2007	5	21,3	7,1
48	Darvazeh Shemiran	192	2006	2 & 4	187,4	97,2
49	Imam Hossein	221	2006	2	253,5	76,0
50	Sabalan	318	2006	2	557,3	149,6
51	Fadak	195	2006	2	422,9	112,1
52	Golbarg	195	2006	2	307,2	84,0
53	Shahid Madani	259	2005	2	178,2	50,6
54	Sarsabz	191	2005	2	327,8	91,7
55	Elm-o-Sanat University	138	2005	2	228,0	62,0
56	Mellat	140	2003	2	33,5	81,7
57	Baharestan	160	2003	2	85,5	96,5
58	Javanmard-e-Ghassab	181	2002	1	154,4	38,4

59	Shahr-e-Rey	141	2001	1	137,7	34,4
60	Shahid Haghani	55	2001	1	39,8	15,2
61	Shahid Hemmat	4	2001	1	5,0	4,5
62	Mosalla	50	2001	1	21,3	5,7
63	Shahid Beheshti	117	2001	1 & 3	73,2	19,1
64	Shahid Mofatteh	191	2001	1	103,7	27,5
65	Haft-e-Tir	217	2001	1	214,2	60,9
66	Taleghani	147	2001	1	147,5	63,1
67	Darvazeh Dowlat	156	2001	1 & 4	88,1	97,7
68	Saadi	145	2001	1	27,7	93,8
69	15th of Khordad (Panzdah-e-Khordad)	163	2001	1	28,8	90,2
70	Khayam	214	2001	1	40,5	143,0
71	Molavi	233	2001	1	55,3	201,0
72	Shush	111	2001	1	27,6	54,5
73	South Terminal	76	2001	1	51,6	12,7
74	Khazaneh	293	2001	1	355,8	88,7
75	Ali Abad	263	2001	1	280,8	69,5
76	Imam Khomeini	116	2000	1 & 2	16,5	56,2
77	Daneshgah-e Emam Ali	139	2000	2	170,2	57,8
78	Tarasht	90	1999	2	225,3	59,5
79	Daneshgah-e Sharif	78	1999	2	193,2	53,8
80	Shademan	179	1999	2 & 4	294,7	84,0
81	Shahid Navvab-e Safavi	231	1999	2	362,9	119,1
82	Meydan-e Horr	158	1999	2	233,5	81,3
83	Hasan Abad	138	1999	2	130,7	68,2
84	Tehran (Sadeghiyeh)	70	1998	2 & 5	206,3	55,7

Tab.5 Detailed data of 84 metro stations including their pedestrian shed density

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IMAGE SOURCES

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Fig. 5: Via Google Maps.

Fig. 6: By Houshmand Masoumi.

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