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Testing the decentralization effects of rail systems: Empirical findings from Israel

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ABSTRACT

Many sustainable urban development approaches are based on mass public transportation ventures, especially railway development, which has been considered a panacea for the unfavorable effects of suburban development. But rail transit also improves accessibility to the fringes, thus encouraging an exodus to the suburbs. This paper explores suburbanization and sprawling effect of commuter rail transit on the rural exurbia of the Tel Aviv metropolis by analyzing its effect on residential location decisions. The findings indicate that the suburban rail system was a determinant factor in the location choice of households which migrated from the inner parts of the Tel Aviv metropolis, since it allowed them to maintain strong commuting connections to their residential origin. This suggests that rail transit, along with its potential to strengthen the inner cities, also accelerates suburbanization and counter urbanization.

1. Introduction

The environmental costs of suburbanization and the growing concerns about the future of the central city are the driving forces of planning approaches that encourage more controlled urbanization and suburbanization, i.e., denser development of both city area and its suburbs. Compact city advocates are worried about extensive consumption of land resources, energy inefficient transport systems, transport congestion and, as a consequence, degradation of the environment (Camagni et al., 2002). Moreover, extensive suburbanization threatens the vitality of the city and its attractiveness for residence and business.

A crucial aspect of the compact city vision is a supportive transportation system. The linkage between urban form and transportation system has been widely investigated (Knight and Trygg, 1977; Giuliano, 2004; Muller, 2004). The conventional model of urban development depicts it as a function of changeovers in transport technologies (Vance, 1986). Thus, by affecting accessibility and location decisions, the transport system affects urban form and development.

Neo-traditional schools, 'new urbanism' advocates and Transit Oriented Development (TOD) approaches suggest that mass transit (mostly rail transport) can support a more sustainable urban structure: dense and mixed activity areas along transport nodes and lines with a friendly pedestrian environment. They target densification both in the city and in its suburbs, in order to support a functioning metropolitan area. This motivation, in part, explains the growth in rail investments in the USA. After decades of relative stagnation in rail development, investments in rail infrastructure (mostly commuter and light rails) have increased in the last decade. Between 1995 and 2005, the total length of commuter rail and light rail in the USA grew from 4160 miles to 8076 miles and from 568 miles to 1188 miles, respectively (BTS, 2007).

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Much of the urban development in the United States and Europe at the end of the nineteenth century was due to the appearance of the railway, which catalyzed the enlargement of the cities on the one hand, and their compactness on the other (Fishman, 1987; Warner, 1970; Levinson, 2008). Although history shows that rail development was a driving force of both urban expansion and suburbanization and, contrastingly, urban densification and concentration, attention has been given mainly to the second type of rail impact. The decentralization effects of rail transit were mainly addressed by pointing out cases with compact suburbanization processes (Stockholm is the most cited example, see for example Cervero, 1995). Much of the research at the macro level, which deals with metropolitan structure, describes the decentralization trends, but often without analyzing possible causal relationships between rail transit and suburbanization. This paper aims at filling this empirical gap by examining the effect of rail improvement on metropolitan fringe development and by providing empirical evidence for the controversial suburbanization effects of rail transit. In this study, using a stated preference approach, we specifically examine the extent to which rail transit improvement encourages spread suburbanization trends at the metropolitan fringe.

The fundamental question raised by this paper is how rail transit and changeover in its level of service (LOS) affect residential location choices at the metropolitan low density fringe. It suggests that rail development and improvement, along with its potential to intensify density and activity in urban centers, also encourages further suburbanization trends and even exurbia development. The focus in this study is suburban development with low density housing patterns. The study takes a behavioral approach, exploring housing and commuting choices of households in the metropolitan fringes of Tel-Aviv which has enjoyed significant regional accessibility improvements in the last decade, mainly due to LOS upgrading of the railway system. Such analysis enables direct examination of the effect of rail services on housing choice and may contribute to our understanding of decentralization effects of rail services and the households that may mostly be affected by such services.

2. Transport and urban structure

Land use and transportation systems have mutual and simultaneous relationships. On the one hand, changes in accessibility that result from transportation improvements or deterioration affect location decisions (Ben-Akiva and Bowman, 1998; Perez et al., 2003). On the other, land use characteristics affect the efficiency and usage patterns of transportation systems (Ewing and Cervero, 2001; Banister, 2005).

Traditional location choice models tried to explore the attractiveness of housing as a function of the reciprocity between the friction of distance and the cost of land (DeSalvo and Huq, 1996; Muth, 1969). The classic model of Alonso (1969) suggested that a household's location choice reflects the balance between the marginal reductions in housing costs and the marginal increases in transportation costs, as a function of the commuting distance from the CBD. Thus, it is expected that employment centers will be located at the metropolitan core due to its high accessibility, and less intense activities will be located further away, while experiencing increased mobility costs. Accessibility improvements are expected to reduce mobility costs, while at the same time raising disposable income and time saving benefits, which might influence the patterns of residential activities and their spatial location (Rietveld, 1994). As mode choice affects commuting costs, Brown (1986) suggested that travel mode and residential choices are not independent goods and affect each other. Some studies suggested that residential location and job choices should be modeled simultaneously since they equally affect each other (White, 1988; Freedman and Kern, 1997), while others found that the workplace is not the main determinant of residential location (Deitz, 1998). However, many of the theoretical models estimate residential location choice assume a fixed job location and predict residential allocation as a function of a set of related variables (Vega and Reynolds-Feighan, 2009).

Historically, metropolitan range and residential patterns changed dramatically at the end of the nineteenth century when rail transit and later on, cars replaced non-motorized transport modes (ECMT, 2007). Changes in transportation technologies reduced commuting costs and enabled households (and later firms) to relocate further from the city center. Meanwhile, the railroads enabled higher city densities by moving large numbers of commuters to the city center (Levinson, 2008). The ascendancy of rail transit gave rail stations a central place in the urban fabric. When the rail system was radial, expansion was along the line and had a figure type development, where the most affected places were at both ends of the system. More convoluted and mature rail networks serve not only the center and the periphery; therefore, they may have a more complex influence.

In contrast with the situation in the nineteenth century, rail investments in the post-industrial era face different conditions as the intensive transport infrastructure that already exists marginalizes the impact of new or improved infrastructure (Giuliano, 1995). In addition, in many large metropolitan areas, most of the landscape already exists, which marginalizes the effect of transport infrastructure on urban development to an even greater extent. As a result, the most influential effect of rail transit in a radial network will be at the metropolis fringes. At these fringes, the accessibility base from the outset is low compared to the center, so any improvement in that base may enhance its attractiveness for economic and residential activity (Ureña et al., 2008; Vickerman et al., 1999; Rietveld, 1994).

Land use development patterns can be distinguished by two aspects. First, development can take place in the central city or in its suburbs (centralization and decentralization effects). Second, development can have dense or spread patterns, or, in other words, compact or sprawled development. Decentralization patterns are not necessarily accompanied by sprawl, but they enable dispersion, such as more available space for development, usually at a lower cost compared with the developed central city. As a result, decentralization is often associated with sprawled patterns. Suburbanization reduces the proportion

of population in the inner city and increases the proportion at the margins of the metropolitan area, localities with much lower densities (Banister, 2007). Hartog (citied in Banister, 2007) found that over time, densities in 40 European cities decreased, after reaching their peaks during the industrial era. For a given population, although rail service may intensify land use at the periphery at the expense of density at the core, this does not compensate for the decrease in density at the core (Levinson, 2008).

The dual influence of the rail system, concentration (and densification) and decentralization (and sprawled patterns), stems from its different characteristics. The concentration effects of rail service are derived from its advantage in carrying large numbers of passengers on exclusive right of ways. As such, rail transit is suitable to serve high density centers with a high demand for trips. Rail consumes relatively less land compared with other transportation infrastructure and reduces the demand for parking space. Therefore, in large and dense cities, rail systems are the main form of access to jobs and other activities in the central business district (CBD) (Crampton, 2000).

On the other hand, decentralization effects of rail transit have also been broadly evidenced through history. Although suburbanization trends on the metropolitan level began before the introduction of the rail, these trends were amplified when rail systems started to operate in Europe and in the United States (ECMT, 2007; White, 2008;). Suburbanization trends that are encouraged by rail systems stem from two characteristics:

1. Total travel time (door to door) is composed of four components of travel, grouped into out of vehicle travel time (OVTT) and in vehicle travel time (IVTT). OVTT consists of access time to the vehicle, waiting time for the transport mode and access from the vehicle to the destination. The IVTT component is the travel time in the vehicle. Rail transit has a clear advantage in the third component (IVTT), compared with other transport modes, since it has exclusive right of way and is less sensitive to congestion. Therefore, it has advantages on relatively long trips, as the IVTT share of the total travel time is large enough to compensate for the relatively high OVTT (Feitelson, 1993). Bovy and van der Waard (1991) found that commuter rails were competitive mainly for trips longer than 25 km.
2. Empirical research has found that although during the last century average commuting distances increased substantially, average commuting time remained constant (Mokhtarian and Chen, 2004; Metz, 2008). It is hypothesized that there is a travel time budget (TTB) that reflects peoples' willingness to allocate time for commuting that may differ among people, but on average, is stable and is estimated at 1.1–1.3 h per day (Zahavi and Talvitie, 1980; Metz, 2008). The existence of TTB can explain the relationships between new transport infrastructures and continuous suburbanization and urban expansion trends: new infrastructure enables an increase in commuting distances without changing commuting time and is used to increase travel distance rather than to reduce travel time, and to gain additional access, not to save time (Metz, 2008). This framework identifies the residents of the suburban metropolitan fringe as the main beneficiaries of rail transit investments.

Although improved transport infrastructure encourages a decentralization process, such a development reduces the efficiency of transit services as in sprawled areas there is not enough demand for travel to support fixed route transit services. Thus, park and ride facilities are introduced in order to extend the catchment area of rail transit stations far beyond walking distance of 10–15 min and to reduce the importance of residential density at the immediate rail transit station (Horner and Grubesic, 2001). Park and ride facilities can 'extend' public transport services to low density areas and promote transit usage when IVTT compensates for OVTT, including driving to the parking place and (when it is not kiss-and ride trip) parking the car. The catchment area of park and ride facilities is determined by its surrounding land use, downtown employment rates, geographic barriers and access afforded by transport arterials in the immediate vicinity of a station (Horner and Grubesic, 2001; Bolger et al., 1992). Thus, in addition to the tendency of suburban stations to have wider catchment areas compared with CBD stations (O'Sullivan and Morrall, 1996), park and ride facilities dramatically enlarge suburban catchment area.

3. Concentration and decentralization effects: existing empirical findings

Most of the empirical studies that explore the relationship between urban transit systems and land-use concentrate on the micro effect, namely the vicinity of the station. At the macro level of metropolitan effects, empirical evidence is scarcer as changes in land-use patterns on a large scale are slower and it is almost impossible to separate the effects of rail transit from other exogenous variables. However, macro level research has increased in the last decade, examining the impact of rail transit at the metropolitan level (Ewing, 1997; Fulford, 1996).

Different rail transit technologies produce a variety of spatial impacts (Porter, 1998; Cervero, 1998). Macro level impacts are particularly sensitive to heavy trains and suburban railway technologies since their service orientation is directed to the metropolitan fringes, as opposed to light train technologies that are expected to have reduced impact due to the dense urban fabric they usually serve (Garmendia et al., 2008; Levinson, 2008; Handy, 2005). Thus, much of the literature examining macro effects has focused on suburban and heavy rail systems.

Empirical examination of the macro effects of rail transit systems reveals the existence of its dual impacts and the differentiated impact on different cities. In some cities, such as Toronto, Portland and Stockholm, rail transit systems have had broad effects on the strength of the CBD, on the one hand, and on containing suburban development at the metropolitan fringes, on the other (Cervero, 1998, 1995; Filion, 2000; Post, 1988). Similar impacts (though at lower magnitude) have been

observed in Chicago (McMillen, 1989), Santa Clara County, California (Cervero and Duncan, 2002), Washington, DC (Green and Jones, 1993) and Washington County in the Portland metropolitan area (Knaap et al., 2001).

Many densification processes have resulted from supplemental circumstances, such as a strong planning regulator that directed the urban development into rail transit corridors and to city centers, good timing of the transit infrastructure establishment, a strong urban transit legacy and carefully reasoned public policies that have restricted the use of the car and limited the housing supply at suburban centers (Gospodini, 2005; Handy, 2005; Cervero, 1998).

When such supportive policies were rare (mainly in the USA), these effects were smaller or did not exist (Catanese, 1988). Modest densification effects were found in San Francisco (Landis et al., 1995) and Philadelphia (Boyce, 1972; Gannon and Dear, 1975). Rail transit systems in Miami and Atlanta failed to affect the city center densities.

Decentralization effects of rail transit and its effectiveness in long distance trips have been reported in several studies. Levinson (2008) found that the rail was a precursor to population growth in the periphery of London, while population growth was a precursor to rail transit development. Several studies identified long distance commuters and businesses at the metropolitan fringe as most affected by rail transit building, extraction or improvement (Hadj-Chikh and Thompson, 1998; Pushkarev and Zupan, 1977; NVPDC, 1993; Gannon and Dear, 1975).

In addition, rail transit was found to be a factor encouraging further spatial separation between residential locations in Switzerland (Lehrer, 1994), Munich (Kreibich, 1978), Naples (Papa, 2005) and Shanghai (Cervero and Day, 2008).

Bagley and Mokhtarian (2002) provided behavioral reinforcement to the above findings when they found that long distance commutes encourage the willingness to take the train. However, they found a positive correlation between rail transit mileages and pro-driving approaches in some suburban settlements. They explain this discrepancy by good access to 'park and ride' lots for suburban rail transit trips. 'Park and ride' lots were also one of the factors in the success of the MARTA rail transit system in Atlanta (Nelson et al., 1997).

A behavioral inquiry that examined the Travel Time Ratio (TTR) between residential location and work place found that commuting by rail transit tends to show the highest values amongst all other travel means (Schwanen and Dijst, 2002).[1] Thus, commuter rail transit enabled a spatial separation between residences and employment locations. In addition, there is a positive correlation between high TTR and higher education and income levels. Indeed, it was found that affluent suburban commuters tend to use the rail transit service more than the poor (Pucher and Renne, 2003; Baum-Snow and Kahn, 1998; Nelson et al., 1997).

The empirical findings suggest a few general observations:

1. Concentration effects mostly occur when accompanied by parallel complementary policies. On the other hand, decentralization effects are evident regardless of such directed policies, as they follow household preference for detached and larger houses (and may even be intensified by other indirect policies that encourage sprawl, as Levinson (2008) has demonstrated).
2. While concentration effects require high density development in the urban center, low density suburbs can be served by rail transit if accompanied by 'park and ride' facilities.
3. Rail transit tends to serve long commuting trips and wealthier households.

To conclude, the belief that rail transit development has the potential to slow suburbanization trends is not supported. Moreover, the expectation that rail transit will promote denser suburbanization is also not supported, perhaps due to 'park and ride' facilities that can compensate for sparsely populated rail transit station catchment areas.

4. Research method and data collection

The current research examines the impact of rail transit improvement on residential choice in the Tel Aviv metropolitan exurbia, i.e., its decentralization and sprawling effects. Tel Aviv is the main metropolitan area and the main economic center of Israel. It has been experiencing intensive growth at its outer rings at the expense of a weakening core.

As in many metropolitan areas, Tel Aviv's core and inner rings are compact, dense and characterized by mixed land use, and therefore have the potential to support an efficient rail transit system.[2] This study examines the northern part of the Tel Aviv metropolitan area, known as "Bikaat Ha-Nadiv" (see Map in Annex 1), that serves as an interface area between Tel Aviv and the northern metropolitan area of Haifa. The research area includes several small villages and towns that serve as the potential catchment area of the rail transit stations between Haifa and Tel Aviv, most of them characterized by low density building.

In the last decade, rail transit services in this area have increased considerably as a result of the dramatic increase in the daily number of trains servicing the two stations in the region. While in 1998 there were 39 daily trains at the Binyamina

[1] Travel Time Ratio is defined at the inquiry as the division between the travel time to a specific activity (such as employment) and the total time needed for this activity (including the travel time to the place of the activity and the duration time at the place of activity).

[2] The traditional definition of the Tel Aviv metropolis divides it into four spatial tiers: the *metropolitan core* (the City of Tel-Aviv-Jaffa); the *Inner Ring* that constitutes the oldest urban settlements that surround Tel-Aviv, and whose external boundary is no more than 14 km from the heart of the city; the *Middle Ring* that constitutes the second tier of urban settlements and encompasses the Inner Ring, and whose external boundary is no more than 25 km from the heart of Tel-Aviv-Jaffa; the fourth ring which is the *Outer Ring* of the metropolis, is characterized mainly by rural settlements. Its external boundary is no more than 40 km from the heart of Tel-Aviv-Jaffa.

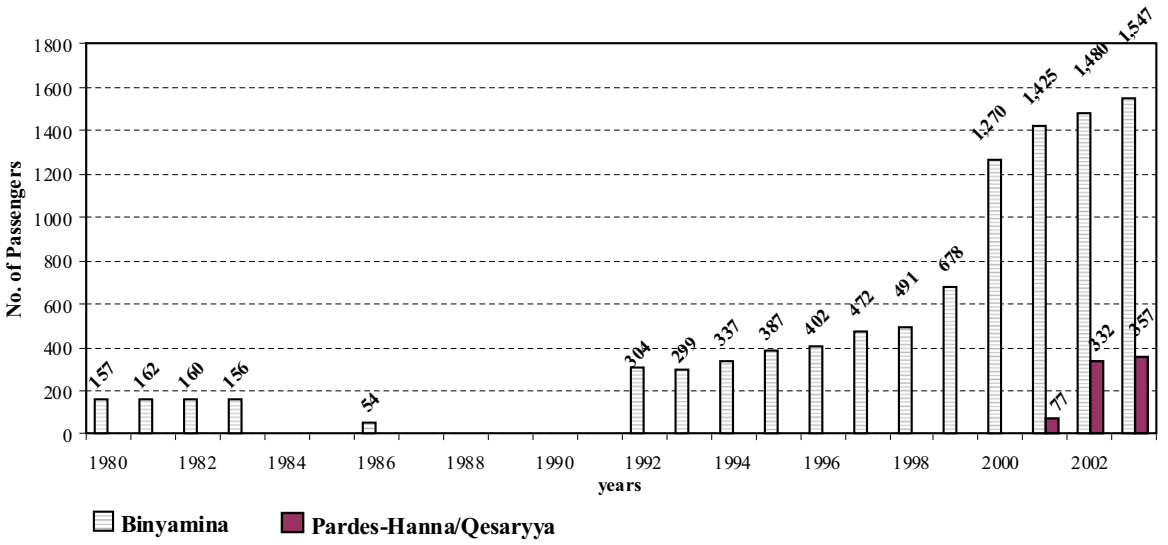


Fig. 1. Annual rail passengers at Pardes Hana and Binyamina 1980–2003 (thousands).

station, this number increased to 124 daily trains in 2004. Most of these are regular interurban services connecting the city of Haifa and the city of Tel-Aviv, originating in Haifa, stopping at this station, with no additional stops until they reach Tel-Aviv. In addition, the station serves as suburban rail transit center, connecting other cities to the main service between Haifa and Tel-Aviv. The station has a park and ride facility with 500 parking spaces. Due to the shortage in parking space, there is also unauthorized parking in proximity to the station. Since the rail transit station is situated in the industrial part of the settlement, it is less accessible by walking but there is both bus service to various destinations and taxi service. Simultaneously, a new station was opened in Pardes Hana in 2001, from which there are approximately 50 daily trains. It offers suburban service with stops at various settlements between the station and Tel-Aviv. Here, too, the rail transit station is situated in the remote industrial area, offering 300 parking spaces, and it is served by a small number of interurban buses which stop at this station. As stated, the access to both rail transit stations is mainly by car or bus, as they are not situated in residential areas. However, the station in Binyamina is more accessible to walkers. The number of passengers at these two stations has increased substantially in the last decade, as shown in Fig. 1. The new and improved rail transit services during this period serve as the exogenous variable in this study, i.e., the change in rail transit service that is hypothesized to affect residential location.

Traditional models depict residential location decision as a balance function between trip costs and land rents (Mills, 1972; Muth, 1969). Updated models have enlarged this conceptual framework, considering other variables such as the physical and social characteristics of the living environment, life cycles, personal characteristics and amenity preferences (Kim et al., 2005; Kim et al., 2004; van Dam et al., 2002). In order to understand household location choices in the research area, it is necessary to explore the relative weight of the rail transit service compared to factors other than transportation, taking into account preferences under a variety of circumstances and constraints. In order to perform such an inquiry, the research combines the findings of a revealed preference and behavioral approach regarding location choice, personal characteristics and familial aspects of travel.

Although, a revealed preference approach has been used in the past (for example see: Wardman, Tight and Page, 2007; Tayyaran and Khan, 2007; Turnbull, 1997), it may be deficient in a number of respects. For example, suburbanization trends may also be evidenced in metropolitan fringes that have not experienced rail transit improvements.[3] Ideally, the study should have compared development of a metropolitan fringe with rail transit building or improvement, and development of a metropolitan fringe without such improvement. However, the size of Israel and its geographical structure (very narrow and relatively long), and the centrality and uniqueness of the Tel Aviv metropolitan area do not enable such comparison. We did not find an area comparable to the research area that had not been affected by rail transit improvements or a new rail transit system.

Therefore, in order to isolate the rail transit effect, we explicitly used questions in the questionnaire that identify the role and weight of rail transit improvements in the residential decisions that were taken. Based on past research inquiries (Shiftan, 2008; Lund, 2006; Hunt et al., 1994), questions were asked about stated preferences, examining the willingness of the respondents to change to a residential location with different rail transit service characteristics. This method enabled us to overcome rational bounded constraints of the sampled population and to examine the extent to which LOS of the rail transit service affected residential decision making.

[3] In the case of Binyamina and Pardes Hana, evidently the growth rate has been higher than the average growth in settlements of similar sizes. Binyamina has had a annual growth of 5.1% in the last decade, compared with a 2.1% annual growth rate in settlements of similar size. (Israeli CBS)

At the first stage of the research, a survey of rail transit users was conducted at the two rail transit stations (Binyamina and Pardes Hana), in order to map the catchment area of these stations. The survey was taken at each station on two weekdays. According to the rail transit data, the estimated number of daily travelers in Binyamina and Pardes Hana is 6000 and 1500 respectively, and it was decided to sample 155 and 104 travelers, accordingly. Every tenth traveler at the stations was sampled, also accounting for gender distribution. The survey identified 13 settlements that serve as the stations' catchment areas, which provided the basis for the second phase of the research. The catchment areas include settlements with a maximum distance of 11 km.

The 13 identified settlements include 16,000 households that served as the research population. At the second stage of the research the study sample included 3% of the population, consisting of 500 households sampled using the random proportional stratified method (i.e., according to the weight of the settlement, as evidenced in the rail transit travelers sample), in order to assure proportional representation of each settlement. Weighting the sample according to the station survey biases the sample towards rail transit users. The logic behind such bias is that the research looks at rail transit users and the extent to which rail transit improvements affected their residential choices. Therefore, we decided to amplify their weight in the sample in order to be sure that they would be included in a random sample; otherwise we could not have insured a sufficient number of rail transit users in our random sample. As a consequence, the research findings are expected to reflect the maximum effects of rail transit improvements in the research area (the catchment area of the two rail transit stations) since settlements with a high percentage of rail transit usage are overrepresented. However, the sample includes both rail transit users and non-rail transit users.

A detailed questionnaire was sent by mail and included questions regarding migration choice of the household, stated preferences of residential households, details about employment status and location, rail transit usage and attitudes towards rail transit, travel behavior and socio-economic characteristics. Two hundred and 83 valid questionnaires were returned with a response rate of 58%. All 13 settlements are represented in the sample fairly proportional to their weight.

5. Sample characteristics, mode split and relocation decisions

Table 1 presents general socio-economic features of the households surveyed within the framework of the study. Clearly, the vast majority of the sample includes an educated, professional upper-middle class population, which often characterizes suburbs and exurbia settlements. Moreover, most of the population lives in detached houses, another typical characteristic of suburb residence with low densities.

Not surprisingly, most of the trips in the sample are made by private car, with 19% of the trips made by trains. Rail transit is the main mode of public transport, compared with buses (19% and 2%, respectively). However, bearing in mind the nature of the settlements in the study (low density with mostly single detached houses), the share of rail transit users is relatively high, compared to their share in Europe or in the USA (EU Statistical Pocketbook, 2007, Table 3.3.2; US National Transportation Statistics, 2007, Appendix A). This relatively high share of rail transit users is also the result of the sample strategy that, as mentioned above, magnifies the weight of rail transit users in the survey. Table 2 presents the frequencies of rail transit trips, according to trip purposes. It shows that 16% of the commuters use the rail transit on an almost daily basis. It also shows that rail transit is used at much lower frequencies for other purposes.

The mean (reported) travel time to the nearest rail transit station is nine minutes (SD = 4.4) with maximum travel time of 30 min. As Fig. 2 shows, farther than a 15 min drive to the rail transit station there is hardly any rail transit usage and proximity to the rail transit station indeed is accompanied by a tendency to use the rail transit by at least one earner in the household.

Table 1
Socio-demographic profile of the sample.

Percentage		Variable
4.3	Far below the average income	Household income
4.6	Below the average income	
14.5	Average income	
36.5	Above the average	
40.1	Far above the average	
7.9	Apartment buildings (with or without a garden)	Dwelling
84.0	Detached single house	
2.1	Detached house	
6.0	Duplex	
4.6	No car	Number of cars in the household
29.4	One car	
62.8	Two cars	
3.2	Three cars and above	
21.3	High school	Education
46.4	B.A degree	
32.3	M.A degree and up	

Table 2
Rail uses by at least one member in the household according to trip purposes (percentage).

Total	5+ times a week	3–4 times a week	1–2 times a week	1–3 times per month	Less than once a month	Never	
100	16	6	3	8	13	54	Commuting
100	–	–	1	6	30	64	Shopping
100	–	1	1	10	38	50	Leisure
100	1	1	3	9	43	43	Study

$N = 283$.

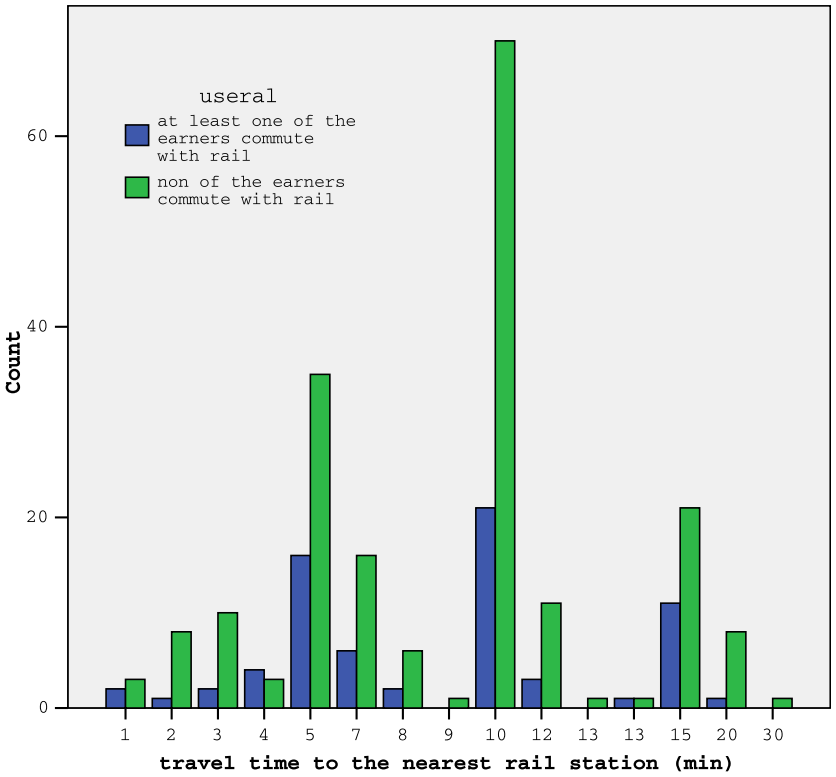


Fig. 2. Travel time to the nearest rail station and usage of the rail by at least one earner in the household.

Table 3
Work location of primary earners according to previous residential location (percentage).

Previous residential location								
Total	Outside metr. area	Metr. fringe	Outer ring	Middle ring	Inner ring	Core		
100	20	3	3	15	41	18	Core ($n = 39$)	Work location of primary earner
100	20	3	3	15	41	18	Core ($n = 39$)	Work location of primary earner
100	18	6	15	15	39	7	Inner ring ($n = 33$)	
100	43	14	–	43	–	–	Middle ring ($n = 7$)	
100	38	4	23	8	19	8	Outer ring ($n = 26$)	
100	34	24	10	9	14	9	Metr. fringe	
100	67	8	4	–	4	17	Outside metr. area ($n = 58$)	
100	63	13	–	–	12	12	Israel ($n = 8$)	
							222	Total
$\chi^2 = 90.622$; df = 30; $p \leqslant 0.000$; R-Square = 0.352; Spearman = 0.336								Statistics

When examining commuting trips to different areas of the Tel Aviv metropolitan area, the advantage of rail transit is evident in longer trips to the metropolitan core. Workers who commute to the inner part of the Tel Aviv metropolitan area are more likely to commute by rail transit.

Most of the workers in our survey commute by car, and used to commute by car before changing residential location. However, 35% of the earners changed their commuting mode when they moved to the research area: 12% of them switched to rail transit, 14% switched from rail transit to car and 9% switched to other modes of transport. Thus, although some of the workers who moved to the research area switched to rail transit, a larger portion of workers kept commuting by car or started commuting by car.

6. Residential decisions and the rail transit system

The aim of this research is to examine the extent to which improvement of rail transit services encouraged or provided additional support for the decision to migrate from the inner part of the Tel Aviv metropolitan area to its fringes. Out of 283 households in the study sample, 239 households immigrated to the study area after 1975 and most of the immigration to the area (67%) occurred between 1996 and 2004, the same period that experienced significant improvement of the rail transit service in the area. Most of the households in the sample that immigrated between 1996 and 2005, emigrated from the core

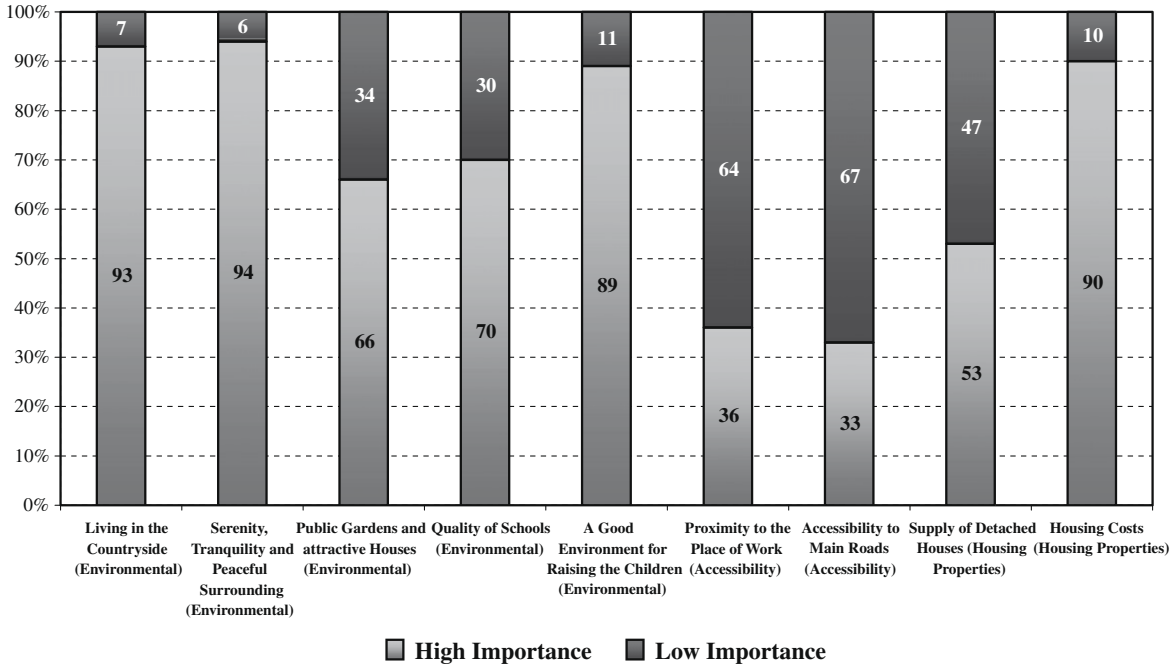


Fig. 3. Distribution of housing location choice considerations among households that ascribed high importance to the rail stations' proximity and the accessibility to the Tel Aviv region ($n = 70$).

Table 4
Importance of rail accessibility in residential decision-ordinal logit model.

Importance of rail accessibility in residential decisions[b]					Dependent variable
% of right predictions in category[c]	Prob > ChiSq	ChiSq	SE	Estimate	
68	<0.001	50.86	0.271.	−1.937	Intercept 1
76	<0.001	24.79	0.254	−1.266	Intercept 2
79	0.0717	3.24	0.239	−0.431	Intercept 3
73	0.0097	6.69	0.252	0.651	Intercept 4
	<0.001	26.87	0.283	1.467	Does the primary employee work in the metropolitan core?[a]
	0.0002	14.14	0.267	1.01	Was the previous residential location in the metropolitan core?[a]
	ChiSqure = 58.05; Prob > ChiSq < 0.001; $N = 283$				Whole model test

[a] 1 = yes 2 = No.
[b] 1 = not important at all; 5 = highly important.
[c] Based on ROC.

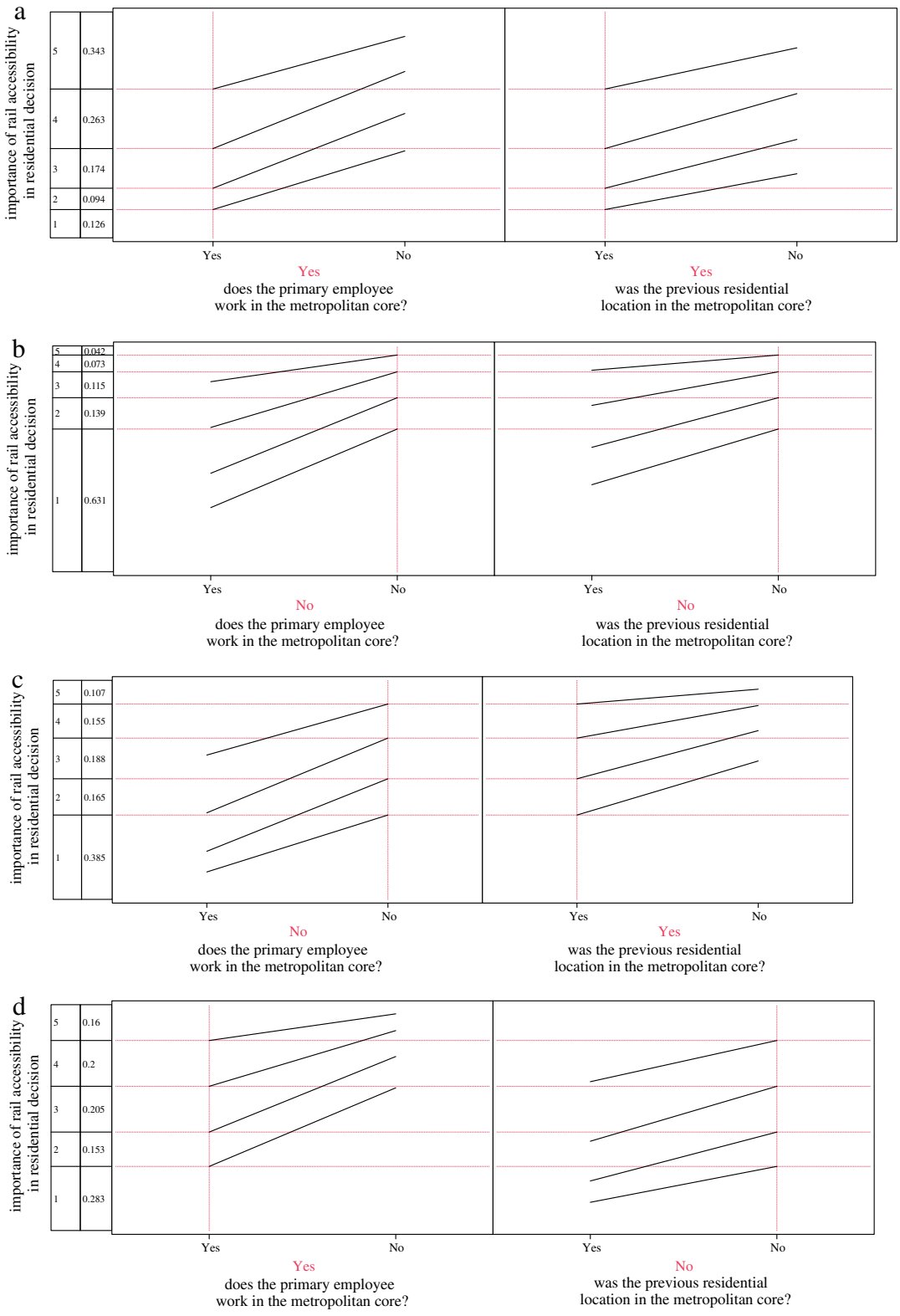
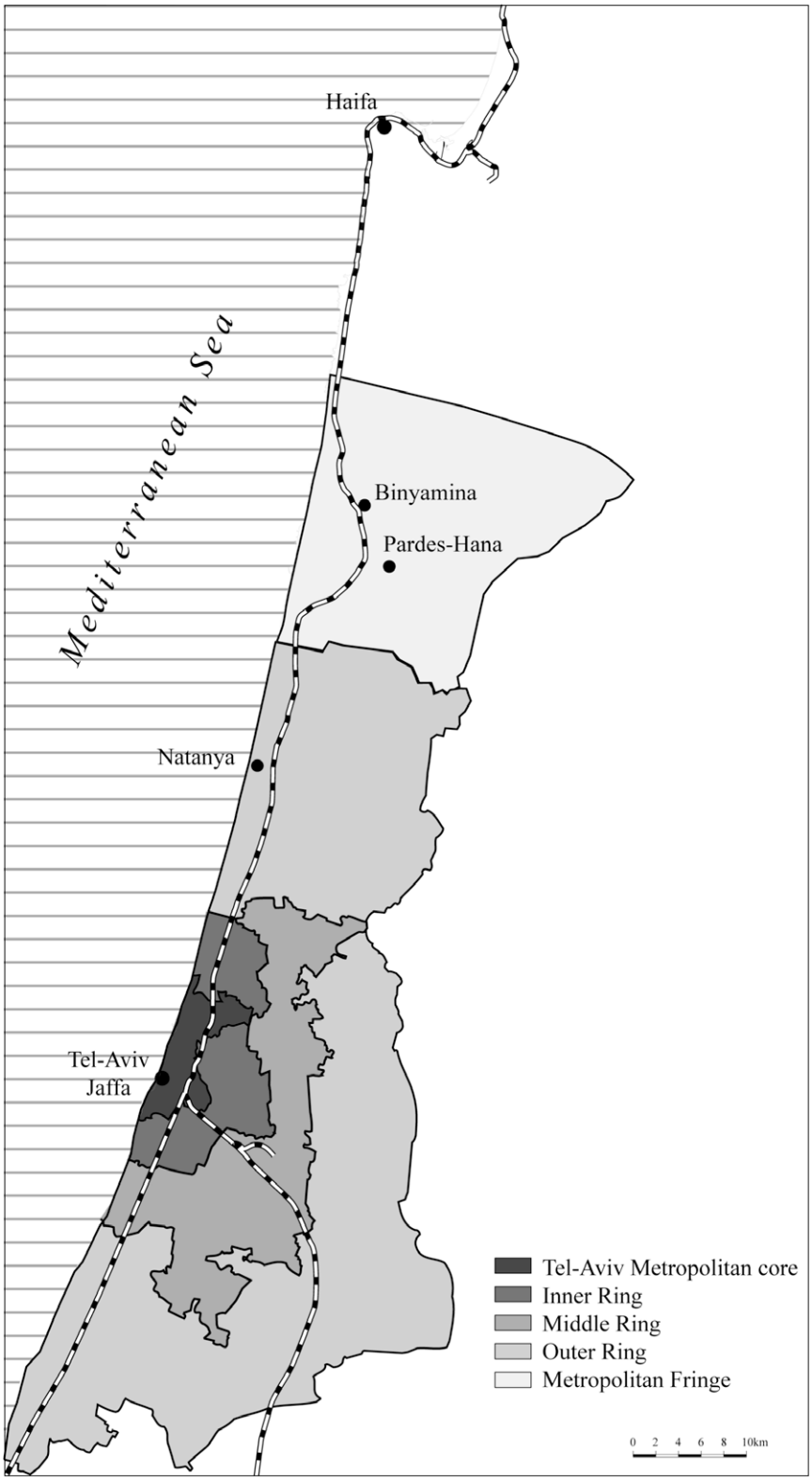


Fig. 4. (a–d): The prediction profiler of the ordinal logistic model.

and inner ring of the Tel Aviv metropolitan area. Not surprisingly, 82% of the immigrants are families with at least one young child (age 0–17). Therefore, it is interesting to test to what extent the improvement in rail transit service played a role in the



Map 1. Tel-Aviv metropolitan area and research area.

decision to move to the area. In order to examine such relationships, it is necessary to understand the affinity of the household to the Tel Aviv metropolitan area and the reasons for the new residential location in the study area.

The Tel Aviv metropolitan area, and especially its core, serves as a main source of employment to households in the study sample. Most of the primary earners who emigrated from Tel Aviv are still employed there. Table 3 presents the work location of the primary earners in the households, considering their past residential location (before immigrating to the research area).

The table shows a strong and significant correlation between work place and previous residential location. This means that most of the primary earners who work in the metropolitan core immigrated to the "Bikaat Ha-Nadiv" area from the metropolitan core and substituted proximity to the work place with better residential choices.

The extent to which improved rail transit services enabled such immigration is tested in two ways. First, household members who moved to the research area were asked about the relative importance of location characteristics in their residential choice, when proximity to rail transit services was one of the characteristics. Second, the household members were asked directly if their residential choice would have been different had there been no rail transit stops at the current two rail transit stations.

The relative importance of proximity to the rail transit station, compared with other residential characteristics is relatively low. The most important factors that were identified by the household members are related to environmental characteristics such as rural environment, quiet environment and child-friendly environment. Although accessibility to rail transit stations was rated higher than accessibility to main roads, both considerations were rated relatively low. Fig. 3 shows the distribution of the housing location choice considerations among the households that ascribed high importance to rail transit station proximity and accessibility to the Tel Aviv region.

The figure shows that those who ascribe high importance to rail transit station proximity are less concerned with proximity to their work place or accessibility to main roads. The housing environment is perceived as very important to their residential decision. The importance of a supportive and high quality environment for their children shows that most of them made their residential choice during the child raising stage, the stage that is most identified with suburbanization decisions. These findings are consistent with other studies of Atlanta (Nelson et al., 1997), California (Lund, 2006) and Spain (Garmendia et al., 2008). In these cases, it was found that new residents were equally or more likely to choose to commute longer distances, concomitantly with their house location choice which was influenced by a wide range of reasons (lower housing costs and the quality of the neighborhood) and relatively less by rail transit access. However, when respondents were asked (employing the stated preferences approach) whether they are willing to move to another rural area, but without current rail transit services, more than 50% of them rejected such an option.

In order to test the most significant variables that explain the importance of rail transit accessibility in a residential location, an ordinal logit regression model was estimated, with a step-wise procedure, allowing testing a dependent variable with ordinal scale. Table 4 presents the final model. The dependent variable, the effect of rail transit accessibility on residential decision is a five scale ordinal variable (ranging from 1 = not important at all; 5 = highly important) that is represented in the model with four intercepts.[4] As can be seen, the most important predictors of the extent to which rail transit accessibility was an important factor in residential decision are the work place of the primary earner and the previous residential location of the household. When the primary earner works in the metropolitan core, there is a high tendency to consider accessibility to rail transit service as important. In addition, if the household's previous residential location was in the metropolitan core, it is more likely that access to rail transit service will be an important factor when considering residential location. The prediction profiler that is presented in Fig. 4 can be read as follows: the change in predicted response as you vary one factor at a time, holding the other factors at their current values. Fig. 4a suggests that when the primary earner works in the metropolitan core (value 1) and was previously located at the metropolitan core (value 1), there is a 34.3% chance that he/she considered rail transit accessibility as very important (value 5) and just a 12.6% chance that rail transit accessibility was not important at all. In contrast, Fig. 4d shows that 63.1% of the households with a primary earner not at the metropolitan core and not previously located at the metropolitan core considered car accessibility as not important at all and just 4.2% accorded high importance to rail transit accessibility when they moved to the metropolitan fringe. The overall model is significant and its predictive power is sufficient. Compared with the initial distribution of the importance of the rail transit to the residential decision, using the model doubled its right predictions, as can be seen by the percentage of right predictions in categories. In other words, the improved rail transit services from the metropolitan fringe enabled households that were highly involved in central city activities (working and/or living in the metropolitan core) to leave the inner city while maintaining their previous activities. Households that had less intensive contacts with the metropolitan core were less affected by rail transit improvements.

7. Discussion and conclusions

This research examined the extent to which improvements in rail transit services affected residential location choices. Specifically, it tested the extent to which such improvements encouraged households to move to the metropolitan fringe. It found that households who used to live and work at the metropolitan core perceived the rail transit as an important feature when choosing to move to the metropolitan fringe. We used a stated preference approach to estimate the extent to which rail transit LOS improvements affected the decision to move from the metropolitan core to its fringe. By using this approach we specifically addressed the decentralization effects of rail transit.

[4] Note that this is not a model to predict rail usage, but to explain the factors that affect the influence of rail services on the decision to move to the metropolitan fringe

Household earners who kept their work place at the metropolitan core are the main group of rail transit users and tend to attach high importance to rail transit when deciding to move far from the metropolitan core. As identified in previous studies, the rail transit tends to serve relatively long commuting trips. Our study reinforced these findings since it found that commuters to the metropolitan core who have the longest commuting trips are the main group of rail transit users. Since most of them use park and ride facilities, their work location affects their mode choice and not their residential location. Most of them drive 5–15 min to the rail transit station, but the relatively short IVTT compensates for the time spent arriving to the rail transit station. The sample used in this study over-represents rail transit users since it was stratified according to settlements that were identified as the catchment area of the rail transit station in the research area according to the weight of the settlement, as evidenced in the rail transit traveler sample. Thus, it under-represents settlements in the research area that have fewer rail transit users and does not reflect the effect of rail transit on residential locations in the whole research area, but rather in settlements with higher rail transit usage.

Improvement in rail transit services is often advocated as a tool to support central cities and induce urban and suburban densification. Alongside its potential to support such processes, rail transit improvement also has the potential to encourage the opposite trend: metropolitan decentralization and sprawled suburbanization. The current research offers an empirical examination of suburban residential choices and the extent to which they were affected by improvements in rail transit LOS. This study did not test the potential concentration effects of the rail transit; rather, it focused on its densification and decentralization effects. Thus, in addition to the evidence for its contribution to urban decentralization trends, it may also have concentration effects in other parts of the metropolitan area. Our research area experienced a relatively high growth rate and development. Clearly, the improvements in rail transit LOS are not the only (or even the main) factor affecting this growth. Since the research design does not control non-transport effects (as explained in Section 4), we cannot weight the significance of rail transit improvement on suburban growth; rather, we can point out the perceived importance of rail transit by households that choose to move to the metropolitan fringe.

The case of Bikaat Ha-Nadiv in Israel shows that the households that were most affected by the rail transit service when choosing to move to the metropolitan fringe are those who previously lived and worked in the metropolitan core. Improvements in the rail transit service encouraged some of them to move to the metropolitan fringes and to materialize their suburban aspirations with perceived acceptable commuting costs. Although most of the respondents in our survey commute by car, rail transit service improvements are perceived as more important than road improvements in their residential choice. It seems that the option of rail transit usage is important in residential choice and the presence of rail transit services affects not only rail transit users but non-regular users as well. These findings highlight the importance of the option value of rail transit and its influence on residential location in general, but more significantly, they indicate the importance of such service even in low density metropolitan fringe. When the service is of high quality (that is, high frequency), and there is access to park and ride services at the station, rail transit services may play an important role when deciding to move to the metropolitan fringe.

According to Florida (2004), economic growth of cities in the United States is correlated with the existence of 'talented' people in the cities and the strength of the creative class (percentage of Bachelor's Degrees and above per 1000 population). He also found that the creative class is attracted to 'cool' cities (cities that offer many entertainment options on the one hand, and diverse population on the other hand). His conclusion is that cities should attract talented people in order to foster economic development and therefore, they should increase their 'coolness'. One criticism of Florida's findings is that they mainly fit one stage in talented people's life cycle. When talented people have children, they may be attracted to other environmental features. Our research findings suggest that these households are more likely to be affected by improvement in LOS of the rail transit to the metropolitan fringe. When the creative class has young children, some of them are willing to move to the metropolitan fringe and improve their residential conditions if they can keep their workplace in the city and maintain an acceptable travel time budget. Rail transit service improvements are perceived, by some of them, as an opportunity to move away from the metropolitan core.

The positive influence of rail transit on the decision to live in the metropolitan fringe is not limited to high density settlements. Although the study area is characterized by low density development, rail transit serves as a relatively important commuting mode, mostly to the core of the Tel Aviv metropolitan area. The study design amplifies the importance of rail transit; yet it indicates the perceived role of good rail transit services in residential choices and demonstrates the potential of rail transit to serve low density settlements when accompanied by 'park and ride' facilities.

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