The Impact of Joint Parking Policies on Motor Vehicle Pollutant Emissions

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Abstract

Many western Metropolitan areas suffer from a deterioration of air quality. A major reason for this phenomenon is related to the increase in vehicle-kilometers traveled (VKT), which is an outcome of urban sprawl and the continuous increase in the rate of car ownership. Despite the positive effects of technological progress in reducing emissions per unit of distance traveled, the overall increase in VKT adversely affects urban air quality.

The motivation of this paper is to investigate policy measures that can be implemented by decision makers in order to improve urban air quality. In particular, this paper focuses on parking policies, aimed at understanding the relationship between parking policies enforcement in the center of the Tel-Aviv Metropolitan Area (TAMA) and air pollution emissions from motor vehicles, including the outcome of pollutant emissions – ambient pollutant concentrations.

The paper focuses on the measures that can have a direct impact on Vehicle-Kilometers traveled (VKT), such as decreasing the supply of on-street and/or off-street parking, and increasing parking fees. Nine different scenarios are tested, representing different combinations of parking fees and parking availability. The results show that parking limitations in the city of Tel-Aviv results in a decrease of VKT and VHT (vehicle-hours traveled), and consequently a decrease in NO_X concentrations. This expected result is followed by an increase of VKT and VHT in other regions, but in the overall metropolitan area the VKT and VHT decreases, and thus the NO_X concentrations decrease by up to 7%.

The paper discusses these policy implications and the reasons for the significant changes in both the traffic variables and pollutant emissions.

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1. Introduction

Many metropolitan areas suffer from a deterioration of air quality. A major reason for this phenomenon is related to the increase in vehicle-kilometers traveled, which is an outcome of urban sprawl and the increase in the motorization rate. Despite positive effects of technological progress in reducing emissions per unit of distance traveled, the overall increase in VKT adversely affects urban air quality.

Tel-Aviv is considered the business capital of Israel. The city attracts employees from the entire metropolitan area, including the outskirts and beyond, who commute to Tel-Aviv on a daily basis. The metropolitan area comprises close to 3 million inhabitants or 43% of Israel's total population. High level of air pollution concentrations in Tel Aviv Metropolitan Area, especially in the Central Business District (CBD) area, is the motivation of this research. It has been determined that mobile sources are the main pollutant source in the CBD area of Tel Aviv (Ranmar et al., 2002; Shefer, 1994).

Several factors affect air pollution emissions from mobile sources: technological factors, urban form factors, and economical factors. Technological factors deal with the internal mechanism of mobile sources (type of motor and technological methods employed to decrease pollutant emissions) and are out of the scope of this article. The two other factors influencing air pollution emissions from mobile sources are investigated in this paper: urban form factors, and economical factors.

A variety of policy methods could be employed in order to decrease air pollution emissions from mobile sources: parking policy, compact urban planning, transit-oriented development (TOD), congestion toll, traffic calming, transit level of service improvement, slow mode planning – planning bicycle lanes and widening sidewalks, and low emission zones (Newman et al., 1988; Lyons et al., 1990; Katz, 1994; Bernick and Cervero, 1997; de Roo, 1999; Burton, 2000; Lyons et al., 2003).

The motivation of this paper is to examine policy measures that can be implemented by decision makers in order to improve urban air quality. In particular, this paper focuses on parking policy, aimed at understanding the relationship between parking policy enforcement in Metropolitan centers and air pollution emissions from motor-vehicles in metropolitan areas.

The objective of this paper is to analyze the relationship between parking policy enforcement in metropolitan centers and mobile source air pollution emissions in metropolitan areas.

This paper relates to similar work done on the subject of parking policy enforcement and its influence on travel patterns which are portrayed in variables such as private VKT, the number of private vehicle trips, and travel time in metropolitan areas (Marsden, 2006; Marsden and May, 2005; Shoup, 1999). The paper investigates the relationship between the economical and physical aspects of parking policy, urban form, transportation planning and their direct influence on private VKT and VHT, including their indirect influence on air pollutant emissions, and concentrations.

The paper reviews several parking policy measures, and focuses on the measures that can have a direct impact on VKT and VHT. For example, parking policies such as decreasing the supply of on-street and/or off-street parking, and increasing parking fees, would lead to a decrease in private VKT and VHT, and hence to a decrease in vehicle air pollutant emissions.

The methodology presented in the paper is applied to a real world situation, using data and models from a Mass Transit project for the Tel Aviv Metropolitan Area. Tel-Aviv is considered to be the business capital of Israel, attracting employees from the entire metropolitan area including the outskirts and beyond, who commute to the CBD on a daily basis.

Two policy measures are studied in this paper. The first policy measure is reducing parking supply. The paper presents results of reducing parking supply in the entire Metropolitan area according to Traffic Area Zone (TAZ) type (CBD, residential – high density, residential – low density, industrial, high tech and offices etc.). A decrease in parking supply in all areas is resulted in a decrease and dispersion of the trips throughout the Metropolitan area.

The second policy measure studied in the paper is parking fees. Since parking fees vary across the Metropolitan area, an increase in parking fees will inadvertently affect parking search time, because drivers will try to look for cheaper parking places or even park far from their destination in order to save on costs. Therefore, this policy measure is evaluated in conjunction with the increase in parking search time.

The paper uses travel demand elasticity values from the original models to calculate the expected decrease in car trips, VKT and VHT for every traffic zone in the Metropolitan area. Assuming different parking fees, the traffic assignment model produces new traffic flows and travel times for each case. The total travel time and VKT are compared against the base case, where parking policies are not employed. The paper shows that there is a major decrease in VHT throughout all the scenarios and in all Metropolitan areas. On the other hand, VKT, NOx emissions and concentrations decrease in the CBD and inner Metropolitan ring. In the outer ring there is an increase in VKT, NOx emissions and concentrations. This occurs because there are combined effects of diverted trips to other areas, which may be less congested, but in turn may lead to an increase in VKT. An additional reason might be the effect of speed on NOx emissions. A decrease in VHT is as a result of an increase in speed (less vehicles on the road lead to an increase in speed). NOx emissions increase as speed increases. The paper presents a discussion on the suitability of transportation policies (such as parking policies) to meet environment objectives.

The rest of this paper is organized as follows. The next section presents a short review of the literature on policy measures and the environmental effects. The methodology used to analyze the impact of policy measures is presented next. The paper presents a general methodology and the specific application to analyze parking policies. The subsequent section presents results of the effects of parking policies. The last section of the paper presents a discussion on the main findings.

2. Literature Review

In spite of the positive effects that technological means of reducing emissions should have on ambient concentrations, urban air quality continues to deteriorate in a great number of metropolitan areas mainly due to a rise in VKT, which is an outcome of urban sprawl (Shefer, 1994; Newman et al., 1988; Lyons et al., 1990; Katz, 1994; Bernick and Cervero, 1997; de Roo, 1999; Burton, 2000; Lyons et al., 2003).

There are numerous ways to deal with urban sprawl and the consequent rise in the number of vehicles and VKT. The objectives of these policies should be aimed at creating conditions for metropolitan residents to reach their destinations with minimum use of private vehicles. These conditions consist of improving accessibility to activities such as work, shopping etc., by public transit, cycling, or walking, and on the other hand enforcing stricter policy measures against those who arrive at their destinations in the metropolitan center with their private vehicles. Examples of such policy measures are congestion toll and parking policies (Geurs and van Wee, 2004; Levine and Garb, 2002; Shoup, 1999; Cervero, 1998).

There is a large body of literature dealing with parking policy methods. Numerous researchers stress the need for a combination of urban and transportation planning policy methods in order to reduce private VKT and consequently pollutant emissions. Parking policy methods are understood to have a small influence on VKT, and are useful only when combined with numerous urban and transportation planning policies such as multi land use (…. The main claim is that parking policies will have a minimal influence on private VKT unless public transit is improved and urban form is favorable for slow mode like cycling and walking (Shefer et al., 2008; Marsden, 2006; Marsden and May, 2005; Rodenberg , 2005; Feeney; 1989).

An interesting point of view elaborated by Shoup (1999) shows the importance of parking policy methods as a catalyst for further implementation of urban and transportation planning policies. The author describes a vicious cycle which enhances VKT, and is briefly outlined as follows.

The vicious cycle starts with transportation engineers who survey parking occupancy at sites that offer ample free parking and lack public transit. The parking generation rate manuals created by transportation engineers are used by urban planners to set minimum parking requirements for all land uses. Since parking supply is so large, most new developments offer free parking. Transportation planners survey vehicle trips to and from sites that offer free parking and the outcome of this procedure is a trip generation rate manual. The roads leading to the sites are designed and planned according to the trip generation rate manuals, which means that the roads and highways provide enough capacity to satisfy expected demand. Urban planners limit land use density in order to prevent congestion of roads nearby new projects because of limited capacity (Shoup, 1999).

This vicious cycle demonstrates the huge effect parking policy has on urban and transportation design and planning. The effect is not that obvious to most researchers in this discipline. As mentioned above, most researchers refer to parking policy as a component to the whole complex of transportation and urban planning policies. In contrast, Shoup (1999) stresses the importance of parking policy as a means for influencing transportation and urban planning in a significant way not only as "glue" connecting between the different parts of urban and transportation planning (Shoup, 2005; Calthrope et al. 2000).

Since urban and transportation planners seldom have the opportunity to plan in completely new settings from scratch, a combined manner of transportation and urban policy planning is usually almost impossible. Usually planning is done in a framework of a new site, neighborhood in an existing city, therefore there are usually leading policies which are adapted at first. This article follows the planning concept that in order to reduce VKT (and hence air pollutant emissions and concentrations), a leading policy, such as parking policy, would trigger and affect other aspects of urban and transportation planning aimed at reducing VKT (Cervero, 2002; Cervero, 1998).

The problem with adapting a leading policy is that it draws a great amount of public criticism if not backed with solutions which will relief the decree. Specifically, if enforcing parking policy means raising parking fees and/or decreasing the amount of parking spaces, the public will demand compensating alternatives such as improving public transit in such areas. This means that if there is no efficient alternative to the use of a private vehicle, this will still be the leading mode, even with the use of parking policy enforcement. In the public eye, the travel mode is only a means of reaching a destination; it is not a purpose in itself. This is to say that if the travel mode is comfortable, fast, efficient, and affordable, the passenger will use it, if it is a private vehicle, public transit, or even slow mode (Hansen, 1959; Hägerstrand, 1970; Ingram, 1971; Levine and Garb, 2002; Geurs and van Wee, 2004).

Enforcing parking policy enables the reduction of private vehicles on the roads, which opens up the opportunity of using other means of reaching destinations. This, at a certain extent of enforcement will bring about an optimal point which will lead to positive effects on the transportation network and at the same time on the environment. This means that public criticism concerning parking policy enforcement should not be a deterrent for municipal authorities to administrate such policies, because this criticism should be channeled towards creating and improving other means of reaching destinations such as public transit and slow mode.

The main objective of this paper has to do with the attempt to reduce air pollutant concentrations to a point which is less than ambient pollutant standards, by employing alternative parking policies.

3. Methodology

The main hypothesis of this paper is that physical and economical aspects of parking policy affect VKT, VHT, consequently vehicle air pollutant emissions and concentrations. Improving urban air quality could be achieved by decreasing the number of on and off street parking in addition to raising parking fee, which could lead to a decrease in private VKT, hence a reduction in vehicle air pollutant emissions. Such a reduction could lead to a point in which pollutant concentrations decrease beneath ambient air pollutant standards.

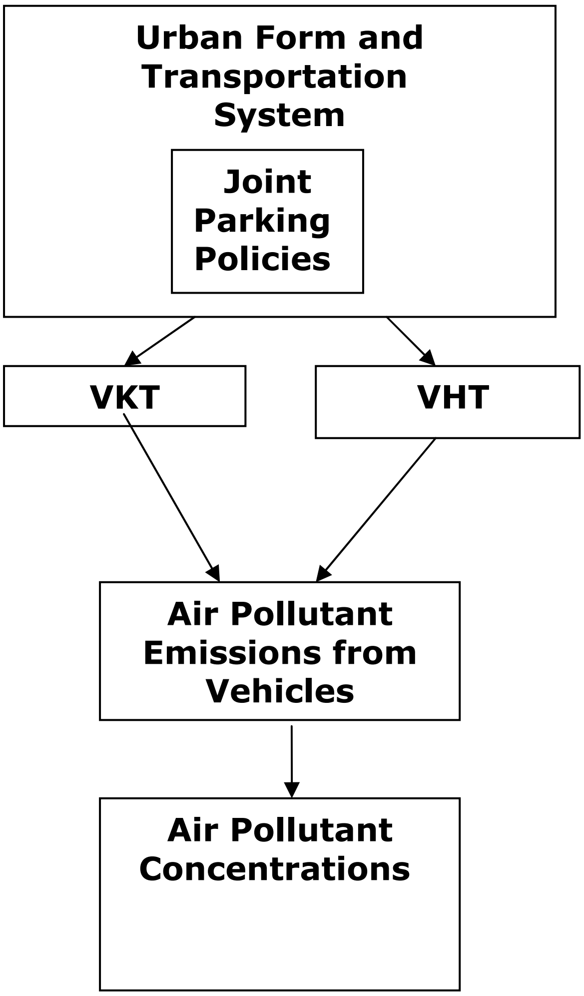
If this hypothesis is proven correct, it could stress the fact that using physical and economical aspects of parking policy would improve the urban environment, both in air quality and transportation variables. This is an important point since there are numerous researchers claiming that using urban and transportation policies in order to improve urban environment such as air quality, might lead to discrepancies between environmental and transportation objectives. In other words, by trying to decrease vehicular air pollutant emissions, transportation objectives might be pushed to the back seat. Urban and transportation planners in such a case have to decide where they want to make concessions: air quality or total travel time. Total travel time is usually the most important variable in transportation planning, where the objective is creating a "system optimum" based on travel time.

3.1 Conceptual Framework

Figure 1 illustrates the basic relationship between the research components. Urban form and transportation system is the core of the research system which influences private VKT and VHT. Both variables have an influence on air pollutant emissions from vehicles and air pollutant emissions influence pollutant concentrations. This system is fed by a set of different policies. Parking policy will be analyzed in the current article.

The extent to which we would like to reduce air pollutant emissions depends on the extent of use of economical and physical parking measures. These measures have a direct impact on private VKT and VHT. VKT and VHT are indicators of air pollutant emissions. The objective is to reach a point in which air pollutant concentrations are below ambient standards.

Figure 1 Relationship between Research Components



3.2 Parking Policies

The first policy measure is increasing parking fees. Since parking fees vary according to the different types of TAZs, an increase in parking fees by 10% and 20% will inadvertently affect parking search time, because drivers will try to look for cheaper parking places or even park far from their destination in order to save on costs.

The second policy measure is reducing parking supply. This measure is modeled by parking search time variable. This variable is modeled separately – a 10% and 20% increase in parking search time, and in conjunction with raising parking fees.

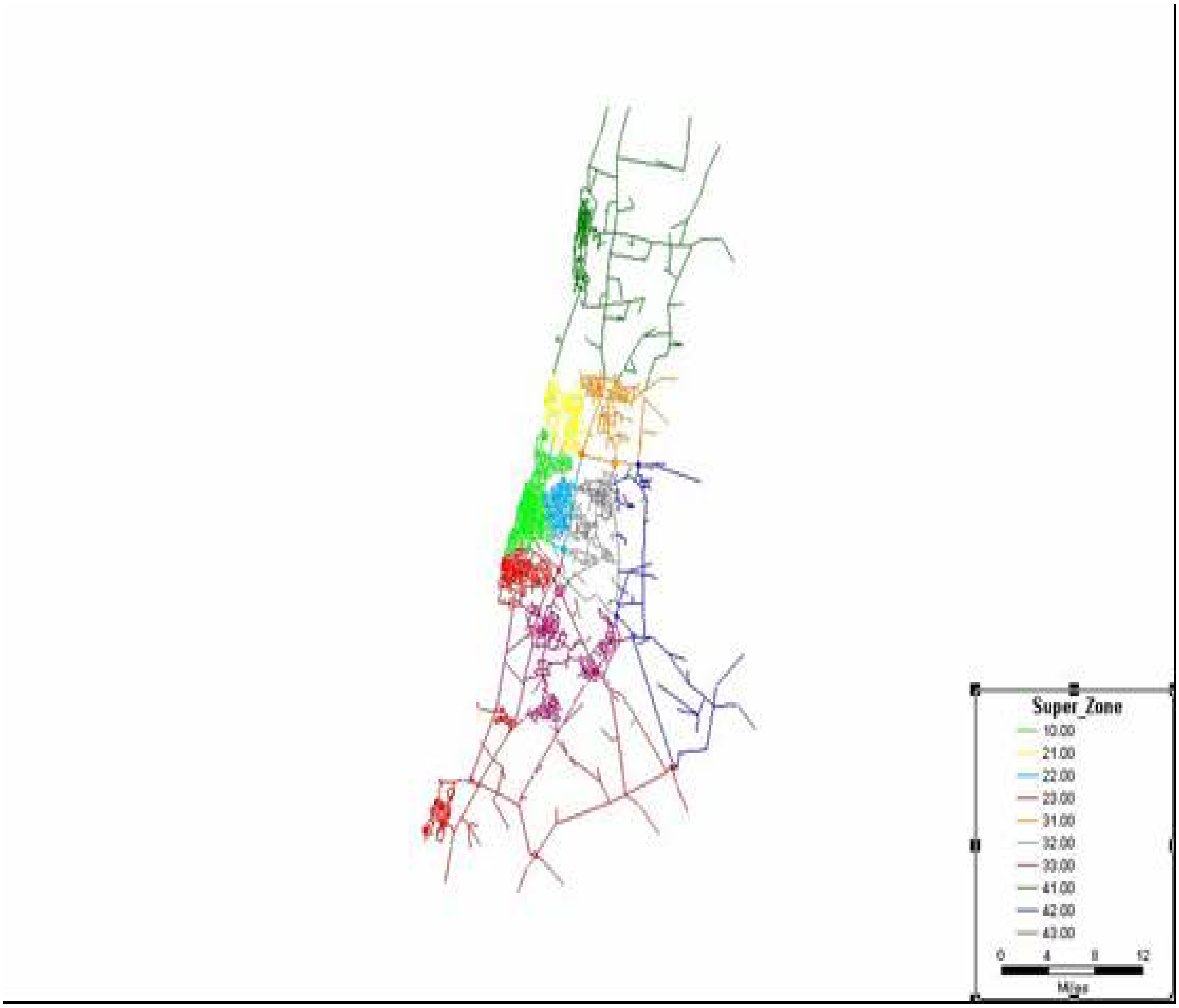
Finally we examine the impact of joint parking policies discussed above.

3.3 Model Specification and data

The transportation model used in this paper was constructed by NTA – an agency that leads the Mass Transit project for the Tel Aviv Metropolitan Area (NTA, 2001). It is a conventional 4-step model with feedback procedures for the combined modal split and assignment and for the combined distribution and assignment process.

The metropolitan area was divided into 10 super zones, according to the division of the Israel Bureau of Statistics, and presented in Figure 2. The transportation model enables the calculation of the VKT, travel time and average speed for every link in the transportation network, and post-processing it to present results at the super zone level. The results shown in the next section are aggregated into 4 major areas: CBD, inner ring, middle ring and outer ring.

Figure 2 Tel Aviv Transportation Network divided into 10 super zones



The trip generation model is based on NTA data which was processed and updated from the 1995 National Census, and the 1996 National Travel Habit Survey (NTHS). The Tel-Aviv metropolitan matrix and network was updated to the year 2003.

The parking policy coefficients (parking cost and parking search time) were retrieved from the NTA mode choice model, which has a nested logit structure. The point elasticity for the logit model is given as follows (Ben-Akiva and Lerman, 1985):

$$E = (1 - P) * \beta x \qquad (1)$$

Where:

P - Probability of traveling by private vehicle (60% for the base case in Tel-Aviv metropolitan area)
β –. parking cost coefficient -0.02883 and parking search time coefficient -0.0587
x - Parking cost or parking search time variables being approximately 10 Israeli Shekel (approx. 2.7$) hourly parking fee, and 5 minutes parking search time.

Using equation (1), the point elasticity for parking cost is -0.115 and for parking search time is -0.1174. A 10% and 20% increase in parking fee and parking search time was examined individually and in combination with each other and the impact of the increase in these two variables on VKT, VHT, NO_X emissions and NO_X concentrations in each and every one of the super zones and in all of them together. This was done in comparison to the base scenario.

<u>3.4 Pollutant emission and concentration models</u>

The concentration model used in this paper is a box model (Lyons et al., 2003). The box model assumes that emissions in an urban area are constant over a distance x, which is the characteristic length scale of the urban area. The pollutant is assumed to be uniformly mixed in a layer between the ground and the mixing height, z_i, and the wind speed, u, is constant within this layer. Neglecting transformation and deposition mechanisms as well as concentrations upwind of the city or above the mixing height, the continuity equation for this volume is:

$$xz_i \frac{\partial C}{\partial t} = xQ_a - uz_i C + x\frac{\partial z_i}{\partial t} \qquad (2)$$

Where C is the pollutant concentration, t time, and Q_a the emission source strength expressed as mass per unit area per unit time (grams per square meter per second).

Assuming steady state conditions, the equation reduces to:

$$C = Q_a \left(\frac{x}{uz_i} \right) \qquad (3)$$

The emission source strength was calculated separately for each super zone as follows:

$$Q_a = EF * VKT \qquad (4)$$

Where EF is the emission factor for NO_X.

The following values were used: wind speed – 1.5 meter per second, and a mixing zone height of 100 meters which is quite low. These are considered inversion conditions. In addition, a formula was used, in order to transform hourly NO_X concentrations to 30 minute concentrations complying with the standard (Wark et al., 1981):

$$C_s = C_c \, (t_c/t_s)^{0.2} \qquad (5)$$

Where:

C_s – calculated concentration over an average time S in microgram per cubic meter
C_c – calculated concentration by the model in microgram per cubic meter
t_c – average time of calculated concentrations according to the model
t_s – the corrected time

The basic emission model includes the product of two variables: the emission factor of the pollutant and the level of activity which produces a certain type of vehicle. The pollutant emissions from a vehicle depends on both variables and the emission factor depends on vehicle speed (Parra et. al, 2005).

The following emission model is based on both of the variables mentioned above but the calculation is done on the basis of emission per road link, per hour, in this case morning peak hour. This enables calculation of pollutant emissions on the level of TAZ or super zones, which creates preferable conditions for analyzing the differences in emissions between the Metropolitan super zones.

$$E_l^{ihot}(h) = \sum_{j=1}^{n} l L_l EF^{ihot}(S_l) \qquad (2)$$

Where:

$E_l^{ihot}(h)$ - Hot exhaust emissions (expressed in g h $^{-1}$) of pollutant i in l link per hour (morning peak hour in our case)

n – Number of vehicles
l – Road link
L_l – Length of road link
EF^{ihot} – Hot exhaust emission factor for pollutant i
S_l – Average speed at road link
j – Category of vehicle

This emission model is based on work done by Jimenez and Baldasano (2005), but a number of changes have been introduced in the model in order to correspond with the needs of this research: hourly pollutant emissions on a road link level.

4. The Scenarios

The following table illustrates 9 scenarios. The first is a basic scenario where no policy is administrated. Scenarios 2 and 3, deal with increasing parking cost by 10% and 20% subsequently. Scenarios 4 and 7, deal with increasing parking search time (hence decreasing parking availability) by 10% and 20% subsequently. Scenarios 5, 6, 8 and 9 deal with combined parking policies – increasing parking cost and parking search time.

Table 1 Scenario Key

Scenario Key				
		Increase in Parking Cost		
Increase in Parking Search Time		0%	10%	20%
	0%	1	2	3
	10%	4	5	6
	20%	7	8	9

5. Results

The results shown in the following tables were normalized and aggregated into 4 major areas: CBD, inner ring, middle ring and outer ring. The results show the change in VKT, VHT, NO_X emissions and NO_X concentrations in each of the presented scenarios.

Table 2 Total Normalized Vehicle – Kilometers Traveled for Each Scenario

SuperZone	**Total Vehicle - Kilometers Traveled for each Scenario**								
	1	2	3	4	5	6	7	8	9
CBD	100	91	91	90	90	90	89	89	88
inner ring	100	98	98	97	97	96	96	96	95
middle ring	100	103	102	102	101	101	100	100	100
outer ring	100	104	104	103	103	103	102	102	102
Average	**100**	**99**	**99**	**98**	**98**	**97**	**97**	**97**	**96**

There is a decrease in VKT of 10-12% throughout the parking policy scenarios, in the CBD area. The decrease in VKT in the inner ring is significantly less (2-5%) and the middle and outer ring show a slight increase in VKT of up to 4%. This is explained by the fact that trips are diverted from the CBD to middle and outer rings. Potential work force which resides in the middle and outer rings decide to shorten their trips and work closer to home. The average Metropolitan VKT shows an absolute decrease of up to 4% this can be explained by changes in modal split in favor of public transit to a certain extent.

Table 3 Total Normalized Vehicle –Hours Traveled for Each Scenario

SuperZone	Total Vehicle - Hours Traveled for each Scenario								
	1	2	3	4	5	6	7	8	9
CBD	100	83	83	82	82	81	80	80	80
inner ring	100	93	92	91	91	90	89	90	89
middle ring	100	101	100	99	98	98	97	96	96
outer ring	100	95	95	94	93	93	92	92	92
Average	**100**	**93**	**93**	**92**	**91**	**91**	**90**	**90**	**89**

VHT decreases more significantly, compared with VKT. In the CBD there is a decrease of 17-21% in all the parking policy scenarios. The decrease in VHT in the inner ring is 7-11% in all the parking policy scenarios. There is hardly any decrease in VHT in the middle ring. The outer ring demonstrates a decrease of up till 10% in VHT.

In general, VHT decreases apparently in all the scenarios, more than other tested variables (as shown in figures 2-4). The reason for this phenomenon has to do with driving speed which increases when applying parking policy. Speed especially increases relatively, in the CBD and inner ring since these are high traffic volume areas. The increase in average speed effects NO_X emissions as well. NO_X emissions increase in accordance with the increase in speed. Therefore, as shown in figures 2-4 .and tables 2 and 3, VHT values decrease most significantly compared to other variables.

Table 3 Total Normalized NO_X Emissions for Each Scenario

SuperZone	Total NO_X Emissions for each Scenario								
	1	2	3	4	5	6	7	8	9
CBD	100	92	92	92	92	91	91	90	90
inner ring	100	99	100	98	98	97	97	97	96
middle ring	100	103	103	102	102	102	101	101	101
outer ring	100	104	104	103	103	103	102	102	102
Average	**100**	**100**	**100**	**99**	**99**	**98**	**97**	**98**	**97**

Table 4 Total NO_X Concentrations for Each Scenario in Microgram per Cubic Meter

SuperZone	Total NO_X concentrations for each Scenario								
	1	2	3	4	5	6	7	8	9
CBD	**1188**	**1097**	**1094**	**1089**	**1088**	**1086**	**1077**	**1074**	**1069**
inner ring	232	229	230	227	226	225	224	224	223
middle ring	200	206	206	205	204	203	202	202	201
outer ring	137	142	142	141	141	141	140	140	139
Average	**439**	**419**	**418**	**415**	**415**	**414**	**411**	**410**	**408**

Table 5 Total Normalized NO_X Concentrations for Each Scenario

SuperZone	NO_X concentrations for each Scenario								
	1	2	3	4	5	6	7	8	9
CBD	100	92	92	92	92	92	91	90	90
inner ring	100	99	99	98	98	97	97	97	96
middle ring	100	103	103	102	102	102	101	101	101
outer ring	100	104	104	103	103	103	102	102	102
Average	**100**	**100**	**100**	**99**	**99**	**98**	**98**	**97**	**97**

Table 6 Total NO_X Concentrations for each Scenario – Percentage of Ambient Half Hour Air Pollutant Standard

SuperZone	NO_X concentrations for each Scenario								
	1	2	3	4	5	6	7	8	9
CBD	**126**	**117**	**116**	**116**	**116**	**116**	**115**	**114**	**114**
inner ring	25	24	24	24	24	24	24	24	24
middle ring	21	22	22	22	22	22	21	21	21
outer ring	15	15	15	15	15	15	15	15	15
Average	**47**	**45**	**45**	**44**	**44**	**44**	**44**	**44**	**43**

Checking out NO_X emissions and concentrations in the CBD area, shows a decrease in concentrations in all the scenarios. NO_X emissions and concentrations decrease respectively. There is a significant difference between concentrations in the CBD and other areas because the emission model does not take into consideration the size of the zone. The dispersion model takes this variable into consideration, therefore, the CBD not only has high emissions, but these emissions are dispersed over a smaller area. In essence the dispersion model calculates concentrations in each zone separately. This is of course not true in reality since the emissions are dispersed over the whole metropolitan area. They are not confined to the CBD only. But this is a way of checking out the big difference between emissions in the CBD and in other super zones. This also could be checked out by calculating emissions per square meter.

Figure 2 Average Metropolitan Normalized VKT, VHT, NO_X Emissions and NO_X Concentrations Values for Each Parking Policy Scenario

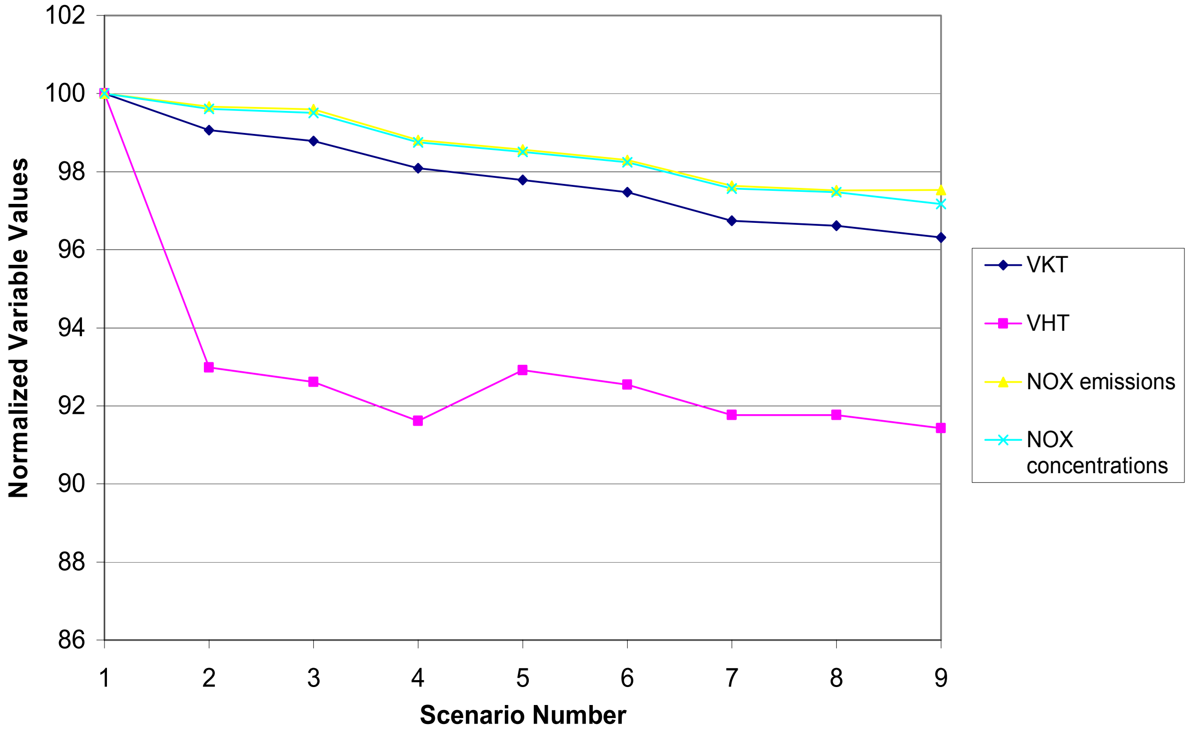


Figure 3 Normalized Metropolitan CBD VKT, VHT, NO_X Emissions and NO_X Concentrations Values for Each Parking Policy Scenario

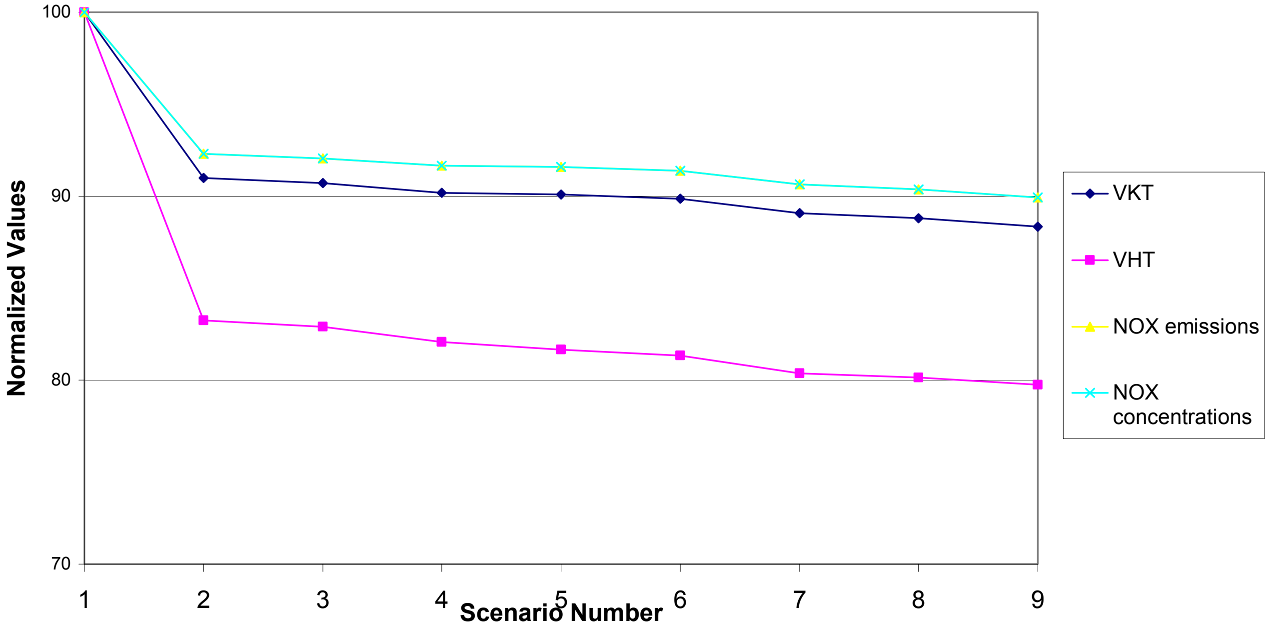
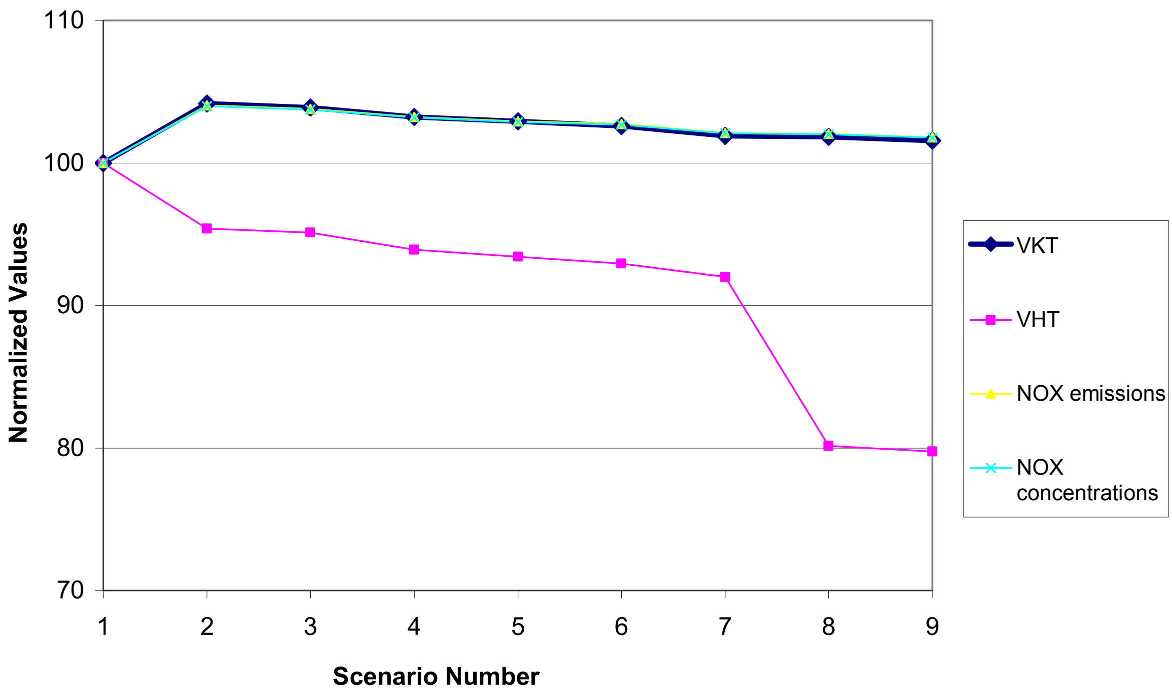


Figure 4 Normalized Metropolitan Outer Ring VKT, VHT, NO_X Emissions and NO_X Concentrations Values for Each Parking Policy Scenario



Figures 2-4 show the trend of all variables in all the scenarios for Metropolitan, CBD and Outer Ring levels. VHT in all figures is lower than other variables. This trend is prominent in the outer ring since there is a larger percentage of highways and major roads in the outer ring. The other variables increase by up to 4% since VKT and NO_X emissions respectively, are diverted from the CBD to the middle and outer ring. In the CBD all variables decrease compared to the base scenario.

Figure 5 CBD NO_X Concentrations as Percentage of Ambient Half Hour NO_X Concentration Standard

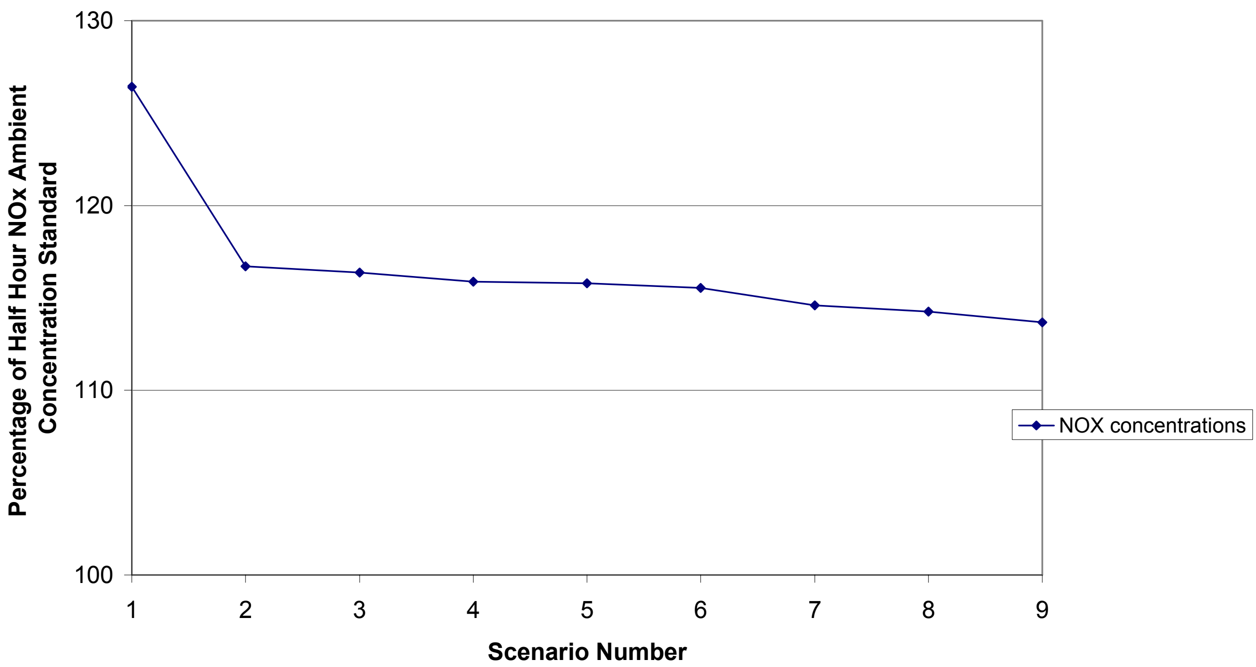


Figure 5 shows NO_X concentrations as percentage of ambient half hour NO_X concentration standard. Throughout all the scenarios there is a decrease in NO_X concentrations, but even results from the combined scenario, where there are a 20% increase in parking fees and parking search time show concentrations of 14% above standards. The ambient half hour NO_X concentration standard is 940 microgram per cubic meter. The ninth scenario shows NO_X concentrations of 1068.59 microgram per cubic meter (table 4).

These results emphasize the possibility of creating a scenario which will bring NO_X concentrations to a standard level or even below the standard level.

5. Summary and Conclusions

"You don't know what you've got till it's gone. They paved paradise and put up a parking lot." – Joni Mitchell (Shoup, 2005). The Tel Aviv Metropolitan Area, like many other metropolitan areas, has a high concentration of parking lots due to the high number of car trips entering the CBD area. The vicious cycle outlined and discussed above in this article is demonstrated in the Tel Aviv area. It seems like building parking lots has become in itself an end instead of being a means to an end which is serving the public by creating accessible conditions for private cars. Planners and decision makers should take into consideration that an increase in parking availability will eventually attract more car trips, which will push up the demand for parking and so on.

This article stresses the need for parking policy measures as a catalyst for further implementation of urban and transportation planning policies. The article findings show that the use of parking policy as a leading policy has much influence on transportation and air quality variables. Parking policy alone reduces air pollutant emissions and concentrations in the CBD, by 8-10%. It creates conditions for "spreading out" the emissions over the entire metropolitan area. The question of "spreading out" emissions is important in itself, since, researchers usually deal with the issue of total emission reduction. If we should try and analyze this problem as transportation planners do on the level of route choice and a system optimum solution, the transportation planner's problem is finding an optimal solution (minimizing travel time) as far as travel time is concern. The traffic assignment problem could be solved by spreading out traffic volume over the entire system. In the same token the emission problem could be solved by both spreading it out as well as reducing it.

Such a solution is in accordance with transit supply. Public transit supply is at its best in dense areas such as the metropolitan core and its close suburbs. The outskirts of the metropolitan can't be served optimally by transit, because of the dispersed spatial configuration. Therefore, as analyzed in this article parking policy measures which include raising parking fees and lowering parking supply, influences both destination and mode choice. There is a modal split which portrays itself by a decrease in private VKT and the number of trips in the metropolitan center, and there is a change in trip destination which could be illustrated by a switch in destination by a certain percentage of trips to the outskirts.

The pollutant emission model results show that there is an advantage of implementing parking policy in the metropolitan core area, even when other policies are absent. Decreasing overall metropolitan pollution emissions and "spreading it out" so as to further lowering emissions at the CBD have a positive effect on metropolitan air quality. The vicious cycle, in which transportation planners use parking availability as a guideline for road capacity needs could be stopped by implementing parking policy measures. This could be a basis for combining additional policy measures and examining the influence of those policies separately and jointly on air pollutant emissions.

References

Ben Akiva M., Lerman Ben-Akiva M., Lerman S. T., 1985. Discrete Choice Analysis: Theory and Application to Travel Demand, Cambridge, Massachusetts, the MIT Press.

Bernick M. & Cervero R., 1997. Transit Villages in the 21st Century, New York, McGraw-Hill Co.

Burton E., 2000. “Measuring Urban Compactness in UK Towns and Cities”, Environment and Planning B: Planning and Design, Vol. 29, pp. 219-250.

Calthorpe P., 1993. The Next American Metropolis: Ecology, Community and the American Dream, New York, Princeton Architectural Press.
Cerveo R., 2002. Built Environments and Mode Choice: Towards a Normative Framework, Transportation Research Part D., Vol. 7: pp. 265-284.
de Roo G., 2000. "Environmental Conflicts in Compact Cities: Complexity, Decision making and Policy Approaches", Environment and Planning B: Planning and Design, Vol. 27, pp. 151-161.
Geurs K. T., van Wee B., 2004. "Accessibility Evaluation of Land-Use and Transport Strategies: Review and Research Directions", Journal of Transport Geography, Vol. 12, pp. 127-140
Hägerstrand, T., 1970. What about People in Regional Science? *Papers of the Regional Science Association*, 24, 7-24
Hansen, W.G., 1959. How Accessibility Shapes Land Use .*Journal of the American Institute of Planners*, 25: 73-76
Ingram D. R., 1971. "The Concept of Accessibility: a Search for an Operational form," Regional Studies, Vol. 5, pp. 101-107.
Katz P., 1994. The New Urbanism: Toward Architecture of Community, New York, McGraw Hill.
Levine J. and Garb Y., 2002. Congestion Pricing's Conditional Promise, *Transport Policy,* Vol. 9, pp. 179-188.
Lyons T. J., Kenworthy J. R., Newman P. W. G., 1990. "Urban Structure and Air Pollution", Atmospheric Environment, Vol. 24B, No. 1, pp. 43-48.
Lyons T. J., Kenworthy J. R., Moy C., dos Santos F., 2003. "An International Urban Air Pollution Model for the Transportation Sector", Transportation Research Part D, Vol. 8, pp. 159-167.
Newman P. W. G., Kenworthy J. R., Lyons T. J., 1988. "Does Free Flowing Traffic Save Energy and Lower Emissions in the Cities?" Search, Vol. 19: pp. 267-272.
NTA, 2001. "Mass Transit Tel-Aviv Metropolitan Travel Demand Forecasting Model – (MIP)", Tel-Aviv.
Marsden G., 2006. The evidence base for Parking Policies - a Review, Transport Policy, Vol. 13, pp. 447-457.
Marsden G., May A. D., 2005. Do Institutional Arrangements Make a Difference to Transport Policy and Implementation? Lessons from Great Britain, Environment and Planning C: Government and Policy,
Parra R., Jimenez P., Baldasano J. M., 2005. *in press.* Development of High spatial Resolution EMICAT2000 Emission Model for Air Pollutants from the North-Eastern Iberian Peninsula (Catalonia, Spain), Environmental Pollution.
Shefer D., Bekhor S., Ferdman A., 2008. Land Use Variables in Trip Generation Models: the Case of the Light Rail Transit in Tel-Aviv, Railway Development Impacts on Urban Dynamics, Eds. Bruinsma F., Pels E., Priemus H., Rietveld P., Van Wee P.
Shefer D., 1994. Congestion, Air Pollution and Road Fatalities in Urban Areas, Accident Analysis and Prevention, Vol. 26: pp. 501-509.
Shoup D. C. 2005. The High Cost of Free Parking, American Planning Association, Planners Press, Chicago, ISBN: 1-84829-98-8.
Shoup D. C., 1999. The Trouble with Minimum Parking Requirements, Transportation Research Part A, Vol. 33, pp. 549-574.

Ranmar D. O., Matveev V., Dayan U., Peleg M., Kaplan J., Gertler A. W., Luria M., Kallos G., Katsafados P., Mahrer Y., 2002. "Impact of Coastal Transportation Emissions on Inland Air Pollution over Israel: Utilizing Numerical Simulations Airborne Measurements and Synoptic Analyses, Journal of Geophysical Research-Atmospheres, Vol. 107 (D17), 4331, doi: 2001JD000808.

Rodenburg C., 2005. Measuring of Multifunctional Land Use, Vrije Universiteit, Amsterdam.

Wark K., Warner C. F., Davis W. T., 1981. Air Pollution: Its Origin and Control, Harper Collins, New. York, NY.