

# Changes in Air Pollution Levels on Yafo Street, with respect to the Light Rail Line construction & operation (2002-2011)

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## **Abstract:**

The installation of the Yafo St. Light Rail Line has significantly altered the traffic patterns on downtown Jerusalem and intends to replace much of the east-west vehicular traffic. The air pollution levels, specifically NO<sub>x</sub> (nitric oxide) and PM<sub>10</sub> (particulate matter – 10 or less micrometers in diameter), have significantly been reduced by the new traffic patterns and the light rail operations. This will be proven with data from a real-time air monitoring station at Davidka Square and via computer models of the pollutant dispersion from the vehicles running on or across Yafo St, simulated from before and after the construction of the light rail line.

## **Historical Background of Yafo St. and the Light Rail:**

Yafo Street has served as and continues to function as Jerusalem's major east-west thoroughfare, running from Kikar Tzahal at the western edge of the Old City in the east to the Central Bus Station, Binyanei HaUmah, and the Chords Bridges in the west. The street was first paved in 1861, when it was on the route from the Yafo Port on the Mediterranean Sea, in what is modern Tel Aviv-Yafo, to the Old City of Jerusalem. Yafo St. was the nucleus for the "New" City or Western Jerusalem, as the new neighborhoods including the Russian Compound and Mahane Yehuda grew on or around it. It served as the commercial center of the city, especially during the British Mandate period, when the governmental functions like City Hall and the central post office were located within close proximity of the roadway.

However, following the 1967 Six Day War, Jerusalem expanded significantly in all directions away from the existing center, leaving Yafo Street to ebb away. Malkah

Mall in the south and neighborhoods such as Kiryat HaYovel in the west are examples of Jerusalem's expansion to distances over 2 km away from Yafo St. This led to a shift of the commercial activity from the downtown area to the peripheries of the city. Yet, the majority of the city's bus lines still ran along Yafo St. or crossed it at some point. Additionally, many landmarks such as the Mahane Yehuda market, the Jerusalem Municipality, and the Ben Yehuda pedestrian mall are still adjacent to the roadway. Unfortunately, due to the massive physical and population growth of the city, Yafo St. was often gridlocked throughout the street's length, due to the sheer number of cars and buses that utilized it.

Thus, in the 1990s, a master plan was developed to create several light rail (LRT) and bus rapid transit (BRT) lines to decrease congestion and the resultant pollution as well as revive the city's central business district: Yafo St. As of now, the two completed projects are the Hebron Road dedicated bus lanes and the Red Line Light Rail along Yafo St. The Hebron Road BRT was planned and constructed over the past decade. It runs 3 km from the Old Train Station to Givat HaMatos, with the main users being the express bus routes of 71, 72 & 74, 75. These lines connect the southern areas of Gilo & Har Homa to the northern neighborhoods of Ramot & Har Nof. The focus of this paper will be the Yafo St. Light Rail or LRT. This specific line was proposed and successfully constructed over an eleven year period, hopefully opening to public riders in the summer of 2011. The street no longer carries vehicles, but now serves as a pedestrian mall with a light rail line running its length.

### **Davidka Square Air Monitoring Station:**

As noted above, the pollution due to vehicular congestion was a significant reason why the light rail project was undertaken. The NO<sub>x</sub> (nitrous oxide) pollutant levels from the vehicular traffic, mostly notably the approximately 200 buses per hour, were substantial, though not above the Israeli legal limit of 298 ppb/day or 500 ppb/half-hour very often. The indicators of air pollution levels that were used to show the changes from year to year are as follow: the annual average (with readings every

half-hour); the annual sum of daily and half-hour legal limit violations; the annual daily and half-hour maximum levels. The national government's air monitoring station at Davidka Square on Yafo St. recorded data over many years, but the focus will be on the most recent ten years, with three major periods. From 2002 through 2007, traffic on the street was open to all vehicular traffic, but was slowly narrowed from a maximum of 4 lanes (two in each direction) to 2 lanes (one in each direction). During 2008-2010, construction on the light rail permitted access only to public transportation (buses and taxis). Additionally, for the first two years, traffic flowed both ways; during 2010, only one lane was available and traffic flow was permitted only east to west. Finally, with the final installation of the actual rails and brickwork in 2011, Yafo St. was closed to all vehicles and now serves as a pedestrian walkway. Testing runs of the trains took place during the spring of 2011 and the train will be opened to the public in the summer. The air monitoring data for 2011 is only through May 21, not for the entire year, as 2002-2010 are.

During the first period of free vehicular access and gradual narrowing of the roadway, the street was often jam-packed with buses and other vehicles, which correlate with the rather high annual average levels of NO<sub>x</sub> fluctuating around 140 ppb. The construction phase during 2008-2010 reduced the usage of the thoroughfare, which led to the annual average NO<sub>x</sub> levels of 140, 126, and 71 ppb respectively. While the first year of construction did not reduce the NO<sub>x</sub> average significantly, this was due to the fact that the frequent bus traffic could not be decreased either. Finally, during 2011 with the final construction touch-ups, testing, and opening of the train, a much lower annual average of 31 ppb has been recorded. This can be directly attributed to the lack of vehicles on the street. In summary, the bus only access led to an approximate drop to only 60% of previous pollutant levels (in 2009 & 2010) and the light rail / no vehicles situation has resulted in a current status of 20-25% of previous maximal levels (Figure 1).

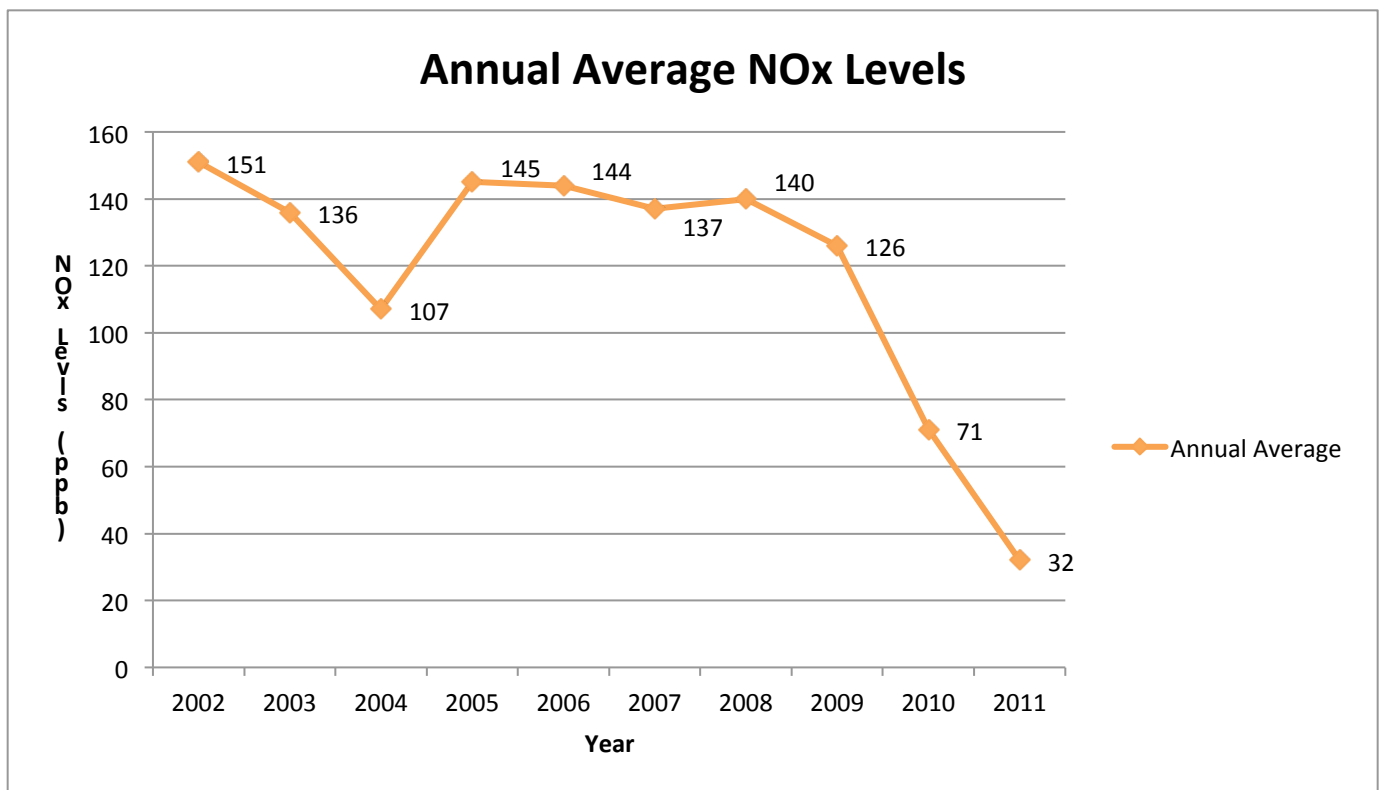


Figure 1

Besides the annual averages, the number of occurrences, when the legal limit of NOx in a half-hour period was exceeded, dramatically dropped as the light rail was opened. For Israel, the legal limit of NOx is 298 ppb for a twenty-four hour period and 500 ppb for a half-hour period. These are identical to the United States of America's legal limits, as stipulated by the EPA (Environmental Protection Agency). During 2002-2007, the number of incidents where the legal limit of a half-hour was exceeded ranged from 190 to 33 per annum. However, even as the number of vehicles on Yafo St. fell during the construction phase, the violations of the half-hour legal limit skyrocketed, with a peak in 2010 of 170 overages. Again, this was directly due to the pollution from the heavy machinery needed to uproot the existing pavement, install the bricking for the light rail and pedestrian mall, as well as affix a temporary blacktop for the one or two lanes of bus/taxi traffic. Most importantly, with Yafo St. now closed to vehicular traffic, no violations have been recorded as of May 2011 (Figure 2).

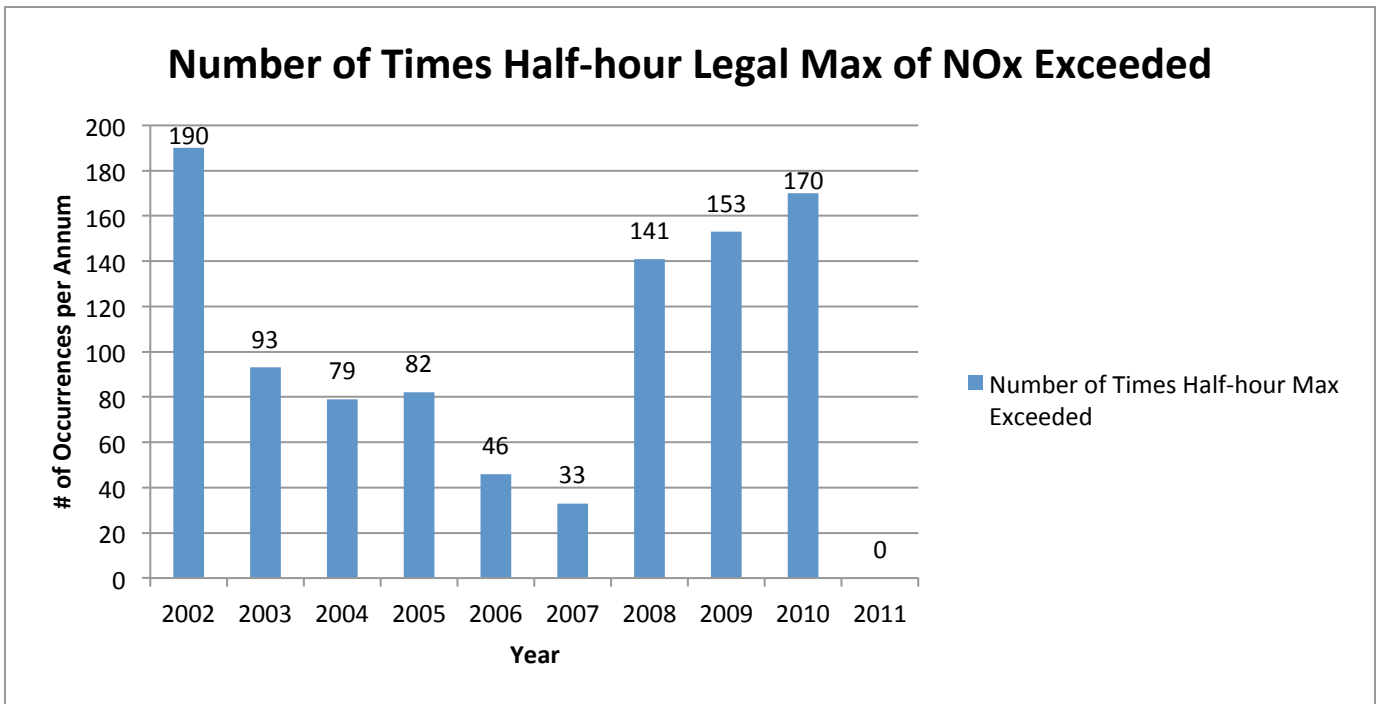


Figure 2

Additionally, the number of times the daily legal limit of NOx was exceeded was anywhere between 9 and 1, during the full vehicular access period & the construction period. This too fell to zero violations for the light rail period (Figure 3).

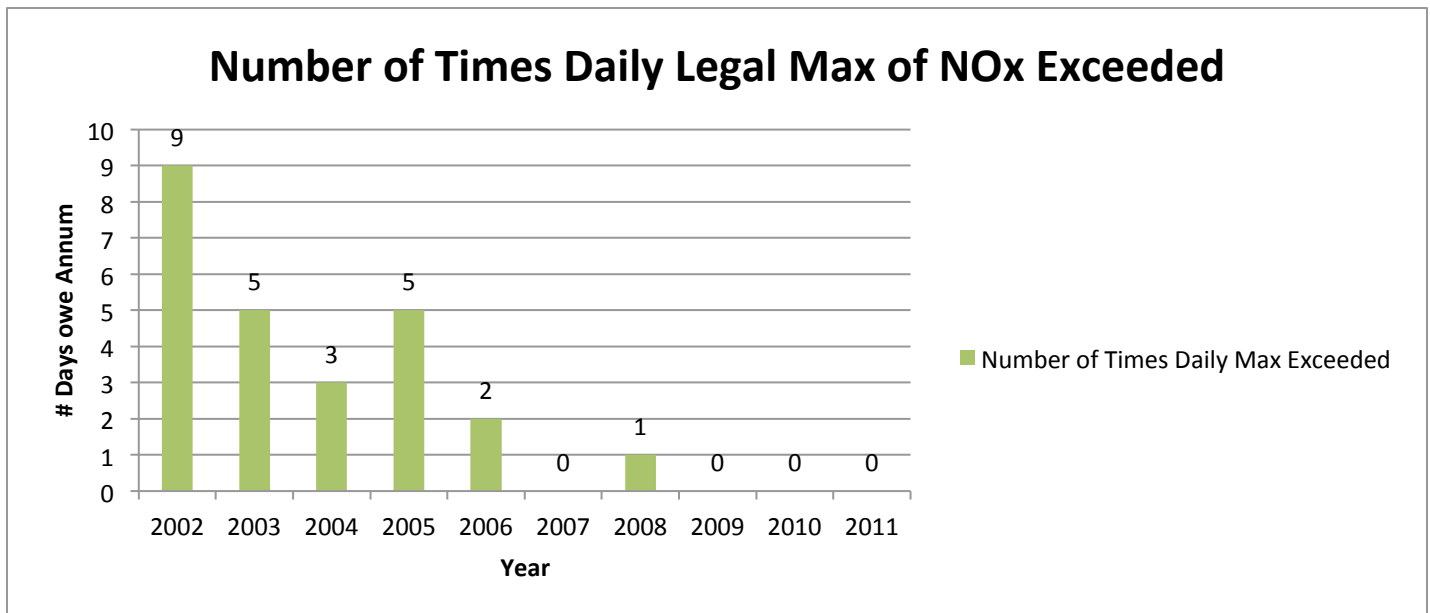


Figure 3

Finally, the maximum half-hour level of NO<sub>x</sub> for any given year has similarly decreased considerably, from an average of over 1000 ppb during the first phase down to 317 ppb during 2011. Again, the construction phase, in 2010, had an unusually high 1267 ppb, which can be attributed to the construction work involved. Lastly, the daily maximum fell from an average of 300 ppb during 2002-2008, to 287 & 200 ppb in 2009-2010 respectively, to a healthier 137 ppb in 2011 (Figure 4).

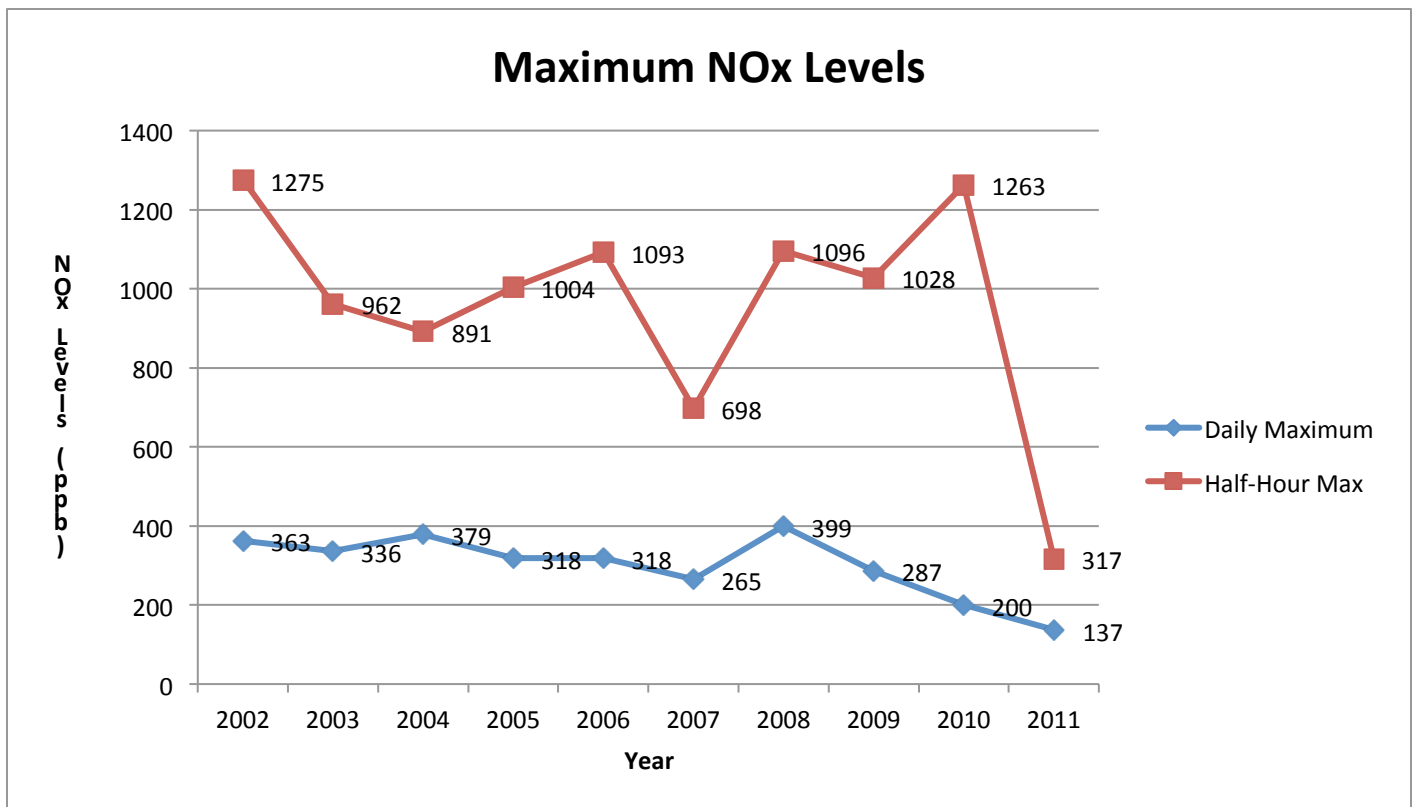


Figure 4

It is safe to say that the light rail project has significantly lowered the NO<sub>x</sub> levels on Yafo Street, on both fronts of the annual averages and of the number of violations of the legal limit of NO<sub>x</sub> per day and per half-hour. A significant milestone is the lack of any violations of the half-hour or daily legal limits for the time period since construction has been completed. It is certainly a solid indication that the master plan, specifically the light rail, even before beginning to convey passengers, is successfully accomplishing a major goal – reducing air pollution levels in the

downtown region. Thus, the LRT, along with the other components of Jerusalem's master plan of mass transit, will continue to assist in the revival of downtown Jerusalem with greater access, safer and rapid transportation, as well as a healthier environment to boot.

## **CALROADs Simulations of Traffic Flow & Pollutant Dispersion:**

### **Scope of the Model & Background Conditions:**

Beyond the monitored air pollutant levels at Davidka Square, the changes in traffic flow on and across Yafo St. can be simulated on a computer model, to demonstrate the drops in ambient NO<sub>x</sub> and PM<sub>10</sub> (particulate matter – 10 micrometers) levels. For this survey, CALRoads was utilized. It is a program created by the United States' Environmental Protection Agency to render contour maps of an area based off vehicular traffic flow. This gives a large advantage of providing a regional outcome, not just localized receptors that only deal with the immediate vicinity. The required inputs are the vehicle travel pathways, the number of vehicles in each path, plus the emission factors. Overall, four models were created. The Pre-Light Rail version utilized traffic data mainly from 2003 and 2004, but some were as late as 2008, with the vehicular flow of the time - Yafo St. running both ways at a width of four lanes (two in each way). The intersections included in this Pre model, from east to west, were: Kikar Tzahal, Chayshin-Shlomtzion HaMalkah, Haleni Hamalkah, HaRav Kook, Straus-King George, HaNiviyim-Kiach, HaTurim, Sha'are Tzedek, and Sarei Yisroel-Nordau. The Post-Light Rail version utilized traffic data mainly from 2008-2010, with some intersections from 2004 or 2003, with only the 2011 active traffic directions being accounted for. This means no vehicles on Yafo St. itself, east of HaTurim, and only east to west flow from there to Sarei Yisroel-Nordau. Also, the same intersections were utilized in the Post model, with the exception of Halani HaMalkah and HaRav Kook, since they now carry no vehicular traffic onto or from Yafo St.

For all of the four models, some basic points remained the same. The required meteorological data (ie wind conditions) were taken from the Municipality monitoring station at Kikar Safra. The most common wind speed and direction, taken from 2006 (the median year of the project, with Yafo St. narrowed but not yet limited to public transport), was 3 meters per second at 288 degrees. This direction runs from northwest to southeast, approximately the path of the roadway, as one travels eastward on it. The GIS map that the vehicle paths were drawn on was also from the Municipality website. The scope of the traffic included in the model, as the data given by the national government's Transportation Department reported, was from Kikar Tzahal in the east to Sarei Yisroel-Nordau in the west. For this study, the only streets considered were Yafo St. and all of its intersecting roadways, with the crossroads extending out to 50 meters away from the intersection. This is the estimated distance the pollutant will have an effect on Yafo St, considering the very dense urban environment.

The simulated twenty receptors that were designated the boundaries of the model were the same for all four runs. There were nine receptors to the north of Yafo St., in a parallel line approximately 300-500 meters off the roadway, distributed evenly from east to west. So too, another nine were placed in a similar fashion to the south of Yafo St. Finally, two more were inserted at a landmark also about 500 meters off each end: Yafo Gate on the east and the Chords Bridge on the west. The speed of the vehicles on and across the road was estimated at 20 kilometers per hour. This had to be estimated, since the timing of each intersection's traffic lights for every direction was not easily available to us and even if it was, would have required a much lengthier time to construct the model. With the speed, the amount of pollutants created by the vehicles could be standardized as according to the national government's Environmental Department's table. Finally, all of these models were of the daily 'rush hour', the hour of maximum traffic levels, specific to each intersection. This is meant to simulate the worst-case scenario, pollution-wise, for Yafo St. and to make the starkest comparison possible between the Pre and the Post periods. For example, for the Post model: Sarei Yisroel-Nordau (SY-N) had a 'rush hour' of 16:00-



17:00, while Kikar Tzahal (KT) was at 8:00-9:00; on the other hand, the Pre model had SY-N's maximum during the time of 16:45-17:45 and KT's maximal hour was 7:15-8:15.

### **A Sample Intersection:**

Due to the very large quantity of raw data that was utilized in this report, it will be summarized and the process of assembling the final inputs will be explained for a sample intersection. However, the numbers for every intersection will not be gone over – they will be attached at the end of the document (Figures 5-8). To begin, CALRoads requires the number of vehicles per hour, the pollutant generated per vehicle (in grams per mile), the path of travel, plus the width of the travel zone. This input was done at every intersection, for every direction of travel possible. To further complicate matters, the amount of pollution created by a vehicle depends very much on the type. For example, the standard car emits .3191 g/km of NO<sub>x</sub> and .0032 g/km of PM<sub>10</sub>. Alternatively, the bus produces 9.8172 g/km of NO<sub>x</sub> and .2745 g/km of PM<sub>10</sub>. The bus will emit nearly 31 times as much NO<sub>x</sub> and 85 times as much PM<sub>10</sub>. Also, a truck gives off half as much as a bus, but this is still 15 times as much NO<sub>x</sub> and 42 times as much PM<sub>10</sub>, as a car (Figure 9). Thus, the need to differentiate between vehicle types is critical.

To illustrate the point, I will list all the details and factors of multiplication for the intersection of Sha'are Tzedek for the Post Light Rail situation. Its 'rush hour' is 13:00-14:00. There are two active roadways that enter this junction: Yafo St. (from the east) and Sha'are Tzedek (from the south). Yafo St. can go straight or make a left, while Sha'are Tzedek only can make a left onto Yafo St. The pathway for Yafo left onto Sha'are Tzedek extends 50 meters south of Yafo St, as noted in the protocol above. Both the Yafo straight and the Sha'are Tzedek left pathways run westward from the junction to the SY-N intersection. The width of the roadway is two lanes, which is 7 meters. But for CALRoads, 3 meters are added for the dispersion alongside the roadway, giving a total effective width of 10 meters. As for the numbers, Yafo straight

had 697 cars, 11 buses, and 11 trucks; Yafo left had 275 cars, 9 buses, and 8 trucks; Sha'are Tzedek (left) had 151 cars, 5 buses, and 5 trucks. Once multiplied by the pollutant factors (see Figure 9) and the weighted average is taken (by adding all of the sums of the products of each vehicle type with its pollutant factor, then dividing that number by the total number of vehicles going in that direction), the composite emission factor is attained. Also, the total must be divided by .61, to convert from the Israeli constants of g/km to the CALRoads of g/mi. For Yafo straight, 719 vehicles were present and the emission factor per vehicle was .8544 g/km of NOx & .0152 g/km of PM10; by Yafo left, 161 vehicles with 1.2054 g/km/vehicle of NOx & .0256 g/km/vehicle; Sha'are Tzedek (left) had 292 vehicles with 1.1763 g/mi/vehicle & .0247 g/km/vehicle (Figure 10). Thus, with the emission factors, one can immediately notice the higher proportion of buses on Yafo left & Sha'are Tzedek than Yafo straight. However, the total effect on the air pollution is still notably lower in either path than Yafo straight, due to the lower number of vehicles.

**Figure 10**                      **Sample Intersection of Sha'are Tzedek (Post Light Rail)**

POST LIGHT RAIL (~2011)		Prati	Autobus	Masait	(per max hour)
Sha'arei Tzedek 13:00-14:00		Cars	Buses	Trucks	Total
From	To				Vehicles
Sha'arei Tzedek	Yafo (west) [L]	151	5	5	161
Yafo (east)	Yafo (west) [S]	697	11	11	719
Yafo (east)	Sha'arei Tzedek [L]	275	9	8	292

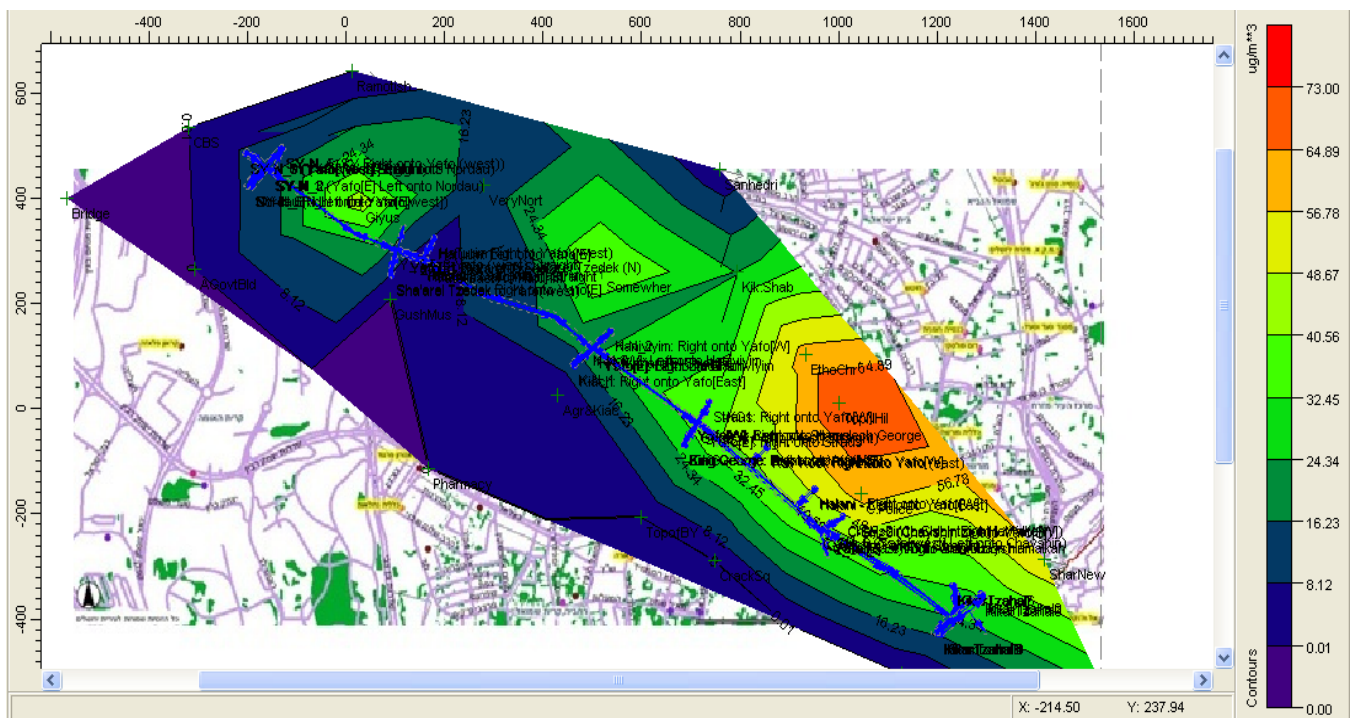
NOTE: Direction of turn from the entry to exit of intersection is indicated by the letter in the brackets,  
where S = straight, L = left, R = right

From	To	NOX	NOX	NOX	PM10	PM10	PM10
		Total	Total	Pollutant Per Vehicle	Total	Total	Pollutant Per Vehicle
		Pollutants (g/km)	Pollutants (g/mi)	(g/mi)	Pollutants (g/km)	Pollutants (g/km)	(g/mi)
Sha'arei Tzedek	Yafo (west) [L]	120.5916	194.0734	1.205425	2.5602	4.120243	0.024679
Yafo (east)	Yafo (west) [S]	381.7092	614.3014	0.854383	6.7998	10.94322	0.01522
Yafo (east)	Sha'arei Tzedek [L]	213.4218	343.4691	1.176264	4.4777	7.20616	0.024679

## Results:

With a sample done, the global results can now be presented. The Pre Light Rail model of NO<sub>x</sub> had a maximum level above 65 ug/m<sup>3</sup> (microgram per cubic meter), nearby the heart of downtown – between Halani and HaRav Kook, at a distance of less than 200 meters from the roadway. Along the length of Yafo St., it hovered between 25 and 35 ug/m<sup>3</sup> (Figure 11).

Figure 11 Pre Light Rail - NO<sub>x</sub>



As for the Post Light rail model of NO<sub>x</sub>, the maximum was only around 32 ug/m<sup>3</sup>, just under half that of the Pre's maximum, and it was concentrated at the SY-N intersection, not in the downtown area. Furthermore, the maximum region covered a much smaller area and the length of Yafo St. had a range between 4-12 ug/m<sup>3</sup>, much less than half of the Pre situation (Figure 12).

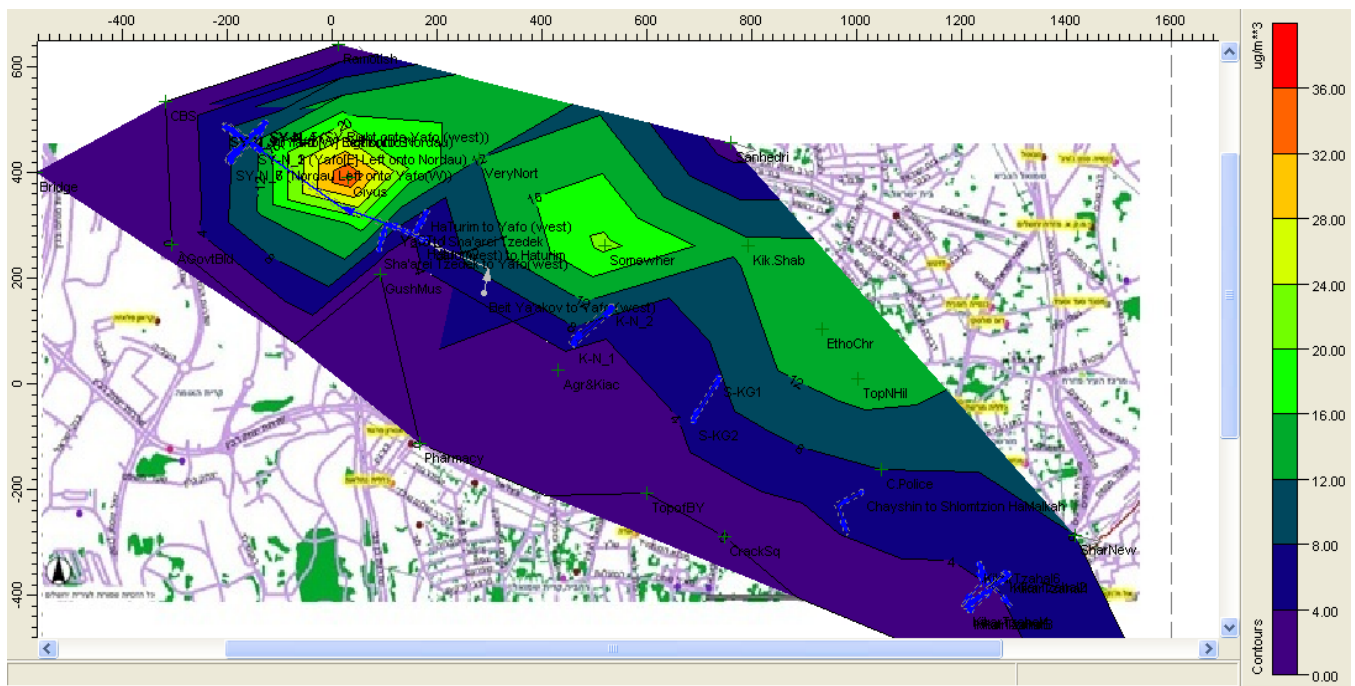
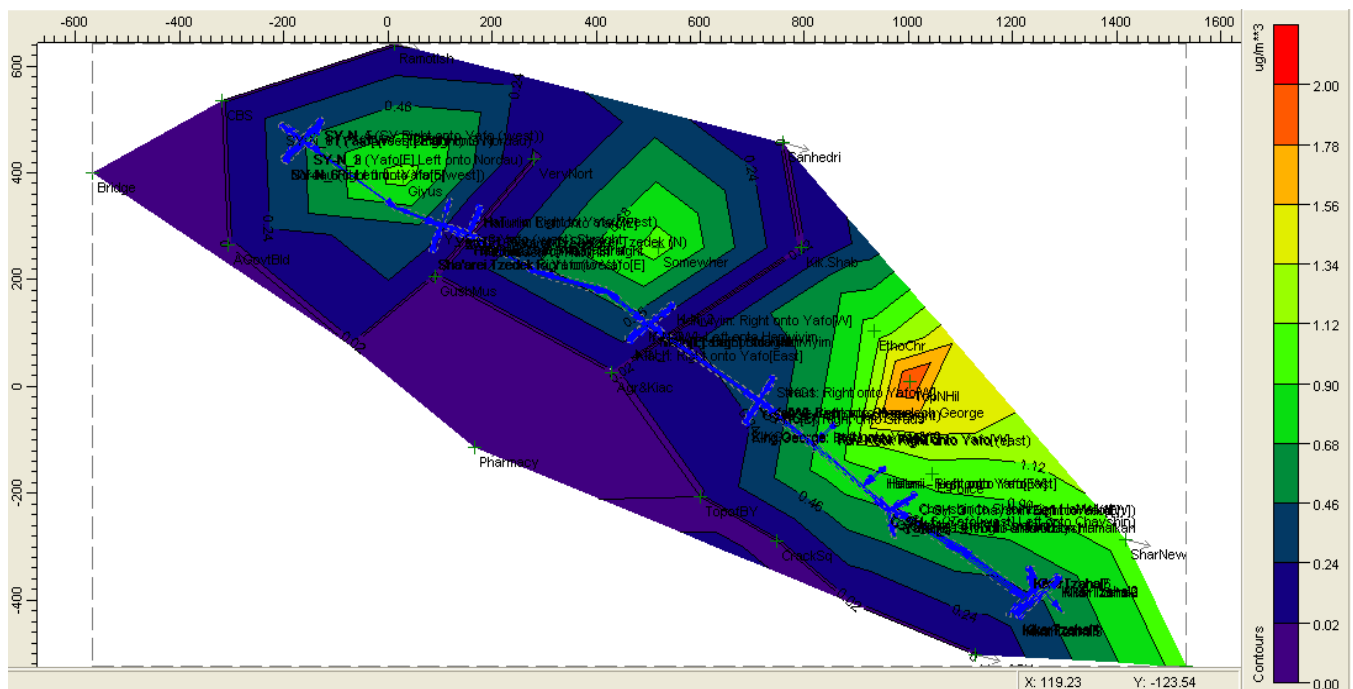


Figure 12 Post Light Rail – NOx

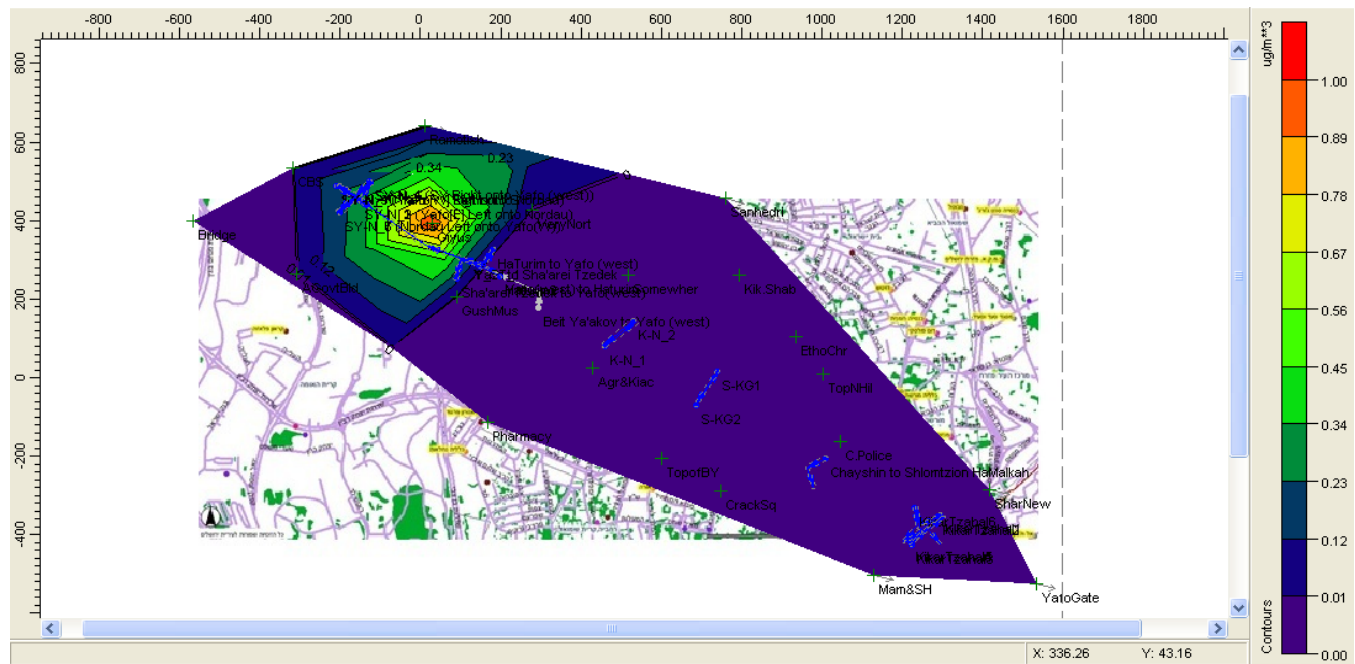
The Pre model of PM10 too had a maximum concentrated in downtown, again near Halani and HaRav Kook, of approximately 1.5 ug/m<sup>3</sup>. The level along Yafu St.'s length was between .5 and 1.0 ug/m<sup>3</sup> (Figure 13).

Figure 13 Pre Light Rail – PM10



Again, the Post situation was remarkably improved, with the maximum shifting towards SY-N and it being less than 1.0 ug/m<sup>3</sup>. Most importantly, the vast majority of Yafo St. east of HaTurim was estimated to have less than .01 ug/m<sup>3</sup>. Essentially, this translates to no PM<sub>10</sub> pollutants at all for the central business district, due to the traffic flow running across Yafo St (Figure 14).

Figure 14 Post Light Rail – PM<sub>10</sub>



### Limitations & Possible Future Improvements:

Regardless how well the CALRoads simulation coincide with the Davidka Square monitoring station, a few limitations of the models and how to improve them in the future must be noted. First of all, the traffic data in some locations was only available from 2004. This meant that the new traffic patterns, especially on Kiach-Haniviyim and Sha'are Tzedek, where the buses are now diverted to from Yafo St., have not been properly modeled. The only option, besides obtaining the new vehicle counts, was to eliminate the directions that are now inactive and to work with the

still active traffic flows. Although this lacks in complete precision, the truth is still brought out by the reduced air pollution levels found at Davidka Square. Additionally, two one-way streets were ignored, due to the very minor levels of traffic: Beit Ya'akov (onto Yafo, just past the Machane Yehuda market) and Gesher HaChaim (exiting Yafo, approximately halfway between Sha'are Tzedek and Sarei Yisroel-Nordau). Moreover, the traffic light timing could have been in place of the estimated speed, as noted above. Lastly, this report only employed the models of the 'rush hour' for each intersection. Future studies would do well to map out each hour of the day for the entire Yafo St., to further hone in on the problematic times and locations, in regards to congestion and pollution from vehicles.

## **Conclusion:**

In spite of the above noted issues, both the CALRoads computer models based off the vehicle counts as well as the live air monitoring station at Davidka Square conclusively show that the situation in the downtown area of Jerusalem has significantly improved from 2002 to the present of 2011. The measured annual average of NO<sub>x</sub> has dropped by 80 percent, from a high of 151 ppb in 2002 to a mere 32 ppb in 2011 (Figure 1). The simulated PM<sub>10</sub> levels along Yafo St. (for the vast majority of it) fell from .5-1.0 ug/m<sup>3</sup> to practically nothing, from the pre-construction traffic patterns and numbers to the present situation of a car-free Yafo Street, east of the Mahane Yehuda market (Figures 12,13). The LRT project seems to have met its goal of reducing air pollution, but only time will tell whether it can meet the demands of the commuting public.

## APPENDIX

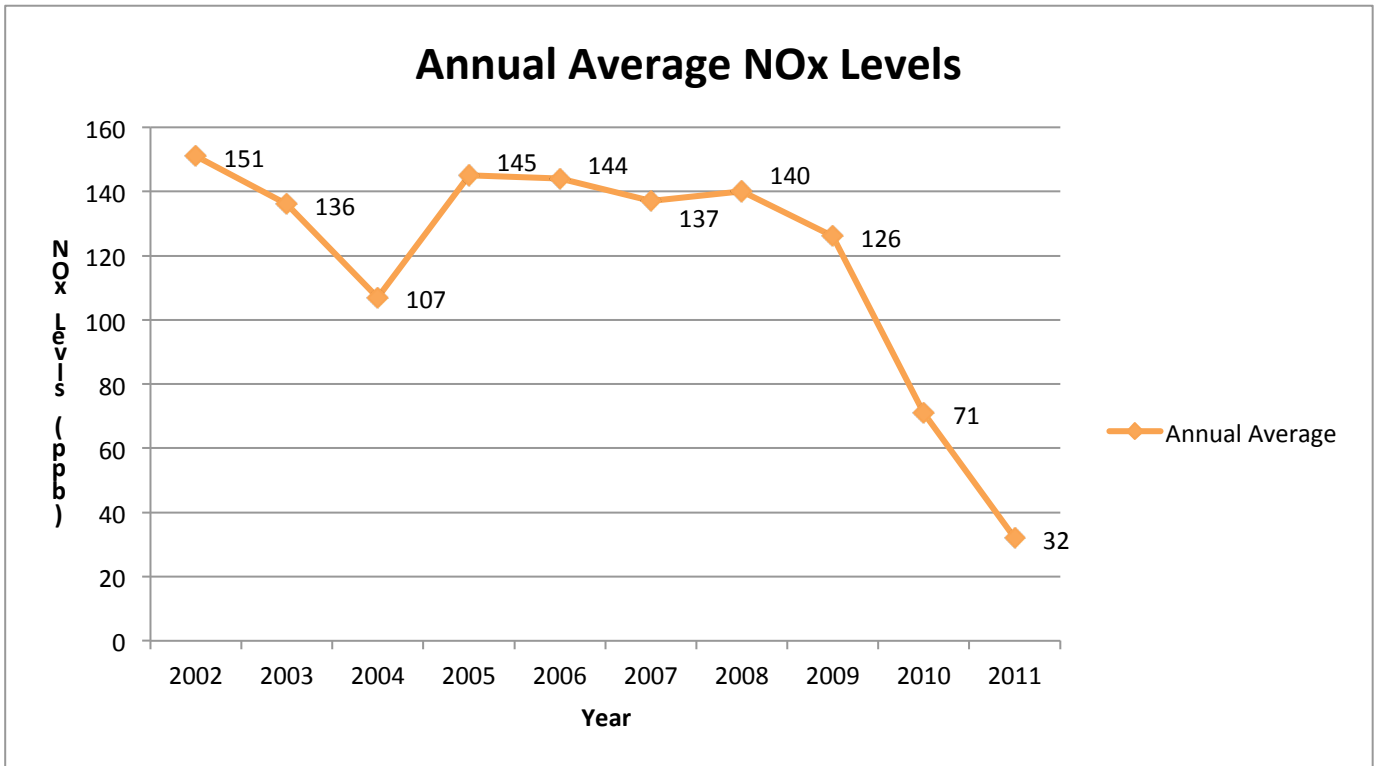


Figure 1

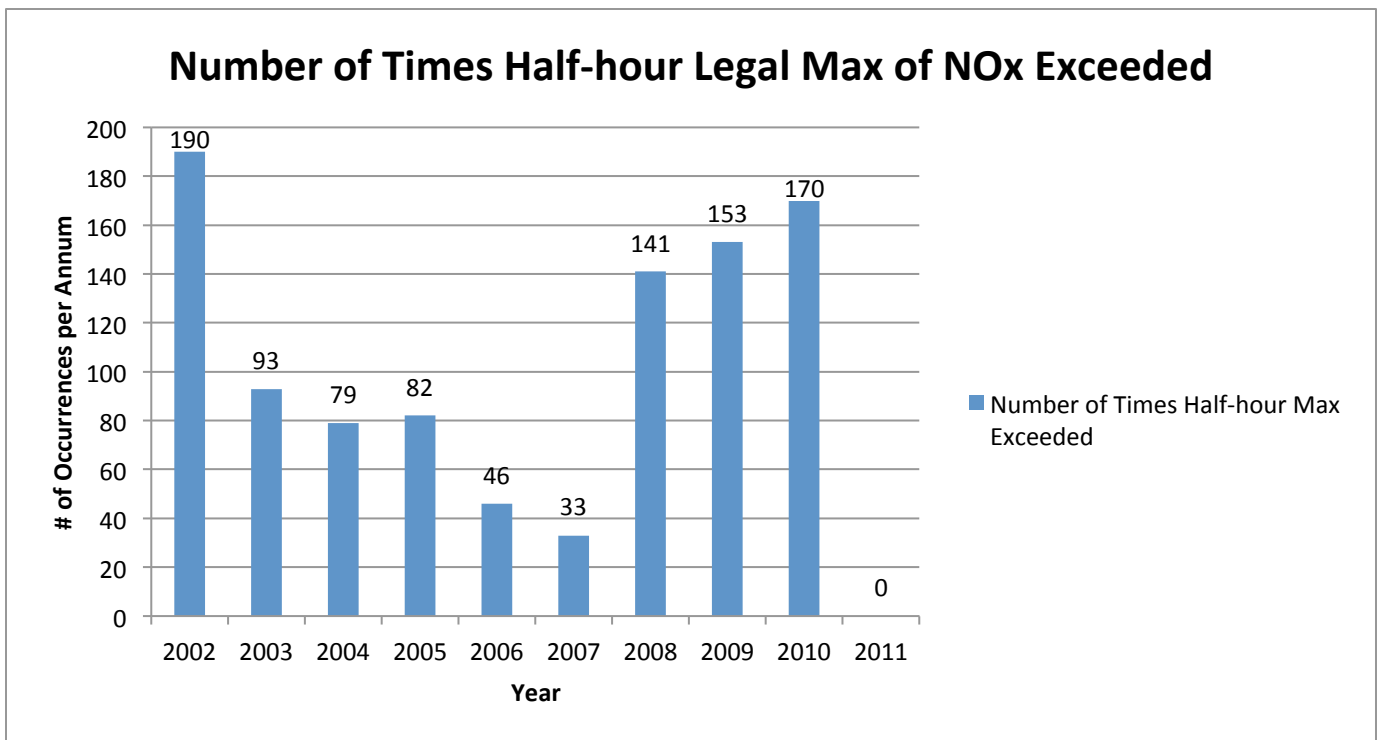


Figure 2

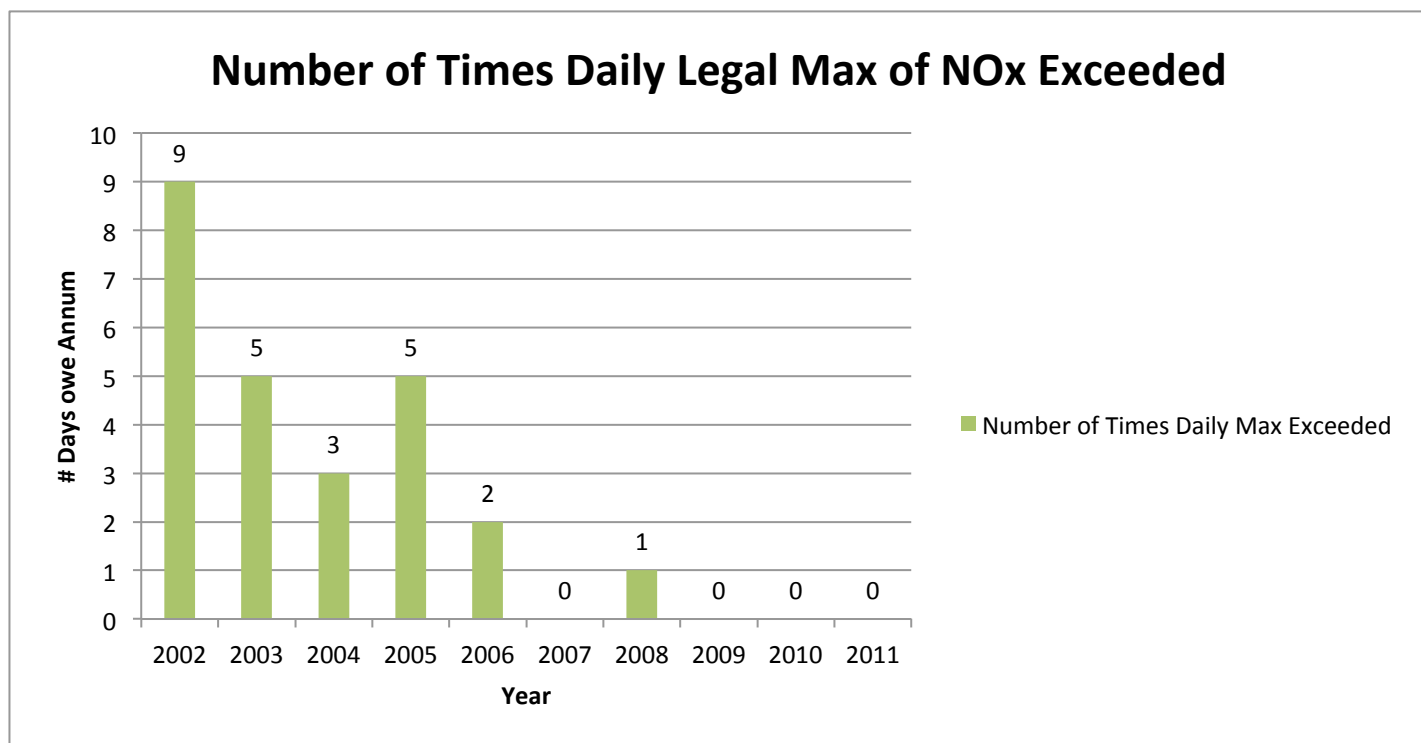


Figure 3

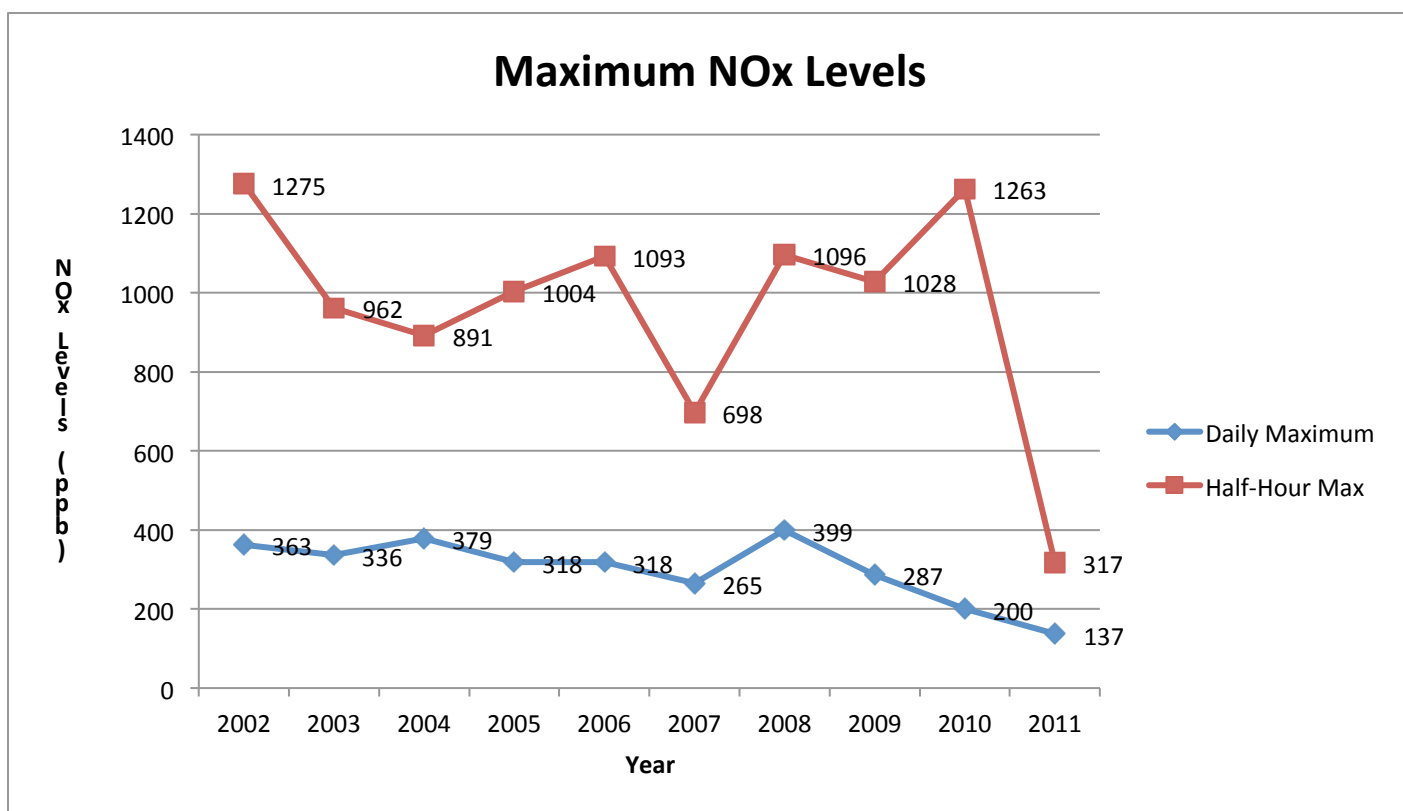


Figure 4



**Figure 5**

**Traffic Data for Pre Light Rail Model (~2004)**  
**HOUR OF MAXIMUM TRAFFIC**  
**(FOR EACH INTERSECTION)**

**Kikar Tzahal 7:15-8:15**

From	To	(per max hour)	(g/mi)	(g/mi)
		<b>Total</b>	<b>NOX</b>	<b>PM10</b>
		<b>Vehicle</b>	<b>Pollutant</b>	<b>Pollutant</b>
		<b>Number</b>	<b>Per Vehicle</b>	<b>Per Vehicle</b>
Shlomo HaMelech	HaTzanchanim [S]	800	1.477596	0.039731
" "	Yafo (west) [L1]	254.5	0.850002	0.021043
" "	Shivtei Yisroel [L2]	254.5	0.850002	0.021043
" "	Yafo' (exit ramp to Derech Chevron S) [R]	32	0.539859	0.006865
HaTzanchanim	Shlomo HaMelech [S]	941	0.964711	0.026519
" "	Shivtei Yisroel [R1]	47	0.950828	0.021935
" "	Yafo (west) [R2]	47	0.950828	0.021935
Shivtei Yisroel	Yafo (west) [R1]	6	0.513542	0.00515
" "	Shlomo HaMelech [R2]	6	0.513542	0.00515

Note - data for turning towards the west side (Shlomo Hamelech & Hatzanchanim) failed to specify whether it was towards Yafo (west) or Shivtei Yisroel, just as the data from Shivtei Yisroel failed to distinguish between turning onto Yafo (west) or Shlomo Hamelech. Thus, the traffic numbers were split equally between the two streets in all cases.

**Chayshin-Shlomtzion Hamalkah 15:00-16:00**

From	To			
Chayshin	Shlomtzion Hamalkah [S]	514	0.693792	0.020017
" "	Yafo (east) [L]	10	0.939133	0.04585
" "	Yafo (west) [R]	18	0.62692	0.026474
Yafo (east)	Yafo (west) [S]	178	6.09279	0.182972
" "	Shlomtzion Hamalkah [L]	132	1.310001	0.04146
" "	Chayshin [R]	44	0.953518	0.028694
Yafo (west)	Yafo (east) [S]	312	5.507457	0.167384
" "	Chayshin [L]	5	1.150327	0.046928
" "	Shlomtzion Hamalkah [R]	35	1.290023	0.057762

**Halani HaMalkah 10:00-11:00**

From	To			
Halani	Yafo (west) [R]	12	0.513542	0.00515
Halani	Yafo (east) [L]	30	0.513542	0.00515

**HaRav Kook 15:00-16:00**

From	To			
Rav Kook	Yafo (west) [R]	128.5	0.731215	0.012048
Rav Kook	Yafo (east) [L]	128.5	0.731215	0.012048

Note - traffic data was for Rav Kook & entry/exit from 2 parking lots,  
but b/c Rav Kook flows one-way onto Yafo, traffic data split equally between turning R or L onto Yafo

**HaMelech George-Strauss 11:00-12:00**

From	To			
Strauss	Hamelech George [S]	86	4.10164	0.134204
" "	Yafo (west) [R]	20	6.66719	0.198698
Yafo (east)	Yafo (west) [S]	209	3.595378	0.118161
" "	Strauss [R]	71	6.336756	0.190669
Hamelech George	Strauss [S]	113	3.042975	0.107644
" "	Yafo (west) [L]	100	5.559506	0.170645
" "	Yafo (east) [R]	123	2.266019	0.085798
Yafo (west)	Yafo (east) [S]	124	5.502342	0.166168
" "	Strauss [L]	43	14.96533	0.421068
" "	Hamelech George [R]	125	5.622118	0.17432

**HaNiviyim-Kiach 8:00-9:00**

From	To			
HaNiviyim	Kiach [S]	390	0.692843	0.010832
" "	Yafo (west) [R]	85	6.679561	0.182558
Yafo (east)	Yafo (west) [S]	288	7.616688	0.208343
" "	Kiach [L]	35	2.348833	0.061946
" "	Haniviyim [R]	71	1.553382	0.036083
Kiach	Haniviyim [S]	396	0.960331	0.018464
" "	Yafo (east) [R]	38	1.099821	0.022472
Yafo (west)	Yafo (east) [S]	131	10.51876	0.291934
" "	Haniviyim [L]	60	11.95627	0.332721

**HaTurim 15:00-16:00**

From	To			
Yafo (east)	Yafo (west) [S]	239	5.854713	0.160577
"	HaTurim [R]	8	4.304653	0.128003
HaTurim	Yafo (west) [R]	375	1.051278	0.022666
" "	Yafo (east) [L]	3	2.844462	0.079019
Yafo (west)	Yafo (east) [S]	103	13.10285	0.365591
" "	HaTurim [L]	1	0.513542	0.00515

**Sha'arei Tzedek 15:00-16:00**

From	To			
Yafo (east)	Yafo (west) [S]	653	1.353775	0.030021
" "	Sha'arei Tzedek [L]	304	1.145826	0.023929
" "	Sha'arei Tzedek [R]	150	14.16892	0.395193
Sha'arei Tzedek	Yafo (west) [L]	200	1.146937	0.023789
" "	Yafo (east) [R]	7	3.696203	0.099182
Yafo (west)	Yafo (east) [S]	187	13.62976	0.379909

**Sarei Yisroel-Nordau 16:45-17:45**

From	To			
Sarei Yisroel/Nordau(North)	Nordau [S]	913	0.759519	0.012631
" "	Yafo (west) [R]	46	3.171954	0.081083
Yafo (east)	Yafo (west) [S]	243	6.049166	0.163266
" "	Sarei Yisroel [R]	174	1.344378	0.029007
" "	Nordau [L]	507	1.885037	0.044842
Nordau	Sarei Yisroel [S]	1076	1.141944	0.023465
" "	Yafo (east) [R]	71	2.235893	0.054346
" "	Yafo (west) [L]	283	1.235834	0.026013
Yafo (west)	Yafo (east) [S]	77	13.81423	0.385062
" "	Nordau [R]	98.99	0.638769	0.0088
" "	Sarei Yisroel [L]	74	4.025161	0.105453

NOTE: Direction of turn from the entry to exit of intersection is indicated by the letter in the brackets, where S = straight, L = left, R = right

**Figure 6**

**Traffic Data for Post Light Rail Model (~2011)**  
**HOUR OF MAXIMUM TRAFFIC**  
**(FOR EACH INTERSECTION)**

**Kikar Tzahal 8:00-9:00**

From	To	(per max hour) <b>Total Vehicle Number</b>	(g/mi) <b>NOX Pollutant Per Vehicle</b>	(g/mi) <b>PM10 Pollutant Per Vehicle</b>
Shlomo HaMelech	Shivtei Yisroel [L]	688	0.8106	0.0137
" "	HaTzanchanim [S]	702	1.2789	0.0276
" "	Yafo' (exit ramp to Derech Chevron S) [R]	71 0	5.0164 0	0.1344 0
HaTzanchanim	Shlomo HaMelech [S]	798	1.0953	0.0218
	Shivtei Yisroel [R]	108	1.8521	0.0436
Shivtei Yisroel	Shlomo HaMelech [R]	24	0.5135	0.0051

**Chayshin-Shlomtzion Hamalkah 15:00-16:00**

From	To	(per max hour)	(g/mi)	(g/mi)
Chayshin	Shlomtzion Hamalkah [S]	514	0.6938	0.02

**HaMelech George-Strauss 11:00-12:00**

From	To	(per max hour)	(g/mi)	(g/mi)
Strauss	Hamelech George [S]	208	3.0486	0.1073
Hamelech George	Strauss [S]	178	3.1544	0.1098

**HaNiviyim-Kiach 8:00-9:00**

From	To	(per max hour)	(g/mi)	(g/mi)
HaNiviyim	Kiach [S]	402	0.8821	0.0167
Kiach	Haniviyim [S]	402	1.0787	0.0221

**HaTurim 15:00-16:00**

From	To	(per max hour)	(g/mi)	(g/mi)
Yafo (east)	Yafo (west) [S]	245	5.7017	0.1554
"	HaTurim [R]	9	4.6604	0.139
HaTurim	Yafo (west) [R]	352	1.1305	0.0247

**Sha'arei Tzedek 13:00-14:00**

From	To			
Sha'arei Tzedek	Yafo (west) [L]	161	1.2054	0.0256
Yafo (east)	Yafo (west) [S]	719	0.8544	0.0152
"	Sha'arei Tzedek [L]	292	1.1763	0.0247

**Sarei Yisroel-Nordau 16:00-17:00**

From	To			
Sarei Yisroel	Nordau [S]	754	2.1766	0.053
" "	Yafo (west) [R]	136	4.4988	0.1191
Yafo (east)	Yafo (west) [S]	139	8.4817	0.2329
" "	Sarei Yisroel [R]	94	1.6986	0.0402
" "	Nordau [L]	329	1.3301	0.0291
Nordau	Sarei Yisroel [S]	1373	1.6883	0.0391
" "	Yafo (west) [L]	0	0	0
Yafo (west)	Nordau [R]	81	3.2258	0.0834
" "	Sarei Yisroel [L]	56	5.3804	0.1457

NOTE: Direction of turn from the entry to exit of intersection is indicated by the letter in the brackets,  
where S = straight, L = left, R = right

**Figure 7**

**Traffic Data for Pre Light Rail Model (~2004)**

**HOUR OF MAXIMUM TRAFFIC**

**(FOR EACH INTERSECTION)**

		<b>Mischar &amp;</b>					
		<b>Prati</b>	<b>Autobus</b>	<b>Masait</b>	<b>Tender</b>	<b>Monit</b>	<b>O'ofnoah</b>
		<b>Cars</b>	<b>Buses</b>	<b>Trucks</b>	<b>Light Trucks</b>	<b>Taxis</b>	<b>Motor-cycles</b>
<b>Kikar Tzahal 7:15-8:15</b>							
From	To						
Shlomo HaMelech	HaTzanchanim [S]	640	34	25	17	66	18
" "	Yafo (west) [L1]	226.5	2.5	5.5	3.5	7.5	9
" "	Shivtei Yisroel [L2]	226.5	2.5	5.5	3.5	7.5	9
" "	Yafo' (exit ramp to Derech Chevron S) [R]	31				1	
HaTzanchanim	Shlomo HaMelech [S]	774	13	18	29	76	31
" "	Shivtei Yisroel [R1]	42.5	1	0.5	0.5	1.5	1
" "	Yafo (west) [R2]	42.5	1	0.5	0.5	1.5	1
Shivtei Yisroel	Yafo (west) [R1]	6					
" "	Shlomo HaMelech [R2]	6					

Note - data for turning towards the west side (Shlomo Hamelech & Hatzanchanim) failed to specify whether it was towards Yafo (west) or Shivtei Yisroel,

Thus, the traffic numbers were split equally between the two streets in all cases

**Chayshin-Shlomtzion Hamalkah 15:00-16:00**

From	To						
Chayshin	Shlomtzion Hamalkah [S]	435	1	5	16	31	26
" "	Yafo (east) [L]	6			3		1
" "	Yafo (west) [R]	13				3	2
Yafo (east)	Yafo (west) [S]	25	60		3	86	4
" "	Shlomtzion Hamalkah [L]	91	4	3	3	24	7
" "	Chayshin [R]	33		1	6	4	
Yafo (west)	Yafo (east) [S]	73	94	2	8	118	17
" "	Chayshin [L]	2			1	2	
" "	Shlomtzion Hamalkah [R]	15	1		2	12	5

**Halani HaMalkah 10:00-11:00**

From	To	
Halani	Yafo (west) [R]	12
Halani	Yafo (east) [L]	30

**HaRav Kook 15:00-16:00**

From	To				
Rav Kook	Yafo (west) [R]	124.5		4	
Rav Kook	Yafo (east) [L]	124.5		4	

Note - traffic data was for Rav Kook & entry/exit from 2 parking lots,  
but since Rav Kook flows one-way onto Yafo, traffic data split equally between turning R or L onto Yafo

**HaMelech George-Strauss 11:00-12:00**

From	To						
Strauss	Hamelech George [S]	6	17			59	4
" "	Yafo (west) [R]	2	7	1	1	9	
Yafo (east)	Yafo (west) [S]	35	34	2	6	123	9
" "	Strauss [R]	5	24	2		39	1
Hamelech George	Strauss [S]	17	14	2	2	68	10
" "	Yafo (west) [L]	5	29	1	1	63	1
" "	Yafo (east) [R]	10	8	2	2	95	6
Yafo (west)	Yafo (east) [S]	28	37	2	3	49	5
" "	Strauss [L]		40	1	2		
" "	Hamelech George [R]	3	36	3	1	79	3

**HaNiviyim-Kiach 8:00-9:00**

From	To				
HaNiviyim	Kiach [S]	380		10	
" "	Yafo (west) [R]	48	32	5	
Yafo (east)	Yafo (west) [S]	152	132	4	
" "	Kiach [L]	27	1	7	
" "	Haniviyim [R]	64	3	4	
Kiach	Haniviyim [S]	379	7	10	
" "	Yafo (east) [R]	36	1	1	
Yafo (west)	Yafo (east) [S]	42	83	6	
" "	Haniviyim [L]	14	44	2	

**HaTurim 15:00-16:00**

From	To				
Yafo (east)	Yafo (west) [S]	146	79	10	4
"	HaTurim [R]	5	2		1
HaTurim	Yafo (west) [R]	353	11	5	6
" "	Yafo (east) [L]	2		1	
Yafo (west)	Yafo (east) [S]	16	83	4	
" "	HaTurim [L]	1			

**Sha'arei Tzedek 15:00-16:00**

From	To			
Yafo (east)	Yafo (west) [S]	603	24	26
" "	Sha'arei Tzedek [L]	286	8	10
" "	Sha'arei Tzedek [R]	16	134	
Sha'arei Tzedek	Yafo (west) [L]	189	6	5
" "	Yafo (east) [R]	5	1	1
Yafo (west)	Yafo (east) [S]	26	160	1

**Sarei Yisroel-Nordau 16:45-17:45**

From	To			
Sarei Yisroel/Nordau(North)	Nordau [S]	888	6	19
" "	Yafo (west) [R]	38	8	
Yafo (east)	Yafo (west) [S]	155	88	
" "	Sarei Yisroel [R]	164	9	1
" "	Nordau [L]	455	40	12
Nordau	Sarei Yisroel [S]	1022	36	18
" "	Yafo (east) [R]	63	8	
" "	Yafo (west) [L]	268	12	3
Yafo (west)	Yafo (east) [S]	10	67	
" "	Nordau [R]	98	0.66	0.33
" "	Sarei Yisroel [L]	57	17	

NOTE: Direction of turn from the entry to exit of intersection is indicated by the letter in the brackets,  
where S = straight, L = left, R = right



**Figure 8**

**Traffic Data for Post Light Rail Model (~2011)**

HOUR OF MAXIMUM TRAFFIC (FOR EACH INTERSECTION)		Prati Cars	Autobus Buses	Masait Trucks	Mischar & Tender Light Trucks	Monit Taxis	O'ofnoah Motorcycles
<b>Kikar Tzahal 8:00-9:00</b>							
From	To						
Shlomo HaMelech	Shivtei Yisroel [L]	673	12	3			
" "	HaTzanchanim [S]	656	26	20			
" "	Yafo' (exit ramp to Derech Chevron S) [R]	49	20	2			
HaTzanchanim	Shlomo HaMelech [S]	766	29	3			
	Shivtei Yisroel [R]	98	9	1			
Shivtei Yisroel	Shlomo HaMelech [R]	24					
<b>Chayshin-Shlomtzion Hamalkah 15:00-16:00</b>							
From	To						
Chayshin	Shlomtzion Hamalkah [S]	435	1	5	16	31	26
<b>HaMelech George-Strauss 11:00-12:00</b>							
From	To						
Strauss	Hamelech George [S]	9	24	3	5	159	8
Hamelech George	Strauss [S]	15	22	3	8	122	8
<b>HaNiviyim-Kiach 8:00-9:00</b>							
From	To						
HaNiviyim	Kiach [S]	382	1	19			
Kiach	Haniviyim [S]	379	8	15			
<b>HaTurim 15:00-16:00</b>							
From	To						
Yafo (east)	Yafo (west) [S]	155	80	7			3
"	HaTurim [R]	5	2	1			1
HaTurim	Yafo (west) [R]	330	12	5			5
<b>Sha'arei Tzedek 13:00-14:00</b>							
From	To						
Sha'arei Tzedek	Yafo (west) [L]	151	5	5			
Yafo (east)	Yafo (west) [S]	697	11	11			
"	Sha'arei Tzedek [L]	275	9	8			

**Sarei Yisroel-Nordau 16:00-17:00**

From	To	666	77	11
Sarei Yisroel	Nordau [S]	100	35	1
" "	Yafo (west) [R]	66	72	1
Yafo (east)	Yafo (west) [S]	84	5	5
" "	Sarei Yisroel [R]	306	13	10
" "	Nordau [L]	1255	95	23
Nordau	Sarei Yisroel [S]	0	0	0
" "	Yafo (west) [L]	65	13	3
Yafo (west)	Nordau [R]	36	16	4
" "	Sarei Yisroel [L]			

NOTE: Direction of turn from the entry to exit of intersection is indicated by the letter in the brackets,  
where S = straight, L = left, R = right

**Figure 9****Pollution Level from Vehicles, assuming average travel speed of 20 km/hr, in g/km**

Prati	NOX	0.3191
	PM10	0.0032
Autobus	NOX	9.8173
	PM10	0.2745
Masait	NOX	4.6642
	PM10	0.1409
Mischar /Tender	NOX	1.2509
	PM10	0.0648
Monit	NOX	0.8424
	PM10	0.0373
O'ofnoah	NOX	0.1682
	PM10	0.0713

**Figure 10**                      **Sample Intersection of Sha'are Tzedek (Post Light Rail)**

POST LIGHT RAIL (~2011)		Prati	Autobus	Masait	(per max hour)
Sha'arei Tzedek 13:00-14:00		Cars	Buses	Trucks	Total Vehicles
From	To				
Sha'arei Tzedek	Yafo (west) [L]	151	5	5	161
Yafo (east)	Yafo (west) [S]	697	11	11	719
Yafo (east)	Sha'arei Tzedek [L]	275	9	8	292

NOTE: Direction of turn from the entry to exit of intersection is indicated by the letter in the brackets,

where S = straight, L = left, R = right

From	To	NOX	NOX	NOX	PM10	PM10	PM10
		Total	Total	Pollutant Per Vehicle	Total	Total	Pollutant Per Vehicle
		Pollutants (g/km)	Pollutants (g/mi)	(g/mi)	Pollutants (g/km)	Pollutants (g/km)	(g/mi)
Sha'arei Tzedek	Yafo (west) [L]	120.5916	194.0734	1.205425	2.5602	4.120243	0.024679
Yafo (east)	Yafo (west) [S]	381.7092	614.3014	0.854383	6.7998	10.94322	0.01522
Yafo (east)	Sha'arei Tzedek [L]	213.4218	343.4691	1.176264	4.4777	7.20616	0.024679

Figure 11

### Pre Light Rail – NOx

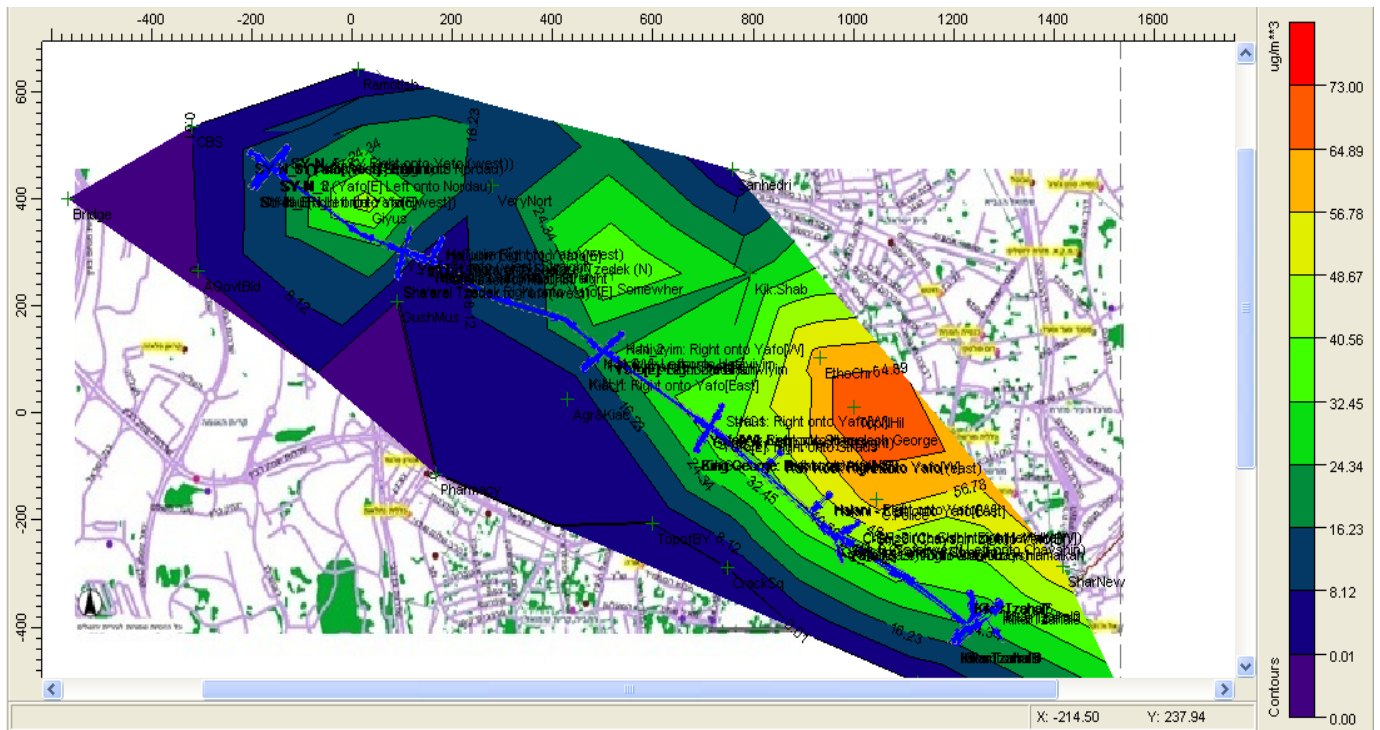


Figure 12

## Post Light Rail – NOx

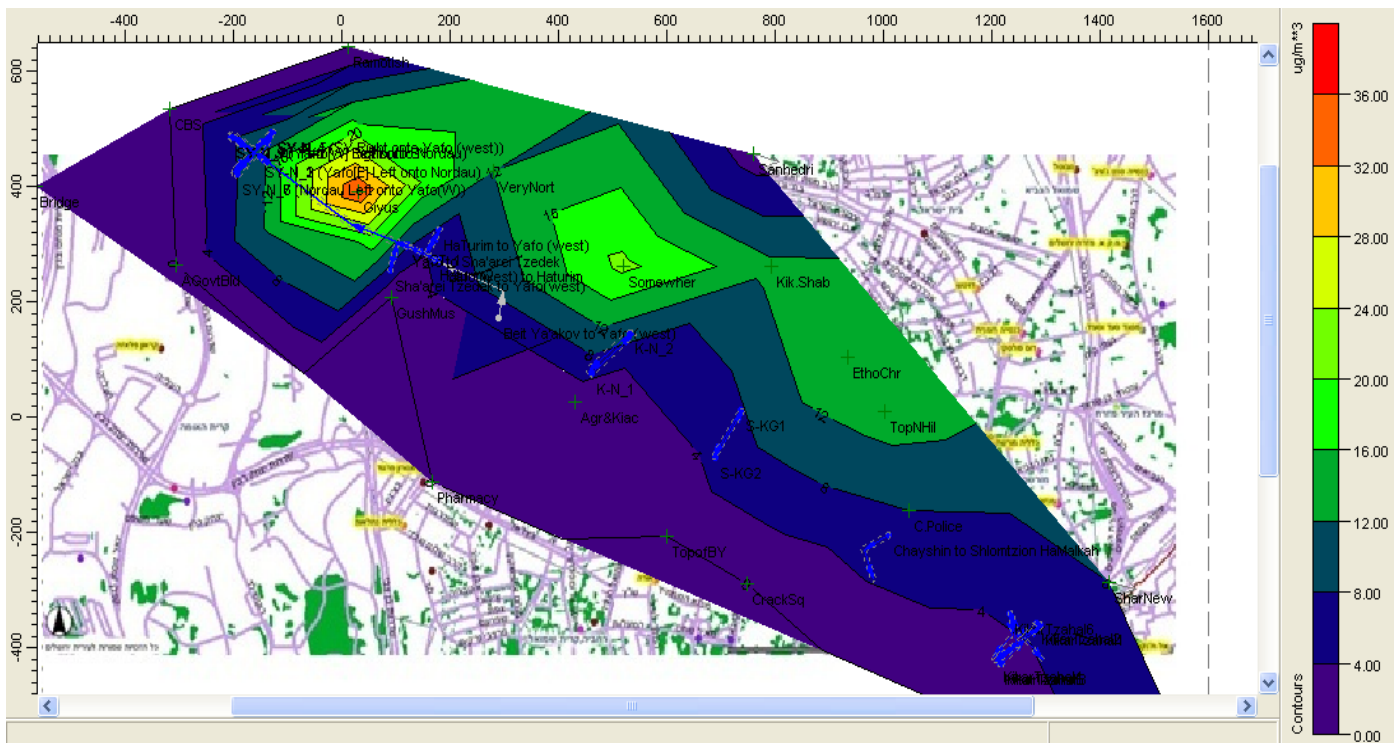


Figure 13

Pre Light Rail – PM10

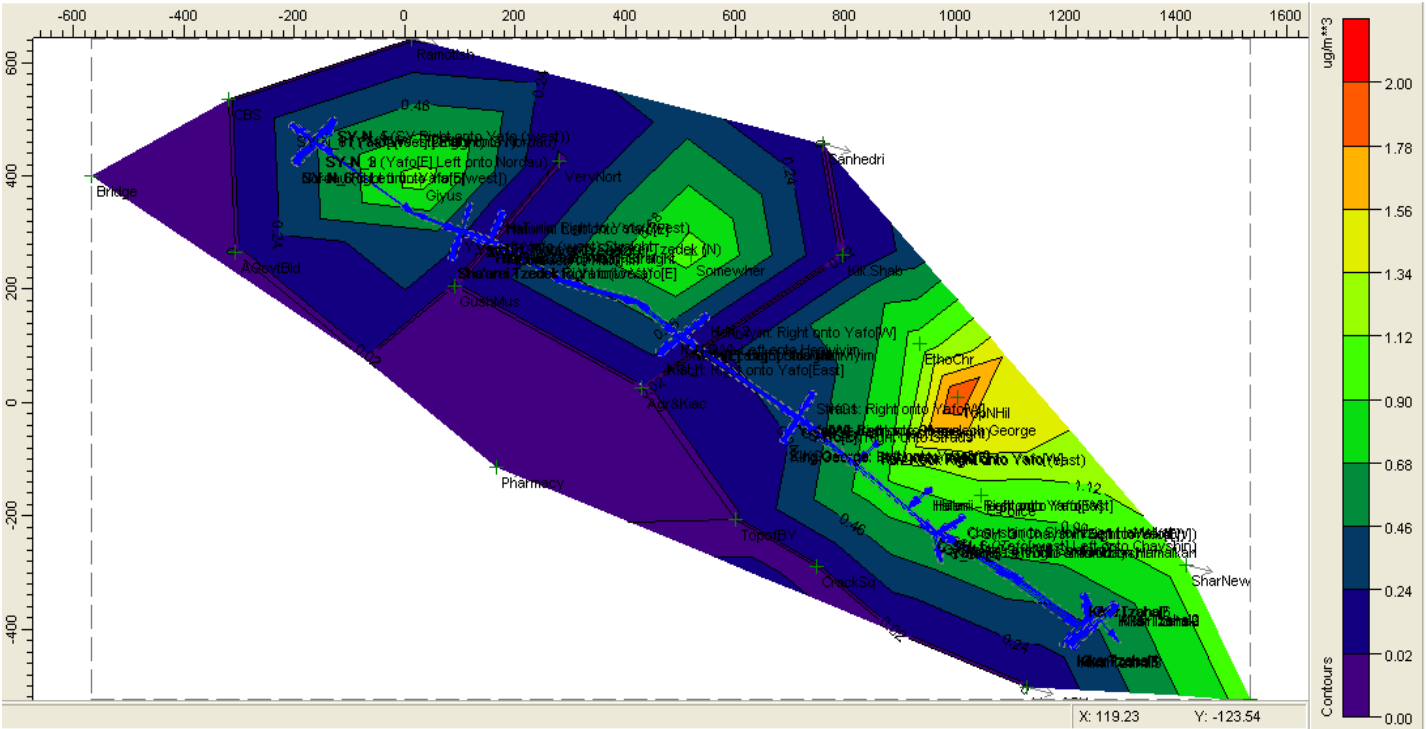


Figure 14

Post Light Rail – PM10

