Controlling Dynamic Traffic by Road Expansion Can be Accomplished by Double Decker Roads - Case Study

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Abstract

Transportation authorities in various countries put to use double decker roads or multi decker roads with the aim of alleviating the traffic congestions. In this paper, we evaluate the suitability of double decker road to road no. 4 in Israel. Models for evaluating the congestion level are suggested. We conclude that a double decker road in the central section of road no. 4 will be the most advantageous solution to the common heavy congestion in this road section.

Keywords: Double Decker Road; Saturation Flow Rate; Congestions; Autonomous Vehicles.

Article Highlights

- Small countries with small areas that can be dedicated for roads, should not look just right and left, but rather should also look up in road planning.
- Road planners not just in small countries, but also in small areas with a dense population should consider Double Decker Roads.

1. Introduction

When a road becomes congested, there is a need to widen the road and to add new lanes; however, some obstacles can get in the way. Sometimes there are buildings in close proximity to the road which leave no area to construct additional lanes. In Some other cases the terrain nearby the road is unpavable.

The alternative option for widening the road is constructing one or more road decks above the current road. There are several transportation authorities in the world that already put into service double decker roads or even multi decker roads with the aim of alleviating the traffic jams and control congestions they have in their territories. For example the city of Seattle in Washington, USA is a large city of more than 4 million residents. Yet, Seattle is located amid many water bodies like inlets of the Pacific Ocean, lakes and streams which make the city dense and challenge the capability of widening the roads. So a main section of the main highway of Seattle (I-5) is a double decker road with the aim of coping with the intense traffic of Seattle [1]. Figure 1 shows a double-decker section of I-5 in Seattle.

There are also double decker roadways in the USA in other places such as Austin, Texas and Chicago Illinois [2]. In Chicago there are even some triple decker roads. In addition, there are double decker roads in other countries in the world e.g. in Kobe, Japan, in Seoul, South Korea, in Manila, The Philippines, in Teheran, Iran and in many more places.

Nowadays, the construction of double decker roads is not a policy of only developed countries. As was mentioned above non-developed countries like The Philippines and Iran also construct double decker roadways.

Figure 1. Double-decker section of I-5 in Seattle.

2. Background

Road no. 4 is the longest highway and one of the longest roads in Israel. The total length of the road is 201km. The road runs from the border of Israel and Lebanon in Rosh Hanikra passing along the coastal plain of Israel to the Gaza Strip. Until 2005 the road continued to Rafah and the Egyptian border, but due to the Oslo Accords, the road now ends at the Erez checkpoint on the Gaza Strip border.

Road no. 4 is one of the busiest roads in Israel. The National Roads Company of Israel continuously monitors the road and its traffic. Once in a while decisions are made by The Israel Ministry of Transportation and The National Roads Company regarding renovations and changes to the road. The common decisions are to construct interchanges in the most congested intersections. The vision of The National Roads Company is to replace all the intersections in the road by interchanges.

Adding lanes in order to alleviate traffic congestions are also unexceptional decisions [3]. In the congested sections adding a fourth lane is certainly considered necessary; however, these sections are passing near buildings in close proximity which leave no area to construct additional lanes, so instead of demolishing buildings in order to free up space for more lanes of the road, a better solution will be to construct a double decker road.

3. Saturation Flow Rate Model

A number of researches have been conducted to calculate the saturation flow rate, that is to say the maximum number of vehicles that can go through a single road lane in one hour. E.g. [4-5]. According to [6] Florida Department of Transportation (FDOT) specifies 1950 vehicles per lane per hour as the saturation flow rate; nonetheless they acknowledge that 1950 vehicles per lane per hour is not accurate. Essentially, the numbers of this threshold essentially range from approximately 1600 to 2300 vehicles per lane per hour. The number of maximum vehicles per hour per lane is usually denoted as VPHPL.

When many vehicles arrive and the number of the vehicles is about to exceed the VPHPL, the number of the vehicles will not succeed to go beyond the VPHPL and the situation will go out of control, congestion will ensue and therefore the speed will be substantially reduced. In [7] the authors show that the speed can be reduced by up to 70% when the number of the arriving vehicles is 4000.

We have examined the main section of highway number 4 in Israel from the intersection with Route 67 to the intersection with Route 7. The length of the section in question is 91km, whereas the length and the number of lanes in each subsection are detailed in Table 1 [8].

Table 1. Length and number of lanes in the subsections

Sub-Section	**From**	**To**	**Length (km)**	**Number of lanes**
Northern section	Interchange with Route 67	North Kfar-Saba interchange	44	2
Central section	North Kfar-Saba interchange	Interchange with Route 20	31	3
Southern section	Interchange with Route 20	Interchange with Route 7	16	2

The number of vehicles per hour travelling on this section of road no. 4 is 4552 [9]. This section is constantly jammed and the below model explains the whys and wherefores for these traffic jams in road no. 4.

$$VPHPL = \frac{\mathrm{v} \cdot \mathrm{t}}{\sum_{i=1}^{n} d_i l_i} \qquad (1)$$

Equation no. 1 gives the vehicles per hour per lane (VPHPL):

Where:

v is the number of vehicles per hour in the road

t is the total length of the road in km.

n is the number of sections in the road

d_i is the length of section i in km.

l_i is the number of lanes in section i.

According to (1) the VPHPL in this section of road no. 4 is 1945 which is approximately the saturation flow threshold. In other words, the road is completely congested and if more vehicles arrive, they will only increase the delay because the flow in the road is at its maximum capacity. The model results are unsurprisingly reflected in reality and can be seen for example in Figure 2.

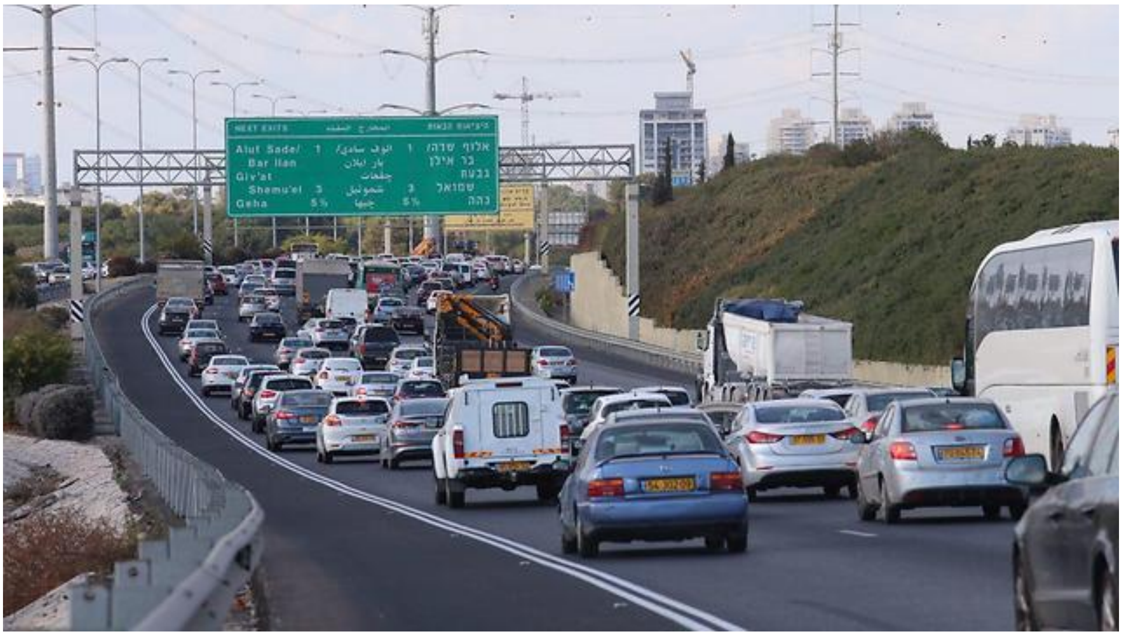

Figure 2. Congestion in road no. 4.

4. Inapplicable Road Expansion

The central section from North Kfar-Saba interchange to the interchange with Route 20 contains 3 lanes. The expansion of this section to 4 or even more lanes causes difficulties because the road is very adjacent to buildings of the neighboring cities and there is no room for the additional lanes.

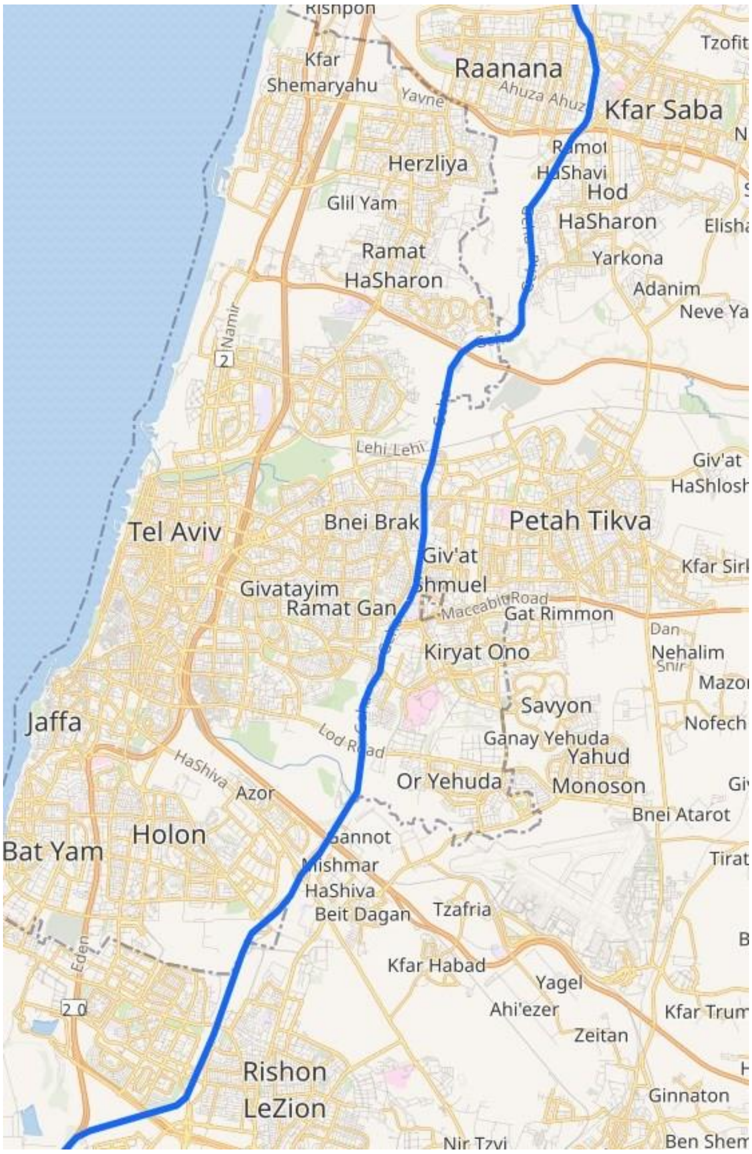

Figure 3. Cities near the central section of road no. 4.

There are many municipalities with structures near this road section including Kfar Saba, Raanana, Ramot Hashavim, Givat Hen, Hod Hasharon, Ramat Hasharon, Morasha Cemetery, Petah Tikva, Bnei Brak, Givat Shmuel, Ramat Gan, Kfar Azar, Ramat Efal, Ganot, Azur, Mishmar Hashiva, Holon and Rishon Letsiyon. The map of the area is shown in Figure 3.

Demolishing so many buildings will be faced by many objections, will cost enormous amounts of money and will cause unhappiness to many people. The bureaucracy and legal proceedings of so many expropriations for the additional lanes will undoubtedly take many years.

Instead of taking this inapplicable attitude, it will be better to construct a second level of lanes above the existing lanes, so no more area will be needed and a portion of the traffic will be directed to the upper lanes.

5. Autonomous Vehicles

Autonomous vehicles are self-guided vehicles that can maneuver and prevail over driving difficulties without any human driver assistance by employing a number of dedicated devices [10]. These devices will provide the autonomous vehicles the ability of monitoring their surroundings and coming to a decision in real time how to handle each situation. Currently, the autonomous vehicles are anticipated to go on the roads we are now familiar with and also with the same traffic signs.

The road capacity and flow rate in the roads will significantly be improved by the autonomous vehicles mainly because of two attributes:

1. Shorter safety distance between vehicles.
2. The variance between the velocities of the vehicles will be much smaller.

In section no. 2 we provided a model for the vehicles per hour per lane (VPHPL). In this section we provide another model to measure the vehicles per hour per lane

$$VPHPL = \frac{1}{\frac{R}{3600} + \frac{L}{V}} \tag{2}$$

(VPHPL) using other parameters:

Where:

R is the reactive time of human beings in seconds.

L is the average length of vehicles in meters.

V is the minimum velocity of the vehicles going on the road in meters/seconds.

The reactive time of human beings is 1.3 seconds [11]. The average length of vehicles is 4.5 meters [12]. We considered a road as jammed when the minimum velocity of the vehicles going in the road in question is getting to 30km/hr or less [13]. According to this data and equation (2), VPHPL is 1956 which is very similar to the number that we got in section no. 2 above – 1945 and it is also very similar to the number of Florida Department of Transportation (FDOT) - 1950.

When it comes to autonomous vehicles, the reaction time is much smaller. According to [14] the reactive time of an autonomous vehicle is about 100 milliseconds. If we put this number in equation (2), we will get a VPHPL of 5625 which is 187% better than the VPHPL of human driven vehicles.

The other parameter we have mentioned above is a smaller variance between the velocities of the vehicles which in addition to the VPHPL can offer a much better utilization of roads.

The obvious question is why investing in double decker roads when the road capacity is going to be considerably extended? In [15] the author summarizes autonomous vehicles implementation previsions. There are few optimistic companies that believe they can offer a full autonomous vehicle environment in the near future; however, most of the companies agree that it will take a long time to offer a full autonomous vehicle environment. Few of them even predict the full autonomous vehicle environment will be available just in 2070-2080. It is unforeseeable which prediction is correct because numerous and various factors are involved in the development and several other unexpected circumstances can arise as well; therefore we cannot wait for the autonomous vehicle technology to be mature enough and we have to solve the congestion problem in the near future.

6. Conclusions

Road no. 4 is a main transportation artery of the State of Israel from the north to the south. The road experiences an acute traffic congestion problem. We showed in this paper models that point out that the number of the vehicles on this road is too high and if we want to keep a reasonable level of service, the road must be widened and contain more lanes.

Currently there is no double decker road in Israel; however, since the central section of road no. 4 is surrounded by many nearby buildings, the commonsensical solution for the congestion in this section is a double decker road in this road section. Israel is a small country with small areas that can be dedicated for roads, so instead of looking just right and left, the government of Israel should also look up.

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