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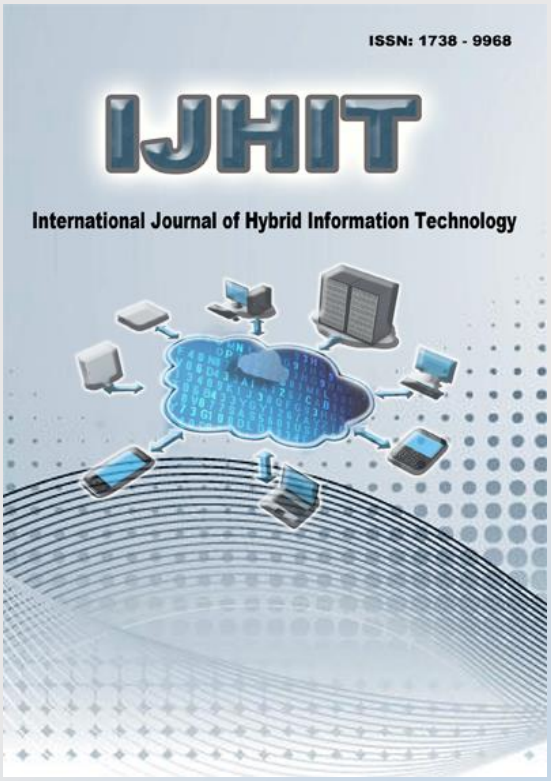

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Abstract

Autonomous vehicles are driven by a computer; therefore they can drop passengers off at any location and then continue to a remote parking lot. In this paper we explore the benefits of this remote self-parking and how the use of autonomous vehicles will change the land uses in many metropolitan areas all over the world. As a paradigm, we explore the case of the state of Israel. Like many other countries, the parking infrastructure in Israel is insufficient and occupies pricey lands in many locations; therefore remote self-parking can be of great advantage.

Keywords*: Autonomous Vehicle, Self-Parking, Remote Parking*

1. Introduction

Autonomous vehicles will improve our quality of life and road safety. The number of traffic accidents will be significantly reduced. Unfortunately, there will still be car accidents like when a child runs after a ball and the autonomous vehicle does not manage to stop on time; however, even such cases the autonomous vehicle knows how to minimize the damage [1,2,3].

In this paper we will focus on a well-known quality of life nuisance - hectic parking systems faced by many people living in urban areas [4]. Autonomous vehicles will put an end to this nuisance [5].

Autonomous vehicles will change the land uses in the metropolitan areas anywhere [6] and unexceptionally in Israel. Many large parking lots can be shifted into alternative uses. In [7] the author claims that almost a third of the central area in major cities in the US is dedicated to parking.

Autonomous vehicles can improve on the parking issues because of several main reasons:

1. Unlike conventional vehicles, autonomous vehicle can drop passengers off at almost any location at any city and then instead of cruising for parking [8], the autonomous vehicle can park itself in a remote location in a rural fringe of the city where inexpensive land is more readily available.
2. An autonomous vehicle can park in a tighter parking slot without having a collision with the nearby vehicle [9,10]. In [11] the author calculates that an average parking can be reduced by 15% because of the compact parking slots.
3. The software of the vehicle will park it [12], so the incidences of egotistic drivers who park their vehicle occupying two parking slots will not be a part of our life anymore. The driver in Figure 1 parked his vehicle in an angle in a perpendicular parking. Figure 2 shows even more egotistic driver who succeeded to occupy three parking slot with a small vehicle.

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Figure 1. Angled Parked Car In Perpendicular Parking

Figure 2. Occupying Three Parking Slot with a Small Vehicle

If the autonomous vehicle is shared between several users or not privately owned, the shared autonomous vehicle can drop off one passenger and pick up another passenger without a need for parking; however, even such shared vehicles should park somewhere

in slack hours when no one wants to go by the shared vehicles, so such a sharing will alleviate the parking requirements, but unfortunately will not completely eliminate them.

2. Remote Parking Lots for Autonomous Vehicles

Clearly, private autonomous vehicles will use other places for parking. The owners of these vehicles can send their vehicles to park in any nearby destination that can offer more space for parking. Afterward, when they will need the autonomous vehicle, they will use a communication gadget [13, 14] to call the computer controlling the autonomous vehicle and the computer will drive the autonomous vehicle back in order to pick up the passenger.

The parking in another neighborhood/community can be challenging because of two main issues:

1. Shifting the parking burden and increasing the traffic in other neighborhoods is unfair.
2. The tax revenues from parking should be set to a price that will convince the vehicle owner to park the vehicle and not to continue to a farer free parking lot. *i.e.* that the gas consumption of the vehicle for continuing to a farer destination will be more expensive than the parking cost at this point.

The cost of constructing and maintaining a parking lot is one of the most important issues. Actually these costs consist of:

1. Land price.
2. Price of constructing the parking.
3. Price of maintaining an existing parking.

The land price is very different in rural fringe, in the urban fringe and in the urban core. In a world with no autonomous vehicle, land for parking is needed many times in the urban core where the real estate values are very expensive. Because of that occasionally underground parking lots or parking towers are constructed. Such a construction is much more expensive than just paving an asphalt concourse; however, the saving in the land price pays back the significant increase in the construction expense.

Therefore, the parking lots of autonomous vehicles are beneficial from several aspects. They can be situated in a rural fringe of the cities when the real estates are much cheaper. As a result, there will be no need for underground parking lots or parking towers. Furthermore, when an autonomous vehicle parks, it will occupy a smaller space, because it can park very close to its peer autonomous vehicle; therefore, more autonomous vehicles than traditional vehicles can park in an identical parking lot.

As was noted in [15], the desirable distance for remote parking is less than 10 miles; otherwise, the user of the autonomous vehicle will have to wait too much time until the vehicle comes. In this paper we explore the locations in Israel for these remote parking lots. We specify the locations in Israel where parking in the city can be a hectic task and we suggest the closest site within the range of 10 miles that can be suggested as a parking lot for autonomous vehicles.

The first place that we explore in Israel is its capital – Jerusalem. Jerusalem is a very historical city. King David made it the capital of Israel about 3,000 years ago and there are abundant of historical sites in the city. The areas of the historical sites were built a very long ago and the constructors did not take in account a need of areas for vehicle parking lots; therefore in some of them there is no parking at all and in others the parking slots are insufficient.

Some other parts of Jerusalem also have parking difficulties similar to other capital cities in the world. In [16] the author claims that it takes in average 5.6 minutes to find

an empty parking slot in Jerusalem. Obviously, in the old city finding an available parking slot takes more time than this average, but in fact the many tourists in Jerusalem are usually interested in the historical sites of the old city, so a solution for the parking problem is indispensable.

In the east of the Jerusalem, there is an area called Mevasheret Adumim aka E1. The size of the area is about 4.6 square miles. The area is pretty hilly as can be seen in Figure 3; however there are many well-known solutions how to overcome this obstacle as was explained in [17].

Figure 3. A View of Mevasheret Adumim from the East

The area of Mevasheret Adumim is almost empty. Only a police station is currently located there which can be very helpful to avoid vehicle thefts [18]. As can be seen in

Figure 3 Jerusalem is just on the edge of this area. The old city of Jerusalem is about 4 miles far; therefore, the area of Mevaseret Adumim can be an ideal parking lot for the autonomous vehicles of Jerusalem.

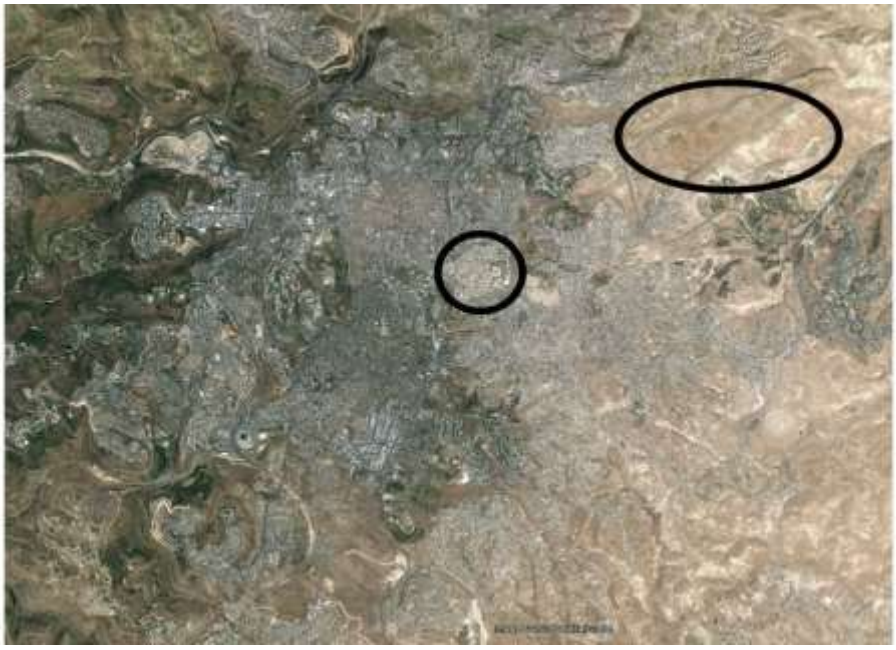

Figure 4. An air photograph of Jerusalem

Figure 4 is an air photograph of Jerusalem. The ellipse in the north east is the area of Mevaseret Adumim. The circle in the middle of the picture is the old city of Jerusalem which is main tourism location of Jerusalem. Unfortunately, the old city of Jerusalem is also the location that is most difficult to find an available parking in Jerusalem. Sending the autonomous vehicles to park in Mevaseret Adumim can be an ideal arrangement for the parking shortage in the old city of Jerusalem.

The second place that we have explored is Tel-Aviv – the business center of Israel. 34% of Tel-Aviv residents received more than one parking ticket during 2014 [19]. In addition, the vehicle of 20% of Tel-Aviv residents has been towed at least one time and Tel-Aviv municipality has been paid 208 million New Israeli Shekels from this goings-on.

13% of Tel-Aviv residents spend more than 30 minutes when they look for a parking; whereas other 39% spend between 15 minutes to 30 minutes when they look for a parking. 82% of Tel-Aviv residents are unsatisfied with the current situation of the parking in Tel-Aviv.

Tel-Aviv is surrounded by several other cities and the bloc of Tel-Aviv extends from the Mediterranean Sea in the west to Rosh-Haayin in the east. Building a floating parking lot on the Mediterranean Sea is very costly [20], so the east side is the better arrangement for the autonomous vehicle parking lot.

Figure 5. A View of Tel-Aviv Bloc from Um El Hamam

Figure 6. An Air Photograph of Tel-Aviv Bloc

Figure 5 is a view of Tel-Aviv bloc from the east side of Rosh-Haayin. This empty place is called Um El Hamam. A part of this area was inhabited by a small Jewish community from the 5th century to the 7th century and was demolished by the Muslims who conquered Israel in the 7th century [21]. Nowadays, there are several scattered ruined buildings, ruined agricultural facilities and tumbledown cisterns, but most of the area is completely abandoned and empty.

Um El Hamam can be an ideal parking lot for the autonomous vehicles of Tel-Aviv bloc. It is far only about 10 miles from Tel-Aviv and about 6 miles from Ben-Gurion international airport aka TLV – the primary and the largest international airport of Israel.

Figure 6 is an air photograph of Tel-Aviv area. The ellipse in the north east is the area of Um El Hamam. The ellipse in the bottom of the picture is Ben-Gurion international airport. As any other international airport, Ban-Gurion airport also has several large adjacent parking lots. A large parking lot in Um El Hamam can free the expensive lands near the airport for other better uses like shopping mall, hotels and other services for tourists. Housing in the surroundings of Ben-Gurion is not advisable because of the noise of the landing and departing airplanes exceeds the common thresholds [22,23] and some researches have pointed out that extremely loud noises may harm the physical and the mental health of the hearer [24].

Tel-Aviv can be seen in Figure 6 near the Mediterranean Sea. The autonomous vehicles of the other cities in its bloc like Ramat-Gan, Givatayim, Bney-Brak, Petach-Tiqwa, Kiryat-Ono, Givat Shmuel and others can also use the large parking lot in Um El Hamam.

3. Financial Benefits

According to [25], constructing of one parking slot in a parking tower can be very costly and can require more than $200 of revenue per month so as to recover the investment and the maintenance. Charging high fees for parking will leave the parking slots empty, whereas charging lower fees will not recover the investment and the maintenance. Just in few very busy locations where all the parking slots are almost always occupied, the parking lot can be profitable. In most cases, the owner of the parking lot should find other solutions how to recover the investment and the maintenance.

Hotels, retail stores and other businesses often suggest free parking or a reduced fee for parking; however, since they need to recover the investment and the maintenance, they increase their products price, so in fact the cost of the parking is paid by the consumer although under a different title [26].

In the public sector we can also sometimes find free or subsidized parking; however, here again the costs should be paid by someone, so actually the taxpayers disburse this subsidized parking.

Autonomous vehicles can be very beneficial in order to eliminate these hidden charges. Someone who comes to a hotel does not have to park the autonomous vehicle within walking distance, but rather he can send the autonomous vehicle to park itself in a distant location. The unnecessariness of the parking will hopefully encourage the hotel owner to reduce the prices.

Likewise, the tax money that goes to subsidize the parking fees can go to other better purposes [27]. As a matter of fact, the current situation that the entire population pays the subsidy of the parking in the public sector regardless if they go to this office or they have a car is unfair. The autonomous vehicle will avoid this excessive and unfair taxation.

It should be noted however that unlike the current parking lots that are merely a paved asphalt concourse, the new parking lots will be wiser and will be able to provide advanced services like automatic puncture and other outside defects detection [28,29,30,31,32] and automatic coordinator and scheduler that decide where each vehicle is going to park [33,34].

The current parking lots can be reused for other purposes. The asphalt concourses are relatively easier for change; contrariwise, underground parking lots and parking towers are more complicated to change, but if the land is in the urban core, the cost of tearing down the parking constructions will be worthwhile. According to [35] destroying underground parking lot is more difficult task than destroying a parking tower even if the tower is relatively high.

Cancelling the on-street parking can create more lanes for the traffic. This will join the narrower lanes that the autonomous vehicle requires, so as a result more cars will be able to go through the same roads.

However, it should be noted that the traffic volume that goes on the roads used by autonomous vehicles will probably increase [36]. Empty vehicles go to a parking lot or from a parking lot to their users will move on the roads. People who were not able to drive because of blindness or other disabilities will now be able to "drive" the autonomous vehicles as well. Therefore, there will be more traffic on the roads, however, traffic flow will be better because differences between driving behavior of drivers will be much smaller and in addition the autonomous vehicles will be able to be closer to their peer vehicles without endanger themselves in an accident since their response time is smaller than human driver.

4. Conclusions

Parking for autonomous vehicles is not supposed to be close to where a passenger needs to arrive; therefore there is no need, for example, for a huge parking lot near the airport as is very common nowadays. Also, the parking lots will be constructed in a more compact manner because the vehicles will park strictly in the right position with almost no unused space. In addition, the parking slots will be signified according to the vehicle type and as a result the parking slots will not be at the size of the largest possible vehicle [37].

In this paper we suggested locations for these remote parking lot locations in Israel and explained why these remote parking for autonomous vehicles are imperative for relieving the notoriously hectic parking system.

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Authors

Yair Wiseman, he got a Summa Cum Laude M.Sc. and a PhD from Bar-Ilan University and completed two Post-Doc - one at the Hebrew University of Jerusalem and one in Georgia Institute of Technology.

Dr. Wiseman's research interests include Computational Transportation Science, Intelligent Transportation Systems, Process Scheduling, Hardware-Software Codesign, Memory Management, Computer Clusters, Data Compression, JPEG, Embedded Systems, Real-Time Systems and Operating Systems.

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In addition, Dr. Wiseman has been teaching in many institutes including Bar-Ilan University, The Hebrew University of Jerusalem, Israel Aircraft Industry, Holon Institute of Technology and Jerusalem College of Technology.

Dr. Wiseman has been supervising many graduate students and an interesting point is that Albert Einstein is Dr. Wiseman's academic great-great-grandfather (*i.e.* the advisor of the advisor of the advisor of Dr. Wiseman's advisor).

Dr. Wiseman has collaborated with other partners and received research grants to run an active laboratory from inter alia Sun Microsystems, Intel, Polak Foundation and the Open University.

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