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Parking Guidance Systems

Evaluating two parking guidance systems' impact on carbon dioxide emissions and parking time for motorists in congested parking facilities

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Abstract

Finding parking space can be difficult these days. Expensive and inconvenient parking lots oftentimes causes many motorists to choose to park on-street which leads to traffic congestion, car emissions and frustration. Trying to park in parking facilities can also become a hassle if they are particularly congested during busy days, which leads to cruising cars within the facilities and causes further congestion.

Parking guidance systems is a way to solve this by making it easier for motorists to find and access parking space in parking facilities with the technology. This study aims to evaluate two kinds of parking guidance systems to see how efficient they are and try to improve upon them. This will be done by physically testing the two systems as well as conducting a survey around one of the systems to gauge the general opinion and usage of it.

The results showed that up to 2 minutes and 21 seconds can be saved in average when using a parking guidance system which would result in around 1133 grams of CO_2 being prevented from release while cruising for parking. Some survey participants had problems with the system, such as not understanding how it worked and feeling that it was redundant at times. This is hopefully resolved in the proposed model that is based on the evaluation of the two existing systems. Overall parking guidance systems can be a great help to ensure that motorists can park as quickly and efficiently as possible.

Sammanfattning

Att hitta parkering kan vara svårt nuförtiden. Dyra och besvärliga parkeringsplatser gör ofta så att bilister väljer att parkera på eller intill gator vilket leder till trafikstockningar, bilutsläpp och frustration. Att försöka parkera i garage kan också bli ett besvär om det är särskilt befolkat under hektiska dagar, vilket leder till bilar som åker runt i marschhastighet i garagen och orsakar ytterligare trängsel.

Styrningssystem för parkering är ett sätt att lösa detta genom att göra det enklare för bilister att hitta och ta sig till parkeringsplatser i garage med teknologin. Denna studie syftar till att utvärdera två sorters styrningssystem för att se hur effektiva de är och för att försöka förbättra dem. Det här kommer utföras genom att fysiskt testa de två systemen samt genom att utföra en opinionsundersökning för att uppskatta den allmänna åsikten och användandet av styrningssystem för parkering.

Resultaten visade att upp till 2 minuter och 21 sekunder kan sparas i genomsnitt när styrningssystem används under parkering, vilket skulle leda till att runt 1133 gram av CO_2 skulle kunna förhindras från att släppas ut medan man letar parkering. Vissa av deltagarna av opinionsundersökningen hade problem med systemet, som att inte förstå hur det fungerade och att det kändes onödigt ibland. Det här är förhoppningsvis löst i den föreslagna modellen som är baserad på utvärderingen av de två existerande systemen. ÖVerlag så kan styrningssystem vara en stor hjälp för att garantera att bilister kan parkera så fort och så effektivt som möjligt.

Contents

1 Introduction

Cars were invented to increase convenience and comfort in everyday life, but as a consequence of their everyday use; fuel consumption and global warming have been widely discussed topics and big problems for many years now. The detrimental effects of fossil fuels has lead to lots of research being put into developing the car of tomorrow. However, there's still a lot of things that can be done about the way we drive and use the cars we have today to make sure we utilize them in a more efficient way.

Parking is a big aspect of driving and the simple task of just finding parking space can take a lot of time, finding parking space isn't always easy and can sometimes be a frustrating task. In congested areas people can spend a lot of time trying to find a parking space because in a lot of of these areas there are next to no indicators that shows if there are any parking spaces available. This leads to more time spent searching, a more frustrated driver and more car emissions.

On-street parking is a big problem in larger cities with heavy traffic. On-street parking is caused by the shortage of off-street parking lots as well as long distances to off-street parking lots. Cars parking on-street clogs up the street which results in traffic congestion and hazards [8].

Furthermore, parking on-street is mostly free while parking in garages and such often comes with a fee, especially for longer parking times that commuters might rack up during the day. As an example, Huddinge Municipality is going to implement a new parking fee for anyone parking on-street near shuttle stations since many commuters choose to park on-street because of the fees that are already in place for nearby parking lots. This in turn has congested the streets and reduced the accessibility which prompted this change by the municipal [10].

In short, on-street parking is popular because it can be more convenient and cheaper, people won't park off-street as long as they can instantly find good spots on-street closer to their final destination. That's why it's paramount to maximize parking efficiency in off-street parking lots by using parking guidance systems that can guide the driver to empty parking spaces in as little time as possible.

As the population increases so does the amount of produced cars which leads to more space being used for parking, space that could be used for other things such as housing. As of March 14 there are 4 768 060 registered cars in traffic in Sweden [11].

According to a study conducted in 2012, the traffic flow peak can increase as much as 25-40% while dealing with the significance of parking problems [4]. Which is further backed up by research from 2005 that mentions that 30% of cars on the roads in downtown areas of major cities are actually cruising around for an average of 7.8 minutes to find a parking spot [4].

To give an idea of the resources wasted, in the city Westwood Village which lies in Los Angeles, USA and has a population of about 50 000, there was a study done in 2006 that summarized the annual waste of resources when trying to find a parking lot in a small business district of the city. The amount of time wasted annularly was calculated to be 95 000 hours, the amount of gasoline wasted was 47 000 gallons (around 180 000 liters) and the CO_2 production from the vehicles was 730 tons [18].

These are the reasons why drivers need increased efficiency when finding spaces. One of the ways to do this is by using "parking guidance systems" or PGS in short. There are different type of parking guidance systems and can range from single display monitors to LED-lights displaying parking availability to mobile interfaces. The main function of PGS is to assist drivers to identify available parking spaces and they can reduce the traffic by 10-60% during different times of the day [6].

Parking guidance systems typically obtains information about available parking spaces in a particular area and then process it in real-time to guide vehicles to any available spots. It involves using low-cost sensors and real-time data collection. In some cases a more advanced system enables mobile-phone payment systems that allow people to reserve parking in advance or very accurately predict where they will likely find a parking spot [2].

The two systems that are going to be evaluated can be found in some of the larger parking facilities in Stockholm. The first one features variable message signs that show the number of free parking spaces on a floor or in the whole facility.

The second system uses LED-lights to guide drivers to empty parking spaces, where the empty spaces have green lights above them and the occupied spaces have red lights.

If implemented successfully, parking guidance systems can lead to large amount of fuels being saved. Fuel is becoming a depleted resource at the same time as it's harmful to the environment when it's used in abundance. With these systems in place, the use of fuel can hopefully be reduced to save on the resources that are left while also lessening their negative impact on the environment.

1.1 Problem Statement

The main question that will be focused on in this study is going to be:

- How much can two different parking guidance systems save in terms of time and CO_2 emission when finding parking space in a congested parking facility?

We will also explore a side question for further discussion:

- How can the parking guidance systems be improved?

1.2 Scope

This thesis will only focus on off-street parking, such as in garages, since evaluating and improving more spontaneous parking, such as on-street parking, would be very difficult. Having a parking system for every road with available on-street parking is simply not possible. The congested areas from the problem statement will be areas with heavy traffic such as commercial districts and inner Stockholm.

Two parking guidance systems will be evaluated in this study. The first one is going to be a simple system involving variable message signs which indicate the number of unoccupied spots in an area. The second one is a bit more complex, it involves guidance lights which glow green above unoccupied spots.

These two systems were chosen primarily because they actually are in use in different garages in Stockholm and can thus be functionally tested.

1.3 Purpose

This report will address the issue of not having an effective way to find a parking spot. The thesis will evaluate how parking guidance systems can lead to less car emissions and less time spent finding a parking space using different parking guidance systems and comparing the different advantages and disadvantages of these two types of systems to try and improve upon them.

2 Background

Early cars weren't as resistant to weather as the cars we have today. Open tops combined with leather seats made them sensitive to rain and other weather hazards. Which is why parking garages popped up, they were a natural consequence of the frailty of the automobile. The first garages were often just ordinary buildings that could store any other thing, such as tools or other machines. One couldn't really tell that they were supposed to store a car, since that probably wasn't their original purpose [12].

By 1929, there were 23 million cars on American roads [14]. There was a clear need for places to store cars and thus multi-story garages, that were more similar to the ones we have today, started being constructed. They were ugly structures that primarily adhered to the principle "form follows function." The first garages were staffed with parking attendants and drivers weren't allowed to park their own cars, let alone enter the garage [14].

Soon enough however, drivers were able to park their cars in garages and while the garages might still have been unsightly, they transformed parking to something more convenient. From not being able to park at all, to not being able to park their own cars, to being able to park at their own discretion. The drivers gained a freedom in being able to come and go at their own accord at a scale previously unseen. It was a freedom that came hand in hand with the freedom felt when driving [7].

Though when everyone is free to park at their own discretion, some efficiency is lost. Each driver has to find an unoccupied parking spot that they can use for themselves instead of entrusting that task to an attendant that likely would have an overview of the whole garage and its parking spots. To ensure that drivers don't cruise around in vain trying to find a spot, parking guidance systems are often implemented to guide them quickly and efficiently to the nearest available spot [15].

The following parts of the background will outline two different kind of parking guidance systems. Wherein each system will be described in how they work and have their advantages and disadvantages listed and compared. The core of these systems needs to be explained first in order to understand how the technology has evolved into what it is now.

2.1 Categories of smart parking systems

The term "smart parking system" incorporates several different kinds of systems that all help in some way during parking, parking guidance systems are one of them. The term can be separated into 5 different segments that all have a connection to smart parking system [17]. The main focus of this study will be kept on parking guidance systems, but a clear understanding of the other segments will give a overview of how they can incorporated with each other in case a new type of smart parking is going to be built in the future.

- Parking guidance and information system: Smart systems that aids the drivers in finding a parking space fast and easy, can either be in a city area or in a parking facility [17]. Consisting of 4 main components that are crucial: information distribution mechanism, information gathering mechanism, control center and network telecommunication[9]. This will be called just "parking guidance system" in this report.
- Transit based information system: Similar to PGIS but the difference is that the focus lies on guiding the user to park and ride facilities[17]. The system provides real-time information about the status such as schedules and traffic condition of each public transportation and car park[3].
- Smart payment system: A Payment system implemented to overcome the conventional way of payment methods that currently is in use when paying for parking and introduce new and fast payment methods [17]. Conventional methods in use at the moment can cause delays and inconveniences. A smart payment system can reduce maintenance and requirement of staff [3].

- E-parking: E-parking is a method for guests to inquire or reserve a parking space at a desired parking facility of the guests choice to ensure the availability of vacant car park space upon arriving. The system is accessible through text-messaging like SMS or through the Internet. Additional benefits are that it can be incorporated with the payment mechanism of smart payment system [17].
- Automated parking: Automated parking involves the use of robots and computer control. The machines handles everything automatically. The only thing required from the driver is to drive to the parking bay. This type of system allows maximum utilization of space [17].

2.2 Variable message sign

Variable message signs (VMS) are control devices in traffic that provides the traveler with information. VMS are commonly installed overhead sign bridges, on highways or other structural elements. The information is displayed on a display panel in real time and can be controlled remotely or locally. VMS is designed to improve traffic flow and operations [5].

Figure 2.1: Variable Message Sign over the E4 route in Stockholm.

Some examples of information displayed are:

- Travel times between known locations
- Congestions
- Construction notices
- Weather announcements
- Incidents

With the development and widespread application of intelligent transportation systems, the variable message signs have been an important tool to improve traffic conditions. Parking variable message sign, also known as parking VMS, is the most common form of information display terminal of parking guidance and has become critical in designing parking guidance systems [13].

2.2.1 Parking variable message sign

The parking variable message sign (PVMS) typically relies on a variable message sign and consists of a LED-display and a counting mechanism at parking lots to monitor the changes of vacant parking spaces to assist drivers to identify parking slots and reduce the traffic generated by cruising even more for vacant spaces [20].

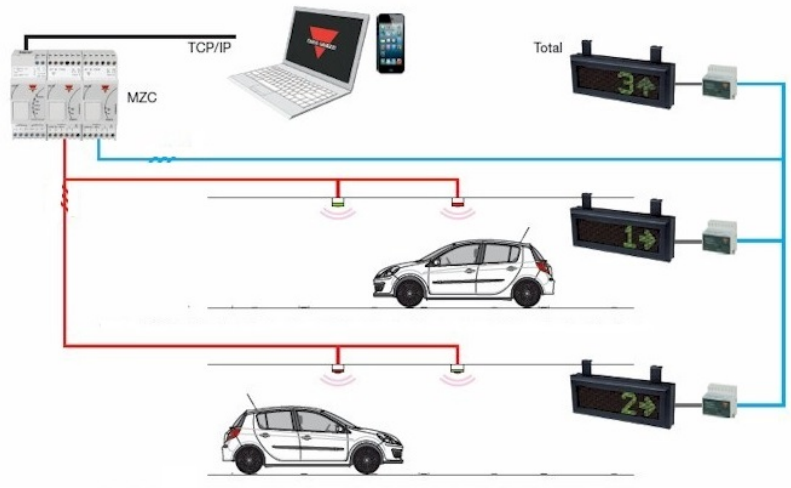

Figure 2.2: Overview of the mechanism for PVMS.

These types of systems normally consists of a counting mechanism, a control center that process the data in real time and controls the parking information and a screen terminal that displays the information to the drivers. The display ranges from 3-digit to 4-digit and in rare situations even more [19].

The display is installed at each exit lanes and the count is initially set to the total number of parking spot and a entry barrier is enabled to keep track of the vehicles entering and exiting using sensors which are typically ultrasonic or loop detectors. The sensor records each vehicle that enters and sends the information to the control unit which then updates the display on the terminal units. The value of the count is incremented by 1 and for each vehicle exiting the value is decremented by 1. If there are no parking space available the count value will be 0 because the number of vehicles currently inside the car park is equal to the total number of parking spaces [16].

2.3 Parking guidance lights

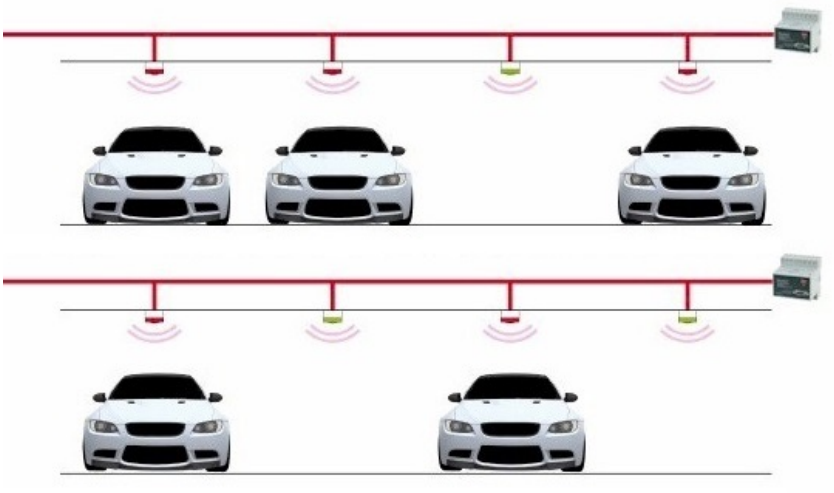

Figure 2.3: Overview of the mechanism for PGL.

Parking guidance lights (PGL) is a system designed to suit all types of car facilities especially multi-leveled car facilities where driver often find themselves spending more time driving in order to find a empty parking space. This system ensures that a parking space is findable by

guiding them directly to it in real time by using LED-lights. If there is a parking spot free then the light turns green, if a spot is occupied the light turns red [15].

A detector is specifically developed for this type of use and fitted with a LED that is installed over every parking space in the facility. Every second, the detector checks for vehicle presence and transmits its status using a communication network to a central computer or control unit. The computer or control unit then processes the data and updates the digital display with information given to the drivers [15].

3 Method

This section explains the study method that is used in order to gather data for our results. The focus is specifically on using a comparison of the different existing systems as well as parking without the help of any system and a poll about people's behavior and attitude towards these parking guidance systems, to see how helpful and user-friendly these systems are. Because of the thesis relying on tests and analyzing different aspects, both relating to hardware and peoples opinion and our own experience, we are therefore interested in both objective and subjective measures.

3.1 Parking system tests

The effectiveness of the systems mentioned in the background will be tested. The first system, parking variable message sign, can be found in almost every average/large parking facility in Stockholm, but the parking facility in "Skärholmens Galleria" was chosen since it's close and also relatively congested during weekends, especially Saturdays during 12-17.

The other system, parking guidance lights, is a more advanced system that is usually implemented in more trafficked areas that has lots of cars moving in and out, so it can be used effectively. The only place that the authors have knowledge of that uses this type of parking guidance system is Mall of Scandinavia which is perfect for this because it's a newly built shopping mall with large multi-leveled parking storage that supports this kind of system very well.

Two sets of tests will be conducted for each type of parking guidance system that was mentioned in the background. The first set will be carried out on heavily trafficked days like weekends and days close to the weekend to be able to fully utilize the effectiveness of the parking systems. The second set of tests will be conducted during low traffic days and hours when the parking garage is mostly empty. Paper stickers will be placed randomly on different parking spaces to symbolize that the space is not occupied by another car, every other space will then be imagined as occupied. This will allow us to test how quickly

parking space can be found without the system since the driver will rely on finding the stickers and not follow the guidance systems.

Each test will be carried out ten times for each type of system. While cruising and looking for a vacant parking space, the average speed will try to be maintained at 15 km/h. Each attempt will be timed and the average time for each test will be calculated. The test driver's opinion of the systems will also be summarized.

The main emission that is being focused in this study is CO_2 (Carbon dioxide), because it's the main emission that affects the environment in a negative way when driving and because 30% of the total CO_2 emission released in the atmosphere in Sweden is caused by the road traffic [21].

The car in use was a Toyota Verso 2010 that according to the Swedish Transport Agency is of EURO 4 standard and has a fuel consumption(city driving consumption) of 8.7l/100km and CO_2 (City driving) emission of 205 g/km [1]. City driving consumption and emissions is the closest category we can test to get somehow accurate results about the numbers since it simulates low cruising speed but of course the motorist cruises at a lower speed than in a city driving environment so the numbers are actually higher than estimated.

The tests that are going to do be conducted will be based around the following points, which will act as guidelines when data is gathered. So the benefits and disadvantages of each system can be more thoroughly summarized and discussed.

- Time spent finding a parking space without the system
- Time spent finding a parking space with help of the system
- Usability (if it's hard to notice signs, lights etc)
- Accuracy (how helpful the system is)

3.2 Survey regarding people's attitude towards and usage of parking systems

Shoppers near the garages of Mall of Scandinavia will be asked some questions to gauge their attitude towards the parking guidance lights. The survey only covers this system because it's more advanced and the authors believe that people will have a harder time understanding how it works compared to the PVMS. This will provide a picture of how often the average driver uses the system and how helpful it is while parking. The participants will be divided into three groups based on age. The survey largely consists of statements which the participant will grade on a scale of how much they agree with them:

- I agree completely - 100
- I agree - 75
- I'm unsure - 50
- I disagree - 25
- I disagree completely - 0

Each grade gives a certain amount of points as can be seen in the list above. The points for each question and age group are then summed up and averaged to an integer to get the average agreement for each question. The survey consists of these questions and statements:

- Did you use the parking guidance lights?
- If yes:
  - The system was helpful.
  - The system gives accurate info.
  - It was easy find parking.
  - The system was easy to notice.
  - The system was easy to understand.

- If no:
  - Why not?
  - The system gives accurate info.
  - It was easy find parking.
  - The system was easy to notice.
  - The system was easy to understand.
- Do you have any additional thoughts about the system?

The last question is not expected to produce a good answer from most participants, but it can incite some more detailed feedback from participants with particularly good or bad experiences with the system, which can be used when discussing potential improvements.

3.3 Limitations

Since the systems are tested physically and in real life scenarios, there will be a lot of randomness considering that real parking is completely random too, one might find a spot quickly or it might take a lot of cruising and searching. This might skew the result a bit since most attempts could just be lucky or unlucky but this will be attempted to be fixed by increasing the number of attempts if the results seems to have too much variation.

The tests without a system, where paper stickers are used, are just an imitation of real life but they had to be run like this seeing that it's very hard to ignore the systems, especially the PGL, during a true real life scenario. The other option would be to use another parking facility without a system in place but this would obviously skew the results since the structure and size of the facilities probably would differ. To try to make it as realistic as possible, the size of the stickers was experimented upon until the test driver could spot them at roughly the same distance as when he could see an empty parking spot.

Survey results can be very flawed and should always be seen with some doubt. Only a certain type of person might be willing to take their time to participate, having only patient or kind participants would

skew the result. The participants might not answer truthfully because they don't care or because they want to give the expected or socially accepted answer, especially if the survey is conducted face-to-face. To prevent this the questions are designed to be as simple as possible to make the survey a quick task for the participant. The questions will also be asked with as much neutrality as possible and the participant is asked to be as truthful as they can be.

4 Results

4.1 Parking system tests

4.1.1 Test of parking variable message sign

Attempt	With system	Without system
1	3:00	3:30
2	3:20	3:25
3	2:55	3:40
4	2:30	4:00
5	1:55	4:10
6	2:30	3:55
7	2:50	3:40
8	3:10	3:50
9	3:45	4:10
10	3:15	3:30

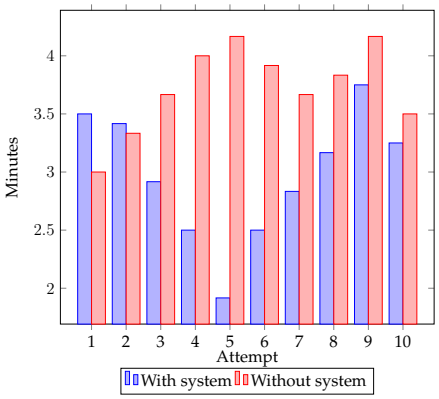

Figure 4.1: Time it takes to find a parking spot with and without PVMS

The average time with the system was 3 minutes and 11 seconds and 3 minutes and 59 seconds without the help of the system. The system gave an average of 48 seconds of saved time for the motorist. The total distance was calculated using simple math by converting the average speed of 15 km/h into meter/min which is 250 m/min and then using the time in the test attempts to get the distance for each attempt and then adding them all 10 distances given into a total distance. With the system it was 6775 meters and without the use of system it was 8975 meters. In order to calculate the carbon dioxide emission that was released, only the total distance is required. According to the test vehicle CO_2 emission, which is 205 g/km, the total amount of CO_2 emissions released during the test with use of system was 1388.9 grams and 1839.9 grams without the system.

4.1.2 Test of parking guidance lights

Attempt	With system	Without system
1	1:20	3:00
2	1:25	3:20
3	0:55	3:30
4	1:20	2:50
5	1:20	3:50
6	1:00	4:10
7	1:30	4:10
8	1:25	3:50
9	2:00	3:15
10	1:45	4:15

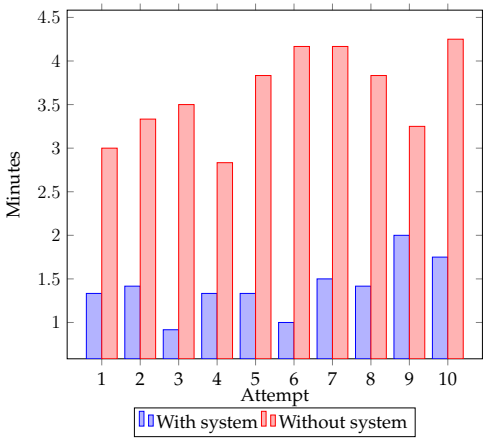

Figure 4.2: Time it takes to find a parking spot with and without PGL

As seen in figure 4.1 and especially the bar chart, the amount of time it took for the attempts that had the help of the system did not vary that much compared to each other. The longest time it took to find a space was 2 minutes and the quickest time was 55 seconds, however this depends on the situation and sometimes luck of course. Without using the system the longest time was 4 minutes and 15 seconds and the quickest time was 3 minutes and 25 seconds

The biggest difference is the time comparison between the two tests done for this system. There is clearly a big time difference between using the system and not using it. According to the tests done, the time spent looking for a space in average was a time of 1 minute and 24 seconds with the help of the system and a total of 3 minutes and 45 seconds without the help of the system. The test gave an average of 2 minutes and 21 seconds in terms of saving time for a motorist.

The total distance with the use of the system was 3100 meters which is 3.1 km and without the use of the system it was an astonishing number of 8625 meters which is 8.625 km. The CO_2 released during our tests is

a total of 635.5 grams for the use of system and a total of 1768.1 grams without the use of the system.

4.2 Strengths and weaknesses of the systems

These are some of the driver's general and subjective observations that were done during the testing of the systems. The observation were mainly focused on the usability and accuracy of the systems.

4.2.1 Parking variable message sign

Strengths:

- Provides Early-on info: Because of the placement of these systems, the driver gets early on information about the parking space occupancy before entering the parking facility and guides the driver to the floor with more parking space.
- Improves traffic flow: The system does improve the traffic flow to some degree leading to less congestions, pollution and less time spent, but not to a degree where it can be labeled as significant numbers in comparison of the other parking system, PGL.
- Cheap and fast installation: A very simple system with not that many components interacting with each other. The system only need to be installed at certain points of the facility, entrance and exists, and they cover a wide field therefore being cheaper and faster to install.
- Clear visibility: The display counter is big and gives a clear visibility for the drivers, providing parking space occupancy on each floor with directions using LED-digits.
- Time efficient: The system does reduce time spent finding a parking space to some degree, but not as effective as PGL, but still effective in it's use and it's better than having no parking guidance system at all.

- Displaying other information: Because of the systems digits size, it can be used to display other information than just available parking space e.g waiting times, handicapped parking using symbol, weather information, signal lane changes etc.
- Low-power consumption: Because of the simplicity of this system, it doesn't require many components interacting and with less use of devices and components it's power consumption is relatively low compared to other systems.

Weaknesses:

- Low effectiveness: The systems effectiveness lies in providing the driver with information early. But once the driver is inside the parking facility they have no idea in which direction there is available parking space, they have to manually find a parking space as if there was no guidance at all in the first place.
- Guidance limitation: The systems incapability of guiding all the way from beginning to the end can cause the driver to ignore the parking display entirely rendering the system ineffective early on.
- Heavy reliance on placement: The entirety of this system lies in good placement strategy and involves many factors such as parking choice behavior, traffic condition, location and capacities of parking lots. A bad and not though-out placement can lead to drivers getting confused and eventually leading to ignoring the systems entirely.

4.2.2 Parking guidance lights

Strengths:

- Suitable and adaptable for a wide range of car facilities: It doesn't matter if the parking facility only has one floor or multi-storied floors of parking, this system will always benefit drivers either way.
- Improves the traffic flow: Because of the visibility of the LED-lights, a driver will always have the system in line of sight and the system will always guide to available parking space thus leading to finding a parking space faster and easier.
- Time efficient: Because of the effectiveness of this advanced system, compared to the other parking system, a driver doesn't need to cruise around as much looking for parking which leads to more saved time.
- Integrable with software, e.g analytics software: This system allows for more integration with other components allowing for expanding the usage of the system to other devices e.g mobiles, tablets and to be integrated with applications providing analytics about the parking area for users.
- Becoming standard parking system: More and more newly built and old parking facilities are installing this parking guidance system and it's becoming a standard system to use in most of the new parking facilities.

Weaknesses:

- Delays in the system: There is a slight delay in the transition between green light to red light and vice versa, depending if the space is occupied or not.
- Expensive and time consuming installation: Because this system relies on LED-lights on every parking space in the parking facility, it's more expensive and takes more time to install, especially if it's a multi-leveled parking facility with a lot of parking spaces.
- Integration with other components: Allowing for other system integration can be a threat or concern to the system scalability

due to wide variety of hardware and software integration. Because most of the hardware, such as the control unit and the lights, are linked then if something goes wrong with one device, the other ones will probably be affected as well. The whole system might have to be shut down in order to just repair one part of it.

4.3 Survey

A total of 50 people participated in the survey. 13 people were between the ages 18 and 29, 17 people were between the ages 30 and 49, and 20 people were over the age of 50.

Figure 4.3 and 4.4 show the general agreement that people who used and did not use the system had towards various statements, where 100 indicates total agreement and 0 would indicate total disagreement. The x-axis is labeled after the statements from the method:

- S1 - The system was helpful.
- S2 - The system gives accurate info.
- S3 - It was easy to find parking.
- S4 - The system was easy to notice.
- S5 - The system was easy to understand.

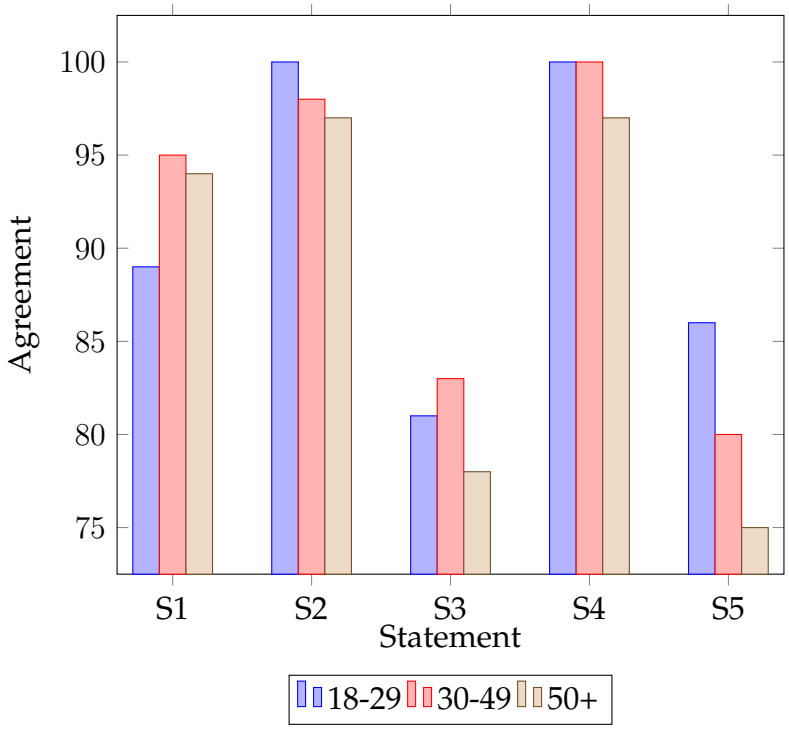

Figure 4.3: Survey of people who used the system.

Figure 4.3 shows a generally positive user experience and that most people had no or few problems using the system. Only some participants, generally older, had difficulties.

27 participants used the system. 9 of those were between 18 and 29 years old, 10 were between 30 and 49 years old, and 8 were over the age of 50.

Figure 4.4 shows that some of the older participants that didn't use the system had trouble finding parking relative to those that did use it. The older participants also had a harder time understanding and noticing the system than those younger.

23 participants didn't use the system. 4 of those were between 18 and 29 years old, 7 were between 30 and 49 years old, and 12 were over the age of 50.

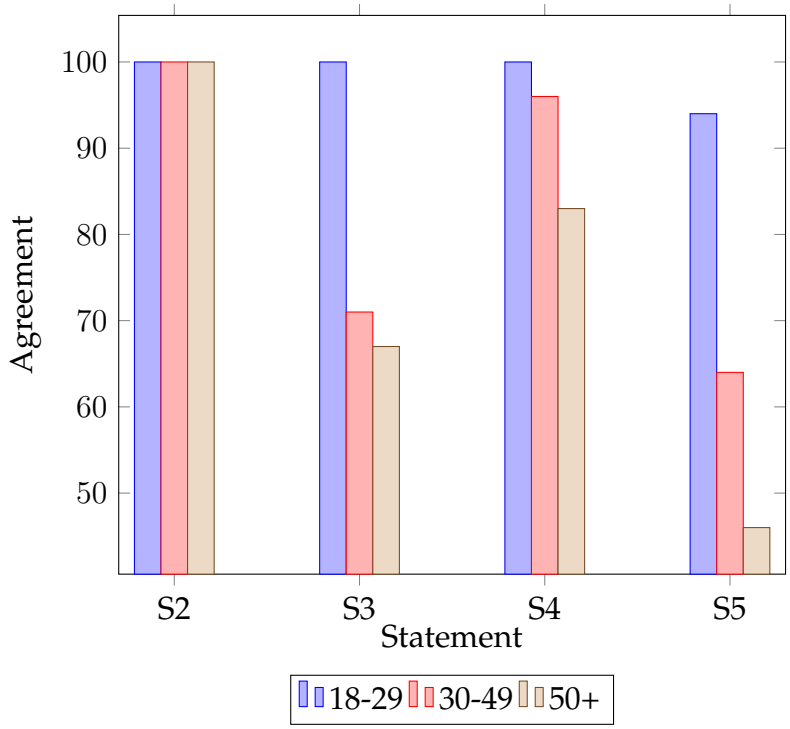

Figure 4.4: Survey of people who didn't use the system.

Age	18-29	30-49	50+
Why did you not use the system?	4 didn't need to.	4 didn't need to. 3 didn't understand it.	5 didn't need to. 7 didn't understand it.

Table 4.1: Asking the participants why they did not use the system.

Table 4.1 confirms that it was mostly the older participants that had trouble understanding the system. The participants who didn't need to use the system mostly either claimed it was because they found parking quickly or at least felt like they would. The ones who didn't understand the system largely explained it by saying it was their first time there or that they seldom used the parking facility and thus had no experience with it. Some of the older participants added that they thought the colored lights were just for decoration and thus ignored them, one of them did realize what the purpose of the lights was when he saw the light above his car had changed color.

The general sentiment towards the system was overall quite positive. However, some participants felt that the lights could be redundant as they sometimes would see an empty parking space at approximately the same time that they saw the green light above it. Some also said they mostly only focused on lights that were in their pathway and that they only found parking space on their route, they didn't look for green lights that were far away or through the lane to the side so they never really diverted their intended route.

5 Discussion

5.1 Parking system tests

Clearly there is a huge benefit to the environment when using parking guidance systems in congested parking facilities. The results might not seem to indicate that much of a difference but when considering that tens of thousands people might visit a mall or a shopping center every day then that difference builds up. All those drivers release a lot of emissions together and these systems helps to prevent tons of CO_2 emission to be released in vain when finding a parking space.

If the usage of the systems increases and their efficiency gets more widely known then it will hopefully also result in less drivers deciding to park on-street. This would increase traffic flow and reduce congestion by both removing the number of cruising cars and the parked cars that narrow down the available road.

The systems did perform differently, the parking guidance lights fared noticeably better than the parking variable message signs. The reasons for this will be thoroughly discussed below.

5.1.1 Parking variable message sign

The reason for the low time difference (48 seconds) between the average times when using the system and when not using it, compared to the test of the other system, is that the system does not provide a huge benefit while cruising inside the parking facility. The parking variable message sign gives information before entering the parking facility and shows which floors have more parking spaces which gives a slight advantage temporally but once the driver reaches the desired floor then they have to manually search for a parking space without further help. This is because the system doesn't guide drivers to individual spots, instead they guide drivers to the parking areas that are the least used, therefore leading to time consuming cruising similar to how it would if there's no system at all.

The system is really only effective if there is a big discrepancy in congestion between floors or if one of the floors is completely occupied, that's when it really cuts down on time because the driver won't have to search through a full floor in vain. Furthermore, this systems effectiveness lies in placement strategy. The placement is crucial in order for the system to be fully utilized. That's why it has to be carefully planned where to install the signs. The best possible solution for this is probably to place the display signs near the entrance of the parking facility and in every floor that has parking in the facility. This is to make sure that the driver gets relevant information to his parking experience as early as possible so that they can make a decision based on the available spots left for a quick parking. For larger parking areas it might also be necessary to place signs at major intersections if a large number of parking spots can be missed when choosing a certain route.

As stated previously, because of the ineffectiveness of the system, the difference between the two tests aren't that major but still usage of the system gives a slight reduction in emission released which is always good in any case. The difference between the two tests in CO_2 emission was 451 grams which yet again may sound little but when it involves thousands of cars using the parking facility the impact increases.

5.1.2 Parking guidance lights

It was expected that this system would provide better results because the system is effective during the whole parking process. The driver is guided all the way through the entire process from first entering the facility until the car is parked. This results in less emissions being released and more time saved because of the systems ability to help through the whole parking process.

Because of every parking space having LED-lights installed above the parking space it actually provides a better visibility for the driver from a far distance and they are visible at all time therefore the driver can quickly and easily find a parking space. The idea of having green light as symbol for available space and red light as occupied space is a great concept that is intuitive and easy to understand for most.

The amount of time and emissions saved, according to the results from the tests, plainly shows that this particular system has a big advantage over PVMS. The comparison of 2 minutes and 21 seconds in saved time and 1132.6 grams in CO_2 saved are relatively high compared to those of PVMS that makes this system a worthwhile consideration for installation in most larger parking facilities.

The issue is that these systems cost a lot of money and are less common in parking facilities of small size. The amount of money spent depends on how many parking spots the facility has since the LED-lights and the detectors needs to be installed in every available parking space. This leads to more money spent depending on the size of the parking facility but larger facilities are also more difficult to navigate which then justifies the cost of equipment that can minimize the difficulties.

5.2 Survey

The attitude towards the parking guidance lights was overall positive, most participants found it helpful and even if they didn't use it they felt that it gave accurate information and that the system was reliable. Young participants had no problems with the system except that it felt a bit redundant at times. Older participants and especially those who rarely used the parking facility had a harder time understanding the purpose of the lights and how the system worked.

Parking guidance lights are clearly at least a benefit and not a hindrance to people's parking experiences. The problem instead lies in getting the usage rate up to 100% by trying to make it more user-friendly and less redundant.

It is not too hard to realize that the green lights indicate free spots and red lights indicate occupied when you've cruised around for a while, most people should be able to connect the dots when they see that all vacant spots have green lights above them. Those who use the system for the first time however, don't have that kind of experience. If they don't know what the lights are for, they will not look for the light but for a vacant spot. They might not realize what the lights are for until they see that the vacant spot that they've already found is the only one

with a green light, or until they park their car and see how the light above them changes. While it's nice that they might have learned how it works on their own, they've already found parking by that point and won't need that information until the next time they use the system. Users should be able to fully understand the system the first time they use it, ideally before they even start using it.

To make it easier for drivers who have never used the facility to understand the purpose of the lights, a straightforward message with the information that green light means free and that red light means occupied could be put near the entrance of the facility. Most new drivers would presumably read it since it could be about parking rules or costs and it's in their line of sight when they slow down to enter the facility. It's a simple but most probably effective solution.

To reduce the redundancy of the system, the user has to be able to know if a parking space is free before they can see the actual parking spot, otherwise there's no need for any guidance lights. So the system needs to guide the driver and influence their route from entrance to parking spot, not just the last 5 meters.

One solution could be to implement a sort of flow light system, like they have in airplanes to guide passengers to emergency exits. The lights would be placed along the pathway, they would then glow stronger or greener if a lot of free parking spots are ahead and be dimmer or redder if there are few free parking spots.

Another solution that would require some more involvement from the driver would be to use a mobile application with a map of all parking spots with indicators to show if the spots are free or not. Then to get to the parking spot the driver could just use it as a standard map or maybe as a GPS if an indoor navigation system could be incorporated into the application.

5.3 Proposed model for an improved parking system based on the evaluation of PGL and PVMS

This model is supposed to be a potential new parking guidance system. It's designed based on the results from the survey about people's thoughts and feedback about parking systems as well as the tests of the two existing parking guidance systems. In this model the two existing parking guidance systems that were tested have been combined and some new features have also been added based on feedback from the participants of the survey.

A new feature that has been added is the ability to connect the driver, parking staff and the system through the Internet with the help of an application. The application is supposed to help with the parking process and enhance the user-experience. It should give both the driver and the parking staff some analytics about the state of the facility, e.g how many cars there are, how many spots are reserved, and how many spots are occupied and not occupied.

Additionally the user should be able to pay for a slot in the parking facility through the application before even arriving so that when the driver arrives the slot is already designated for them and nobody else should be able to take it, this should save a lot of time. The parking slot that is being reserved can be seen through the application and the driver can use it as a map or GPS to plot the best route.

Of course you should be able to find parking without reserving a spot or even using the application. In which case the sensors at the entrance will notice that the license plate is not linked to any spot which will cause the system to just guide the motorist to the closest available spot. The payment would be then be done in a normal fashion by using a parking meter.

Figure 5.1 provides a visual overview of the system with numbered descriptions of the different features that are incorporated into the system.

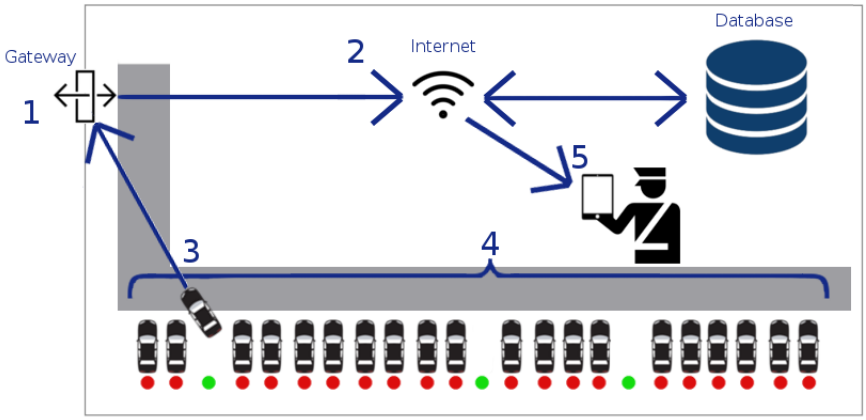

Figure 5.1: Overview of the model.

1. The gateway is intended to act as the entrance to the parking lot. A parking variable message sign is installed around that area to give drivers early information about the parking slots occupancy at the different floors in the facility. Cameras are installed around that area in order to check vehicle license plate in and out of the facility, to easily check the parking time of each motorist. A simple overview of how the system works will also be placed here to make sure that new users understand the system in case they don't use the application.
2. The gateway collects all information from within the facility and sends it via Internet to a database in real-time. Such as when a vehicle enters or exits through the gateway, or when a parking space get occupied or unoccupied.
3. If a vehicle parks at a parking spot, the sensors will detect it. The occupancy is also sent to the gateway which then sends the information further to application users and the database. The light above the car will also switch from green to red to signal the occupancy to any cruising car nearby and vice versa if a vehicle leaves instead.

4. The central control unit can gather real-time analytics utilizing the sensors and cameras in the parking facility to give information about parking bays, amount of cars, amount of spots taken and so forth.
5. Information that is being sent to the central control unit can be used to see how many slots are left through the application and parking wardens can use a tablet to identify non-paying cars and work more effectively. Customers can also gain access to information on the way to the parking facility and plan their route accordingly.

6 Conclusion

This study has given an overview of what a parking guidance system can contribute to the parking environment as well as motorists' parking experiences. The tests conducted in this study gave a result that shows that parking guidance systems are beneficial for drivers in congested areas of major cities. These systems prevents unnecessary resources to be wasted and saves time when finding parking space.

The evaluation conducted has provided results that indicate that the benefits of the systems are many, they can be summarized through the following key points:

- Optimized parking by making sure that the drivers find the best parking spot available in the facility thus saving time, resources and effort which in turn ensures that the parking facility fills up more efficiently.
- Fewer drivers would choose to park on-street if off-street parking was more efficient. This in turn would lead to less traffic congestion since there would be less cruising cars on the streets and also less cars parked that would otherwise make the streets narrower.
- An overall reduction in CO_2 emissions from less cruising, both on the streets and in the parking facilities.
- A more positive parking experience for the drivers with the help of helpful and trustworthy parking guidance systems.

Our first test indicated that parking variable message signs saved an average of 48 seconds and prevented the release of 451 grams of CO_2. Parking guidance lights performed better than parking variable message signs. Our second test showed that there is an average time of 2 minutes and 21 seconds to be saved when using parking guidance lights and thus preventing 1132.6 grams of CO_2 from being released while cruising. Parking guidance lights performed better than parking variable message signs. However, components from both systems were beneficial and should give even better results when combined. The proposed model incorporates the best parts of both systems as well as additional useful features that would make for interesting testing in future research, perhaps by simulation.

The conclusion of this study is that given these benefits mentioned, an implementation of a parking guidance system would be an great investment in many major cities and as the global population continues to increase and urbanize it is necessary and essentially vital to have a well-planed parking guidance system implemented that can be utilized in almost every parking facility.

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