

SMART PARKING WITH QR - IMPROVING CAL POLY'S PARKING SYSTEM
FOR ALL USERS

A Senior Project submitted
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Abstract

Cal Poly Smart Parking, herein referred to as CPSP QR Code Initiative, is developed to reduce the wait times student, staff, and guest drivers experience when searching for a parking spot on campus. Cal Poly is currently undergoing a large growth in student population, and, as a result, is experiencing congestion in parking lots. Drivers will commonly spend frustrating amounts of time “vulturing” these parking lots for an open spot. CPSP QR Code Initiative consists of a database that is controlled by user submitted data through QR codes scanned on a user’s smartphone. This system will provide drivers with a convenient tool that allows them to visualize which parking spots are available in each respective lot. The entire concept has been experimentally implemented on a Windows Server 2008 RS host using ASP.NET programs to interact with a smartphone which has QR Reader application installed at Cal Poly parking lot H-12.

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I. Introduction

This report summarizes the research, analysis, and proposed implementation of a “smart” parking system for Cal Poly’s campus. Cal Poly’s current on-campus parking system requires drivers to obtain a permit (paid hourly, daily, quarterly, or annually) and drive around parking lots “shopping mall-style” until an available spot is located. In Fall 2015, Cal Poly’s parking resources became even more taxed with the recent closure of the G-1 and R-2 parking lots in order to construct the new Student Housing South dorms¹. In the first week of Fall Quarter 2015, annual and quarterly student parking permits had sold out and were unavailable for purchase². These compounding issues have seriously impacted Cal Poly’s parking system, delaying thousands of Cal Poly students, faculty, staff, and guests visiting the campus daily. However, it provides a unique opportunity for Cal Poly’s Industrial and Manufacturing Department to demonstrate its process and system improvement capabilities and make a positive impact on the campus’s future.

The term “smart” has been used fervently in the 21st century to imply that a system is “intelligent” or “autonomous” due to its electronic/technological capability. Smart TVs, smart cars, and smart elevators are a few examples of the everyday appliances that have adopted autonomous attributes in the past decade. For example, smart elevators are designed to optimize elevators routes so that riders can input their destination floor and

¹ Per <https://afd.calpoly.edu/parking/announcements/>

² Per <https://afd.calpoly.edu/parking/permits/fees/>

the shortest path will be taken for all riders. According to NPR, many elevator manufacturers have adopted this technology, as it has made elevators faster, easier to ride, and more energy efficient. Smart elevators now move people around more efficiently and can pick up more people by stopping at fewer floors.

As no parking system is currently present at Cal Poly that informs drivers of parking availability, Dr. Tao Yang, a professor in the IME department, has been seeking methods to implement a “smart” parking system on campus. Adopting the “smart” moniker, the proposed system’s purpose is to recommend available parking spots to drivers and update lot availability autonomously. By introducing this system at campus parking lots, drivers will be able to more easily navigate the campus and secure an open parking spot. By developing a prototype of a smart parking system suitable for Cal Poly, this project aims to reduce traffic congestion, improve parking times, and provide students, faculty, staff, and guests with a more positive, convenient parking experience on campus.

Objectives:

- Identify and utilize most appropriate and economically feasible technology
- Design a working model for testing and assessment of the system
- Estimate the time benefits, if any, of the new system

Key Tasks:

1. Identify a practical and cost-efficient technology (RFID, NFC, QR) that will meet the needs of the smart parking system

2. Design and build a prototype parking system in a Cal Poly parking lot
3. Estimate student time savings using the parking system tool
4. Conduct final presentation on parking system details and benefits

One technology that many smart parking systems rely on today is sensors. Oregon State University collaborated with Streetline, Inc. to install sensors in ADA (Americans with Disabilities) accessible parking spaces around campus. Using a free app called Parker™ users can get real-time availability information for parking spots in selected areas through campus. It will also give information regarding parking lot policies. Gabriel Merrell was the top lead for this project and graciously answered many questions involving this parking project. OSU installed sensors in 76 (out of about 300) ADA spots in the core of the campus. For this project, OSU received full funding for a two year pilot to implement this smart parking concept with Streetline. However, at the end of the two years the university could not be convinced to continue supporting this initiative due to funding constraints. Gabriel described it as a very useful technology and had hopes of expanding the project beyond the ADA lots; however because of cost issues this did not happen. Many costs could not be calculated from this project including the OSU employee's time. The relevant email thread can be located in Appendix A.

II. Background & Literature Reviews

According to Streetline, Inc., a parking system company that focuses on integrating parking sensors with mobile apps to provide data and analytics, over 70 million hours are spent annually searching for parking spots. To address this growing issue, smart parking technologies, utilizing QR, RFID, and NFC technologies; have been developed to autonomously provide drivers with parking information. As cost was a significant constraint in this project, cost-effective methods of smart parking implementation were explored.

While QR codes are primarily used in today's society as marketing and advertising tools, they can also be used to transfer valuable data like parking spot availability. A QR code system is virtually costless to implement and is much more cost-effective than other smart parking technologies such as RFID or the implementation of sensors. When Oregon State University pursued a smart parking project with RFID, the cost of 76 sensors totaled \$25,000 in addition to annual maintenance fees of \$10,000 if they wished to keep the sensors after the trial period (see Appendix A for the email explaining cost breakdown). Because Cal Poly has significantly more than 76 student parking spaces, smart parking via RFID was not feasible for our project. After further research and utilizing a decision matrix (Table 1), it was determined that QR was the most appropriate technology for the purpose of this project, provided the cost and technology limitations.

Table 1: CPSP Technology Decision Matrix

Technology	Cost to Implement	Annual Costs	Convenience	Total Score (larger is better)
QR	5	5	2	12
RFID	1	1	5	7
NFC	3	2	3	8

Literature Reviews

1. PocketParker: Pocket Sourcing Parking Lot Availability by Anandathirtha Nandugudi, Taeyeon Ki, Carl Nuessle, and Geoffrey Ghallen

Similarly to our group’s problem statement, this article discusses the frustration that many people face when searching for a parking spot during a busy time. The solution this article presents is a subset of crowdsourcing through an application, which they call PocketParker. The application detects arrivals and departures in a lot without the phone leaving the user’s pocket. This application does not require any user interaction and uses algorithms to order lots accurately by the probability that they contain an available spot. The methods described in the model are for a campus that has 40 lots and over 80 entrances so our group is sure that the methods used will definitely work on Cal Poly’s campus, which has less lots and entrances. In the end, camera monitoring was used in several parking lots to test PocketParker through 105 different users. Over 45 days, these 105 users generated 10,827 events in which PocketParker was able to predict lot availability 94% of the time.

2. Smart Parking and Reservation System for QR-Code-Based Car Park by Wai Chong Chia and Nami Salimi

This article summarizes a research group's proposal for a parking lot reservation system using QR-codes from drivers' smartphones. Rather than a traditional parking ticket system, drivers scan QR codes from their smartphones, which allow them to pay for parking via Paypal. This eliminates the traditional queuing system that most parking lots use, and reduces the time required to find a parking space (a space is assigned to the driver upon scanning of the QR code). QR was one of the technologies that our team was exploring for smart parking use, and this article provides many important details on how a QR-based smart parking system can be implemented. If QR technology is ultimately selected, this article will be one of the main resources for our project.

3. The Research on Optimal Parking Space Choice Model in Parking Lots by Mingkai Chao Hu Chen and Tianhai Chang

This article explores the many factors that affect people's decisions in selecting parking spaces. Walking distance, traveling distance, status of available parking spaces, safety, and shade are all significant factors that drivers may consciously assess before committing to a parking space. This is particularly useful for our project, as our team hopes to assign optimal parking spaces for students, faculty, and guests as they enter campus. Factors to consider include the weather, travel distance between the parking lot and offices/classes, as well as safer areas to park during the evening/night.

4. New “Smart Parking” System Based on Resource Allocation and Reservations by Geng Yanfeng and C.G. Cassandras

This article comprehensively explores the models, technologies, and equipment necessary for a proposed smart parking system. Information on system realization, including parking space detection, communication, and reservation guarantee are all explored in detail. Optimization models and simulation for driver parking allocation are also reviewed. The article also tells how a smart parking smartphone app is implemented. Information on system realization and implementation can be used to guide our project in the right direction. Optimization models are outside of the scope of the project; however simulation may be used if enough accurate data can be collected.

5. The psychology behind QR codes: User experience perspective by Dong-Hee Shin, Jaemin Jung, and Byeng-Hee Chang

QR codes, 2-dimensional barcodes that are read through special software on smartphones, are undergoing rapid development. This article illustrates the study of how a Technology Acceptance Model could predict the user’s intentions to continue using QR codes through the primary determining factors of interactivity and quality motivations. The results of this study show that users prefer high levels of interactivity when using QR codes. QR codes were originally used to track auto parts, but have become popular for much broader purposes and can be seen in magazines, on signs, on buses, on business cards or almost any object which users might desire information. This article relates to our project as it examines how the Cal Poly student body may accept and react to a new

QR code based Smart Parking system. Users do not always welcome new technologies and it is important to know what aspects of technologies are generally accepted.

6. QR-Maps: an Efficient Tool for Indoor User Location Based on QR-Codes and Google Maps by Costa-Montenegro, Enrique, Francisco J. Gonzalez-Castano, David Conde-Lagoa, Ana Belen Barragans-Martinez, Pedro S. Rodriguez-Hernandez, and Felipe Gil-Castineira

According to this article, there is an increasing number of new geolocation services that are exploiting the new capabilities of smartphones. However, many of these technologies require a deployment of a wireless infrastructure and, in some cases, specific technology that is seldom found in smartphones. The authors of this article researched the use of visual QR-Codes and Google Maps API to track location. There are four basic elements to their proposed system: a QR-Code, a Smartphone, a Location server, and a Map Server. Although the article was written specifically for Indoor User Locations, we can take the same methodology and apply it to our parking project. The location server could contain all of the parking spots, and the map server could display the parking lots through Google Maps API.

7. Q-Arrgh! by Robinson, Simon, Jennifer Pearson, and Matt Jones

QR codes have normally been used to retrieve a small amount of information. This information may be used to identify a particular product or re-direct you to a link. Although this is useful in some industries, in efforts of improving the parking system on Cal Poly's campus, we may need to retrieve more information than that. This article discusses ways to add a social layer to the code, which would make it possible for other

users to read additional messages. This article calls this method “commandeering” and developed an Android app for it all called “Q-Arrgh!” This would allow users to “tag” any object with a message or code they want someone else to find. “Our approach turns any scan able digital marker code into an ad-hoc public noticeboard’ [robinson]. This directly relates to our project and how we want to be able to publically post available spots to a “noticeboard” that any driver can access. Two studies were conducted to test the app. In the first study, 20 participants were given an incentive to participate. “The majority of the participants felt that using the system was interesting” with nineteen out of twenty reporting positive experiences.

8. A QR Code-Based On-Street Parking Fee Payment Mechanism by Wen-Chuan Wu

QR codes are convenient in that they provide an easy method for smartphone users to input webforms onto their phones. This can be used as an advantage for parking payment systems, as a direct link to pay for parking fees can be linked to the user. In Taiwan, parking tickets with QR codes containing an E-bill are issued by parking fee collectors and placed on windshields of cars. The car driver can pay for the tickets easily by scanning the QR code on the ticket and accessing the E-bill, where they may submit their payment via their preferred method. A similar concept can be applied to our project: each hourly parking spot on campus can have a QR code code assigned to it. When the driver scans the code, they will be directed to a webform where they can pay for the amount of time they will be spending at the spot.

9. Indoor Localization and Guidance using Portable Smartphones Hammadi, Monran Al, Ahmed Al Hebsi, and Jamal Zemerly

This article discusses another application that assists users in efforts of guiding them using an indoor map guidance system using NFC and QR code technologies. Similar to our project, these technologies are less expensive than RFID technology, which is why they were selected to be used. “It provides a variety of helpful features such as finding destination, calculating shortest path, storing car parking location,...”[Hammadi]. The article discusses the most common way to accomplish these things, which uses Global Positioning System (GPS). Other ways to accomplish this guidance in an indoor setting is Near Field Communication (NFC) technology, which is a wireless technology. NFC is a short-range communication that's main uses are payment, identification and sharing information. This technology is also something our group is looking into to implement to our project.

10. ParkJam: Crowdsourcing Parking Availability Information with Linked Data (Demo) by Kopecký, Jacek, and John Domingue

This article talks about the development of a “mobile Android app that uses openly available geographic data and crowdsources parking availability information, in order to let its users conveniently find parking when coming to work or driving into town.” The authors claim that one of the biggest problems with the app is how crowdsourcing replies on: *How to recruit and retain users? What contributions can users make? How to combine user contributions to solve the target problem? How to evaluate users and their contributions?* Our Smart Parking system will be operating on crowd-sourced data

supplied through unique QR codes. This article relates to our project because it will be difficult to incentivize the usage of our Smart Parking system for drivers who are specifically in a rush.

III. Design & Users Approach

After researching various parking technologies around the world, we realized that the cost of testing and implementing some of these technologies were not in our project budget. Thus, we concluded that the most feasible technology in the scope of our project was the use of QR codes and a database. Using a database, users can constantly update parking spot statuses' through a webform on their phone. In turn, users arriving on campus would be able to view the availability of these spots in real time. Before we actually began creating the database, webforms, and QR codes, we wanted to establish the important features for this system. The team and our advisor collaborated for several weeks and established the following characteristics which our QR code tool will provide:

- **User Friendliness**

For user education and long-term retention, it is imperative to have a user interface that is easy to use.

- **Homepage** - As users will be using this web application on their phone in the car while searching for a parking spot, similar to how a GPS is used, it is important that users can easily identify available parking spots with minimal distraction. When users first open the web application, it automatically centers on Cal Poly Parking Lot H-12 (for the purposes of

this project) and identifies open parking spots with a green pin; parking spots that are unavailable will not have a green pin. This is more advantageous than a list or drop down as users can quickly see and visualize where an available parking spot is and if it is available. If users wish to know the exact count of available parking spots in addition to the visual representation provided on Google Maps, they have the option of simply clicking a drop down menu that will display the count of open parking spots.

- **Check In/Out** - Once users scan the QR Code, they are prompted to a Check In/Out page, depending on the circumstance. The Check In/Out page is extremely user friendly, as it only contains the information of the parking lot & Spot the user is arriving/departing from and a confirmation button. The confirmation button is large and easy to press, as users will be using the web application on a mobile device. These pages were designed in ASP.NET and their code can be viewed in Appendices C (Check-In) and D (Check-Out).
- **Live Updates** - The web application is linked to a Microsoft Access database that is updated instantly whenever the user hits the confirmation button during Check In/Out. Every time the database is updated, the homepage -- web application containing the visual representation of parking lot H-12 -- is refreshed automatically. Once refreshed, the green pin will appear for updated available spots and disappear for updated unavailable spots. Likewise, once refreshed, the

numerical count of open parking spots will update depending on the number of pins shown on the map.

- **Google Maps** – Google Maps is a mobile application that many smartphone users are familiar with and use, specifically in America. A survey was done by Quartz in June 2015 to identify the top 25 most popular mobile apps. According to the survey, Google Maps was the highest used mobile map application with a user base of 76.5 million, beating out Apple Maps by 27.2 million users. Because of the overall familiarity the general population has with Google Maps, and its readily available API and ease of use on the software development side of this project, Google Maps is a great foundation for the CPSP homepage. In other words, the homepage used in the CPSP web application is created around Google Maps framework. Users will have the same capabilities of zooming in/out of the parking lot, just as Google Maps features are able to do.
- **QR Scanning** - When a driver enters the spot, they will allow others to know that their spot is unavailable by scanning their QR code on their smartphone from the pole, which has the “entering” barcode. Once this is scanned, this information will be sent to the database that will immediately update the parking tool and the spot will be shown as unavailable. Once this same driver leaves, they will need to send this information back to the database by scanning out of their spot on the “leaving” barcode on the pole. Each individual parking spot will have a unique set of QR codes due to the design of our database. Therefore, each individual parking spot will have a sign that contains the QR codes for both checking in and

checking out. See below in Figure 1 for a picture of an example pole. Sample QR codes for parking spots 1-3 can be found in Appendix E.

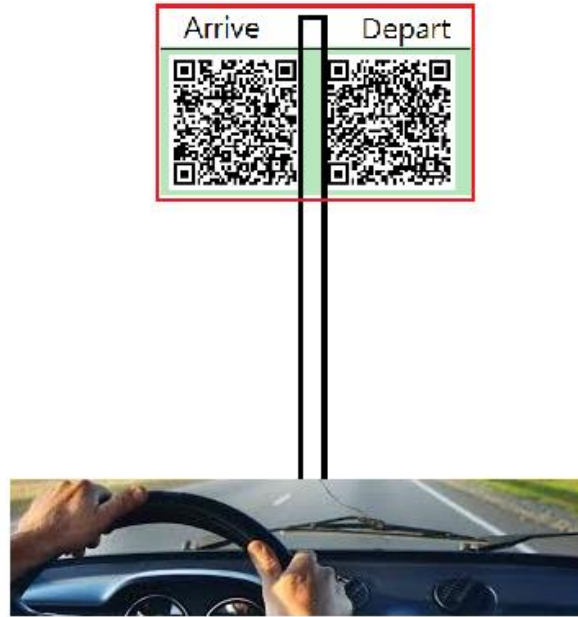


Figure 1: Example QR Pole

- **Parking Lot** - We will be focusing on the design and test of only one parking lot that primarily provides parking to students. Due to the fact that faculty/staff still have the ability to park in these general parking lots, we concluded that students with general parking passes would benefit the most from our tool due to their parking pass limitations. Our group surveyed thirty students that currently have a parking pass to determine which lot the majority of students tend to go to first to begin their search for an available spot. The results of our survey are shown below in Table 2. With 53% of surveyed students beginning their search at lot H-

12 (lot closest to the Highland campus entrance and building 192), our group decided to focus on this lot. See Figure 2 for an aerial view of Parking Lot H-12.



Figure 2: Parking Lot H-12 on Map

Parking Lot	% Of Surveyed Students
H-1	0%
H-12	56.7%
H-14	13.3%
H-15	0%
H-16	10%
G-S (Parking Garage)	10%
G1	3.3%
G2	6.7%

Table 2: Student Survey of Most Popular Parking Lot

*Survey performed on April 28, 2016 from 12-4pm

Testing

To test the design of the proposed smart parking system, a small-scale parking system was simulated in the IME labs. Set-up consisted of two sample QR codes, containing check-in and check-out webform URLs and a smartphone with a working internet connection. The following steps were performed to test the design:

1. Sample QR codes containing check-in and check-out webform URL's were generated.
2. A QR barcode reader was downloaded and installed onto the smartphone (iPhone 6).
3. To simulate the check-in process, a user was asked to scan the check-in QR code, and verify the parking spot he or she would be occupying.
4. After confirmation, the parking availability webform was accessed, and the parking spot's availability was verified (OCCUPIED). Number of available spots was confirmed to have decreased by 1.
5. To simulate the check-out process, the same user was asked to scan the check-out QR code, again verifying the parking spot he or she would be leaving.
6. Again, the parking availability webform was accessed, and the parking spot's availability was verified (AVAILABLE). Number of available spots was confirmed to have increased by 1, returning to the original number before the test.

Flow Charts

The following flow charts illustrate the operational procedure of the web application on the physical and software sides of the spectrum. Figure 3 is a front-end flow chart displaying the system's process from the user's perspective. Figure 4 is a back-end flow chart displaying the same process but on the software/server side.

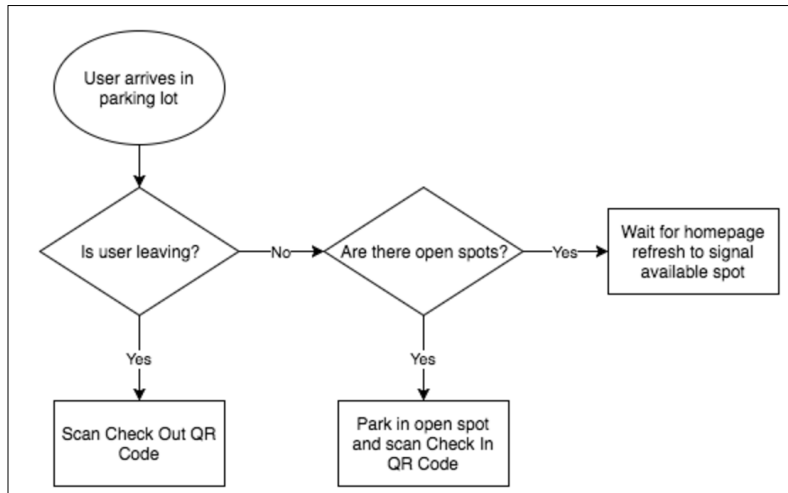


Figure 3: Front-End Flowchart

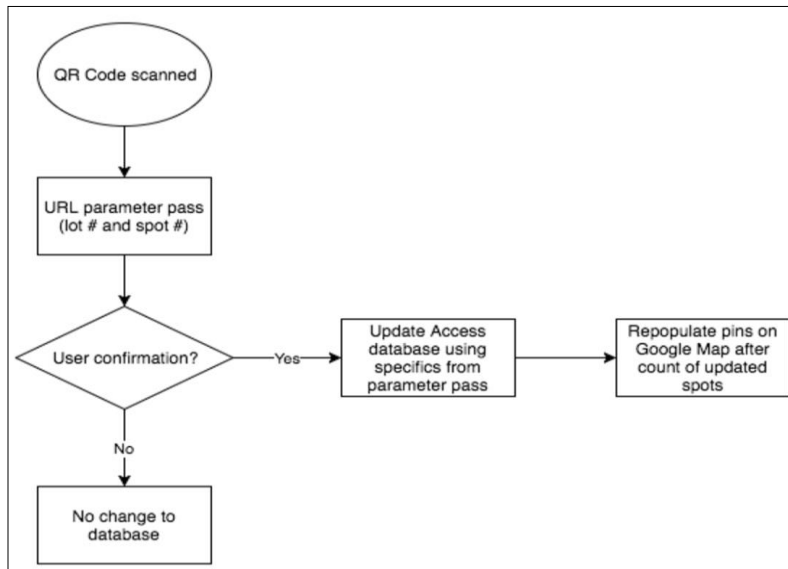
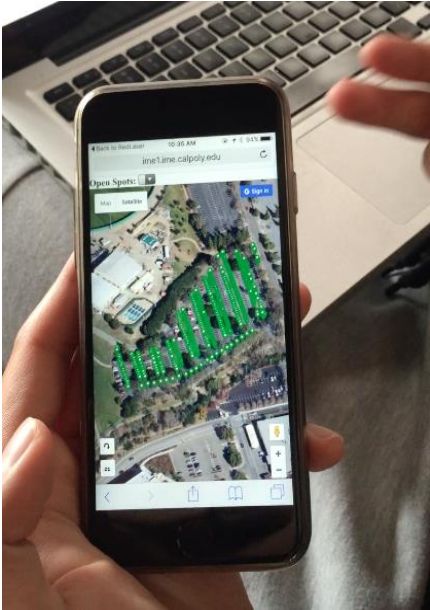


Figure 4: Back-End Flowchart

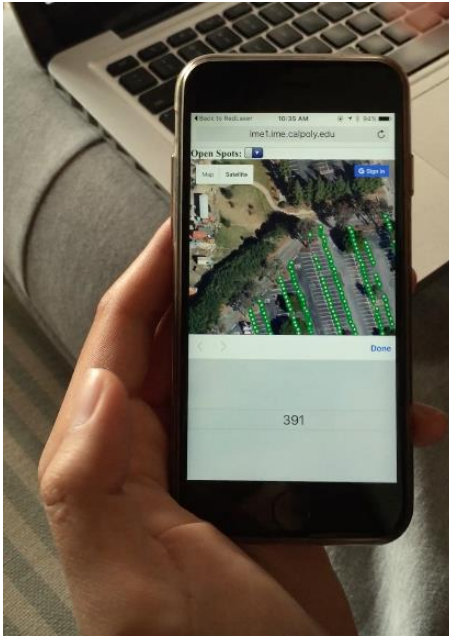
Operational Procedure

Table 2 illustrates the operational procedure of using the CPSP web application on an iPhone 6.

Table 2: Operational Procedure for CPSP QR Initiative

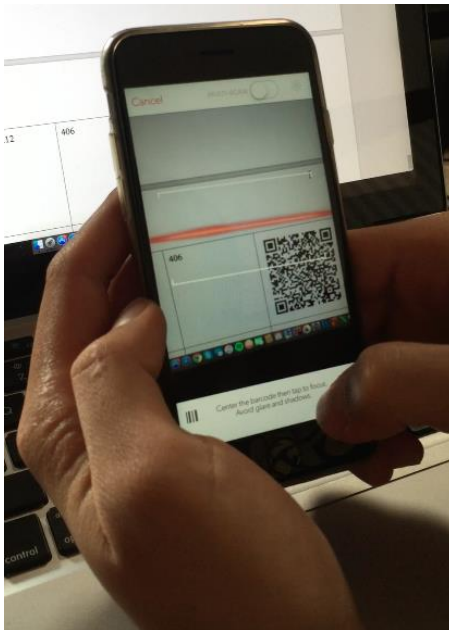
Step	Picture	Description
1		<p>When first opening the homepage, users will see an aerial illustration of parking lot H-12 with green pins identifying open each open parking spot. Users can use this page to get a visual representation of the count and location of each open parking spot, as well as the ones that are occupied.</p>

2



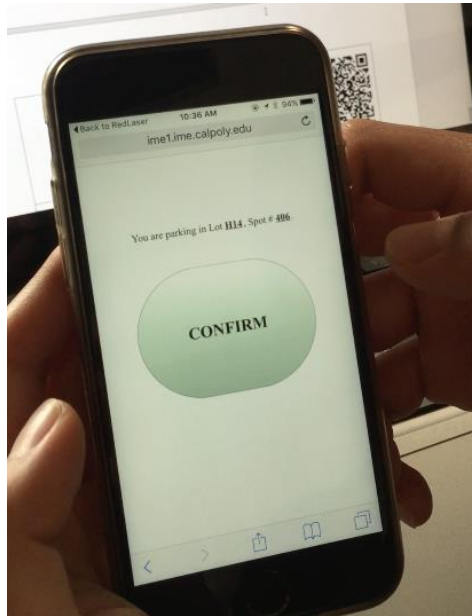
Users also have the option to calculate the exact count of available parking spots by tapping on the drop down menu. Here, it is evident that there are 391 open spots in parking lot H-12.

3



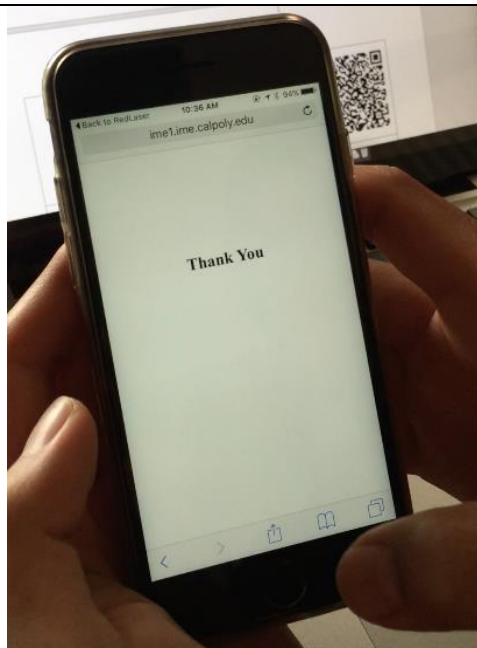
After locating an open parking spot, users will "Check In" by scanning the respective QR Code. When scanned, the QR Code automatically redirects the user to Check In page. If the user is instead leaving the parking spot, he/she will simply scan the "Check Out" QR Code and be redirected to the Check Out page.

4



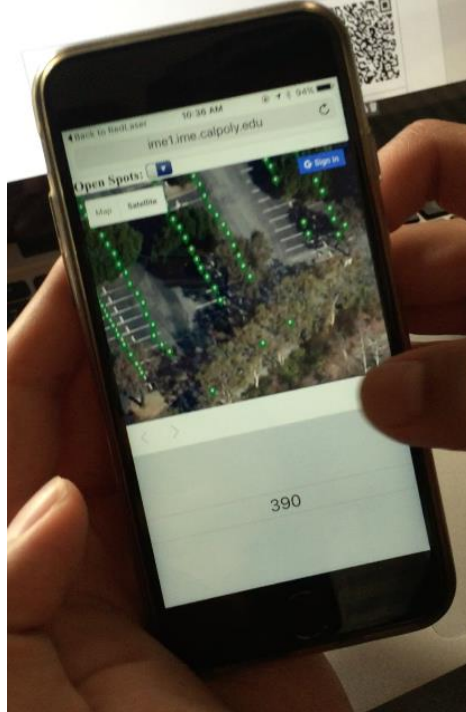
In order to confirm the update, the user will tap on the confirmation button. After confirming the user is redirected to a confirmation page.

5



The confirmation page, stating "Thank You", tells the user that the process is now complete. The database is then updated for all users using the homepage.

6



For purposes of this demonstration, the user was going through the Check In process. Note how the count has been updated from 391 open parking spots to 390.

Economic Analysis

Using the information provided by our Oregon State University (OSU) contact, Gabriel Merrell, an economic analysis was conducted evaluating the costs of the various parking technologies. The cost of the OSU parking system, which utilizes a combination of parking sensors and a mobile app created by Streetline, Inc., was compared to the estimated costs to be incurred by the CPSP QR tool. The bill of materials for the QR code post can be found in Appendix B. Table 3 summarizes the estimated cost of each QR code post in comparison to OSU's cost per parking spot during their pilot study. Gabriel mentioned that only 50 sensors were in the contract but the Streetline, Inc. was gracious

enough to provide 76. Thus, the total cost per spot is discounted and could potentially be higher. For the sensors, there was no annual maintenance cost due to the fact that the vendor was contractually obligated to provide maintenance during this period. If OSU were to continue with this technology, an additional \$10,000 annual fee would be required to continue the use of these 76 sensors. All of these costs can be found in the email conversation in Appendix A. Because this initiative was discontinued, this fee was not included in the comparison found in Table 3. It was discovered that the total cost per parking spot was approximately \$460.53 for the OSU parking system, while the CPSP QR code posts only incurred \$58.20 per spot. This price comparison justifies the cost efficiency of the QR technology found in the CPSP QR tool.

	OSU Parking System	CPSP QR Code Post
Number of spots	76	1
Materials	-	\$58.20
Initial Contract	\$25,000	-
Annual Maintenance	\$10,000	-
USD/Spot	\$460.53	\$58.20

Table 3: OSU Parking Sensors v. CPSP QR Initiative

IV. Results

Final Product – The entire CPSP front-end contains 4 webpages:

1. **Homepage:** This web page is what users will use to identify parking spots. Screen shots of the homepage can be found in Figure 5. Each unoccupied parking spot will display a green pin on Google Maps centered at the parking lot of interest. Users can also use the list box at the top of the homepage to display the numerical count of unoccupied parking spots.

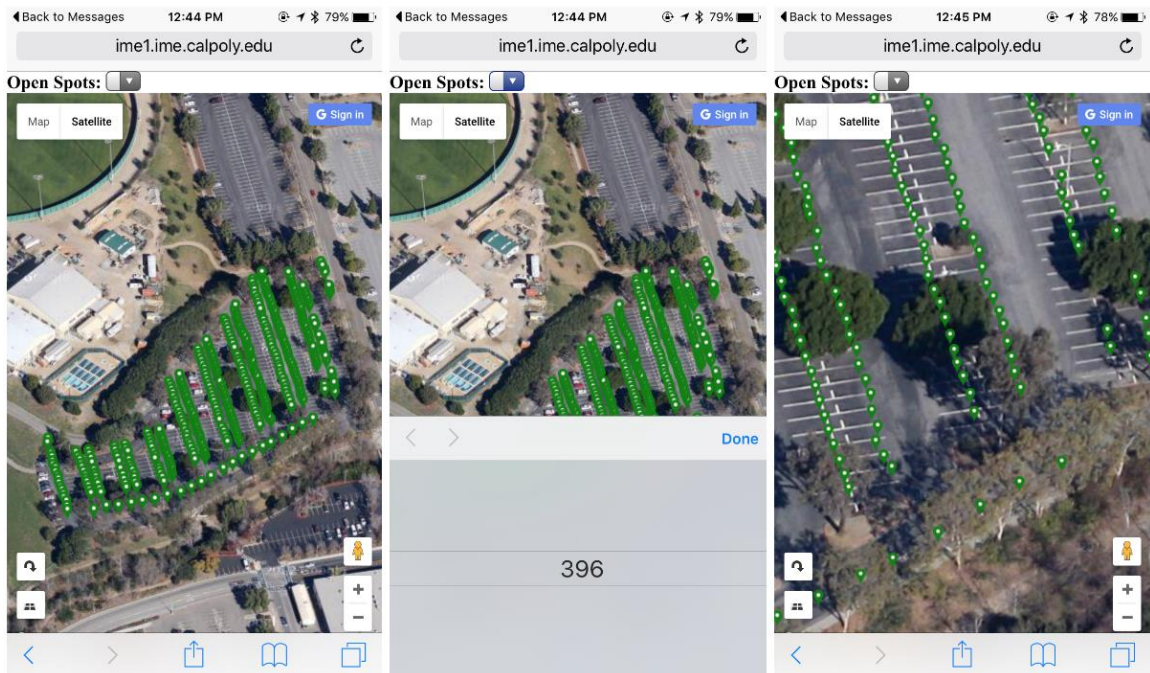


Figure 5: Screenshots of CPSP Homepage

2. **Check-In:** Upon arrival, the user will be directed to a check-in page for their respective parking spot after scanning a QR code. A screenshot and example QR code for the check-in page is found in Figure 6. This page will display spot information (Lot #, Spot #) and contains a confirmation button that will update the availability of the spot on the homepage when clicked.

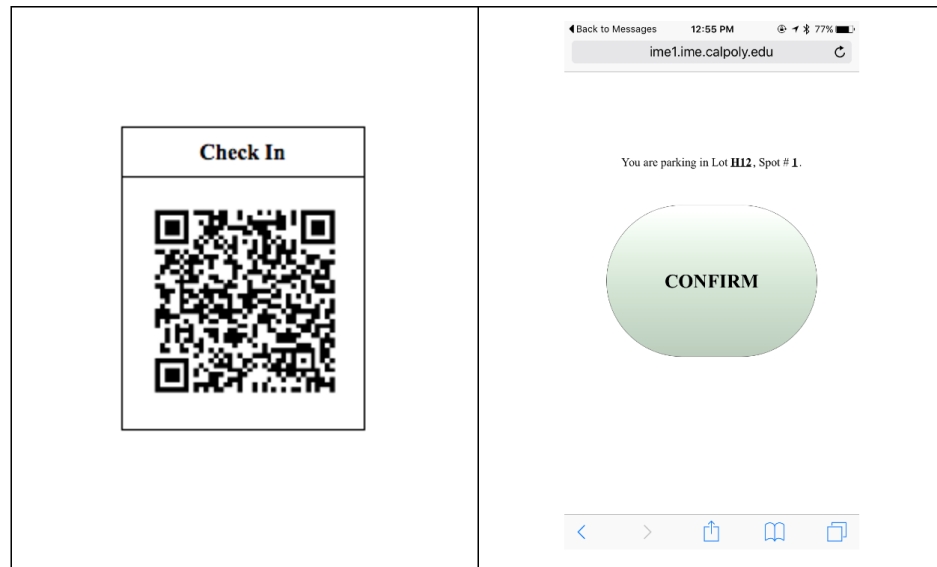


Figure 6: Screenshot & QR Code for Check-In Page

3. **Check-Out:** Upon departure, the user will be directed to a check-out page for their respective parking spot after scanning a QR code. A screenshot and example QR code for the check-out page is found in Figure 7. This page will display spot information (Lot #, Spot #) and contains a confirmation button that will update the availability of the spot on the homepage when clicked.

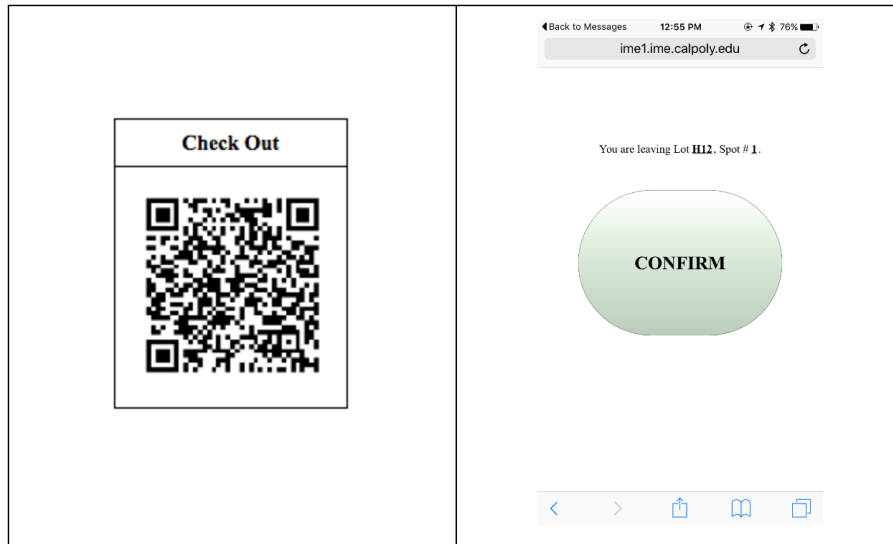


Figure 7: Screenshot & QR Code for Checkout Page

- 4. Thank You:** After a user confirms that they are arriving or departing a parking spot, a confirmation message "Thank You" will appear as seen below in Figure 8.

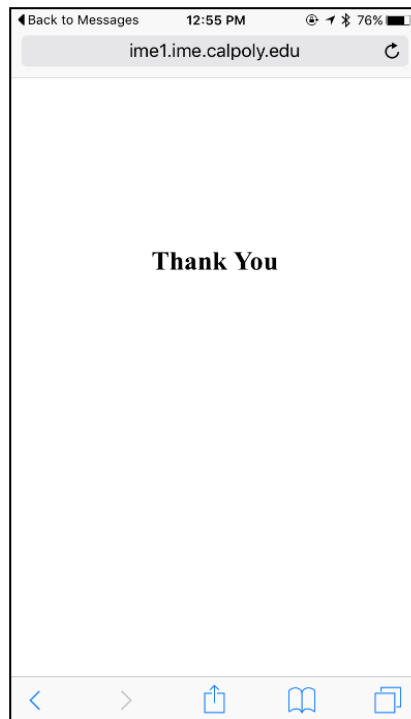


Figure 8: Screenshot of Thank You Page

Survey Results

After completing the CPSP tool, a survey was conducted to estimate time savings for Cal Poly students.

Students were approached with the tool and asked two questions:

1. Do you find the CPSP tool useful?
2. How much time (in minutes) would you estimate this tool would save you when finding parking?

The results of question 1 and 2 are found below in Figure 9 and Figure 10 respectively.

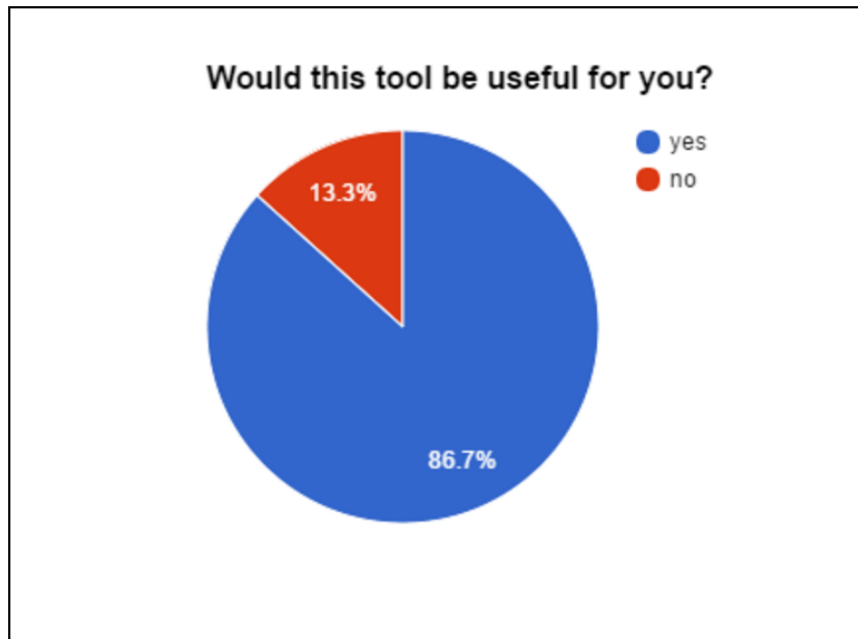


Figure 9: Student Survey Response to Question 1

*Survey performed on May 18, 2016 from 1-4pm

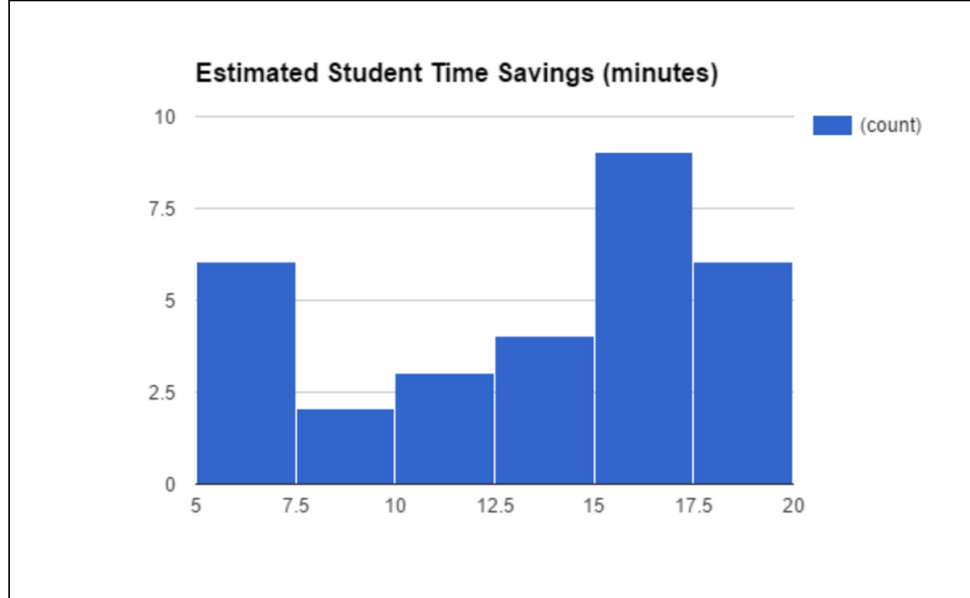


Figure 10: Student Survey Response to Question 2

*Survey performed on May 18, 2016 from 1-4pm

V. Summary and Discussion

Upon completion of the CPSP QR Code Initiative, the following conclusions were developed:

- QR is a cost-effective technology for parking purposes when compared to other smart parking technologies available in the market today. It has major cost advantages over more advanced technologies such as RFID and NFC, which require significant implementation and annual costs to maintain.
- The CPSP tool has the ability to provide live parking results to end users provided that parked users responsibly check-in and check-out of their spots.

- Students find the CPSP tool beneficial especially when searching for a parking spot during Cal Poly peak hours.

Discussion

For many reasons, projects may change throughout the design and development process.

Throughout the development of the CPSP QR Code Initiative, many decisions were made on what features would be added to the web application. Factors like technical feasibility, cost, and time were the most prohibitive constraints.

- Early in the project, the decision was made to utilize QR codes instead of parking sensors due to our project's cost constraints. As seen in Appendix A, the installation of parking sensor technology incurred heavy costs to Oregon State University, who spent approximately \$25,000 on a 50 sensor pilot project which was later cancelled. As the focus of the project was concentrated on cost-efficient technology, parking sensors were therefore eliminated from project relevance.
- Throughout the programming part of our project on Visual Studio, we learned that some visual features on the user interface could not be feasibly designed. For example, our original intention was to display the number of available parking spots using a textbox or label on Visual Studio. With this method, no user interaction would be required to have the numerical count of available parking spots display on Google Maps. However, to our knowledge, the only way to pull the data was through utilization of a listbox. While the listbox displays the same

data as a textbox or label, it requires the user to press it in order to view the information.

- Suggestions were made to add a GPS-based security feature to the web application. The GPS security feature would look up and display the coordinates of the mobile device accessing the webform. The intent of this security layer was to only allow users who were physically within the parking lot to check in or check out of a spot, preventing those with the URL to tamper with the reservation system from a computer or mobile device at home. However, with further analysis and evaluation, the decision was made to discontinue efforts in adding this security feature. The GPS-based security feature would only be beneficial if added alongside a login-based security layer. For example, the GPS security feature would not prevent other individuals, who are physically in the parking lot, to tamper with spots that are not reserved for them. Even with the GPS security feature, any individual could walk up to any random occupied spot, pass the GPS coordinate test, and check the car out.

The unknown stemming from a complex project should not be feared. Just as the unknown had put us at a technical disadvantage, there were beneficial discoveries that were made as our project progressed. For example, we learned how to pass parameters through a URL. Without stumbling across this concept and learning how to execute it, the CPSP system never would have come to a viable full circle. Upon making this discovery,

we were able to develop the CPSP QR-Code Initiative to a new level that is feasible for drivers to use while visiting Cal Poly's campus. .

Future Research

In scope of the entire CPSP project, the CPSP QR-Code Initiative only grazes the surface of what can potentially be a very large scale parking solution. With additional research and development supplemented by future senior projects, the CPSP QR-Code Initiative has the potential to become more practicable and desirable to use. Some possible future additions include:

1. Security Features - One of the largest potential threats to the web current application is the lack of user security. For example, at the web application's current state, users are able to check in and out of parking spots without any security layers like Cal Poly student authentication or a uniquely generated one-time username/password combination. This presents problems as users who are not actually parked into a spot still have the authority to check out cars other than their own. In result, this poses a threat to the overall accuracy of open spots available. In other words, without any security layers, users have the potential of being notified of an open spot when it is actually occupied.
2. Payment Method - The web application has the potential to be linked to a student based financial account or guest account. This eliminates the need for users to get out of their car, walk to a parking ticket kiosk, purchase a ticket, walk back to

their car, and place the ticket on their dashboard. Instead of purchasing parking tickets, users could simply scan the QR codes and pay with a timed based method.

3. UPD Utilization - Combined with payment features, the web application has the potential to provide University Police with an efficient tool to locate cars that have not checked in and are therefore not paying for parking. In result, UPD has the ability to patrol parking lots much more efficiently without the need to check if every single car within a parking lot has a ticket placed on the dashboard.
4. Use of autonomous parking sensor technology - Provided a greater project budget, parking sensors utilizing technologies such as infrared could be utilized to eliminate the need for user input for the parking system to function. Sensors could autonomously update the status of parking spots, rather than drivers scanning QR codes to update spot availability. Installation of these sensors requires a major investment in infrastructure changes and budget.

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APPENDICES

Appendix A: Email Thread with OSU Parking Project Lead

Hi Theresa,

My name is Chris Ragasa and I'm a 4th year Industrial Engineering student at Cal Poly - San Luis Obispo. I'm working with my group mates, Andrew Lee & Kelsey Bazshushtari, on a senior project where we are exploring the possibilities of implementing a SMART parking system here on campus. Upon our research, we stumbled across your article on the Parker app just recently implemented at OSU. Here is the link to the article we found:

<http://www.streetline.com/2013/01/oregon-state-university-installs-parking-sensors-to-show-ada-parking-space-availability-via-mobile-devices/>

We were wondering if we could ask you a few questions about the system:

- 1) How many parking spots are designated to the system?
- 2) How much did the initial setup cost?
- 3) What is the approximate annual maintenance cost?
- 4) Any other additional costs associated with the system?

If it's easier for you to answer these questions over the phone, we would love to set up a call. Thank you for your time and help. We look forward to hearing back from you.

Best Regards,
Chris, Andrew, & Kelsey

Hi Chris, Andrew, & Kelsey,

I was the top lead for the project, the person who managed most of the work no longer works for OSU – but if I can't answer all of your questions I'd be happy to get you in contact with her too.

The snapshot of our project was that we received funding for a two-year pilot to implement smart parking (Streetline). At the end of the two-years we could not convince our university leadership or parking office to support continuing the project through dedicated funding – so we did not renew our contract with Streetline. It was very useful technology for us to have on campus, and we had visions of expanding the project beyond ADA/disabled parking but that never came to fruition mostly based on costs. I've heard from Streetline that the costs have dramatically reduced as technology has improved – so the numbers below may not be accurate for a project today. If you'd like to chat with Streetline, I'd

be happy to share contacts there too.

- 1) We installed parking sensors in 76 ADA spaces on campus – in total we have almost 300 ADA spaces, we focused on core/middle of campus spots as those are the most heavily used and hardest to drive to – through a lot of pedestrian traffic.
- 2) The initial contract was \$25,000 for 50 sensors (though the company graciously provided us 76).
- 3) There was no annual maintenance cost, it was built into the 2 year contract that the vendor would provide maintenance for the length of the contract.
- 4) There were additional costs that can't be calculated – including the time for OSU employees to manage the project/system, create and manage a website with information, and advertise the availability to campus.

I've attached a presentation a few of us gave about the technology at a conference last summer (pages 22-29). One of the reasons for discontinuing the technology was the \$10,000 annual fee to continue using the 76 sensors – maintaining only the current level of service. That is a lot of money for offices that are only budgeted to break even. This is one of the numbers that appears to have changed with technology improvements; Streetline has also told me that they can now install fewer sensors to achieve the same level of services. For instance, we had to install a sensor in every single parking space, they now say that they only need a sensor every few spaces.

Happy to talk through any other questions you may have.

Best,
Gabe

Appendix B: Bill of Materials for QR Post

Part Number	Level	Description	Qty/Parent	Price/Each	Vendor
ASSM_1	0	QR Code Post Assembly	1	\$37.57 (per 60 posts)	NA
PN_1	1	PVC Piping 20 ft.	0.2	\$7.87	Home Depot
PN_2	1	Gorilla Mounting Plate for Asphalt	1	\$35.00	Tapco
PN_3	1	Staples	0.001	\$1.47	Home Depot
PN_4	1	Self-Laminate	NA	\$14.96	Lamination Depot
PN_5	1	White Latex Paint	NA	\$21.96	Home Depot

Appendix C: ASP.NET Code for Check-In Webform

```
Public Class WebForm_CheckIn
    Inherits System.Web.UI.Page

    Protected Sub Page_Load(ByVal sender As Object, ByVal e As System.EventArgs) Handles Me.Load
        lHidden.Visible = False

        Dim ParkLot As String
        Dim ParkID As String

        ParkLot = Request.QueryString("Lot")
        ParkID = Request.QueryString("ID")
        LabelLot.Text = ParkLot
        LabelID.Text = ParkID
    End Sub

    Protected Sub Button1_Click(sender As Object, e As EventArgs) Handles Button1.Click
        Dim conn As New OleDb.OleDbConnection
        conn.ConnectionString = SqlDataSource1.ConnectionString
        conn.Open()
        Dim cmd As New OleDb.OleDbCommand
        Dim value As String
        value = lHidden.Text
        cmd.CommandText = "UPDATE LOTA SET [AVAILABILITY]='" & lHidden.Text & "' WHERE [SPACE]='" & LabelID.Text & "';"
        cmd.Connection = conn
        cmd.ExecuteNonQuery()
        conn.Close()
        Response.Redirect("~/WebForm_ThankYou.aspx?")
    End Sub
End Class
```

Appendix D: ASP.NET Code for Check-Out Webform

```
Public Class WebForm_CheckOut
    Inherits System.Web.UI.Page





    Protected Sub Page_Load(ByVal sender As Object, ByVal e As System.EventArgs) Handles Me.Load
        lHidden.Visible = False

        Dim ParkLot As String
        Dim ParkID As String

        ParkLot = Request.QueryString("Lot")
        ParkID = Request.QueryString("ID")
        LabelLot.Text = ParkLot
        LabelID.Text = ParkID
    End Sub

    Protected Sub Button1_Click(sender As Object, e As EventArgs) Handles Button1.Click
        Dim conn As New OleDb.OleDbConnection
        conn.ConnectionString = SqlDataSource1.ConnectionString
        conn.Open()
        Dim cmd As New OleDb.OleDbCommand
        Dim value As String
        value = lHidden.Text
        cmd.CommandText = "UPDATE LOTA SET [AVAILABILITY]='" & lHidden.Text & "' WHERE [SPACE]='" & LabelID.Text & "';"
        cmd.Connection = conn
        cmd.ExecuteNonQuery()
        conn.Close()
        Response.Redirect("~/WebForm_ThankYou.aspx?")
    End Sub
End Class
```

Appendix E: Sample Check-In/Out QR Codes for Spots 1-3

Parking Lot	Spot Number	QR - Arrival	QR - Departure
H12	1		
H12	2		
H12	3	