POLYPARKING

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Abstract

The purpose of this senior project is to analyze the various options for the implementation of a parking lot information system on the California Polytechnic State University, San Luis Obispo campus. This system would involve three main components: physical counting hardware, a database and analysis organization system, and a user interface for disseminating the gathered information. The project investigates and provides commentary on various available and commonplace systems, and the benefits and drawbacks of these systems.

During the course of the project, a flexible database and user-interface was developed in Microsoft Access, which will allow counter output to be gathered and displayed on a parking map for the campus. This map dynamically updates, and color codes the lots based on space availability. Also provided in the project is the recommendation for Cal Poly to implement ultrasonic and magnetometer sensing technology to count cars entering and exiting parking lots. In order to distribute the gathered information, a set of internet-based interfaces is recommended, and more investigation into display boards suggested.

Table of Contents

List of Tables and Figures

1. Introduction

Finding a parking spot on Cal Poly's campus can often be a very irritating task. Having to hunt through a parking lot in hopes of finding that one elusive spot only to find that the lot is already full can be even more so. This time spent in search of a spot is not only an inconvenience for a person in terms of time, gas consumption, and patience, but it also takes its toll on the environment when people loop around parking lots multiple times before moving on to another lot. This can create a high stress environment for those who are looking for a spot, which can escalate quite quickly, causing accidents and possible lawsuits. This situation becomes even more hectic during large events, where a parking spot is an even more valuable commodity. Cal Poly, along with many other businesses and institutions suffer from this issue, and creating an economic solution for Cal Poly is the focus of our project.

In order to propose a solution for this problem, this need had to be more closely examined. As is shown below in our literary review, this need is a problem that many large institutions have faced and ultimately been forced to address as their popularity and the availability of cars increases. With parking demand and student enrollment increasing at Cal Poly, a more effective way to organize parking and meet the demand is needed.

1.1 Scope

After finding and identifying the project, a scope was selected. In order to better focus our project on a solution to the identified need, we decided that our project would examine existing parking management and information systems, and we would recommend an appropriate fit for Cal Poly's needs. In order to better understand these needs, we selected and polled the two main stakeholders in the project: Cal Poly students, and the staff responsible for parking planning in Cal Poly Corporation's Administrative and Finance Division (AFD). Through these two sources, we were able to proceed with our project as shown below.

1.2 Deliverables

Upon completion of this project we hope to provide Cal Poly AFD with the following:

A proposal for the implementation of a parking information system including:

- A graphical interface provided to students to view current parking lot utilization
- A databasing system for organizing and forecasting parking demand by lot
- An analysis of hardware options to supply the necessary information to the database
- A cost analysis for the suggested implementation
- The results of a student survey gauging interest in a parking lot information system

1.3 Relevant Coursework

In the completion of this project, material learned in many Cal Poly courses was utilized, including:

ENGL 149: Tech Writing for Engineers

Proper technical writing and report preparation.

CE 114: Intro to CAD in Civ & Env Engr

Use of Auto CAD in creating construction plans and documents.

IME 239: Industrial Costs and Controls

Analysis of projects and their costs and benefits. Concept of payback period and financial analysis.

IME 312: Data Management and System Design

Database design and implementation in Microsoft Access, including forms and queries.

STAT 312: Statistical Methods for Engineers

Use of proper data gathering and analysis techniques.

IME 314: Engineering Economics

The time value of money, and further analysis on the project's fiscal worth.

IME 322: Leadership and Project Management

Project timeline and implementation scheduling.

IME 405: Operations Research II

AHP analysis and criteria weighting. Survey design and aspects of human behavior.

IME 410: Production Planning/Control Systems

Use of proper forecasting method and techniques.

IME 570/571: Selected Advanced Topics: Advanced RFID and Electronic Manufacturing

Introduction to RFID tags and systems and their implementations. Limitations of RFID systems.

2. Literary Review

The analysis begins by reviewing literature on a variety of topics relevant to this topic. The impacted parking situation and the need for more efficient parking operations is listed in Cal Poly's Master Plan as a key area of needed improvement, which states "Parking demand typically peaks during Winter Quarter, mid-week in the middle part of the day. At these times, occupancy reaches 95% or higher. This level is considered full occupancy and, therefore, lots in the core area are fully utilized during peak daytime periods." Based on this the plan recommends more efficient and effective parking strategies, including re-designation of existing spots based on usage and construction of new parking structures to replace some lots. With this in mind, the project proposal should aim to maximize the efficiency of lot usage, and to plan and be scalable for future improvements on the horizon for Cal Poly.

In reviewing other projects completed at Cal Poly regarding parking, some very useful data was collected. The first, a report titled "A MICROSIMULATION OF TRAFFIC, PARKING, AND EMISSIONS AT CALIFORNIA POLYTECHNIC STATE UNIVERSITY- SAN LUIS OBISPO" provides a comprehensive look at the traffic flows and their physical and environmental effects during the peak hours of the day. While this report does not directly study the effects of parking availability, it reinforces the need for a more organized approach to parking on campus, as the simulation demonstrates a large backlog of vehicles while looking for a parking spot during these times. The paper goes on to explore the emissions created during these peak traffic times, and proposes a conservative estimate for pollution at 40% of the total greenhouse gasses created by the university. As stated in the university's "2010 Sustainability Report" greenhouse gas production is a key metric in improving the campus's sustainability.

The benefits of a transition to a "smart parking" system are also highlighted in a December 2012 press release titled "San Mateo Launches Smart Parking Technology". This article discusses the implementation of a parking system installed in the city of San Mateo, California that uses sensors and a free mobile app to provide real time information to parkers about spot availability, parking rates, hours of enforcement, and guide them to areas with open spots. The article also cites a study on parking done in major cities which found "In Paris for example, the average motorist spends 4 years of their life just trying to find a parking space." The implementation is highlighted as having

many other benefits as well, including reducing emissions, traffic, and driver frustrations in the downtown area. Also cited in the article is a year-long UCLA study that found "…drivers in a 15 block district in Los Angeles drove in excess of 950,000 miles, produced 730 tons of carbon dioxide and used 47,000 gallons of gas searching for parking."

3. Project Design

With these goals in mind, our review turns toward existing technologies that can address our requirements. In selecting hardware solutions to meet the project's needs, several articles were reviewed, including "Intelligent Parking Lot Application Using Wireless Sensor Networks". This publication detailed a 2008 study completed at USC and focused on selecting the most appropriate types of sensors and algorithms to count cars exiting and entering a parking lot or structure. Of the sensors tested (acoustic, visual light, infrared, temperature, magnetometer, and ultrasonic) they found the magnetometer and ultrasonic sensors (or a combination of the two) the most accurate, and the easiest to acquire accurate data from. In addition to their sensor analysis, a key part of the counting algorithm that we will be recommending below was introduced.

Figure 3.1: Ultrasonic Sensor (left) and Sensor Bundle (right)

In addition to these sensing methods, we also examined two other techniques. The first, Radio Frequency Identification (RFID) is a very powerful and attractive option, but also has some severe hurdles to implementation. An RFID system would require all vehicles to be tagged with passive RFID tags, which would be read by tag readers installed at the entrances and exits of parking lots. This system would allow vehicles to be uniquely identified and tracked in on-campus lots, and spaces to be counted by spot designation. This would also open the doors for the process of automating ticketing, automatic meter payments, and pay-per-use parking. Because of the dynamic environment of the campus, and the relatively high cost of these passive tags, the likelihood that this system could be economically implemented in the short term is almost non-existent.

The other option that we examined was the implementation of induction loop sensors. These sensors are installed at the lot entrances and exits beneath the pavement in the form of a wire coil. (see Fig. 3.2) This coil is fed energy by a sensing circuit, which measures the inductance present in the coils. When a large metal object (a vehicle) passes over the top of the coil, its presence changes the inductance of the coils. The sensing circuit detects this change in inductance, and emits an output that signifies the presence of a vehicle. This type of system is in widespread use for detecting waiting vehicles at traffic lights and automatic gates.

Figure 3.2: Induction Loop Sensor

After the information is gathered by the counters, it is routed to a database which records, processes, analyzes, and serves all of the records generated by all of the counting hardware. While some of the commercially available solutions provide their own database and software management programs, we decided to design our own for two main reasons. The first reason is that we wanted our application to be custom and unique to the campus, and be easily adapted to the dynamically changing parking system. The second reason is that we wanted to be able to easily support a variety of sensor types, so that we would be able to pick the best sensor for our application, regardless of sensor output type. In order to accomplish this, we designed the database to accept incremental counting inputs. Therefore, upon a sensor output (ie: a car leaving or entering the lot), the database

will be able to calculate the effect on the number of available spaces in the lot.

In order to distribute the information gathered in the database, a user interface is needed. While evaluating existing options to accomplish this, we had to take into account our audience. To do this, we developed an idea of the average user of the system. The average user we identified was college-aged and comfortable with technology. He/she owns and uses a smartphone, and frequents the internet. Additionally, he/she needs to have access to this data from multiple locations, and when they are late for class. From this, we can select the hardware and software we want to provide. The options include:

- a web-application
- a mobile app
- a text message service
- physical display boards

All of these options are available in other parking systems we looked at, and we determined that they would be the most appropriate fit for our average user.

In order to weigh these alternatives, the performance of the systems must be measured against criteria gathered from the system's users. Input from the two main user groups ("parkers" and parking staff) was gathered in two distinct ways. "Parkers" are defined as anyone who enters the system to park (students, staff, visitors...etc.). To gauge usefulness and criteria required from these users, a survey was designed to evaluate the possible system choices (see Survey below). To generate the criteria for the other user group, the parking staff, an interview was held with Gwen Neilsen. She was able to provide insight into the desired characteristics for a system from an administrative position (see Interview below). She was also able to provide us with specifications and historical data to base our design off of.

By reviewing the data provided to us about the parking lot capacities, we were able to narrow the focus of our project to a subset of the many parking lots on campus. Because our project intends to provide information to visitors and students who commute to campus daily, we decided to focus on parking lots that are entirely or almost entirely made up of General parking spots. These spots are open to any person with a General parking pass, including: commuter students with a

quarterly or annual pass, students with a weekly or daily pass, and any community members with a weekly or daily pass. We selected six of the major parking lots that met this requirement: H2, H12, H14, H16, G1, and GS. These six lots represent 2,506 of the 3,030 General spots on campus. We feel that this adequately represents the majority (83%) of the spots, and is an economical approach for the proposed implementation plan. We do, however, understand that a system would ideally be expandable to the other lots on campus, and that this expandability would also enable the system to easily adapt to parking changes and new structures such as those discussed in Cal Poly's Master Plan. Because of this, we aim to select a system that can easily and cost efficiently be scaled as the university deems necessary.

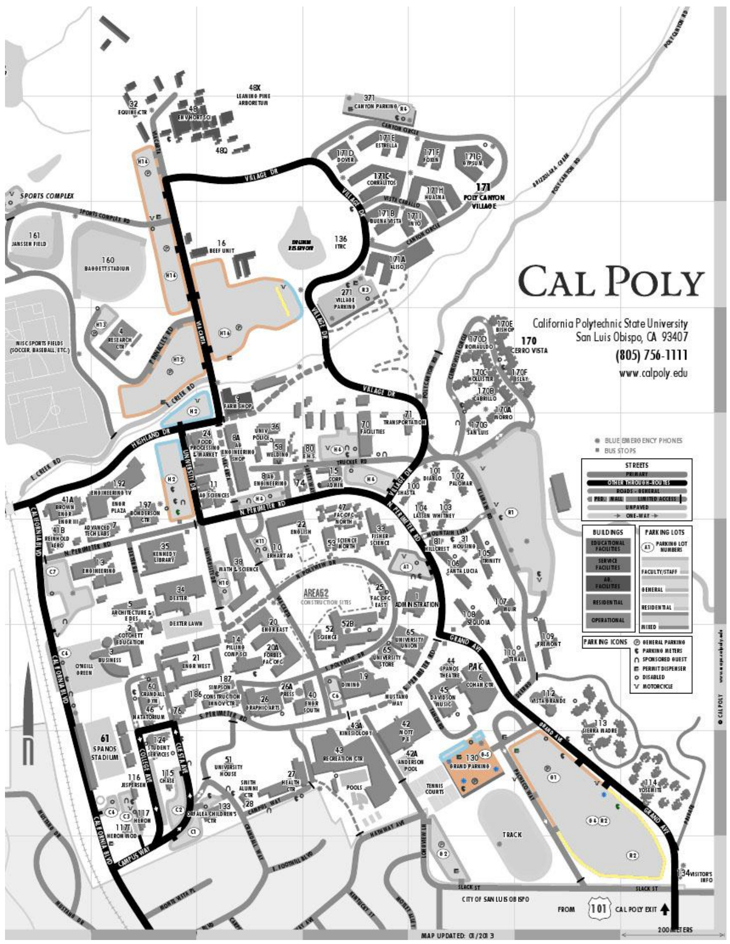

Figure 3.3: Selected Parking Lots

3.1 Survey

To ensure that our survey was successful and yielded meaningful data, we took great care in selecting the questions and possible responses. In order to effectively distribute and record the results of our survey, we chose to utilize a popular website to host our survey, www.surveymonkey.com. We chose to incorporate ten questions in our survey, so that it was short and meaningful. The first two questions allowed us to verify our target audience. The next eight questions helped us gather data on parking lot use, perceptions about parking on campus, and criteria that a user would want in a smart parking system.

In selecting our questions, we were very careful to follow certain principles of good survey design. This was important so that we could get meaningful and accurate data out of our respondents. We made sure that before we provided the web link for taking the survey, we explained the purpose of the survey so that the respondents would understand why their answers were important to us. We also made sure to keep our survey and the questions short, simple, and relevant. In addition to this, wrote all of our questions so that they were unbiased and fair, and that the order of answers was randomized on each survey, to ensure no bias toward certain responses. At the end of the survey, we made sure to display thanks to the respondent, and let them know that we valued their opinion.

After the survey was distributed (via email, handouts, and flyers) we analyzed the collected data. Using the qualifying questions, we found that the respondents matched our intended user group. We also found that of the 100 responses to Question 5 “How easy is it to find a spot in the following lots?”, only 31 of the responses were “Easy”. This shows that a majority of users experience some difficulty when looking for a spot in the six parking lots we chose for our project. Using the responses to Question 7 “How much time, on average, do you spend looking for a parking spot after you have arrived in the lot”, we calculated that the average driver spends 3.3 minutes looking for a spot after they arrive in their chosen lot. When asked which options they would utilize in order to check parking availability, 95% of respondents chose “Mobile App”, followed by “Display Board/Sign” with 77%, and “Webpage” and “Text Message” tied with 55%. Question 9 “Please rank the importance of the following criteria in a parking lot information system” provided us with data about the specific needs of the end user in a parking lot information system. While the responses

were mixed, the two most important criteria the respondents selected were “Cost to You” and “Easy Access to Data”. From these responses, it was obvious that the system selected needed to minimize the cost to the user, and provide multiple options to check parking availability. For full survey results, see Appendix A.

3.2 Interview

In order to better understand the current parking lot data management system and analysis, we held an interview with Gwen Nielsen, an administrator and analyst for the University Police Parking Services Department at Cal Poly. She was able to answer several questions, as well as provide insight to what kind of data/analysis would be useful as output to Parking Services. She gave us an overview of their current system, including how/when they surveyed lot usage, how that data was stored, as well as gave us their existing lot survey and lot count tables they used during their quarterly lot counts.

Currently, Parking Services takes a physical count of the empty spaces in lots across campus. This takes place twice a day on weekdays during the first two weeks of every quarter. They do this count at this time as it is often when the lots on campus are most utilized during the quarter. This data is then entered into Microsoft Excel for reference in event planning, manual forecasting calculations, as well as being used in the revision and creation of parking lot policy.

All of this data was extremely helpful in determining the format our database tables, making them as accurate, useful, and user friendly as possible. We were also able to use Gwen’s input in designing our analysis and forecasting modules. Additionally, her input served as a basis for the functionality necessary in our hardware selections.

4. Project Implementation

4.1 Database

4.1.1 Design Overview

This database is designed to take the raw output of a physical counting module and interpret that data, analyze it, and output it into a usable and aesthetically pleasing format.

Upon opening the database, the user is greeted by a “welcome” splash screen where they are able to access the two sections of the database either as a student or an administrator. Users will be able to click one button and be immediately brought to an overhead map view of the major parking lots, where they are graphically shown the % free space within each lot in the form of a colored overlay, as well as the actual number of spots available in each lot. This data will be constantly updated in discrete intervals (and can also be updated via an update button) in order to provide the most accurate and useful data possible, as students will most likely be accessing this database most when they are running late.

Administrators are also greeted by this same welcome screen, and are able to access the administrative side of the database after entering validated log-in information via a popup log-in form. This data will be linked with Cal Poly’s existing administrator database, and will only allow access to those qualified to edit the database information and design. This will help prevent unauthorized changes from being made, strengthening database integrity. After entering valid log-in credentials, administrators are brought to an administrator home page from which they can access 3 modules; a lot survey module, a real-time data and graphical display module, and a forecasting module.(For database code samples, see Appendix C)

4.1.2 Lot Survey Module

The lot survey module consists of two tables. The first is a survey of every parking lot on Cal Poly campus as well as those in the crops, poultry, dairy units, etc. This table displays the maximum capacity of each lot, broken down into each space designation such as general, staff, handicapped, etc. This data can be freely edited, and will be used for administrator reference only, as no analysis or output is directly linked to this table. The second table in the survey module is a breakdown of the lot capacity by desired space designations that will be used in the available space calculations and analysis. This data can also be freely edited, but subsequent analysis is performed based on the "total usable spaces" field in this table. Administrators can feel free to add lot designation fields they deem as "usable" to the users of this database, however the "total usable spaces" field data will be the only data that will have an impact on the analysis if changed. Any changes made will be immediately updated upon opening any of the other modules.

4.1.3 The Lot Status Module

The lot status module is the same output viewable by students, with added debug features and additional analysis. In this version, administrators are able to see and edit the information viewable by the students, as well as test and change the images loaded into the database for the graphical output. Real-time capacity percentage is also displayed alongside the actual current spaces available.

4.1.4 The Lot Forecast Module

The lot forecast module is a tool that uses historical lot usage data to predict how many spaces will be available at a specified date and time in the future. The administrator is asked to select the lot, date, and time of day that they wish to forecast the available spaces for, and through the process of a three period moving average, along with calculating the average spaces available during that hour on the historical dates, the number of spaces available is calculated with reasonable accuracy and displayed to the administrator. These forecasts are also stored in a table viewable within this module for reference, and can be cleared from the database through a button in the module.

4.2 Design Analysis

The theoretical module output data we have decided to create for the use in designing this database is quite basic. It consists only of the record number, lot ID, date, time, change in lot capacity, and current running total of spaces available, governed by the predetermined number of usable spaces available. This output will vary from module to module, however our database is easily adaptable to varying formats of output, and will be able to adjust as necessary with little or no modification to the design.

4.2.1 Use of Database

Our database has been designed with two main groups in mind; Students, Faculty, and Staff, and the Administrators who will be using our database. With these groups in mind, we designed our database such that it would not only be functional and provide necessary data to these groups, but also to provide it in a way that is most appropriate for how this database will be used. (For database User Guide, see Appendix B)

For students, faculty, and staff, we have designed this database to be as streamlined as possible. The first step in achieving this was to allow anyone to view the current lot status without needing to log in. This feature will most likely be used by individuals who are about to head to class or work, and might be running late, and therefore would need to access this information as quickly as possible. Allowing them to access the information they need with the click of one button will save them seconds in a potentially hectic situation, which in the end will save them even more time when do not need to circle a parking lot looking for a spot that may not be available. Moving along to the lot status page, all necessary data is displayed in an easy to read format with no extraneous data or obstructions. This also helps the user to quickly access this information they need, furthering the ease of use of this database. These key features of this side of our database make using our database a simple and quick task.

For administrators our main goal was to make the database as functional as possible, while still maintaining a streamlined and clutter-free design. However in order to allow only authorized users to be able to access administrative side of the database, some form of ID verification must be in

place. To do this, we designed a login form that will pop up if someone desires to access this side of the database, which will verify the username and password they enter with a table of authorized users. This ensures that only qualified users will be able to access and edit the data behind the analysis our database provides, improving database security.

After logging in, the administrators are brought to a minimalistic home page with a standardized header which includes the title of the page, a navigation menu, and a log-out button. This header is common across every module the administrators are able to access, making it easy to locate features and navigate between modules with ease.

The features we decided to include in the administrative side of our database came from our interview with Gwen Nielsen (see Section 3.2 for details). First and foremost, our database will eliminate the need for parking officials to do manual lot counts, as it will receive the direct output of a parking lot counter as its input. This will save several hours of useful time each month for other purposes, and while doing so, it will provide much more accurate data than is currently possible with their current system. This data will not only be useful to keep a more accurate record of how lots are used, but it will also be used in the forecasting module we included in this side of our database. This module allows for accurate forecasting of how full lots will be at any given hour of the day, up to a week in the future. This feature will be extremely helpful to parking services in event planning and lot reservation. We have also included a module for keeping track of and updating the current lot survey. This will allow easy access to the current lot survey, which details every lot Cal Poly uses, and breaks down each lot into spaces by designation. This table will also allow administrators to add additional lots and/or designations to the survey in one easy to find and access location simplifying the more complicated existing process of finding and revising lot surveys.

4.3 Hardware Analysis

4.3.1 Counting Hardware

Using the results of both our survey and our interview, we can develop rankings among the criteria, and evaluate each of the systems against each other. We also have to take into account the

other criteria we identified during the scope and project design assessments.

Of the three hardware options, each has distinct advantages and disadvantages. The first, a combination of ultrasonic sensors and magnetometers, is shown to be very accurate in all types of conditions. When paired with a detection algorithm (as discussed below), this combination would likely be the most accurate and most reliable of the three options. This option is also very cost efficient, with the sensor and transmitter combination that would be needed at each lot entrance or exit totaling just under $200. No major construction would be necessary in order to install these sensors, but they would require some sort of support structure.

Our second hardware option, RFID, is a much more powerful system, with many more possible functions, however these come at quite a cost. With a properly specified and designed system, the accuracy and reliability of this system would approach that of the ultrasonic sensors and magnetometers. This system would also be able to track anything from vehicle spot designation (ie: Staff/General/Residential/etc.) all the way down to identifying the specific vehicle. This would allow for much more specific statistics to be generated for each lot, and would allow for pay-per-use and other complex parking and ticketing strategies. While this could potentially lead to a much more efficient and profitable parking service, it would introduce several large complexities into the system. The first complexity would be the need for every vehicle entering the system to be tagged. The price and difficulty of acquiring tags has come down significantly in the past few years, but is still a major hurdle. A car counting system would likely require long range passive UHF tags, which can cost anywhere between 50 cents and 2 dollars per tag. This would not be as much of a problem for students with long term permits, as they could be issued one of these tags for the duration of their time at Cal Poly, (replacing their current parking placard or embedded in it) and it could be uniquely tied to a database record indicating if they had paid for parking or not. The cost for this would be recouped by the reduction in issuing a permit every time they purchased a new one. This becomes more of a problem when you consider the multitude of visitors and day-use permits that would need to be accounted for. While permits purchased at a parking kiosk or dispenser could also be printed on an RFID tag, it becomes much more of a cost to absorb per permit if they are single day or even weekly use. Assuming a median cost of $1.25 per passive tag, and a current daily parking cost of $5.00, this equates to a loss of 25% of the revenue generated on daily parking permits. In addition to the complexities of implementing a vehicle tagging system, the RFID reader

hardware required at lot entrances and exits is much more expensive. While a good reader can support multiple antenna inputs, and therefore support multiple entrance or exit lanes (from two to four per reader), the total hardware cost per reader can range from 1,200 to 2,400 dollars. Like the previous option, this system would require little in the way of major construction for implementation, and would just require a support structure for the antennas.

The third hardware option, induction loop sensors, is a much more traditional car-sensing method. This method has been used for decades to provide input for traffic control systems and automatic gates. By installing multiple loops at each entrance or exit, the sensors can be used to detect vehicle direction. As with the first hardware option, the sensor output will be run through a counting algorithm (as shown below) to process each vehicle and ensure an accurate count. The cost associated with this hardware method falls in between the other two options, with the total hardware cost per entrance/exit ranging from 500 to 800 dollars. Along with the direct hardware cost, this option also requires a more complex installation, with the need for closing the lanes and trenching the loop shapes into the pavement to be fitted with the wiring and sealed over. The cost of installation is estimated at 850 dollars per loop.

During our review of existing counting systems, we discovered that many different techniques were used to convert raw sensor input into useable data. We decided that a modified version of one of the algorithms we came across in the “Intelligent Parking Lot Application Using Wireless Sensor Networks” study would allow us to achieve the most valid output. Our proposed technique would be as follows:

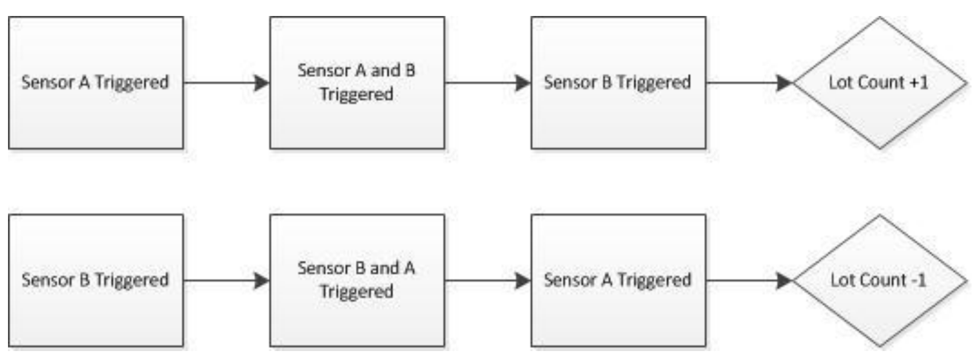

Figure 4.1: Counting Method Flowchart

By using this method, with the sensors properly calibrated, only a vehicle traveling in the correct direction and activating all three states in the correct order will be able to be counted. This will help prevent false counts, and will ensure higher system accuracy. By adjusting the overlapping sensor coverage as well, the system can be set up to only count sensed objects of appropriate size, and not accidentally trigger counter output on pedestrians and bicyclists. This counting technique can be applied to all three sensor systems, and should greatly reduce the likelihood of false triggers.

4.3.2 User Interface Hardware

In addition to the hardware used to gather the data, we also investigated several methods of providing the data to the end users. These included: variable message signboards, mobile applications, web-based applications, and an on-demand text messaging system. Based on the results of our survey, the average student user would be most interested in a mobile app. All four of these methods are currently in use by many of the systems in place at other institutions.

The most popular option among the reports we reviewed was the physical signboard. These installations varied greatly by application, but most included a large matrix display at the entrance to the facility indicating the status of all of the lots, and separate status displays at each lot to indicate current capacity. This is also the option that requires the most cost and has the most complex implementation. Equipment costs for this type of display range from 400 to 600 dollars per programmable display panel (800 to 1,200 dollars per equipped lot). Each panel would be capable of displaying the number of spots available in its assigned lot. For implementation of each signboard, some supporting hardware would also be necessary. This would consist of a microcontroller, a wireless modem, a power supply or power source, and a support structure. The cost of obtaining and installing these item can conservatively be estimated at another 1,000 dollars, but varies quite substantially depending on location, availability of power, etc.

The next two options (the web-based application and the mobile app), are also very popular, and could be much more efficiently implemented, due to the lack of necessary physical hardware. As shown by our database implementation, a series of forms and queries can be designed to access the parking data, provided the database was hosted on an internet accessible server. Hosting costs would be trivial, especially if integrated into Cal Poly's existing web presence. The web-based

application design would also be easily implemented by converting the existing forms in our database to a browser-friendly format. A mobile app would need to be developed by someone versed in the platform (likely iOS or Android, as this would serve the majority of mobile users at Cal Poly). In order to approximate the cost for this, a mobile app developer was contacted to provide an approximate quote for the development of both of these apps. The quoted cost was 4,000 dollars per platform. Another possibility is that this functionality could be added into the existing Cal Poly mobile app, allowing the cost to be significantly reduced.

The final option we investigated was an on-demand text message system. This system, provided by a third party, would allow a user to text a preset mobile number with the parking lot they were interested in. This system would then interface with the parking database hosted at Cal Poly, and request current parking data. The system would then reply with the current status of that lot, and allow the user to inquire about other lots as well. This system’s cost is dependant on messaging volume, but based on 500 requests a day, TXTImpact, a mobile marketing company, provided us with a quote for a monthly price of 450 dollars.

4.4 Comparison Tables

	Ultrasonic and Magnetometer Sensors	RFID	Induction Loop Sensors
Hardware Cost per Lane	$200	$600	$800
Implementation Costs	- Basic Support Structure	-Basic Support Structure	-Trenching -Lot closures for installation
Other Associated Costs	-	-$1.25 per tag -Retrofit of existing dispensers	-

Table 4.1: Counting Options

	Signboard	Web-based Application	Mobile App	Text Messaging
Cost	$800-$1200/ Lot	Trivial	$4000/ Platform	$450/ Month
Other Associated Costs	-Additional hardware costs (variable)	-	-	-

Table 4.2: Interface Options

5. Conclusion

Because of the high cost and complexity of implementation, the RFID counting option must be excluded. While this system would allow a much greater functionality, the current high cost of components cannot justify its implementation. This project does however recommend this type of system be re-evaluated in the future, as it would provide many more options than a basic counting system.

Of the remaining two counting hardware systems, there is a clear advantage to the reduced cost and less difficult implementation of the ultrasonic and magnetometer combination. Additionally, this system will be more flexible, and allows for changes and expansion as is necessary in Cal Poly's dynamically changing environment.

On the user interface side, the need for several options makes the web application and mobile app combination a good solution. Because the database and forms have already been designed, the cost of deploying the systems is greatly reduced. Both applications require the hosting of the database, and providing both options means the data is more easily accessible for most users. In addition, if the text-message system was desired, it would be a simple integration with the already hosted database, requiring just the monthly access fee. While the signboards are also a good option, and make the system much more visible to the everyday user, this project recommends that more investigation into their impact and implementation costs is done before moving forward with them.

In selecting the best option to recommend for implementation, all of the above input was considered. Because of the accuracy and cost effectiveness, it is recommended that Cal Poly implement the following parking lot management system: a system composed of ultrasonic and magnetometer sensors, coupled with the suggested counting method, and export the data to the database that has been designed. This database will be hosted on Cal Poly's servers, and the provided data analysis tools will be made available on Cal Poly's website. In addition to the web application, a mobile app should be developed for distribution on multiple mobile operating systems, allowing users to get real-time parking information on their smartphones.

The database provided (in conjunction with a lot counting system) will vastly improve the knowledge Parking Services has regarding parking lot usage, as well as provide real-time, easy to access data on current lot usage to thousands of potential users. It will streamline some of the major tasks that parking services must accomplish on a regular basis, including lot counts, surveys, and lot usage forecasting. It will also give parking services more decision making power by providing them with much more accurate and detailed information on how lots are used. All of these accomplishments will create a more efficient and effective parking experience at Cal Poly, and contribute to an improved parking environment.

6. Pilot Study

In order to test our suggested implementation, we would propose a pilot study be conducted in order to measure the potential results of our project. By following the recommendations above, Cal Poly could implement a test case in one selected parking lot, and the effect could be compared to previously gathered data for that lot. We would suggest that the Grand Avenue Parking Structure (G-S) be chosen for our pilot study for several reasons. Firstly, this lot has both general and staff spaces, because of this, the lot has steady traffic throughout the day, occurring in both scheduled waves and randomly. Secondly, the structure has only one entrance/exit area, simplifying the implementation of our sensing hardware, and the programming needed to maintain an accurate count of cars in the lot. Thirdly, the structure has existing signs and overheard arches, adding to the ease of mounting our sensing hardware.

In order to implement the pilot study, the following costs would be incurred:

-$800 for sensing hardware ($200/lane * 4 lanes)

-$200 for installation hardware and power and data cabling

-$75 for embedded Linux board with power supply and WiFi adapter for data collection and transmission (Raspberry Pi)

-$800 for installation labor and training (80 hours at $10/hour)

This would allow the data to be collected by the sensors and passed to the Raspberry Pi, which in turn would wirelessly transmit the data onto the Cal Poly WiFi network. For the purposes of the pilot study, we will assume our database will be hosted at no cost on one of Cal Poly's servers. By using the database and code provided, the pilot's cost can be limited to this $1875. This will allow Cal Poly to test our implementation with almost no risk to them. We would suggest that the hardware and software for the pilot system be installed at the end of a summer break, to minimize impact to daily traffic flow. We estimate that the time required for hardware installation and calibration is approximately one week, with an additional week for software interfacing and end user training. Because of the high cost of implementation of other hardware and software options, we would recommend that the data for the pilot project be shared in a web interface, as demonstrated in our project. This would allow the core functionality to be tested, at a reduced risk to Cal Poly. If the test proved successful, we would then recommend further investigation into the cost effectiveness of the other suggested options for data distribution.

After the installation is complete, the results and success of the project could be measured by parking services staff in the following method.

The main key performance indicator of the physical system would include a near real-time spreadsheet of every time a car enters or leaves the lot, including a timestamp and a running total of how many spots are available at that time. This data should then be compared to current lot counts carried out by Parking Services to confirm its accuracy. This may prove difficult as this database will include many more records than are currently collected, however this test will provide enough evidence that our system is accurate and that the data is powerful enough for a second pilot study or a full scale implementation of the Poly Parking system.

To test the usefulness of the user interface side of this database, a test group of 20 to 30 willing candidates who park regularly on campus should be provided with access to the public side of the database. These candidates will be able to access the current lot status from a remote location through an internet connection to the server within the Cal Poly network. They will also be asked for feedback on their experience using the interface through a web based survey after every few uses. This intermittent feedback request will allow the user to have practical use of the interface without being hassled by a survey after every use and becoming frustrated, increasing the likelihood that their feedback will be more useful than if they just responded to get the survey out of the way. This data would then be interpreted by Parking Services and a decision on its usefulness will be made. The result of this decision will determine whether the system is effective enough to warrant a public implementation of the interface, or if the test is not powerful enough and a second (if any) larger scale test must be carried out to determine the interface's effectiveness. Any changes to the interface or database should be done by appropriate authorities within Parking Services.

7. Works Referenced

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Kilbert, Steven Michael. “A MICROSIMULATION OF TRAFFIC, PARKING, AND EMISSIONS AT CALIFORNIA POLYTECHNIC STATE UNIVERSITY- SAN LUIS OBISPO” (2011). Master’s Thesis. California Polytechnic State University, San Luis Obispo:USA.

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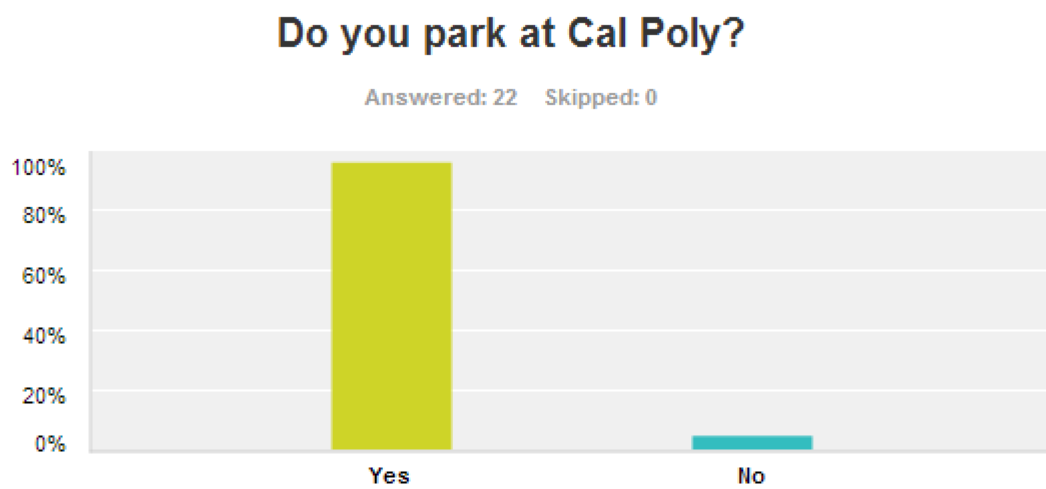
Wang, Bessie. "San Mateo Launches Smart Parking Technology from Streetline and Cisco”. December 4, 2012. Web. February 1, 2013. < http://newsroom.cisco.com/press-release-content?type=webcontent&articleId=1111591 >

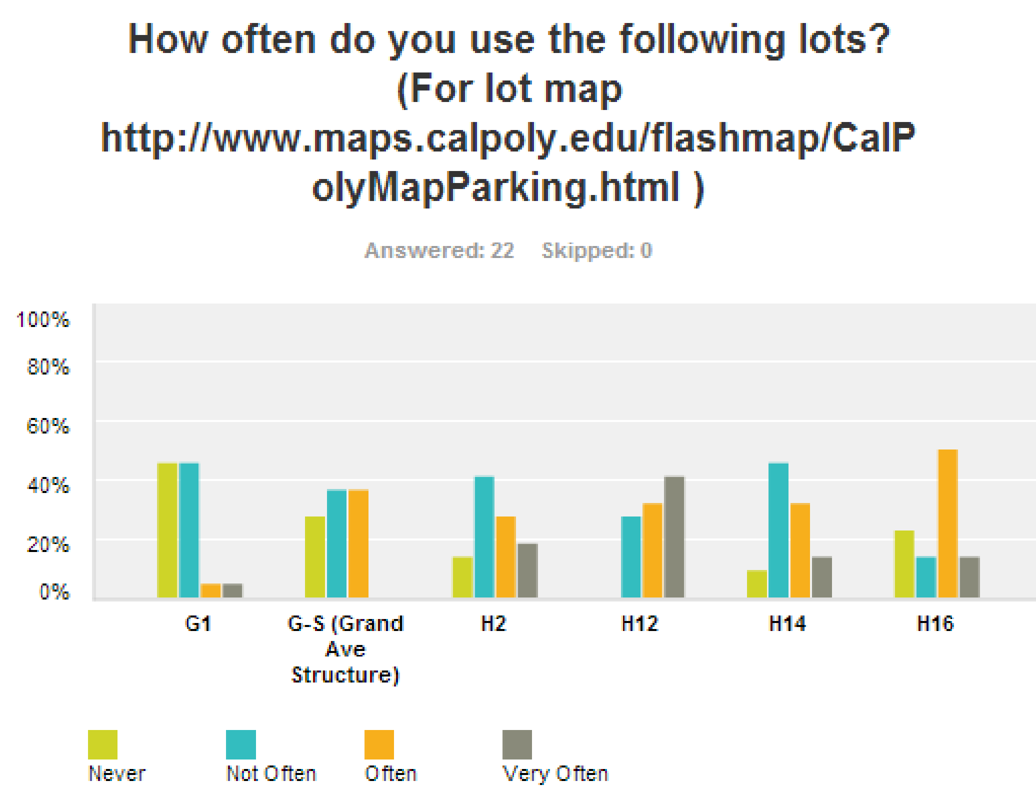
"Cal Poly Master Plan”. March 21, 2001. Web. January 21, 2013. <http://www.afd.calpoly.edu/facilities/master_plan.asp>

Appendix A: Survey

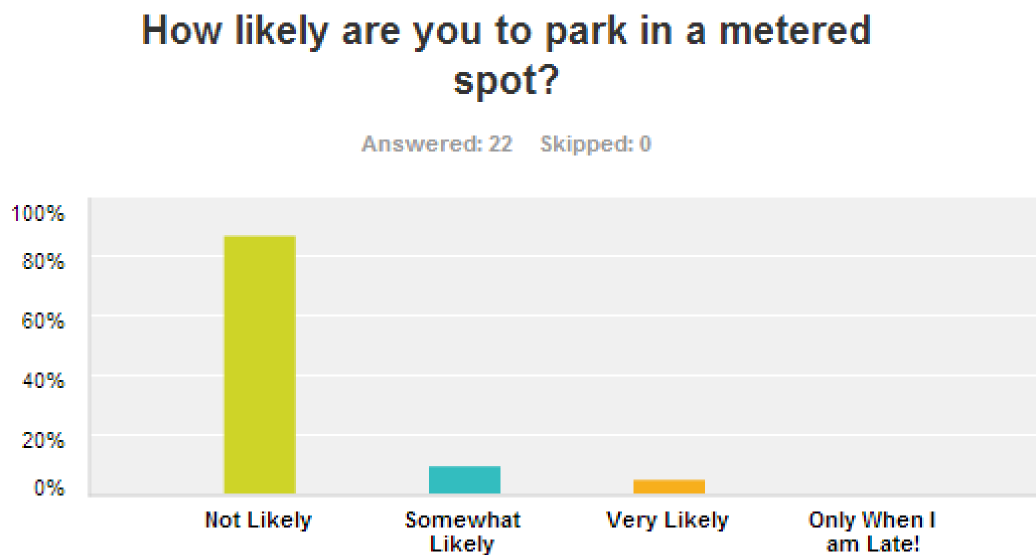
Question 1



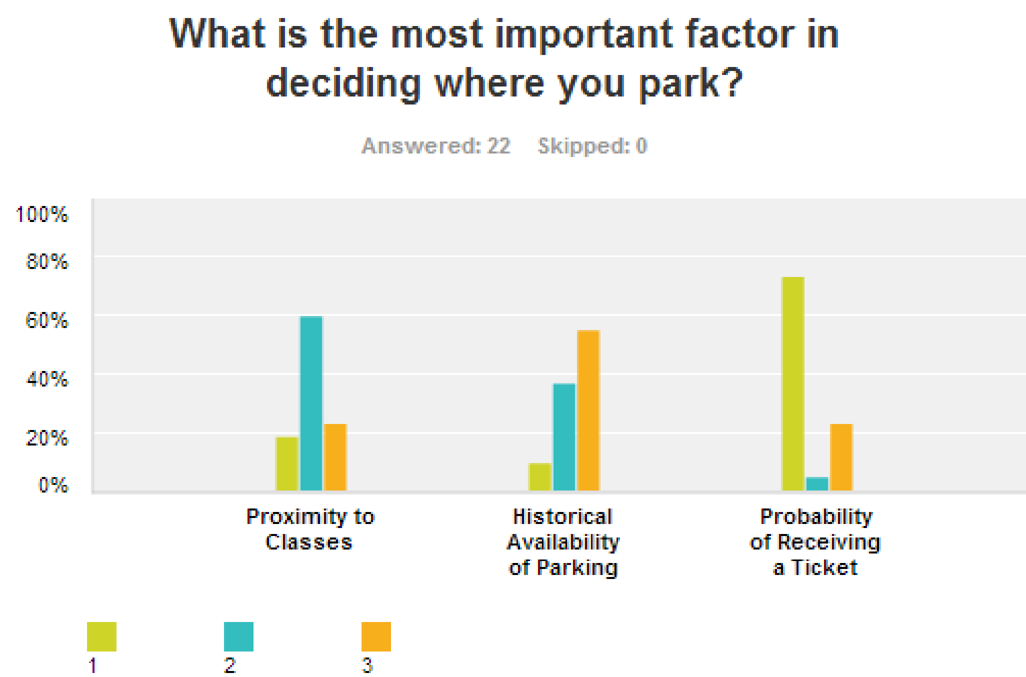
Question 2



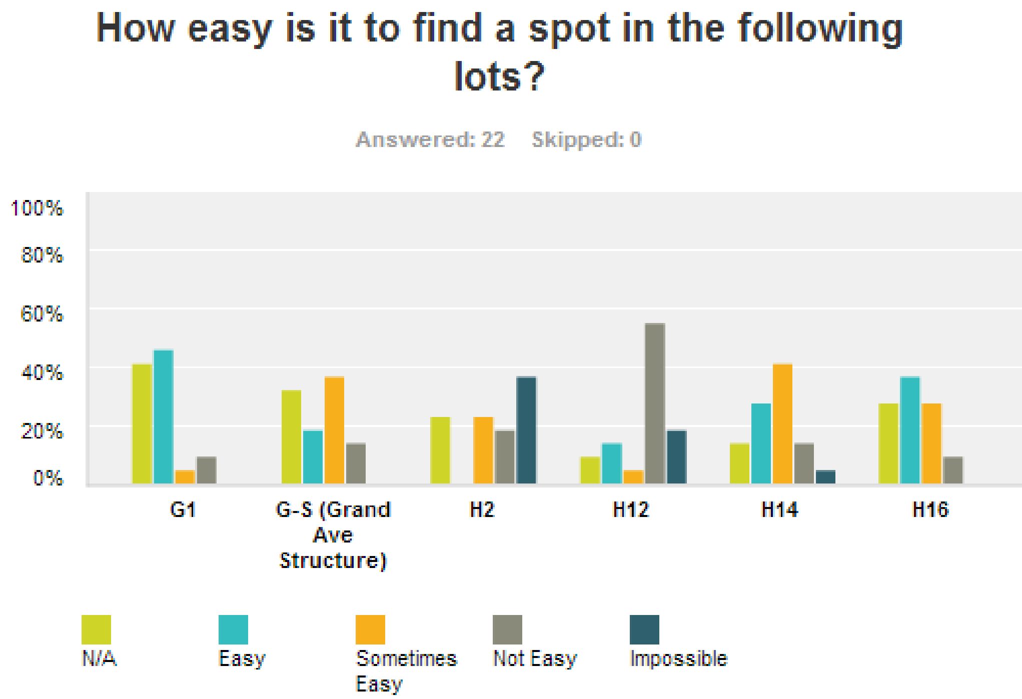
Question 3:



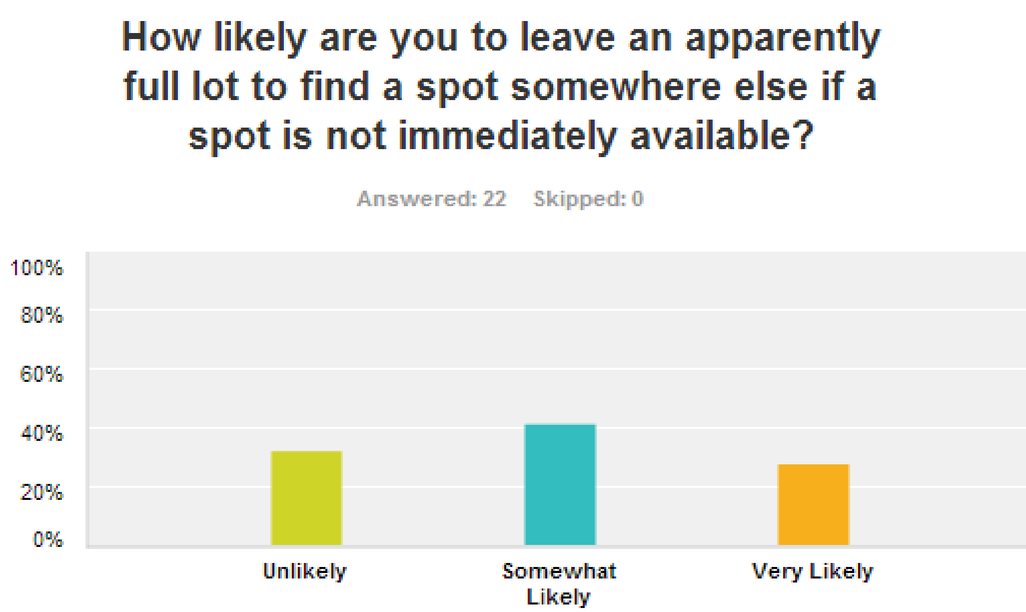
Question 4:



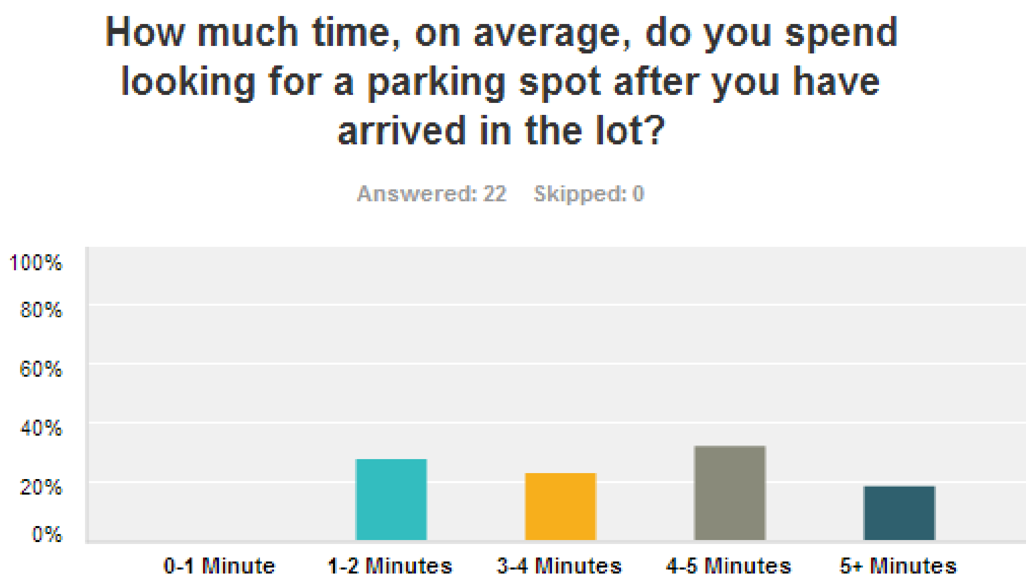
Question 5:



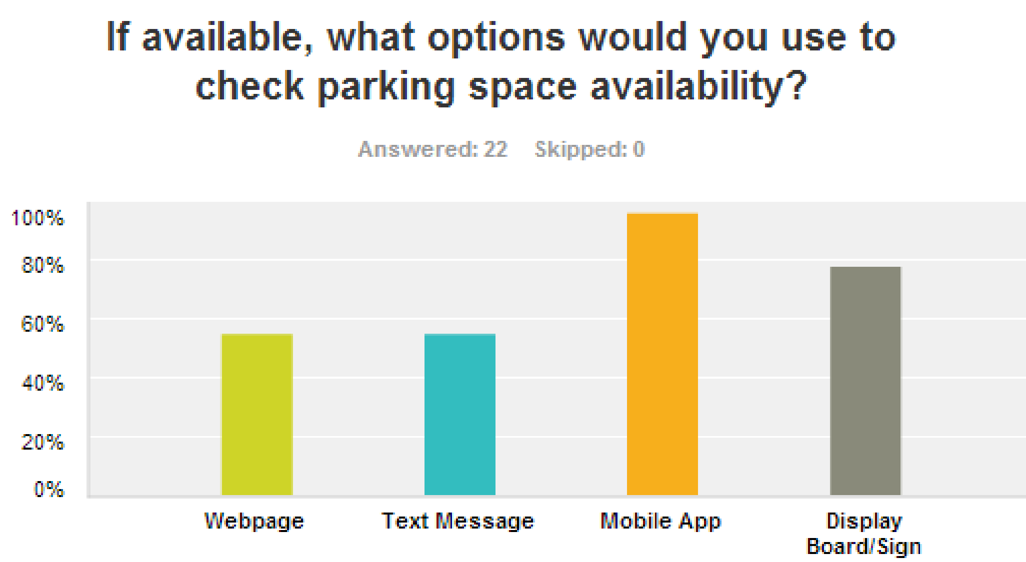
Question 6:



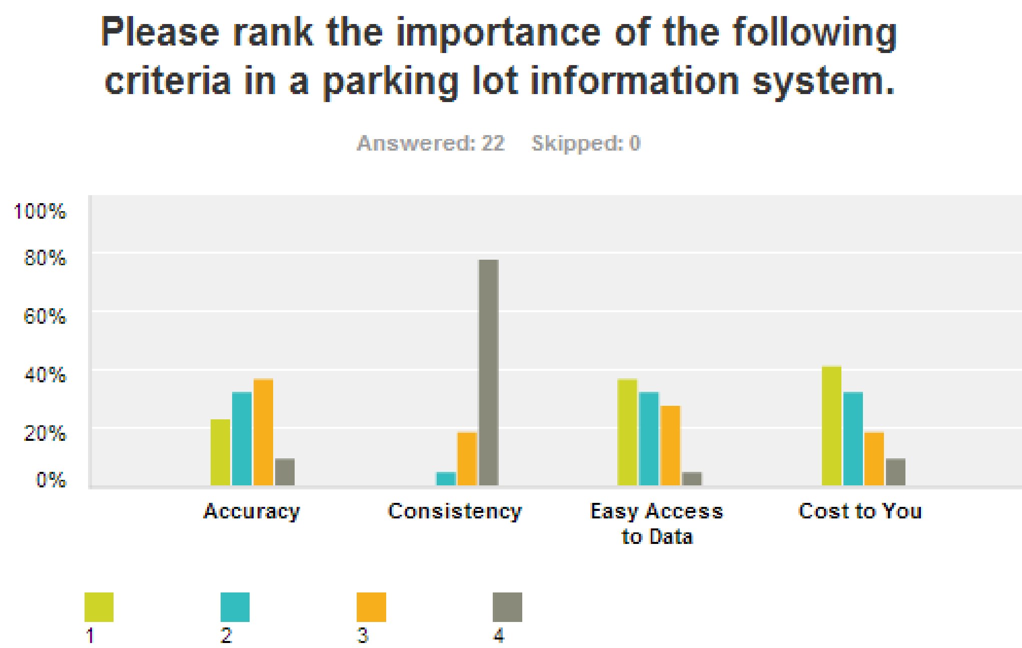
Question 7:



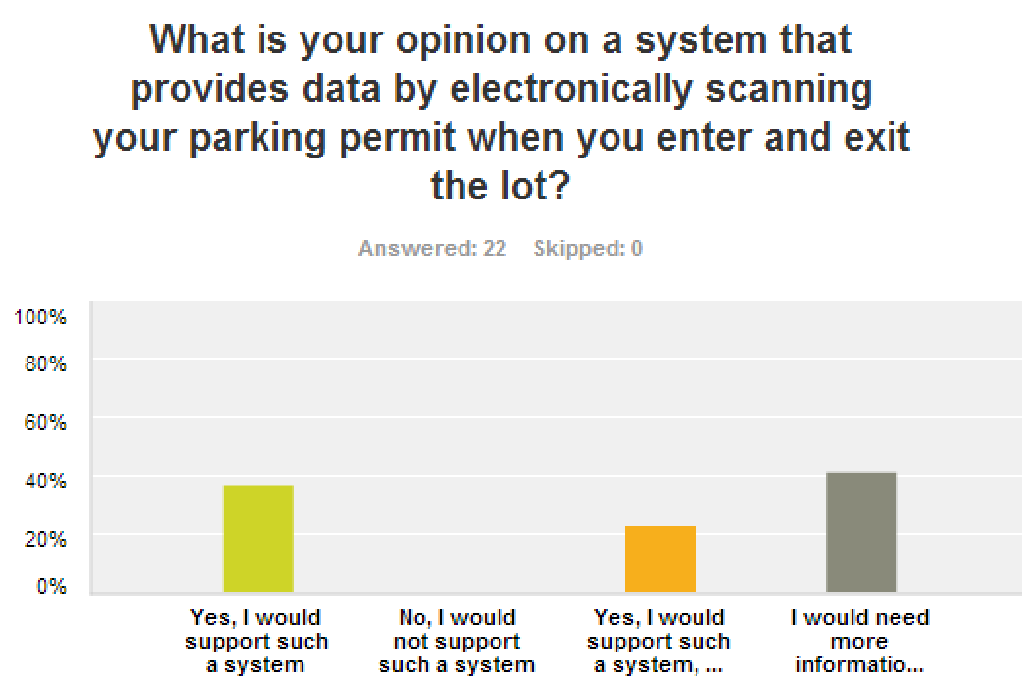
Question 8:



Question 9:



Question 10:



Appendix B: User Guide

Students/Faculty/Staff
Viewing current lot status

1. On the welcome screen select the "View Lot Status" button to bring up the "Current Lot Status" page.

Figure 1 - Poly Parking Home

2. Upon opening the page, the current lot usage is displayed. Each lot has a colored overlay which will change color depending on the lot's current status, following the color key in the form. To refresh this data manually, click the update status button on the right hand side of the screen.

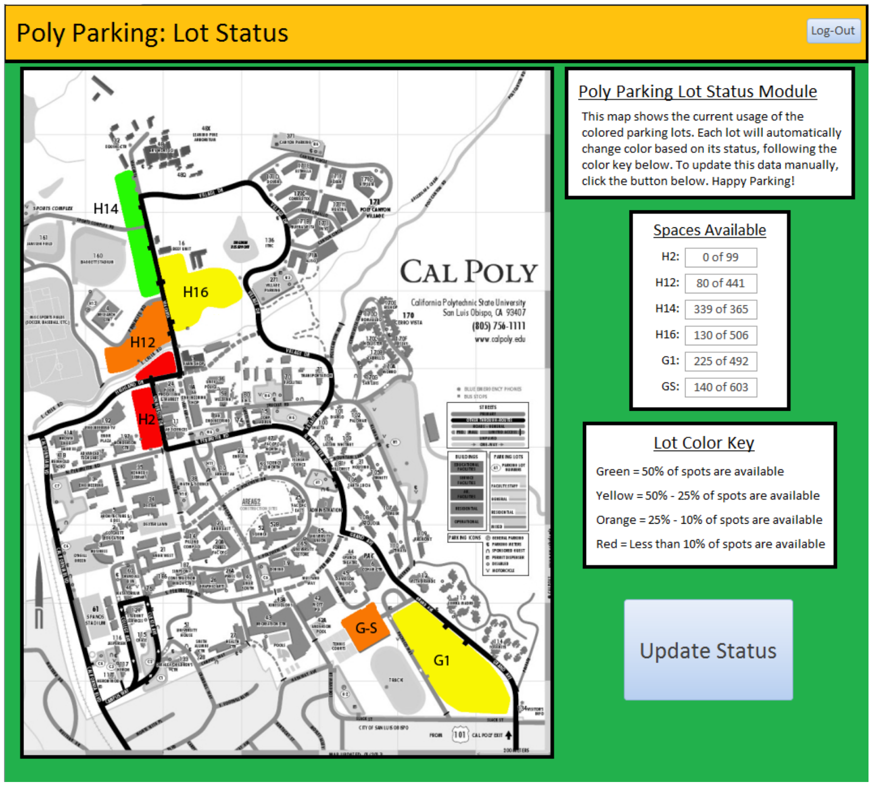


Figure 2 - Poly Parking Lot Status

3. When finished, log out by clicking the "Log-Out" button in the upper right hand corner.

Administrators

Viewing Current Lot Status

1. On the welcome screen select the "Administrators" button and log in. (See Figure 1)

Figure 3 - Administrator Log-In

2. After logging in, the “Poly Parking Admin Home” page will display. From here you can navigate to the various modules by selecting a module from the navigation menu and clicking the “Go” button.

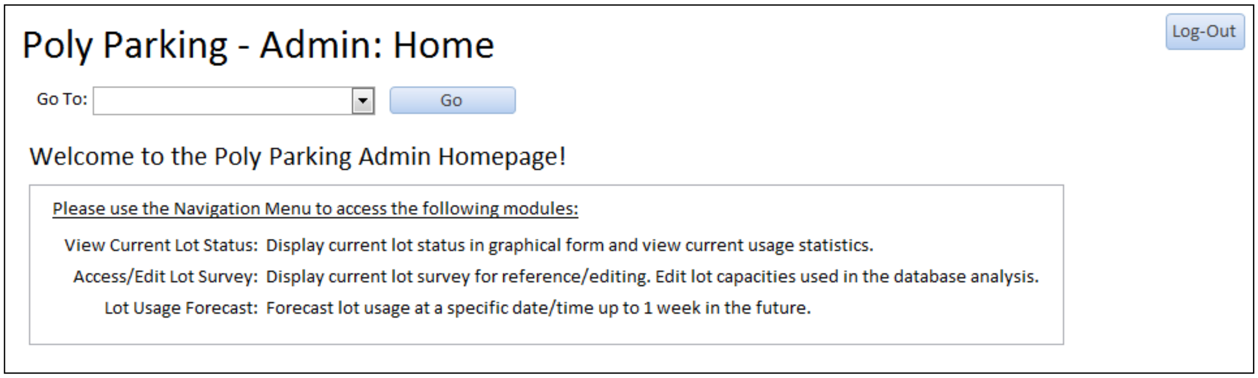


Figure 4 – Admin Home Page

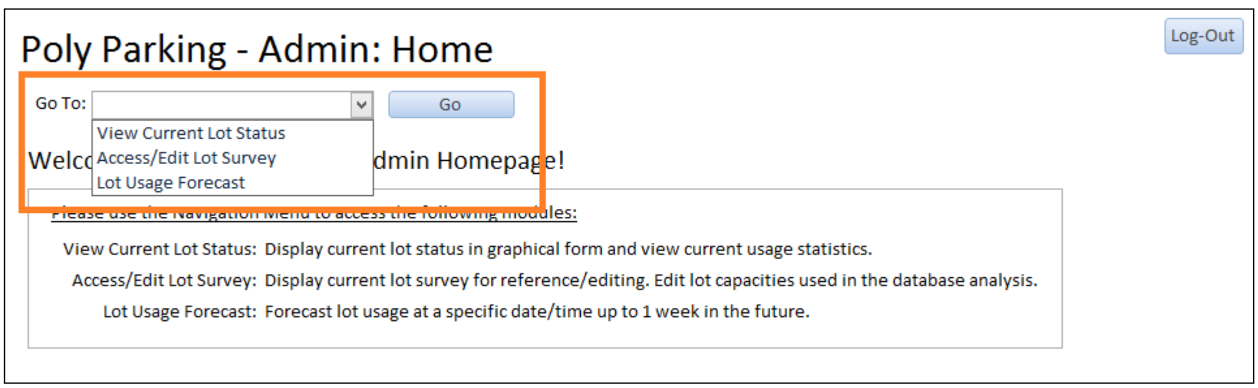


Figure 5 - Admin Navigation

Admin: View Current Lot Status Module:

1. After selecting this module from the menu and clicking go, the module will load, displaying the current lot status graphically along with the number of spaces available and the percentage of the usable spaces currently not in use. To refresh this data manually, click the “Update Status” button on the right hand side of the screen.

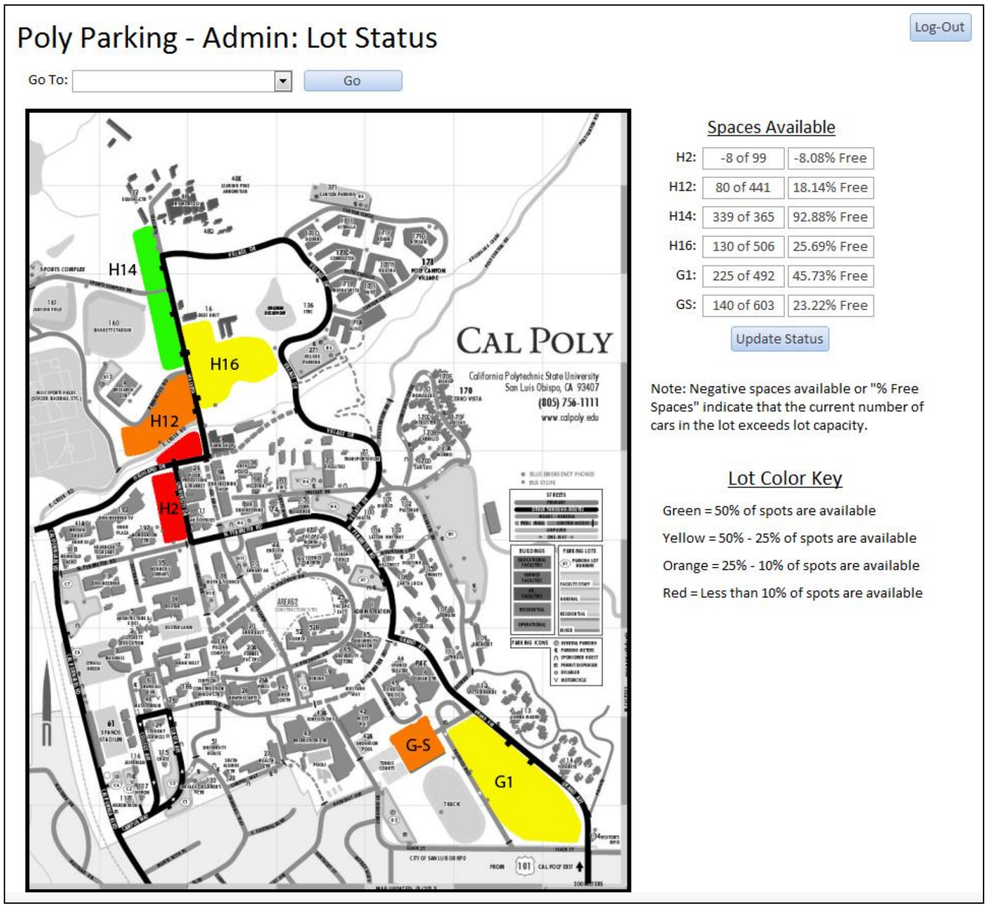


Figure 6 - Admin Lot Status

2. At the bottom of this page there is also a set of radio buttons that will test the loading of the images in the module. These images will be loaded upon clicking its respective button and all other images will become invisible. To return the module to the current status, click the “Reset” button next to the radio buttons.

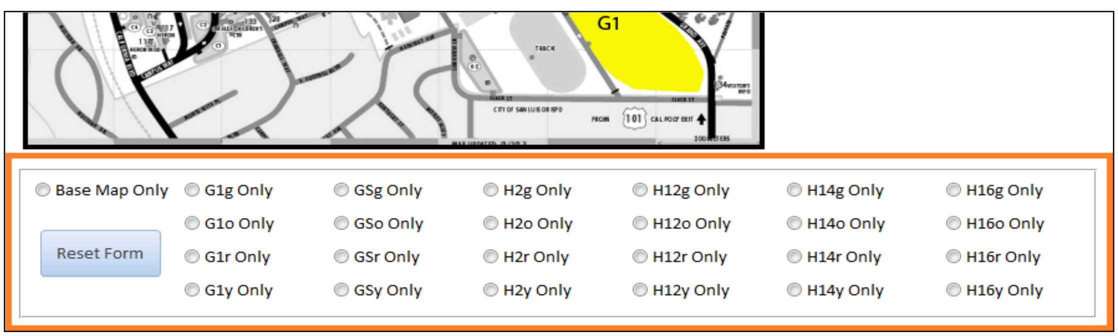
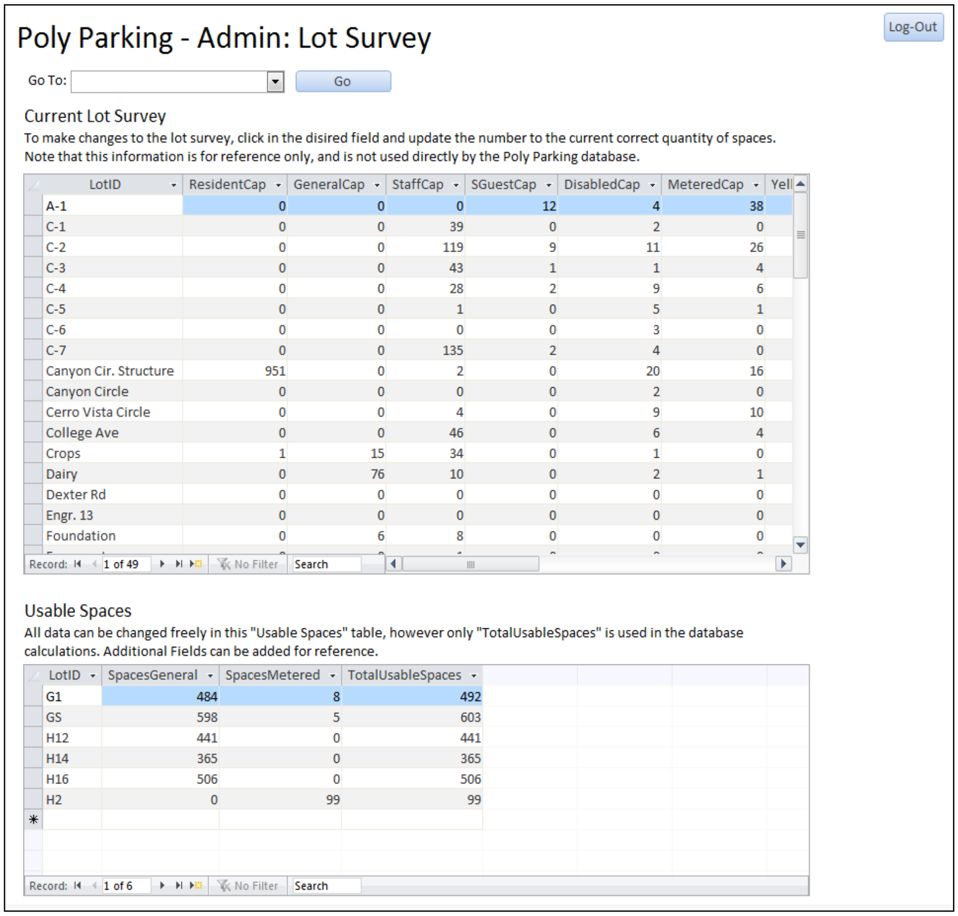


Figure 7 - Image Load Debug

Access/Edit Lot Survey Module:

1. After selecting this module from the menu and clicking go, the module will load, displaying two tables; "Current Lot Survey", and "Usable Spaces".



Poly Parking - Admin: Lot Survey

Log-Out

Go To: Go

Current Lot Survey

To make changes to the lot survey, click in the disired field and update the number to the current correct quantity of spaces. Note that this information is for reference only, and is not used directly by the Poly Parking database.

LotID	ResidentCap	GeneralCap	StaffCap	SGuestCap	DisabledCap	MeteredCap	Yell
A-1	0	0	0	12	4	38	
C-1	0	0	39	0	2	0	
C-2	0	0	119	9	11	26	
C-3	0	0	43	1	1	4	
C-4	0	0	28	2	9	6	
C-5	0	0	1	0	5	1	
C-6	0	0	0	0	3	0	
C-7	0	0	135	2	4	0	
Canyon Cir. Structure	951	0	2	0	20	16	
Canyon Circle	0	0	0	0	2	0	
Cerro Vista Circle	0	0	4	0	9	10	
College Ave	0	0	46	0	6	4	
Crops	1	15	34	0	1	0	
Dairy	0	76	10	0	2	1	
Dexter Rd	0	0	0	0	0	0	
Engr. 13	0	0	0	0	0	0	
Foundation	0	6	8	0	0	0	

Record: 1 of 49 No Filter Search

Usable Spaces

All data can be changed freely in this "Usable Spaces" table, however only "TotalUsableSpaces" is used in the database calculations. Additional Fields can be added for reference.

LotID	SpacesGeneral	SpacesMetered	TotalUsableSpaces
G1	484	8	492
GS	598	5	603
H12	441	0	441
H14	365	0	365
H16	506	0	506
H2	0	99	99

Record: 1 of 6 No Filter Search

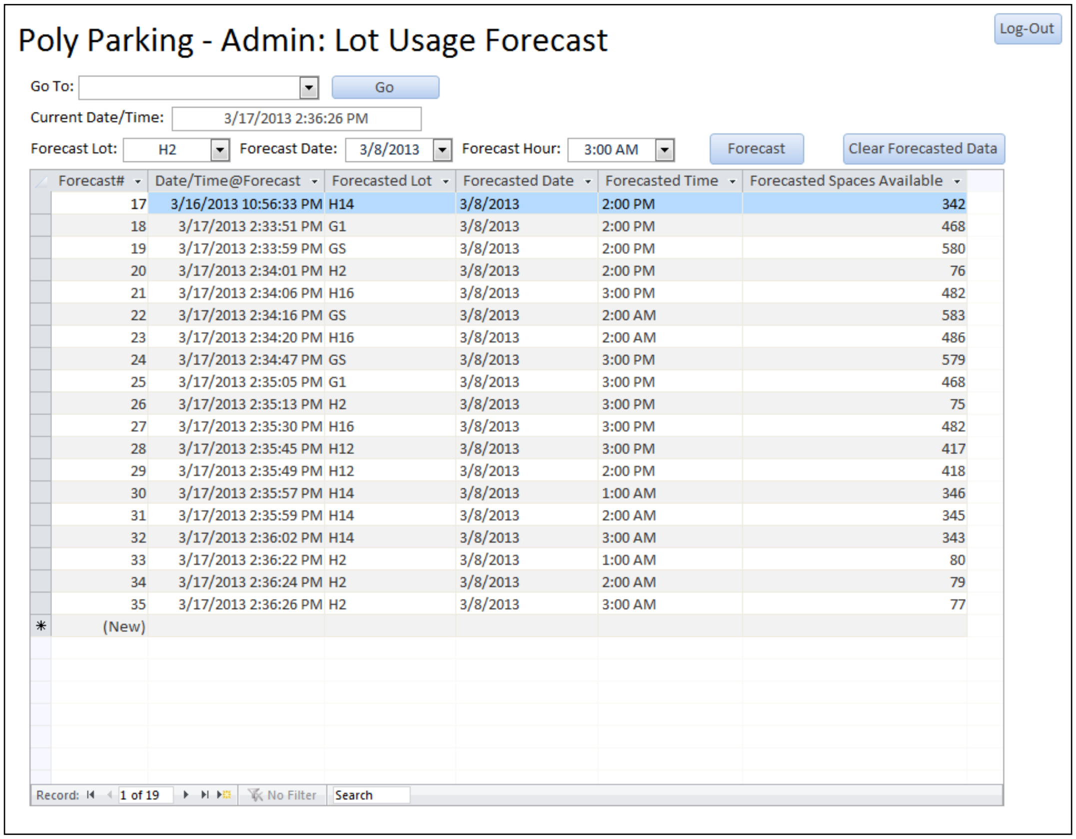
Figure 8 - Admin Survey Form

2. The data in "Current Lot Survey" is used purely for reference, and can be edited freely by clicking in the cell to be modified and changing the value to the new current value. Additional lots and spot designations can also be added if desired with no consequential effect on the database. Any changes made will automatically be saved.

3. The data in "Usable Spaces" can also be freely edited in the same way as in "Current Lot Survey" however the data in the "TotalUsableSpaces" field will inflect changes in the subsequent database analysis. These values are used as the maximum capacity for each lot, and should only be comprised of lot designations that are traceable or have no need of tracing, such as general or metered spaces.

Lot Usage Forecast Module

1. After selecting this module from the menu and clicking go, the module will load, displaying a series of input parameters and a table of previous forecasts created by this module.



Forecast#	Date/Time@Forecast	Forecasted Lot	Forecasted Date	Forecasted Time	Forecasted Spaces Available
17	3/16/2013 10:56:33 PM	H14	3/8/2013	2:00 PM	342
18	3/17/2013 2:33:51 PM	G1	3/8/2013	2:00 PM	468
19	3/17/2013 2:33:59 PM	GS	3/8/2013	2:00 PM	580
20	3/17/2013 2:34:01 PM	H2	3/8/2013	2:00 PM	76
21	3/17/2013 2:34:06 PM	H16	3/8/2013	3:00 PM	482
22	3/17/2013 2:34:16 PM	GS	3/8/2013	2:00 AM	583
23	3/17/2013 2:34:20 PM	H16	3/8/2013	2:00 AM	486
24	3/17/2013 2:34:47 PM	GS	3/8/2013	3:00 PM	579
25	3/17/2013 2:35:05 PM	G1	3/8/2013	3:00 PM	468
26	3/17/2013 2:35:13 PM	H2	3/8/2013	3:00 PM	75
27	3/17/2013 2:35:30 PM	H16	3/8/2013	3:00 PM	482
28	3/17/2013 2:35:45 PM	H12	3/8/2013	3:00 PM	417
29	3/17/2013 2:35:49 PM	H12	3/8/2013	2:00 PM	418
30	3/17/2013 2:35:57 PM	H14	3/8/2013	1:00 AM	346
31	3/17/2013 2:35:59 PM	H14	3/8/2013	2:00 AM	345
32	3/17/2013 2:36:02 PM	H14	3/8/2013	3:00 AM	343
33	3/17/2013 2:36:22 PM	H2	3/8/2013	1:00 AM	80
34	3/17/2013 2:36:24 PM	H2	3/8/2013	2:00 AM	79
35	3/17/2013 2:36:26 PM	H2	3/8/2013	3:00 AM	77
(New)					

Figure 9 - Admin Forecast Module

In order to create a forecast, first select the lot, date and hour to forecast be forecasted via the drop down menus at the top of the form. After selecting these values, click forecast, and a new record will be created in the table below. To clear the table, click the “Clear Forecasted Data” button at the top of the form.

Appendix C: Sample Code/Tables

Record#	LotID	Date	Time	Change	SpacesAvailable	Click to Add
1	G1	2/6/2013	10:00:00 AM	-1	491	
2	G1	2/6/2013	10:00:00 AM	-1	490	
3	G1	2/6/2013	10:36:00 AM	-1	489	
4	G1	2/6/2013	11:45:00 AM	1	490	
5	G1	2/6/2013	3:07:00 PM	1	491	
6	G1	2/7/2013	6:11:00 AM	1	492	
7	G1	2/7/2013	7:00:00 AM	-1	491	
8	G1	2/7/2013	7:05:00 AM	-1	490	
9	G1	2/7/2013	8:00:00 AM	1	491	
10	G1	2/7/2013	12:00:00 PM	-1	490	
11	G1	2/7/2013	12:00:56 PM	-1	489	
12	G1	2/7/2013	12:01:00 PM	-1	488	
13	G1	2/7/2013	12:03:00 PM	-1	487	
14	G1	2/7/2013	12:05:00 PM	-1	486	
15	G1	2/7/2013	1:00:00 PM	1	487	
16	G1	2/7/2013	1:05:00 PM	1	488	
17	G1	2/10/2013	3:00:00 PM	-1	487	
18	G1	2/10/2013	3:01:00 PM	-1	486	
19	G1	2/13/2013	8:00:00 AM	-1	485	
20	G1	2/13/2013	8:05:00 AM	-1	484	
21	G1	2/13/2013	9:00:00 AM	-1	483	
22	G1	2/13/2013	12:00:00 PM	1	484	
23	G1	2/15/2013	1:20:00 AM	-1	483	
24	G1	2/15/2013	1:30:00 AM	-1	482	
25	G1	2/15/2013	2:10:00 AM	-1	481	
26	G1	2/15/2013	2:30:00 AM	-1	480	
27	G1	2/15/2013	2:31:00 AM	-1	479	
28	G1	2/15/2013	3:00:00 AM	-1	478	
29	G1	2/15/2013	2:00:00 PM	-1	477	
30	G1	2/15/2013	2:30:00 PM	-1	476	
31	G1	2/15/2013	2:45:00 PM	-1	475	
32	G1	2/22/2013	1:20:00 AM	-1	474	
33	G1	2/22/2013	1:20:15 AM	-1	473	
34	G1	2/22/2013	1:30:00 AM	-1	472	
35	G1	2/22/2013	2:10:00 AM	-1	471	
36	G1	2/22/2013	2:30:00 AM	-1	470	
37	G1	2/22/2013	2:31:00 AM	-1	469	
38	G1	2/22/2013	3:00:00 AM	-1	468	

Record: 1 of 55 No Filter Search

Figure 3 - Theoretical Counter for Lot G1

PolyParkingAdminForecast | COUNTEROUTPUTG1 | ADMINROSTER | FORECASTRECORDS | LOTSTATUS

LotID	Date	Time	SpacesAvailable	PercentFreeSpaces	Click to Add
G1	3/15/2013	4:00:00 PM	225	0.457317073170732	
GS	3/13/2013	1:00:00 PM	140	0.232172470978441	
H12	3/10/2013	2:30:00 AM	80	0.18140589569161	
H14	3/13/2013	1:00:00 PM	339	0.928767123287671	
H16	3/13/2013	1:00:00 PM	130	0.256916996047431	
H2	3/13/2013	1:00:00 PM	-8	-8.08080808080808E-02	

Figure 4 - Lot Status Table

```
Option Compare Database

Private Sub Form_Load()

Me.FocusTextbox.SetFocus

DoCmd.SetWarnings False

DoCmd.OpenQuery "UpdateLotStatusG1"
DoCmd.OpenQuery "UpdateLotStatusGS"
DoCmd.OpenQuery "UpdateLotStatusH12"
DoCmd.OpenQuery "UpdateLotStatusH14"
DoCmd.OpenQuery "UpdateLotStatusH16"
DoCmd.OpenQuery "UpdateLotStatusH2"

Me.Refresh


'G1 MAP SELECT
G1Status = DLookup("[PercentFreeSpaces]", "[LOTSTATUS]", "LotID = 'G1'")
If G1Status >= 0.5 Then PolyMapG1g.Visible = True
If G1Status >= 0.5 Then PolyMapG1y.Visible = False
If G1Status >= 0.5 Then PolyMapG1o.Visible = False
If G1Status >= 0.5 Then PolyMapG1r.Visible = False
If G1Status < 0.5 And G1Status >= 0.25 Then PolyMapG1g.Visible = False
If G1Status < 0.5 And G1Status >= 0.25 Then PolyMapG1y.Visible = True
If G1Status < 0.5 And G1Status >= 0.25 Then PolyMapG1o.Visible = False
If G1Status < 0.5 And G1Status >= 0.25 Then PolyMapG1r.Visible = False
If G1Status < 0.25 And G1Status >= 0.1 Then PolyMapG1g.Visible = False
If G1Status < 0.25 And G1Status >= 0.1 Then PolyMapG1y.Visible = False
If G1Status < 0.25 And G1Status >= 0.1 Then PolyMapG1o.Visible = True
If G1Status < 0.25 And G1Status >= 0.1 Then PolyMapG1r.Visible = False
If G1Status < 0.1 Then PolyMapG1g.Visible = False
If G1Status < 0.1 Then PolyMapG1y.Visible = False
If G1Status < 0.1 Then PolyMapG1o.Visible = False
If G1Status < 0.1 Then PolyMapG1r.Visible = True

'GS MAP SELECT
GSStatus = DLookup("[PercentFreeSpaces]", "[LOTSTATUS]", "LotID = 'GS'")
If GSStatus >= 0.5 Then PolyMapGSg.Visible = True
If GSStatus >= 0.5 Then PolyMapGSy.Visible = False
```

Figure 5 - Lot Status Color Overlay Display Code Sample

```
'Space Available Textbox Load
Dim H2Spaces As Integer
Dim H12Spaces As Integer
Dim H14Spaces As Integer
Dim H16Spaces As Integer
Dim G1Spaces As Integer
Dim GSSpaces As Integer

H2Spaces = DLookup("[SpacesAvailable]", "[LOTSTATUS]", "LotID = 'H2'")
H12Spaces = DLookup("[SpacesAvailable]", "[LOTSTATUS]", "LotID = 'H12'")
H14Spaces = DLookup("[SpacesAvailable]", "[LOTSTATUS]", "LotID = 'H14'")
H16Spaces = DLookup("[SpacesAvailable]", "[LOTSTATUS]", "LotID = 'H16'")
G1Spaces = DLookup("[SpacesAvailable]", "[LOTSTATUS]", "LotID = 'G1'")
GSSpaces = DLookup("[SpacesAvailable]", "[LOTSTATUS]", "LotID = 'GS'")

If H2Spaces <= 0 Then H2Spaces = 0
If H12Spaces <= 0 Then H2Spaces = 0
If H14Spaces <= 0 Then H2Spaces = 0
If H16Spaces <= 0 Then H2Spaces = 0
If G1Spaces <= 0 Then H2Spaces = 0
If GSSpaces <= 0 Then H2Spaces = 0


Me.H2SpacesAvailableTextbox = H2Spaces & " of " & DLookup("TotalUsableSpaces", "UsableSpacesSurvey", "LotID = 'H2'")
Me.H12SpacesAvailableTextbox = H12Spaces & " of " & DLookup("TotalUsableSpaces", "UsableSpacesSurvey", "LotID = 'H12'")
Me.H14SpacesAvailableTextbox = H14Spaces & " of " & DLookup("TotalUsableSpaces", "UsableSpacesSurvey", "LotID = 'H14'")
Me.H16SpacesAvailableTextbox = H16Spaces & " of " & DLookup("TotalUsableSpaces", "UsableSpacesSurvey", "LotID = 'H16'")
Me.G1SpacesAvailableTextbox = G1Spaces & " of " & DLookup("TotalUsableSpaces", "UsableSpacesSurvey", "LotID = 'G1'")
Me.GSSpacesAvailableTextbox = GSSpaces & " of " & DLookup("TotalUsableSpaces", "UsableSpacesSurvey", "LotID = 'GS'")

Me.FocusTextbox.SetFocus
```

Figure 6 - Lot Status Textbox Output Code Sample

```
Option Compare Database

Private Sub Form_Load()
Me.FocusTextbox.SetFocus
End Sub

Private Sub GoButton_Click()
If [Form].[NavigationCombo] = "View Current Lot Status" Then
    DoCmd.OpenForm "PolyParkingAdminLotStatus"
    DoCmd.Close acForm, "PolyParkingAdminHome", acSaveNo
    Exit Sub
End If
If [Form].[NavigationCombo] = "Access/Edit Lot Survey" Then
    DoCmd.OpenForm "PolyParkingAdminSurvey"
    DoCmd.Close acForm, "PolyParkingAdminHome", acSaveNo
    Exit Sub
End If
If [Form].[NavigationCombo] = "Lot Usage Forecast" Then
    DoCmd.OpenForm "PolyParkingAdminForecast"
    DoCmd.Close acForm, "PolyParkingAdminHome", acSaveNo
    Exit Sub
End If
Me.FocusTextbox.SetFocus

End Sub

Private Sub LogOutButton_Click()
    DoCmd.Close acForm, "PolyParkingAdminHome", acSaveNo
    DoCmd.OpenForm "PolyParkingHome"
End Sub
```

Figure 7 - Admin Home Code Sample

```
If IsNull(Me.ForecastDateCombo) Or Me.ForecastDateCombo = "" Then
    MsgBox "Please Select A Date To Forecast."
    Exit Sub
End If
If IsNull(Me.ForecastHourCombo) Or Me.ForecastDateCombo = "" Then
    MsgBox "Please Select A Hour To Forecast."
    Exit Sub
End If


ForecastDate0 = Me.ForecastDateCombo
ForecastDate1 = DateAdd("d", -7, ForecastDate0)
ForecastDate2 = DateAdd("d", -7, ForecastDate1)
ForecastDate3 = DateAdd("d", -7, ForecastDate2)
'MsgBox (ForecastDate1)
'MsgBox (ForecastDate2)
'MsgBox (ForecastDate3)
ForecastDate0Textbox = ForecastDate0
ForecastDate1Textbox = ForecastDate1
ForecastDate2Textbox = ForecastDate2
ForecastDate3Textbox = ForecastDate3

ForecastTime0 = Me.ForecastHourCombo
ForecastTimeStart = DateAdd("n", -30, ForecastTime0)
ForecastTimeEnd = DateAdd("n", 30, ForecastTime0)
'MsgBox (ForecastTime0)
'MsgBox (ForecastTimeStart)
'MsgBox (ForecastTimeEnd)
ForecastTime0Textbox = ForecastTime0
ForecastTimeStartTextbox = ForecastTimeStart
ForecastTimeEndTextbox = ForecastTimeEnd

If Me.ForecastLotCombo = "G1" Then DoCmd.OpenQuery ("AppendForecastRecordsG1")
If Me.ForecastLotCombo = "GS" Then DoCmd.OpenQuery ("AppendForecastRecordsGS")
If Me.ForecastLotCombo = "H12" Then DoCmd.OpenQuery ("AppendForecastRecordsH12")
If Me.ForecastLotCombo = "H14" Then DoCmd.OpenQuery ("AppendForecastRecordsH14")
If Me.ForecastLotCombo = "H16" Then DoCmd.OpenQuery ("AppendForecastRecordsH16")
If Me.ForecastLotCombo = "H2" Then DoCmd.OpenQuery ("AppendForecastRecordsH2")
```

Figure 8 - Forecast Module Menu Code Sample

```
If Me.ForecastLotCombo = "GS" Then
    If IsNull(DLookup("LotID", "ForecastDate0GS")) Or DLookup("LotID", "ForecastDate0GS") = "" Then
        MsgBox "Insufficient data for forecast. Too few records exist between given parameters."
        Exit Sub
    End If
    DoCmd.Requery
End If
```

Figure 9 - "Insufficient Data" Forecast Message Box