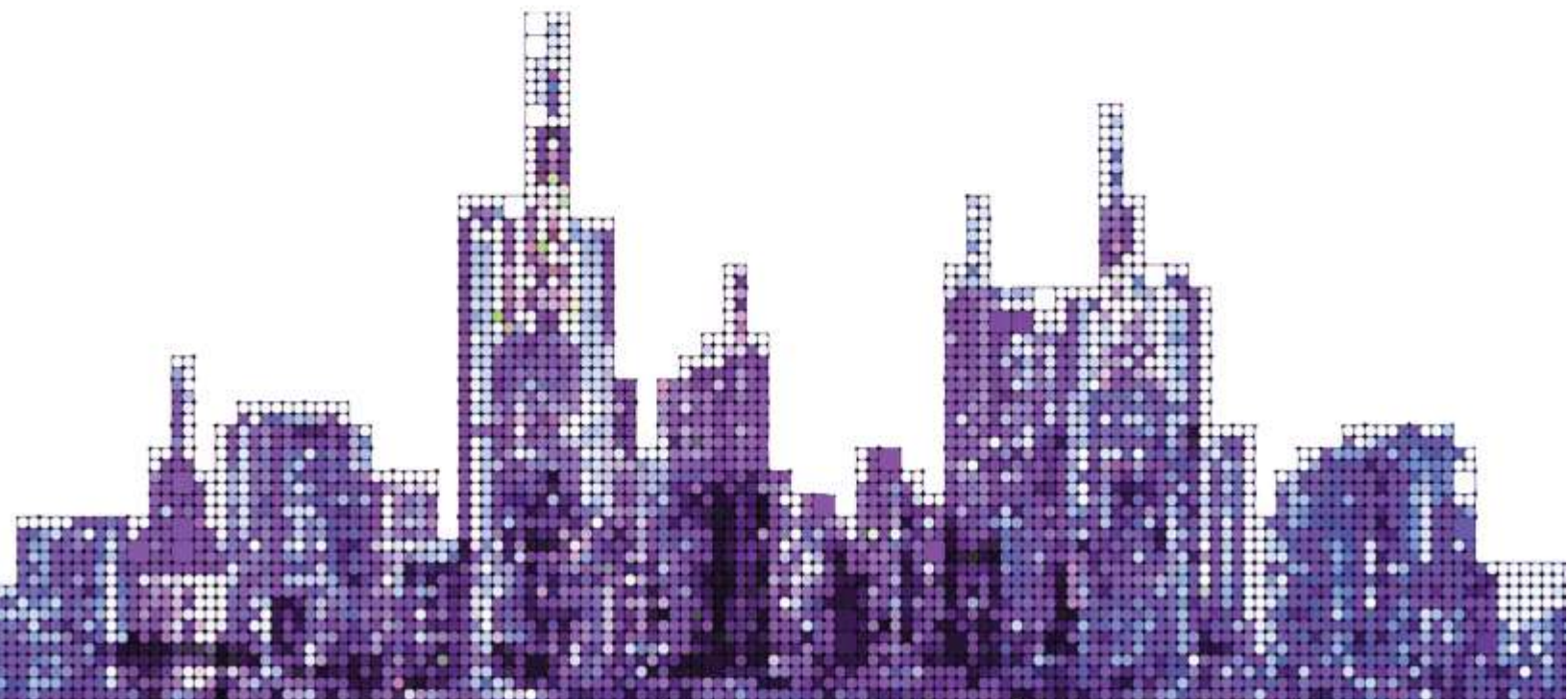


SPARKMAN: A Smart Parking Management Tool for University Campuses

February 2020



Sparkman: A Smart Parking Management Tool for University Campuses

Ruey Long Cheu
The University of Texas at El Paso

Okan Gurbuz
The University of Texas at El Paso

C2SMART Center is a USDOT Tier 1 University Transportation Center taking on some of today's most pressing urban mobility challenges. Using cities as living laboratories, the center examines transportation problems and field tests novel solutions that draw on unprecedented recent advances in communication and smart technologies. Its research activities are focused on three key areas: Urban Mobility and Connected Citizens; Urban Analytics for Smart Cities; and Resilient, Secure and Smart Transportation Infrastructure.

Some of the key areas C2SMART is focusing on include:

Disruptive Technologies

We are developing innovative solutions that focus on emerging disruptive technologies and their impacts on transportation systems. Our aim is to accelerate technology transfer from the research phase to the real world.

Unconventional Big Data Applications

C2SMART is working to make it possible to safely share data from field tests and non-traditional sensing technologies so that decision-makers can address a wide range of urban mobility problems with the best information available to them.

Impactful Engagement

The center aims to overcome institutional barriers to innovation and hear and meet the needs of city and state stakeholders, including government agencies, policy makers, the private sector, non-profit organizations, and entrepreneurs.

Forward-thinking Training and Development

As an academic institution, we are dedicated to training the workforce of tomorrow to deal with new mobility problems in ways that are not covered in existing transportation curricula.

Led by the New York University Tandon School of Engineering, C2SMART is a consortium of five leading research universities, including Rutgers University, University of Washington, the University of Texas at El Paso, and The City College of New York.

c2smart.engineering.nyu.edu

Disclaimer

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the information presented herein. This document is disseminated in the interest of information exchange. The report is funded, partially or entirely, by a grant from the U.S. Department of Transportation's University Transportation Centers Program. However, the U.S. Government assumes no liability for the contents or use thereof.

Acknowledgements

This research is funded by the Connected Cities for Smart Mobility towards Accessible and Resilient Transportation (C2SMART), a Tier 1 University Center awarded by U.S. Department of Transportation under contract 69A3351747124.

The authors gratefully acknowledge The University of Texas at El Paso (UTEP) for contributing to the local matching fund that made this research possible.

This project could not have been successful without the support of the Campus Parking for Transportation Association. The assistance provided by Mr. Gary Smith for the evaluation of SPARKMAN 1.0 is gratefully acknowledged.

The assistance of UTEP student Rodrigo Garcia in gathering SPARKMAN's user feedback is well appreciated.

Executive Summary

A common transportation problem faced by most universities is inadequate parking supply (capacity) to meet demand. To manage parking, Campus Parking Offices or CPOs usually group parking lots into zones and restrict the use of zones by the type of permit and permit price. Commuter students is the largest group of parking facility users on campus. This research focused on commuter student parking, with the following objectives:

1. To develop a commuter student parking lot Zoning and Zone Permit Pricing (Z2P2) methodology;
2. To develop a software tool called SPARKMAN (acronym for Smart PARKing MANagement) to assist CPOs with estimating commuter student permit prices;
3. To conduct a survey to understand university students' preferences among different Intelligent Transportation Systems (ITS) applications in campus parking and as part of this survey, develop Level of Service (LOS) criteria for parking.

The permit price of a parking zone is dependent on the proximity of the zone to the campus core. This new Z2P2 methodology uses the weighted average of Last-Mile Travel Time (LMTT) by different modes from parking lot to campus core as the key input. Neighboring lots with similar weighted LMTTs are grouped into a zone. The zone that has the median weighted average LMTT is set as the base zone with a base permit price (\$/year). The other zone's permit price (relative to the base zone's) is determined by first comparing the annual total LMTT with the base zone and then converting the difference into the recommended annual sale price by the value of travel time.

A Microsoft Excel-based software tool called SPARKMAN (Smart PARKing MANagement) was developed. SPARKMAN integrates the total demand model and the base price model (both introduced in earlier research by the authors) with the Z2P2 methodology introduced in this research. Version 1.0 of SPARKMAN was tested with parking data from The University of Texas at El Paso (UTEP) and evaluated by six practitioners at different universities.

To understand students' parking needs and preferences for different ITS applications for parking, a survey was conducted on the UTEP campus with 1,022 student participants. It was found that the top three ITS enabled parking services that participants preferred were: (1) online year-round permit sales; (2) flexible parking zones and (3) real-time parking occupancy information. A flexible parking zone is a system that allows use of one permit to park in multiple zones. Based on the survey findings, Level of Service (LOS) criteria for parking, using search time as a parameter, were developed. The criteria ranged from 2 minutes or less for LOS A to more than 15 minutes for LOS F.

Table of Contents

Sparkman: A Smart Parking Management Tool for University Campuses	i
Executive Summary	iv
Table of Contents.....	v
List of Figures.....	vi
List of Tables	vii
Section 1 Introduction	1
1.1 Background	1
1.2 Objectives and Scope	2
1.3 Research Methodology	3
1.4 Outline of Report	4
Section 2 Literature Review	5
2.1 Total Demand Model	5
2.2 Base Price Model	5
2.3 Zoning	6
2.4 Value of Time	6
2.5 ITS for Parking	7
Section 3 Development of Z2P2 methodology	11
3.1 Approach	11
3.2 Value of Time of Students	12
3.3 Z2P2 Methodology	12
3.4 Case Study	14
Section 4 Development of SPARKMAN	19
4.1 Background	19
4.2 System Requirement and Installation.....	19
4.3 Dashboard	20
4.4 Input Panel	21
4.5 Output Panel	24
4.6 Case Study	25
4.7 User Feedback.....	26
Section 5 Student Survey	30
5.1 Survey Information	30
5.2 Survey Findings	31
5.3 Data Validation and Discussion.....	44
Section 6 Conclusions, Limitations, and Future Research.....	46
6.1 Conclusions	46
6.2 Contributions	46
6.3 Limitations.....	47
6.4 Future Research	47
References	48
Appendix.....	52

List of Figures

Figure 2.1: Image processing applied to an open surface parking lot.....	9
Figure 3.1: UTEP map showing the campus core (Leech Groove)	15
Figure 3.2: Comparison of lot-based permit prices in \$/year at UTEP campus	18
Figure 4.1: SPARKMAN’s welcome screen	20
Figure 4.2: SPARKMAN’s dashboard.....	21
Figure 4.3: SPARKMAN’s input panel for university-wide data	22
Figure 4.4: SPARKMAN’s input panel for parking lot data	24
Figure 4.5: SPARKMAN’s output panel	26
Figure 5.1: Survey result - student classifications	31
Figure 5.2: Survey result - mode shares	32
Figure 5.3: Survey result – permit types.....	33
Figure 5.4: Survey result - arrival times before first class of the day	34
Figure 5.5: Survey result - parking lot locations.....	35
Figure 5.6: Survey result - mode shares of last-mile trips	36
Figure 5.7: Destination areas on UTEP campus	37
Figure 5.8: Survey result - trip destinations by areas	38
Figure 5.9: Survey result - search effort	41
Figure 5.10: Survey result - upper bounds of search time.....	43

List of Tables

Table 1.1: Total population in large universities in U.S. in 2017	2
Table 2.1: Value of time as percent of median hourly income (USDOT, 2016)	7
Table 3.1: Lot-based data for weighted average LMTT calculations	16
Table 3.2: Lot-based permit prices from case study at UTEP campus.....	17
Table 5.1 Survey result - permit purchase decision factors.....	39
Table 5.2: Survey result - preferred ITS applications.....	40
Table 5.3: Level of service criteria for parking	42
Table 5.4: Comparison of UTEP CIERP data and survey data	45

Section 1 Introduction

1.1 Background

Every vehicle trip starts and ends with parking which makes parking facilities among the most important transportation infrastructures. In a parking facility, when the demand for stalls is near or exceeds capacity, a driver will spend increasing amount of time searching for an empty stall to park. This not only leads to a longer trip completion time; it also contributes to traffic congestion and more mobile source emissions (Shoup, 2005).

A university campus has different types of infrastructure such as classrooms, laboratories, offices, libraries, dormitories, auditoriums and sport venues. These facilities attract different types of users (students, faculty members, staff and visitors) with different trip purposes and characteristics (Gurbuz et al., 2019). Most universities, which have limited land resources to serve the parking needs of the increasing number of users, are facing parking congestion problems. Parking facilities at university campuses are usually managed by a unit known as Campus Parking Office (CPO). A CPO's main duty is to match parking demand with the available supply. Over the years, CPOs have developed and implemented different strategies to handle the issues they have faced. The common parking management strategies are zoning of parking lots and differentiation of permits and prices for the different zones. Some CPOs have started to implement Intelligent Transportation Systems (ITS) technologies to manage campus parking. These ITS-enable parking assist systems not only help CPOs in enforcement but also enable the end-users to reduce parking search time.

As mentioned, university campuses attract different types of users. Students form the largest group of users. Students can be: (1) Commuter students who do not live on campus and need transportation to travel between home and campus; (2) Resident students who live on campus and do not generate an extra vehicle-trip to travel to campus. Since parking demand and the parking turnover rate of resident students are relatively low compared to that of commuter students, CPOs generally focus on serving commuter students. The parking behaviors of commuter students also depend on their status and classifications. Full-time students spend more time on campus and are more likely to use alternative modes of transportation, for example, transit. On the other hand, part-time students take fewer courses and they tend to travel to campus only when they have classes. Graduate level students who mostly have research or teaching assistantships spend the entire weekday on campus.

According to the National Center for Education Statistics (NCES, 2017), there were 310 universities which offered bachelor, masters, and Ph.D. programs with total campus enrollment of at least 10,000 students. These 310 universities were selected to demonstrate the population distribution among the different types of parking facility users on campus. As seen in Table 1.1, majority of the university

population (85.2%) are students followed by university staff and faculty members. Therefore, students, especially commuter students, are most likely to contribute to large-scale parking problems on a campus. Any policy or solution proposed to solve the campus parking problem should address the parking needs of students.

	Students	Staff	Faculty	Total
Full-time	5,598,879	629,409	403,376	6,631,664
Part-time	1,870,999	91,362	170,894	2,133,255
Total	7,469,878	720,771	574,270	8,764,919

Table 1.1: Total population in large universities in U.S. in 2017

1.2 Objectives and Scope

This project addressed the management of parking on university campuses. The scope was limited to commuter students. There were three objectives:

1. To develop a methodology to zone parking lots for commuter students and set permit prices. The integrated zoning and pricing methodology is called Zoning and Zone Permit Pricing (Z2P2) methodology;
2. To integrate and program the already developed campus-wide total demand model and base price model with the Z2P2 methodology into a user-friendly software tool named Smart PARKing MANagement (SPARKMAN); and
3. To conduct a survey to understand students' preferences among different ITS applications for parking on university campuses and use the survey data to develop the Level of Service (LOS) criteria for parking.

1.3 Research Methodology

The research work was divided into three sequential tasks. The work performed and output of each task have been written into a section of this report.

Task 1 – Development of Z2P2 methodology

A parking zone consists of one to several adjacent parking lots that have the same type of permit sold at the same price. To a commuter student, the attractiveness of a zone depends on the zone's permit price and the "last mile" travel time from the zone to the final destination (such as a classroom) on campus. In the first task, a methodology called Zoning and Zone Permit Pricing (Z2P2) was developed to group several adjacent parking lots into a zone and at the same time determine the zone's annual permit price from the base price, value-of-time, walking time, shuttle bus service headway, etc. The Z2P2 methodology was benchmarked against the student parking zones and zone permit prices across The University of Texas at El Paso (UTEP) campus.

Task 2 – Coding and Testing of SPARKMAN

This task incorporated the Z2P2 methodology developed in Task 1 and two previously developed models (total demand and base price models) and coded into a software tool called SPARKMAN. SPARKMAN is an Excel-based, user friendly program. SPARKMAN users are asked to enter information from their universities. The total demand and base price models will solve for the campus wide equilibrium total commuter student parking demand and base permit price. Users of the SPARKMAN program can either accept the equilibrium solutions or manually override these solutions. SPARKMAN then executes the Z2P2 methodology to define zones and calculate the annual permit price of each zone. An instructional video on how to use SPARKMAN has also been produced.

Task 3 – Conduct survey on ITS Preferences and LOS Criteria

The third task was to conduct a survey to understand students' preferences among different ITS applications that can potentially apply to manage campus parking. With the approval of the Institutional Review Board (IRB), the survey was conducted on the UTEP campus from February 27 to April 25 2019. This survey involved 1,022 student participants, of which 533 were commuter student parking permit holders. The survey consisted of a question that asked the students' opinion on LOS for parking search time. Based on the feedback received, the LOS criteria for parking search time were proposed.

1.4 Outline of Report

The outline of this report is as follows:

- Section 1 explains the background of this project, the objectives and research methodology.
- Section 2 reviews the pre-developed models, the concept of zoning, Value of Time (VoT) and ITS technologies for parking.
- Section 3 introduces the Z2P2 methodology.
- Section 4 describes the coding of SPARKMAN.
- Section 5 describes the survey including students' preferences for ITS applications and the resulting LOS criteria for parking.
- Section 6 concludes this project with remarks, limitations and potential future work.

Section 2 Literature Review

This section reviews the models, concepts and technologies that have been developed to support the execution of the research tasks. This section has five sub-sections.

2.1 Total Demand Model

One of the challenges faced by CPOs is the difficulty in predicting parking demand. To predict the total number of commuter students who will buy parking permits, Gurbuz et al. (2019) have developed a model called the total demand model. They collected data from 208 universities in the U.S., all of which offered bachelor', master and Ph.D. degrees and have enrollment above 10,000. Attributes of each university were collected from publicly available websites. The attributes from the 208 universities were used to develop a Beta regression model which predicts the proportion of students who will purchase permits (Y). The fitted Beta regression model takes the form of

$$Y = \frac{\exp(U)}{1+\exp(U)} \quad (2.1)$$

$$U = 0.019X_1 - 0.00000915X_2 - 1.349X_3 + 3.134X_4 - 0.002P_{base} \quad (2.2)$$

where

X_1 is the average fall semester temperature (F);

X_2 is the in-state tuition fee (\$/year);

X_3 is the proportion of undergraduate students;

X_4 is the proportion of part-time students; and

P_{base} is the base price of student parking permits (\$/year). The base price is the median price of all categories of student parking permits.

2.2 Base Price Model

Another challenge faced by CPOs is the difficulty of setting permit prices. As the first step in determining zone specific permit prices for commuter students, Gurbuz et al. (2019) have developed a model called the base price model. The base price is the median price of all categories of student parking permits on a campus. Using the same data set from 208 universities in the U.S., Tobit regression analysis was applied to fit the data. The recommended base price model is:

$$P_{base} = 154.71 X_5 + 2.98 X_6 - 293.08 X_3 + 2187.71 X_7 - 516.81 X_8 \quad (2.3)$$

where

X_5 is the campus setting (1 for urban, 0 otherwise);

X_6 is the cost of living (\$/day);

X_7 is the faculty to student ratio; and

X_8 is the number of students who will purchase parking permits, which is Y multiplied by enrollment.

Since Equations (2.1), (2.2) and (2.3) have variables that are related, Gurbuz et al. (2019) have developed an iterative procedure to solve for Y and P_{base} .

2.3 Zoning

A university has many parking lots across the campus. The lots have different distances and travel times to the campus core. The parking lots are generally identified by numbers or letters. The parking lots in the same area are grouped into a zone and this practice is called zoning. CPOs usually sell zone specific commuter student permits. Only commuter students who have purchased permits for a zone may park in that particular zone. Permits for different zones are priced differently to manage demand. According to Zhang et al (2011), zoning is the key solution when managing a limited supply of parking stalls.

The CPOs may use the parking lots' proximity to the campus core as the criterion to set zones. Permits for parking lots which are closer to the campus core are sold at higher prices compared to other zones. Zoning and pricing allow CPOs to control demand between different zones. When the permit price of a zone increases, demand is more likely to shift to cheaper zones.

Until now, there has been no scientific approach for zoning and determining the permit prices for different zones. CPOs use their experience with a trial and error approach to define zones and set permit prices. The only consideration is the proximity of a zone to the campus core. Some universities like California State University at Fullerton (Fullerton, 2019) set permit prices for remote parking lots 70% cheaper than permit prices for closer lots. Some other universities make parking at remote lots totally free. Examples of such universities are Massachusetts Institute of Technology (MIT, 2019), University of Nevada at Las Vegas (UNLV, 2019), University of Oklahoma (OU, 2019), University of North Texas (UNT, 2019), New Mexico State University (NMSU, 2019), University of Vermont (UVM, 2019).

2.4 Value of Time

The Value of Time (VoT) is widely used by transportation agencies and engineers in making investment and policy decisions (USDOT, 2016). The history of the VoT was discussed by Jara-Diaz and Guevara (1999) and Mackie et al. (2001). Many researchers have developed models to estimate the VoT. The USDOT publishes guidance on VoT every year since 1997 to assist transportation planners and engineers in making consistent project evaluations. The VoT estimation is based on hourly income, which can be estimated from household income data gathered by the US Census Bureau. The USDOT defines

three types of trips for the estimation of VoTs. They are: local travel by surface modes, intercity travel by surface modes, and intercity travel by air. For commuting students, the trips to university are local travel by surface modes. According to USDOT, the VoT for this type of trip is estimated at 50% of hourly median income. On the other hand, the VoT is subjected to trip purpose and income variation across drivers. For this reason, USDOT gives a plausible range of VoT (see Table 2.1).

Category	Surface Modes (except High Speed Rail)	Air and High Speed Rail
Local Travel		
Personal	35% - 60%	--
Business	80% - 120%	--
Intercity Travel		
Personal	60% - 90%	60% - 90%
Business	80% - 120%	80% - 120%

Table 2.1: Value of time as percent of median hourly income (USDOT, 2016)

Hess et al. (2004) conducted a student survey at the University of California, Los Angeles (UCLA). They found that the VoT of a UCLA student in 2004 was \$8.50/hr or \$0.14/min. The equivalent VoT in 2007 dollars was \$0.18/min (\$10.98/hr).

2.5 ITS for Parking

Intelligent Transportation Systems (ITS) are gaining popularity as tools to manage parking problems. According to the International Parking Institute (IPI, 2018), half of the top ten emerging trends in parking were related to ITS. They were:

- Mobile smartphone applications;
- Technologies to improve access control;
- Guidance systems to help drivers find parking;
- Technologies for electronic payment; and
- Vehicle automation for self-parking.

Kotb et al. (2017) reviewed ITS techniques and systems for parking. Their focus was to use ITS to provide information for parking guidance, monitoring, and reservation. In ITS, parking information is disseminated by dynamic message signs, through mobile devices, or with geographic information system technologies (Vlahogianni et al., 2016). Teodorovic and Lucic (2006) stated that drivers with parking information had lower parking search time, energy consumption and gas emissions. Caicedo et al., (2006) declared that real-time parking occupancy information led to less effort in search of parking stalls.

In the context of university campus parking, ITS may assist CPOs in the following applications:

- Online permit sales;
- Access control;
- Enforcement;
- Lot occupancy/availability information;
- Dynamic pricing; and
- Real-time, pay-as-you-park.

CPOs tend to sell parking permits by semester or annual basis. Permits go on sale before the semester starts. Although some CPOs give senior students (UCLA, 2019; KU, 2019a), or existing permit owners (OSU, 2019) earlier time windows to purchase permits, most of them sell permits on a first-come-first-serve basis. In some campuses where capacity is low compared to demand, further restrictions on sales of parking permits are put in place. For example, at University of California, San Diego (UCSD, 2019) and Stanford University (Stanford, 2019), freshman students are not allowed to purchase parking permits. Irrespective of the policy, the sale and purchase of parking permits may be made convenient and transparent to users via online portals. The user experience should be similar to buying air tickets, concert tickets and booking hotel rooms.

Access control and rule enforcement are two common applications of the ITS for parking. Some CPOs use image processing systems to identify and recognize license plates. This system uses the license plates as parking permits. This eliminates the need for physical parking permits. Any new permit purchase can be done through the online permit sales system that is linked with the license plate recognition-based access control and enforcement systems. Examples of universities which use license plate recognition technology are Stanford University (Stanford, 2019), University of Kansas (KU, 2019b), and University of North Dakota (UND, 2019).

Parking occupancy/availability information are important inputs for CPOs to make policy decisions and drivers to make parking decisions. With real-time stall availability information communicated to drivers via smart devices or dynamic message boards, drivers can plan their trips and routes to available parking stalls.

For open surface parking lots, there are two ways to collect vehicle occupancy data: (1) by entry-exit barrier counts; (2) by image processing techniques. Figure 2.3 is a satellite image that covers an open parking lot overlaid by outputs of an image processing algorithm which detects the number of vehicles. Similar approaches can be used to capture stall occupancy with pre-installed cameras at parking lots.

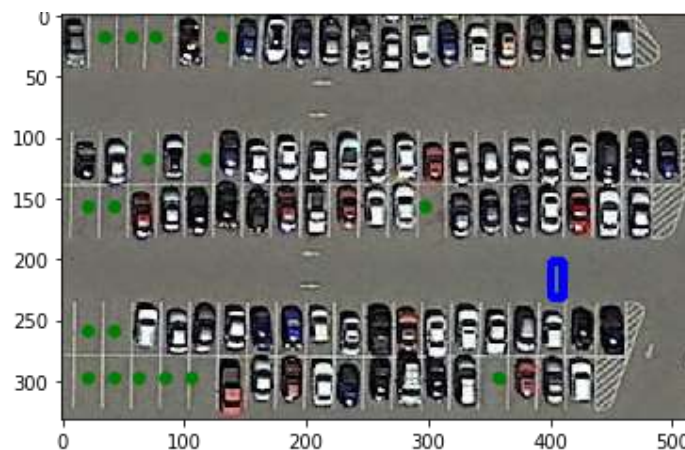


Figure 2.1: Image processing applied to an open surface parking lot

Dynamic pricing in parking is an extension of congestion pricing which has been tested in downtowns of London, Singapore, Stockholm, and San Francisco (Pierce and Shoup, 2013). The FHWA defined this as performance-based parking pricing (FHWA, 2018). The City of San Francisco introduced the SFPark parking management and pricing system in 2011 (SFPark, 2018). In this system, parking occupancy data at more than 6,000 stalls were collected 24/7. The city adjusted parking prices by location, occupancy, time-of-day and day-of-week every month. Seattle (SDOT, 2018), Los Angeles (LA Express Park, 2018), and District of Columbia (DDOT, 2018) have already implemented dynamic pricing for their downtown parking. To the best of the authors' knowledge, no university has implemented dynamic parking pricing yet.

The existing semester or annual permit system is a fixed price pre-paid system. Once a driver has purchased a permit, he/she can park as long as possible. This system does not lead to efficient use of the limited number of parking stalls. By making students park their vehicles on campus only when it is necessary, a stall may be used by more vehicles. The CPO may be selling more permits. In the pay-as-you-park system, permit holders pay for usage of stalls like telephone bills, carsharing and bike sharing. The

pay-as-you-park system may be combined with mobile applications, access control systems, lot occupancy/availability information system and dynamic pricing.

Section 3 Development of Z2P2 methodology

3.1 Approach

Universities provide parking lots that are spread across campus. Some lots are closer to the campus core, while some are located at the perimeter, remote or satellite areas. CPOs assign one or group several adjacent parking lots into a zone. Every zone has its own student parking permits which are sold at the same prices per semester or per year. Permit holders are only allowed to park in the zone specified in their permits. The permit price of a parking zone is dependent on the proximity of the zone to the campus core. This section of the report introduces the Zoning and Zone Permit Pricing (Z2P2) methodology which is a scientific approach in zoning and setting the permit price for each zone.

The methodology assumes that:

1. All students make “last-mile” trips from their parked vehicles to final destinations on campus;
2. All last-mile trips end at the center of student activities if trip destination data are not available;
3. Students save Last-Mile Travel Time (LMTT) when they park closer to their final destinations; and
4. The savings in LMTT is converted to a monetary value by using the VoT of commuter students.

The Z2P2 methodology is based on the following approach:

1. The first step is to locate the centroids of the campus core and each parking lot, assuming that the campus core is the final destination of all last-mile trips.
2. Between each parking lot and campus core (origin-destination pair), transportation options (e.g., walking, bicycling, shuttle bus plus walking) are identified and mode specific travel times estimated.
3. For each parking lot-campus core pair, the average LMTT is taken as the average travel time of all the available modes, weighted by the mode shares.
4. Parking lots that are physically in proximity have similar LMTTs. These parking lots may be grouped to form a zone. The zones are sorted in increasing order of weighted average LMTT.
5. From this sorted list, the median average LMTT is identified. The zone that has the median average LMTT (denoted by $LMTT_{base}$) is called the “base” zone and is assigned the base price (P_{base}).
6. The next step is to determine zone z ’s parking permit price (P_z). Zones that are closer to the campus core, that have average LMTT ($LMTT_z$) lower than $LMTT_{base}$, will have permits sold at prices P_z above the base price P_{base} . That is, if $LMTT_z < LMTT_{base}$, then $P_z > P_{base}$. On the other hand, zones that have $LMTT_z > LMTT_{base}$ will have $P_z < P_{base}$. Note that, the base price P_{base} is a reference from which other zones’ permit prices P_z are calculated. A CPO may decide to arbitrarily set the base price according to its established policy. In this case the proposed Z2P2 methodology is still applicable.

3.2 Value of Time of Students

The concept of VoT has been reviewed in Section 2. This sub-section describes a methodology that estimates the VoT for university students that is used as an input to the Z2P2 methodology.

The following equation converts the median annual household income to VoT for students:

$$VoT (\$/minute) = \frac{C \times \text{median annual household income}}{\text{average working minutes in a year}} \quad (3.1)$$

where C is the coefficient that converts the {average household income per working minute} to VOT for commuting trips to university (in \$/minute). The coefficient C was calibrated using the following data from Los Angeles, California in 2017:

- VoT for students at UCLA = \$10.98/hour or \$0.183/minute (Hess et al., 2004);
- Median annual household income in Los Angeles county = \$61,015 (Census, 2017); and
- Average working time = 2,080 hours/year or 124,800 minutes/year (USDOT, 2016).

The above values gave $C=0.37$. Note that the C value takes into account the average household size and different trip purposes.

3.3 Z2P2 Methodology

This sub-section describes the Z2P2 methodology. The methodology consists of four steps. In steps 1 and 2 calculations are based on lots. In steps 3 and 4 calculations are based on zones.

Step 1: Determine the weighted average lot-based LMTT

- Identify the geographical centers of each parking lot and campus core.
- Assume that the final destination of all the commuter student trips is the campus core.
- Between each parking lot and campus core, identify (i) transportation modes; (ii) the travel times of the different modes; (iii) the mode shares; and (iv) calculate the average lot-based LMTT weighted by mode shares.

Step 2: Group parking lots into zones

- Sort the list of parking lots in increasing order the weighted average lot-based LMTT.
- From the sorted list, identify adjacent parking lots of the same type (e.g., open surface lots) that have similar weighted average LMTTs. Group these adjacent lots into a zone. A zone consists of one or multiple lots of the same type of parking facility (typically open surface lots or parking garages).

Step 3: Identify the base zone and base permit price

- For each zone (zone z), calculate the weighted average LMTT from the centroid of the zone to the campus core. Denote this as $LMTT_z$. This $LMTT_z$ may be estimated by taking the average LMTT of the lots within the zone weighted by the lot capacities (number of stalls).
- Sort the list of zones in increasing order of $LMTT_z$.
- Identify the zone that gives the median $LMTT_z$. Name this zone the “base zone” and assign the base permit price P_{base} to this zone. The P_{base} may be calculated by using Equation (2.3). Alternatively, a CPO may due to constraint or policy set a different P_{base} value.

Step 4: Calculate the permit prices of all the zones

After deciding the base zone and P_{base} , the permit prices (P_z) of the remaining zones (zone z) are calculated by:

$$P_z = [P_{base} + (LMTT_{base} - LMTT_z) \times VoT \times 2D]a_z \quad (3.2)$$

where:

P_z is the annual permit price of zone z (\$/year);

P_{base} is the annual base permit price (\$/year);

$LMTT_{base}$ is the last-mile travel time from the base zone to the campus core (minutes/trip);

$LMTT_z$ is the last-mile travel time from zone z to the campus core (minutes/trip);

VoT is the value of time of commuter students (\$/hr);

D is the average number of days in a year a student will drive to campus (days/year);

The factor 2 is to account for round trips between zone z and the campus core per day; and

a_z is the price adjustment factor for zone z .

The permit price adjustment factor is to increase the cost of parking in a garage to recover the garage’s operations and maintenance cost. Since parking garages provide shelter and limited access to users, their permit prices are expected to be higher compared to open surface lots or zones. Kenney (2014) found that the cost of maintaining and operating a stall in a garage was three times the cost of maintaining and operating an open surface stall. Without considering the construction costs of the open surface lots and multi-story garages, for which data are difficult to obtain, the price adjustment factor may be written as:

$$a_z = \begin{cases} 1 & \text{if } z \text{ is an open surface lot} \\ \frac{3 \times ns_g + ns_s}{ns_g + ns_s} & \text{if } z \text{ is a parking garage} \end{cases} \quad (3.3)$$

where:

a_z is the price adjustment factor for zone z ;

ns_g is the total number of parking stalls in parking garages on the entire campus;

ns_s is the total number of parking stalls in surface lots on the entire campus.

P_z , the annual permit price of zone z in\$/year, is then pro-rated to the permit price per semester, during the summer, and any period.

3.4 Case Study

This sub-section reports a case study conducted to demonstrate the application of the Z2P2 methodology. The University of Texas at El Paso (UTEP) was selected for the case study. This case study used data from the 2017-18 academic year. UTEP sold commuter student parking permits by lots and permit holders were allowed to park only in the permitted lots. In this scenario, every zone had only one lot. The university did not allow students to drive to the campus core. Majority of commuter students parked outside the core area and walked to their final destinations.

The case study started with selecting a geographic center for the campus. Leech Grove was assumed as the center of the campus since it is centrally located and at the intersection of many pedestrian routes (Figure 3.1).

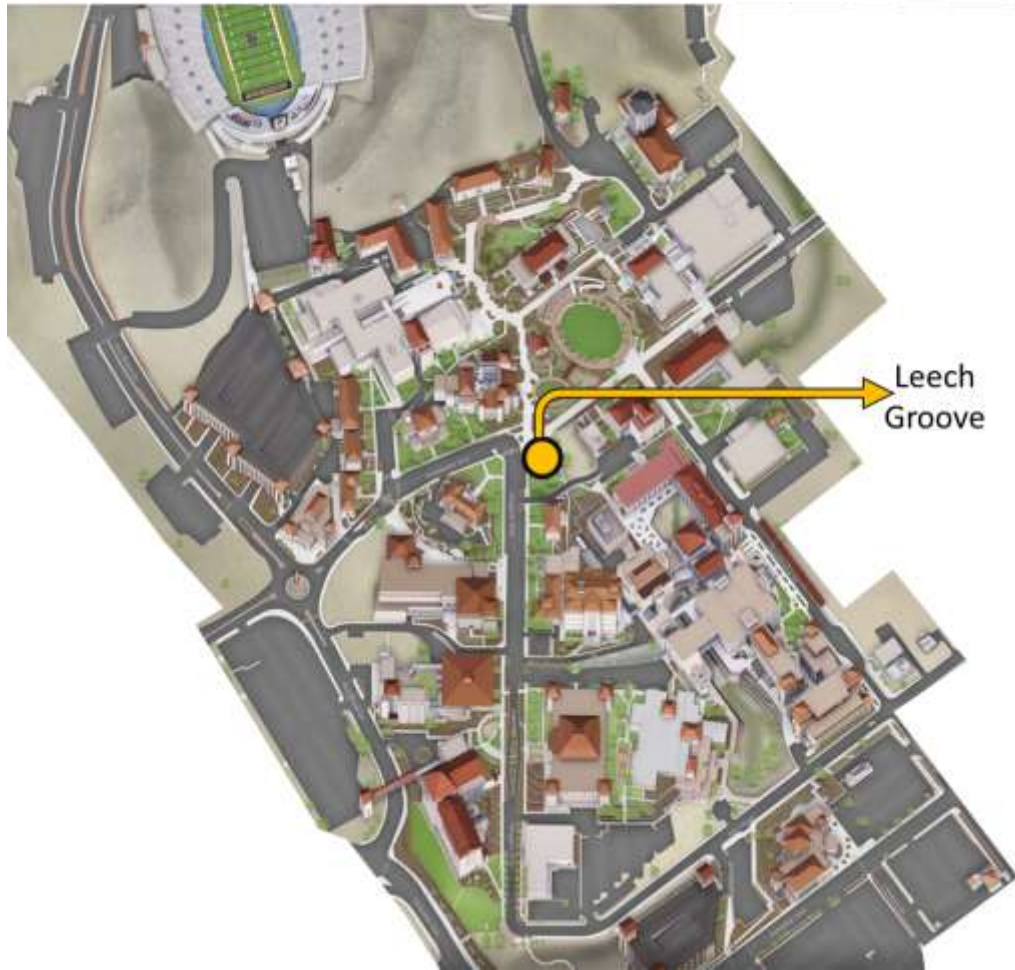


Figure 3.1: UTEP map showing the campus core (Leech Grove)

In UTEP, during the 2017-18 academic year, 19 of the 22 parking lots were open surface lots. The remaining three facilities were parking garages. The travel times by walking from the centroid of each lot to the campus core (denoted by TT_z^{walk}), by bicycling (denoted by $TT_z^{bicycle}$), and by shuttle bus followed by walking from the bus stops (denoted by TT_z^{bus}) were measured on-site. The last-mile mode shares were taken from data gathered in a student survey (covered in Section 5). These data are shown in Table 3.1. All the travel time values have been rounded to the nearest 0.5 minute. The parking lots which are not served by the campus shuttle bus system have their $LMTT_z^{bus}$ filled as “N/A”. Using the data in Table 3.1, the median $LMTT_{base}$ was found to be 8.5 minutes, at parking lots SC3, SC4, SB5, and OR2. They are all open surface lots.

Parking zone (z)	$P_{z,actual}$ (\$/year)	TT_z^{walk} (minutes)	Walking mode share (%)	$TT_z^{bicycle}$ (minutes)	Bicycling mode share (%)	TT_z (minutes)	TT_z^{bus} (minutes)
SBG	\$319.50	6.0	100%	5.0	0%	4.0	N/A
SB2	\$240.75	5.5	100%	5.0	0%	4.5	N/A
SB3	\$240.75	4.5	100%	4.0	0%	4.5	N/A
DA1	\$188.25	5.0	100%	5.0	0%	5.0	N/A
SB4	\$240.75	6.0	100%	5.5	0%	6.0	N/A
SG	\$319.50	8.5	100%	7.0	0%	7.0	N/A
RA2	\$240.75	7.0	100%	7.0	0%	7.0	N/A
GR3	\$188.25	8.0	100%	7.5	0%	8.0	14.0
SC4	\$188.25	8.5	100%	7.0	0%	8.5	N/A
SC3	\$188.25	8.5	100%	7.5	0%	8.5	N/A
OR2	\$188.25	8.5	100%	7.0	0%	8.5	13.0
SB5	\$188.25	8.5	100%	8.0	0%	8.5	N/A
SB6	\$188.25	9.0	100%	8.0	0%	9.0	N/A
SC5	\$188.25	9.5	100%	7.0	0%	9.5	N/A
SC2	\$188.25	9.5	100%	8.0	0%	9.5	N/A
GR2	\$188.25	10.0	96%	9.5	4%	10.0	17.0
GR5	\$188.25	10.0	100%	8.0	0%	10.0	14.0
SC1	\$188.25	10.0	99%	9.0	1%	10.0	N/A
GRG	\$246.00	12.0	100%	8.0	0%	11.5	14.0
GR1	\$188.25	11.5	100%	10.5	0%	11.5	19.0
Rem	\$138.05	15.0	100%	12.5	0%	12.5	12.5
Rem2	\$138.05	25.0	100%	15.0	0%	15.0	15.0

Table 3.1: Lot-base data for weighted average LMTT calculations

Next, it was assumed that parking zones are the same as the existing lots. That is, every lot is a unique zone. This assumption was necessary so that the resulting zone permit prices may be compared with the actual permit sale prices $P_{z,actual}$. Therefore, the base zones were SC3, SC4, SB5, and OR2. Using Equation (2.3) with UTEP information, base price was calculated as \$235/year. On the other hand, the actual permit price set by the UTEP CPO for the 2017-18 academic year was \$188.25/year (see Table 3.1). Two alternatives have been analyzed for this case study. The first alternative assumed $P_{base} = \$235/\text{year}$, whereas, the second alternative considered $P_{base} = \$188/\text{year}$.

For the calculations of P_z for all the remaining zones, Equation (3.2) was used. In the calculations, it was assumed that an average UTEP student goes to campus 4 days a week, 32 weeks in an academic year. Therefore, $D=128$ days.

Majority of the UTEP student population comes from the El Paso region. The median household income for El Paso County was reported in Census (2017) as \$43,244. Based on Equation (3.1), the VoT of an average UTEP student was \$0.13/min.

For the two P_{base} alternatives, the calculated P_z values are presented in Table 3.2. The first alternative assumed that $P_{base} = \$235/\text{year}$. The second alternative considered $P_{base} = \$188/\text{year}$ (the current practice).

z	P_{actual} (\$/year)	Alternative 1	Alternative 2
SBG	\$319.50	\$574.29	\$477.40
SB2	\$240.75	\$342.90	\$287.85
SB3	\$240.75	\$367.80	\$321.05
DA1	\$188.25	\$351.20	\$304.45
SB4	\$240.75	\$318.00	\$271.25
SG	\$319.50	\$413.60	\$331.32
RA2	\$240.75	\$284.80	\$238.05
GR3	\$188.25	\$251.60	\$204.85
SC4	\$188.25	\$235.00	\$188.25
SC3	\$188.25	\$235.00	\$188.25
OR2	\$188.25	\$235.00	\$188.25
SB5	\$188.25	\$235.00	\$188.25
SB6	\$188.25	\$218.40	\$171.65
SC5	\$188.25	\$201.80	\$155.05
SC2	\$188.25	\$201.80	\$155.05
GR2	\$188.25	\$185.20	\$138.45
GR5	\$188.25	\$185.20	\$138.45
SC1	\$188.25	\$185.20	\$138.45
GRG	\$246.00	\$209.09	\$126.81
GR1	\$188.25	\$135.40	\$88.65
Rem	\$138.05	\$102.20	\$55.45
Rem2	\$138.05	\$19.20	\$0.00

Table 3.2: Lot-based permit prices from case study at UTEP campus

Figure 3.2 shows the variations and the comparison of the P_z values for the two alternatives. The orange bars in Figure 3.2 demonstrate the actual prices, the dark blue ones are findings of the alternative 1 ($P_{base} = \$235/\text{year}$) and the white bars represent the findings of alternative 2 ($P_{base} = \$188/\text{year}$) results. As it can be seen both from Table 3.2 and Figure 3.2, the actual permit prices used by UTEP CPO in 2017-18 have some issues. First, the lots were not grouped based on proximity to the campus. That is,

parking lots with similar LMTTs but located at different parts of the campus did not have the same actual permit price. For example, students who purchased an annual parking permit for DA1 parking lot pay the same amount as a parking permit for GR1. However, students who parked at DA1 saved 13 minutes/day in LMTT relative to GR1 (see Table 3.1). On the other hand, the Z2P2 methodology sets prices differently for all the zones (see Table 3.2).

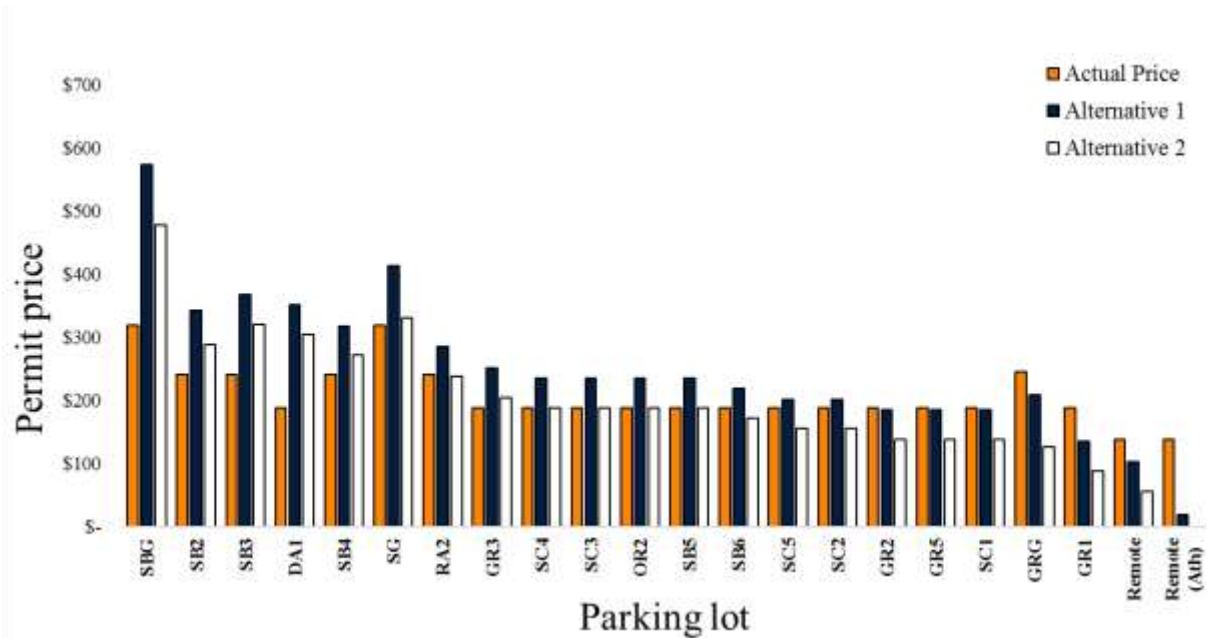


Figure 3.2: Comparison of lot-based permit prices in \$/year at UTEP campus

Section 4 Development of SPARKMAN

4.1 Background

SPARKMAN is a Microsoft Excel-based tool that has integrated the: (1) total demand model, (2) base price model, and (3) Z2P2 methodology, to help CPOs to make zoning and zone pricing decisions. The Total demand model (Equation (2.1)) and base price model (Equation (2.2)) were developed previously by Gurbuz et al. (2019). They have been reviewed in Sections 2.1 and 2.2 respectively. The Z2P2 methodology was developed as Task 1 of this research. This methodology was introduced for the first time in Section 3. This section describes the SPARKMAN software tool.

4.2 System Requirement and Installation

SPARKMAN's target users are the staff of CPOs. Since all universities provide Microsoft Office to their staff as a standard software tool and most of the staff are expected to be familiar Microsoft Excel users, Microsoft Excel was selected for the environment to develop SPARKMAN. SPARKMAN has been coded as a Microsoft Excel macro in a file called "Sparkman.xlsm" using the Visual Basic for Applications (VBA) programming language. The current version of SPARKMAN, Version 1.0, was coded and tested in Microsoft Excel for Office 365.

To install SPARKMAN, a user may simply download the "Sparkman.xlsm" file from the C2SMART website (www.c2smart.engineering.nyu.edu), save it in a local folder, then click on the "Sparkman.xlsm" file icon to open it. This will automatically execute the pre-installed Microsoft Excel with the macro and display a dashboard on the screen. Before the addition of the Excel macro, the user may be asked by Excel to "enable content". He/she must answer "yes" in order to proceed. With the initialization of the tool, a welcome screen pops-up introducing the tool with the funding acknowledgement and the author's credit (Figure 4.1). Upon closing the welcome box, the user will see a dashboard such as the one shown in Figure 4.2.



Figure 4.1: SPARKMAN's welcome screen

4.3 Dashboard

The dashboard (Figure 4.2) is the primary screen where users interact with SPARKMAN. There are two panels in the dashboard: (i) the input panel on the left and (ii) the output panel on the right. The input panel is for users to enter data or make changes to the data. The output panel displays the results. The "RESET FORM" function in the bottom left corner is to clear all memory and to start a new analysis case. In addition, users may click the "FURTHER INFORMATION" button to access related publications. Finally, users have the chance to provide comments to the software developers via the "GIVE FEEDBACK" button at the bottom right corner.

The dashboard is divided into three main sections:

- INPUT PANEL:** Contains three input fields: "Please select the location of the university", "Please select the university setting:", and "Please enter information related to your university". Below these are buttons for "ABOUT UNIVERSITY" (with a 'P' icon), "PRICING" (with a '\$' icon), and "RESET FORM" (with a red circle icon).
- OUTPUT PANEL:** A table with the following structure:

EXPECTED DEMAND	Name of the Parking Lot	Current Price	Proposed price with current base price	Proposed price with model result
#N/A students				
CURRENT BASE PRICE				
#NUM! per year				
MODEL BASE PRICE				
#N/A per year				

 Below the table is the "SPARKMAN" logo and the text "Version 1.1, January 02, 2020".
- Navigation/Action Buttons:** On the right side, there are three buttons: "EXIT SPARKMAN" (with a red 'X' icon), "FURTHER INFORMATION" (with an 'i' icon), and "GIVE FEEDBACK" (with a speech bubble icon).

Figure 4.2: SPARKMAN’s dashboard

4.4 Input Panel

In the input panel, the first item to enter is the location of the university. SPARKMAN has embedded information of the 580 counties across the United States. Users are asked to type the university’s location and with the help of SPARKMAN, select the correct county name. The location information is used to determine the average fall semester temperature (an input for the total demand model), the daily per-diem (an input for the base price models), and the annual household income of the county to derive the VoT.

The second input is to pick the correct university setting: urban or rural. This information is used in the base price model.

The third step is to click the button called “ABOUT UNIVERSITY”. This button activates a pop-up window (Figure 4.3) which asks the user to enter more detailed information about the university including:

- In-state tuition and fees (\$ per academic year, fall and spring semesters);
- Full-time equivalent enrollment;
- Number of part-time students;
- Number of undergraduate students;
- Number of full-time faculty;
- Number of part-time faculty; and
- Number of student parking permit holders.

A university's CPO, the registrar office and the public information webpage are expected to have this information. After all the requested values have been entered, the user should click the "SAVE" button to save the data followed by the "EXIT" button to return to the dashboard.

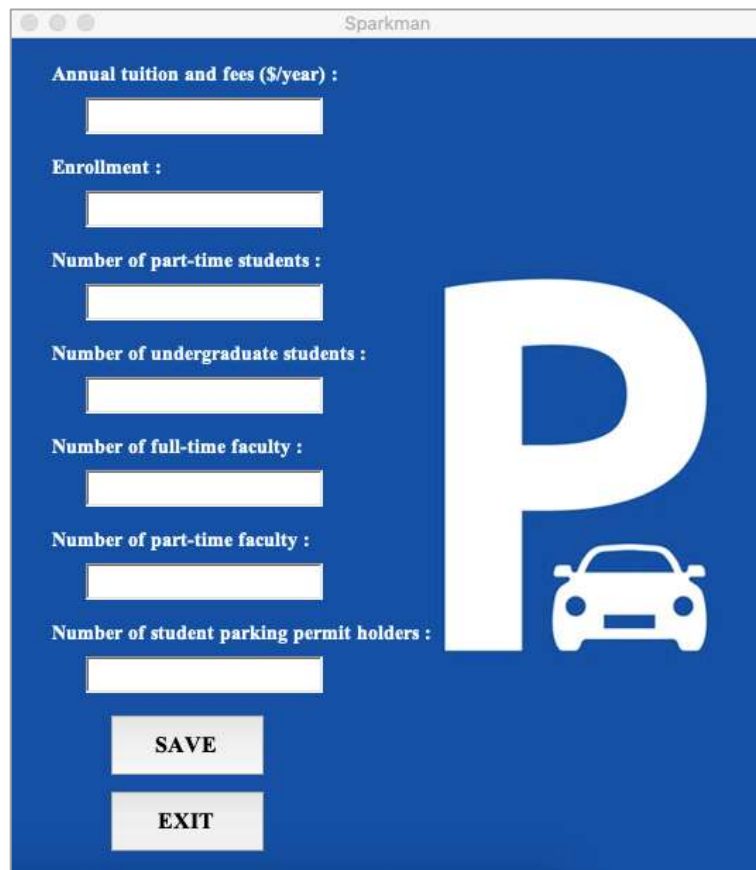
The image shows a web application window titled "Sparkman". The background is blue. On the left side, there are seven input fields, each preceded by a label: "Annual tuition and fees (\$/year) :", "Enrollment :", "Number of part-time students :", "Number of undergraduate students :", "Number of full-time faculty :", "Number of part-time faculty :", and "Number of student parking permit holders :". Each label is in white text. To the right of these fields is a large white letter "P" with a white car icon parked in front of it. At the bottom of the form are two buttons: "SAVE" and "EXIT", both in white text on a blue background.

Figure 4.3: SPARKMAN's input panel for university-wide data

The last step to provide input data is to click the "PRICING" button. This action will open a series of the same pop-up windows. Each pop-up window (Figure 4.4) asks the user to enter detailed information about one parking lot and the available transportation options to travel to the center core of the campus. The user can navigate from one pop-up window to the next by clicking the "SAVE" button. The "EXIT" button directs the user back to the dashboard after the information for the last parking lot have been entered. As a university has many parking lots, the user is recommended to gather the following information for all the parking lots before entering the data into SPARKMAN:

- Name of the parking lot;
- Number of available stalls for students;
- Price of a student parking permit (\$ per academic year);
- Type of parking facility: “open surface lot” or “parking garage”;
- Walking time from the parking lot to the campus core (minutes);
- Lot served by campus shuttle bus system: “yes” or “no”;
- If the parking lot is served by a shuttle bus system, provide the
 - Average waiting time for shuttle bus at the parking lot (minutes);
 - Average time riding in the shuttle bus (minutes); and
 - Walking time from the bus stop to the campus core (minutes).

To collect the above data, it is important to first identify a point on campus as the campus core, the transportation options between each parking lot and the campus core, and the respective travel times. Field measurement may be necessary.

Once the user has completed the data entry by clicking the “EXIT” button, SPARKMAN will proceed to perform the calculations and display the results in the output panel.

Sparkman

Name of the parking lot :

Number of available stalls for students :

Student permit price (\$/year) :

Type of facility :

☐ Open Surface Lot ☐ Parking Garage

Walking time from that parking lot to campus core (min)

Is shuttle service available? :

NO YES → Average shuttle waiting time (min) :

Time riding in the shuttle (min) :

Walking time from shuttle stop to campus core (min)

SAVE

EXIT

Figure 4.4: SPARKMAN's input panel for parking lot data

4.5 Output Panel

The output panel consists of two blocks. The block on the left lists the estimated total demand, the current base price and the recommended base price:

- The total demand is the number of commuter students on the entire campus who are expected to purchase parking permits. The value is estimated by solving Equations (2.1), (2.2) and (2.3) iteratively (Gurbuz et al., 2019).
- The current base price is the median price of the student parking permits of all zones. It is determined by sorting the permit prices of all lots in increasing order (ignoring the number of permits in each zone) and then selecting the median price.
- The recommended base price is calculated using Equation (2.3) using the iterative solutions of Equations (2.1), (2.2) and (2.3).

The block on the right-hand side displays the lot-based permit prices. Here, Version 1 of SPARKMAN assumes that every parking lot is a zone by itself. Each parking lot occupies one row and has three permit prices:

- Current price, which was taken directly from the input data
- Proposed price calculated by deviating from the current base price
- Proposed price calculated by deviating from the recommended base price

The proposed prices are calculated by the Z2P2 methodology, using Equations (3.2) and (3.3) as described in Section 3. These give the user two options of new permit prices and can easily be compared with the current prices.

4.6 Case Study

This section presents a case study using a university campus as an example to illustrate the application of SPARKMAN Version 1.

The UTEP campus was selected for the case study. The UTEP campus setting has been described in Section 3, where parking data were used to demonstrate the Z2P2 methodology. In this section, the input data, taken from the Fall semester of 2017, were entered into SPARKMAN Version 1. The campus-wide inputs to SPARKMAN were:

- In-state tuition and fees = \$ 7,651/year, fall and spring semesters
- Student enrollment = 25,078 full-time equivalent
- Number of part-time students = 9,642
- Number of undergraduate students = 21,341
- Number of full-time faculty = 789
- Number of part-time faculty = 360
- Number of student parking permit holders = 12,030

Results from the output panel are shown in Figure 4.5.

Comparing the recommended base price and the current base price for the UTEP case, it has been found that model base price overestimated the actual price by a difference of \$47/year. SPARKMAN provided the proposed permit prices for each parking lot based on both base permit prices in the output panel. The first column represents the actual prices, the second column lists the proposed prices using the current base price, and last column lists the prices based on the base permit price model outcome. Comparing the results with the actual prices, some parking lots were underpriced (e.g., SBG, SB2, SB3, DA1, SB4). On the other hand, other parking lots were overpriced (e.g., SC1, GRG, GR1, Remote).

OUTPUT PANEL				
EXPECTED DEMAND	Name of the Parking Lot	Current Price	Proposed price with current base price	Proposed price with model result
16,599 students	SBG (garage)	\$319.50	\$477.40	\$574.29
	SB2	\$240.75	\$287.85	\$342.90
CURRENT BASE PRICE	SB3	\$240.75	\$321.05	\$367.80
\$188.00 per year	DA1	\$188.25	\$304.45	\$351.20
	SB4	\$240.75	\$271.25	\$318.00
MODEL BASE PRICE	SG (garage)	\$319.50	\$331.32	\$413.60
\$235.00 per year	RA2	\$240.75	\$238.05	\$284.80
	GR3	\$188.25	\$204.85	\$251.60
	SC4	\$188.25	\$188.25	\$235.00
	SC3	\$188.25	\$188.25	\$235.00
	OR2	\$188.25	\$188.25	\$235.00
	SB5	\$188.25	\$188.25	\$235.00
	SB6	\$188.25	\$171.65	\$218.40
	SC5	\$188.25	\$155.05	\$201.80
	SC2	\$188.25	\$155.05	\$201.80
	GR2	\$188.25	\$138.45	\$185.20
	GR5	\$188.25	\$138.45	\$185.20
	SC1	\$188.25	\$138.45	\$185.20
	GRG (garage)	\$246.00	\$126.81	\$209.09
	GR1	\$188.25	\$88.65	\$135.40
	Remote	\$138.05	\$55.45	\$102.20
	Remote 2	\$138.05	\$0.00	\$19.20

Figure 4.5: SPARKMAN's output panel

4.7 User Feedback

Task 5 of this project included an assessment of the user-friendliness of SPARKMAN Version 1. This evaluation was conducted with the help of the members of the Campus Parking and Transportation Association (CPTA). The CPTA (<https://www.cptaonline.org/>) was formed in 1991 to “promote and represent the parking industry on the campuses of colleges and universities” (CPTA, 2020). CPTA has 163 Education Affiliate Members from 70 universities. These members are the responsible officers of UPOs. The list of Education Affiliate Members, universities and contact information (including email addresses and telephone numbers) were downloaded from the CPTA's website. The research team contacted Mr. Gary Smith, Secretary of CPTA, on June 6, 2019 and started to engage CPTA early in the project. He kindly agreed for the project team to invite members of CPTA to perform the evaluation of SPARKMAN.

When SPARKMAN Version 1 was ready to be tested, the research team applied for UTEP's Institutional Review Board (IRB) exemption and obtained approval on October 11, 2019. Email requests were sent to 76 Education Affiliate Members (whom the authors had contact information) on October 14,

2019. The emails included SPARKMAN Version 1 as an attached file, the link to the instruction video, and the link to the QuestionPro website where respondents could enter their comments. Alternatively, the evaluators could provide written feedback by replying to the emails. These initial email requests were followed by email reminders, sent on January 9, 2020. Telephone calls were made to the numbers provided in the official membership roster between January 20, 2020 and February 21, 2020. These telephone calls were to remind the invited CPTA members about the evaluation. The telephone calls also gave the researchers opportunities to explain the project and what was expected from the evaluators.

Because the researchers were able to speak to the CPTA members directly, numerous feedback was obtained from the telephone conversations. The delay in responses and low response rate were due to several reasons:

1. Most potential evaluators were too busy performing their duties in their day-to-day job functions;
2. Some email recipients thought that the invitation emails were junk emails, or from a vendor that tried to promote a commercial product;
3. Some universities did not have the data or part of the data that were required as inputs to SPARKMAN Version 1; and
4. Some potential evaluators thought that they must input all data accurately during the evaluation. Even if these data exist, entering these data, for example, for 20 parking lots in a campus, took time. In fact, the research team was only expecting the evaluators to perform a brief test of, say, five parking lot or zones.

By February 15, 2020, feedback from 6 respondents was received. The number of respondents exceeded the original target of three. They were from campuses in the states of Maryland, California, New Mexico, Texas, and one from Saskatchewan, Canada. The names of the universities were not disclosed in this report so as to protect the evaluators' identities. The comments are listed as in the original written form below.

From Evaluator #1

"User Friendly – self intuitive- no prior knowledge of excel necessary. Easy Inputs – Data easy to input manually. However, wondering if system was set up for file share/info download Currently can only be used to decide prices for permit parking at specific lots – Daily parking pricing is a big part of university parking Acts almost like a Tuition Calculator but for parking permit rates System set up for yearly rates, however we plugged in based on semester rates. Does not give specific calculations or reasons of how the calculated prices came to be (We understand there is inputted walking times, available space and # of potential users, however needs to be more descriptive and provide solid reasoning behind pricing)"

From Evaluator #2

"While I can how useful SPARKMAN could be for generating a base price for permits, I believe it would be beneficial for universities who sold permits by individual parking lots and not used for universities that have multiple lots that use the same permit."

From Evaluator #3

"There are so many variables not considered. Pricing is never by year, students only purchase parking for the semesters they need parking. Most are not on campus over the spring/summer semesters. Demand fluctuates based on many factors. We are a City campus but with limited bus service. Also are weather is very extreme and we provide electrical options to plug your car in when it is below -15 (4-5 months of the year). Within the same parking t there are multiple permit types. The price is usually dictated by bottom line, i.e. I am given a mandate to have a surplus of \$400K. So I work backwards to get to this number. We do not separate student parking from employee/faculty parking. Walking time from the parking lot can differ greatly. We have a long narrow lot with 1,000 stalls. It takes twice as long to get from the furthest row to campus vs. front the front rows. I'm not sure what benefit the software provides."

From Evaluator #4

"I wasn't sure what to put as the university setting (rural or city). What would suburb be considered? Also, when entering the University information, I wished all the information I listed stayed there so I can remember what I had inputted. For the pricing information, I was confused by what you meant by average shuttle waiting time vs shuttle drive time to shuttle stop. Do you mean the shuttle times between the stops the shuttles make? Besides needing more clarification on a few of the items, I do think that this software does have potential and would be interested to use this more. Thanks!"

From Evaluator #5

"Information in "excepted demand" and "model base price" did not generate any information not did the tool show e.g. "estimated base price", "model output... pricing strategy", etc."

From Evaluator #6

"none"

Although one evaluator commented that SPARKMAN was simple and easy to use, the other evaluators have made remarks that suggested the following improvements:

- Explain the difference and similarity between lot and zone, and SPARKMAN's flexibility in applying lot-based and zone-based price calculations;
- Provide guidance on campus setting: urban or rural;
- Provide explanations on the total demand, model base price, and how they are calculated;
- Provide an option for users to change the model base price; and
- Provide an explanation on why the permit prices are in \$/year and show prices by semester.

While these revisions are not part of this project, they will be implemented in SPARKMAN version 2

Section 5 Student Survey

5.1 Survey Information

A survey was conducted to understand students' parking needs and preferences for ITS applications in a university campus. Moreover, this survey acquired statistics on students' perception of parking search time which was used to derive LOS criteria for parking.

5.1.1 Survey Instrument and Approvals

The UTEP campus was selected as the survey site because the research team had access to potential subjects and parking information. The students of UTEP were chosen as the survey subjects. A survey instrument including a consent form was created. The UTEP's IRB reviewed and approved the survey instrument, consent form, and the survey protocol on 27 February 2019. The consent form and the questions are attached in Appendix A. The survey instrument consisted of 12 questions which are explained in Sub-Section 5.2.

5.1.2 Recruitment and Implementation

The following methods were used to recruit student participants between February 28, 2019 and April 25, 2019:

- Advertised the survey in the online issue of Prospector, the student newspaper on March 15, 2019 (Prospector, 2019);
- Had students fill the hard copy of the survey forms in their classes, with permissions of the instructors;
- Distributed the survey flyers at major activity centers; and
- Distributed the survey flyers at parking lots.

The newspaper advertisement and flyers directed potential participants to a UTEP approved survey website where the participants answer questions electronically. For the classroom visits, the participants were asked to view the hard copy questionnaire. The answers were then transcribed by researchers onto the website.

5.1.3 Sample Size

A total of 1,022 responses were collected between February 28, 2019 and April 25, 2019. Since UTEP had a student population of 25,151 (Fall 2018 enrollment), the minimum sample size that gave 95% confidence level with 5% of margin error was 379 (Israel, 1992). According to the data provided by the UTEP Center for Institutional Evaluation, Research, and Planning (CIERP), there were 9,430 student parking permit owners in the 2018-19 academic year. The minimum sample size of the permit holders

that gave 95% confidence level and 5% margin of error was 370. Outliers were detected for each question using the interquartile range (IQR) rule. The remaining responses for each question met the above sample size criteria.

5.2 Survey Findings

This sub-section reports the results obtained for each question.

5.2.1 Question 1: Classification

Question: What is your classification?

The number of participants who answered this question was 1,022. The classifications are shown in Figure 5.1.

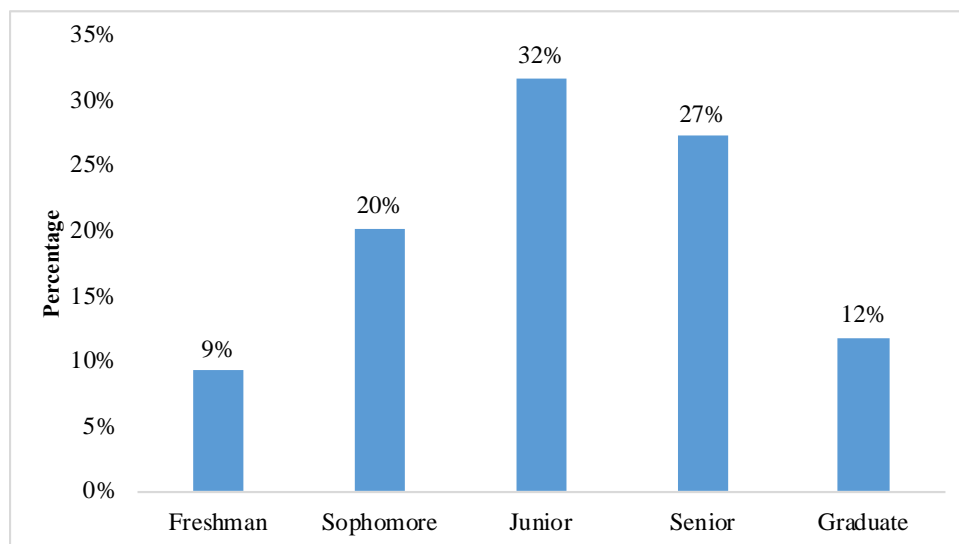


Figure 5.1: Survey result - student classifications

5.2.2 Question 2: Status

Question: what is your student status?

In this question, each student participant was asked to select one of the two choices: full-time or part-time. Of the 1,022 participants 86% were full-time students and 14% were part-time students.

5.2.3 Question 3: More Transportation Choices to UTEP Campus

Question: how do you travel to UTEP campus?

The purpose of this question was to understand mode share of commuter students for trips to the UTEP campus. All the 1,022 participants answered this question. Mode shares are presented in Figure 5.2.

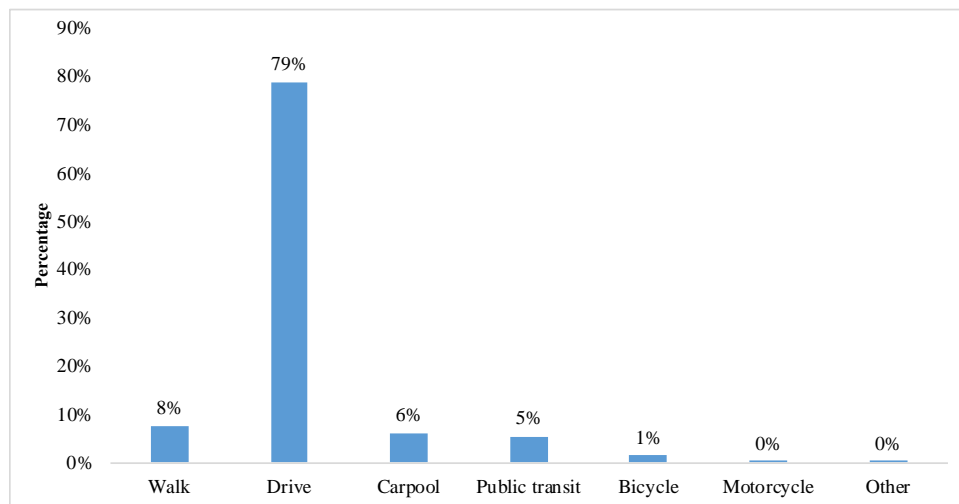


Figure 5.2: Survey result - mode shares

5.2.4 Question 4: Type of Permit

Question: what type (color) of parking permit do you have?

UTEP CPO restricts permit holders to parking only at lots stated in their parking permits. Nearby lots are categorized under the same zone and are coded with the same color. The CPO grouped the 22 parking lots on campus into four major colored-coded zones. This question asked the survey participant for the color of the permit he/she owned. There were 1,022 responses for this question and the results are presented in Figure 5.3. Although 79% of participants reported in their previous question that they drove to campus, 47% of participants stated that they did not have a parking permit.

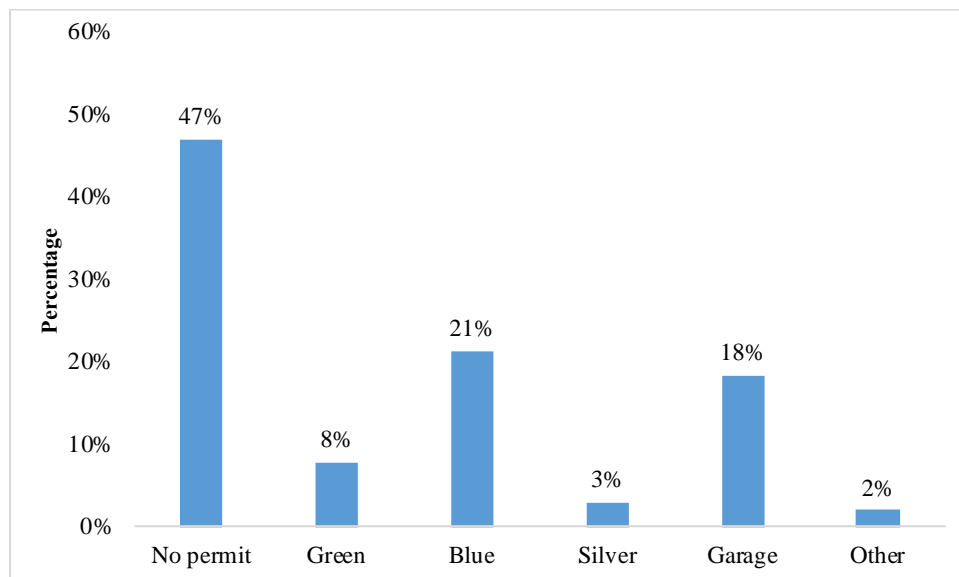


Figure 5.3: Survey result – permit types

5.2.5 Question 5: Arrival Time

Question: how early do you arrive at campus before first class of the day?

As a student's presence on campus is related to his/her class schedule. This question asked the participant the difference between his/her arrival time to campus and the first class of the day. The replies from the 1,022 responses are plotted in Figure 5.4.

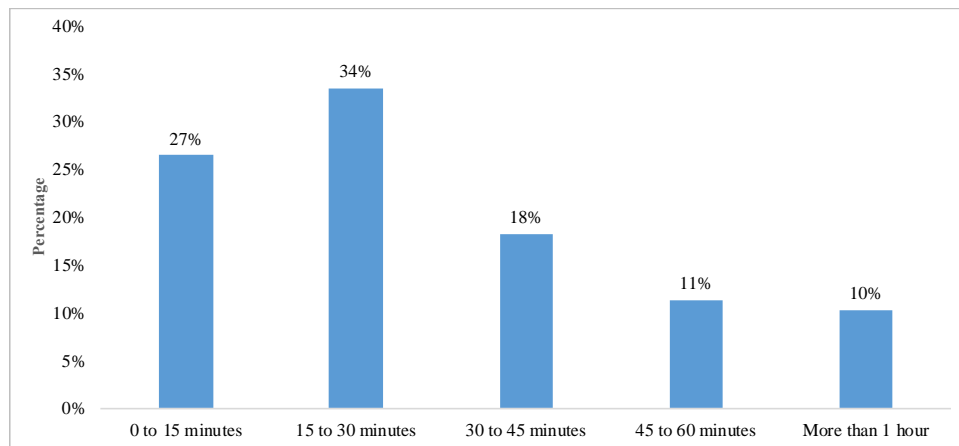


Figure 5.4: Survey result - arrival times before first class of a day

5.2.6 Question 6: Parking Location

Question: where do you park your car?

This question collected data about the parking lot utilization. It asked every participant to select, if they drive to campus, the lot in which he/she parked. The results of the 1,022 participants are represented in Figure 5.5.

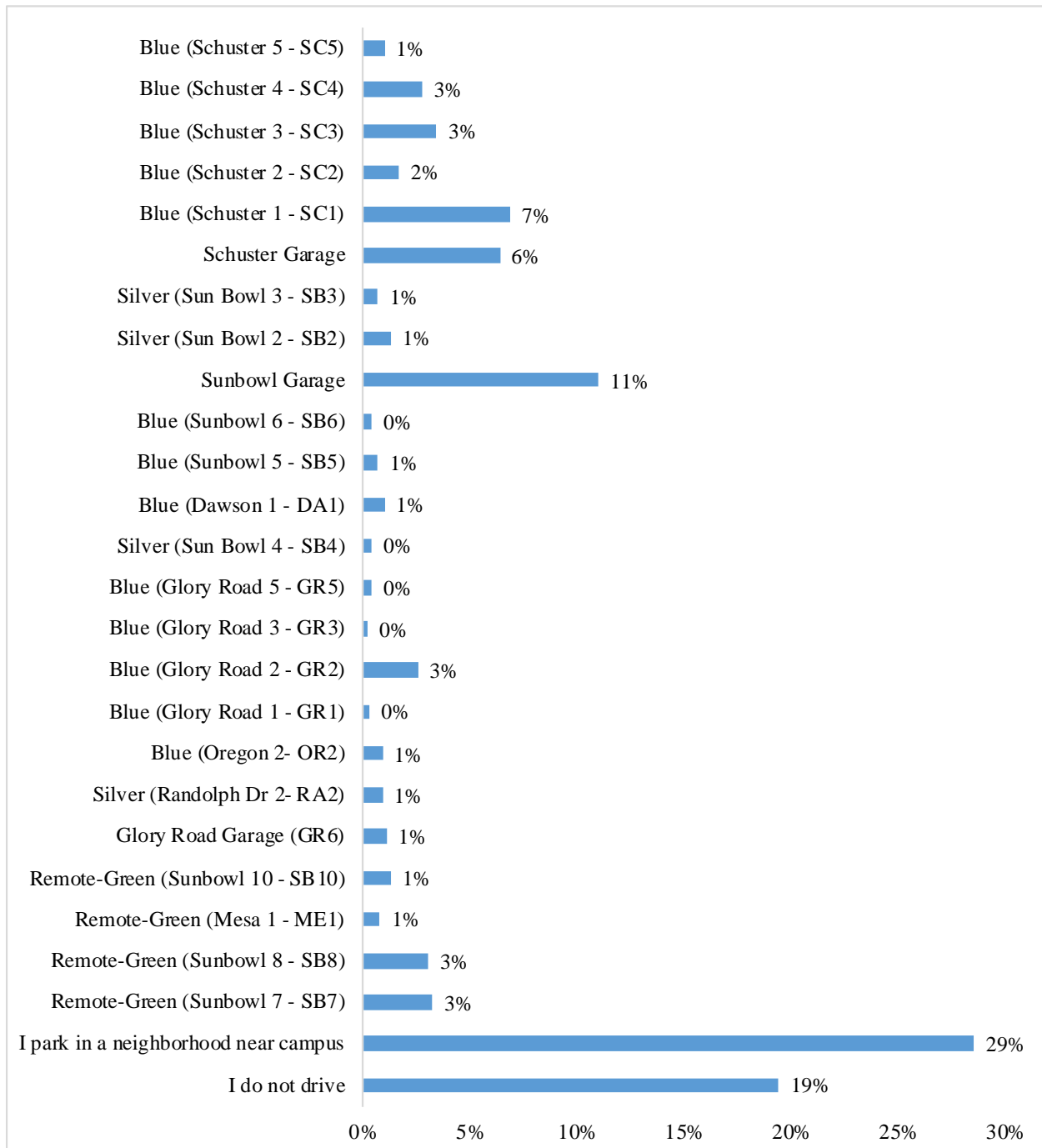


Figure 5.5: Survey result - parking lot locations

5.2.7 Question 7: Last-Mile Mode Choice

Question: in a typical day last week, how did you go from your parked car, drop off point, or bus stop to the final destination (classroom, office, lab, etc.) on campus?

This question asked the participant to select the mode of their last-mile trip. The results of 1,022 participants of the survey are presented in Figure 5.6. Majority of the students preferred walking from parking lots to their final destinations on campus.

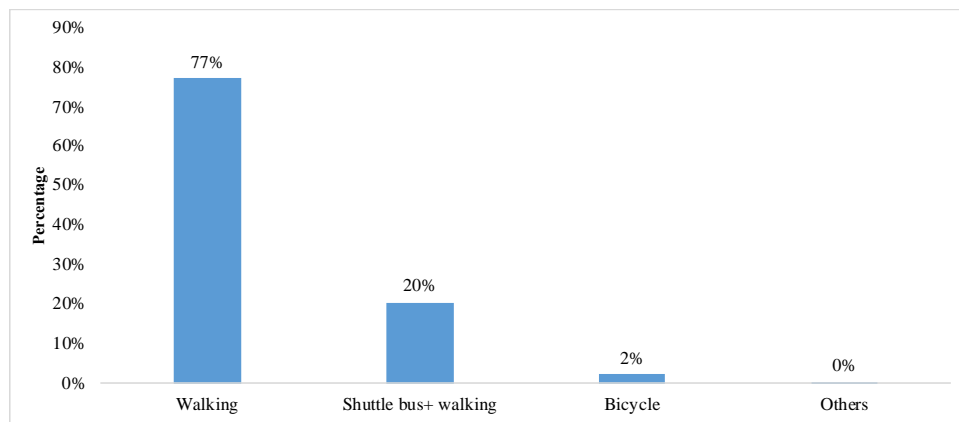


Figure 5.6: Survey result - mode shares of last-mile trips

5.2.8 Question 8: Final Destination on Campus

Question: select the location you stay most of the time while you are on campus.

This question was designed to identify the trip destination on campus. The UTEP campus was hypothetically divided into 6 areas (Figure 5.7). This question asked the participant to indicate one area in which he/she spent most of their time. The aggregated results received from the 1,022 participants are illustrated in Figure 5.10. 31% of the students stayed in Area 6 (College of Science and College of Engineering) followed by 20% in Area 5 (library and College of Health Sciences) and 16% in Area 4 (Undergraduate Learning Center).



Figure 5.7: Destination areas on UTEP campus

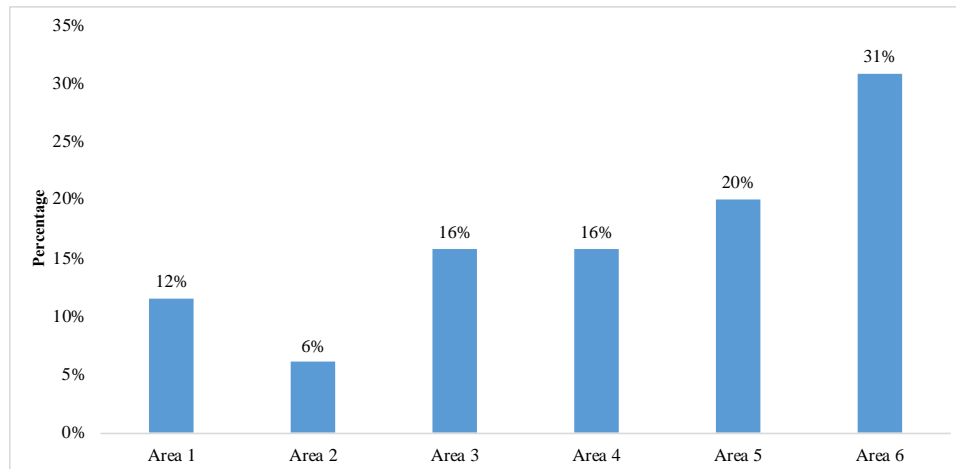


Figure 5.8: Survey result - trip destinations by areas

5.2.9 Question 9: Permit Purchase Decision Factors

Question: if you are buying a parking permit right now, select the three most important factors that may influence your decision to purchase the type of parking permit, and rank them from 1 to 3, with 1 being the most preferred.

This question asked the student participant to rank the factors that influenced his/her decision when buying a certain type (color) of parking permit. Each participant was given seven factors. He/she was asked to pick the top three factors and rank them 1, 2 and 3. Nine hundred and eighty-two participants completed the answers. Table 5.1 lists the numbers of ranks 1, 2 and 3 votes received by each factor. For each factor, the weighted sum of votes was computed by applying factors of 3, 2, and 1 to the votes for rank 1, 2 and 3 respectively. The weighted sums were listed in the rightmost column in Table 5.1. The top three factors are: (1) the cost of the permit; (2) walking time to the final destination and (3) the ease of finding an empty parking stall.

	First	Second	Third	Weighted Sum
Cost of permit	636	160	111	2,339
Walking time to final destination	189	369	200	1,505
Ease of finding a parking spot	83	255	339	1,098
Protection of car from weather (e.g., shade)	25	66	95	302
Time to take shuttle bus + walking to final destination	32	83	127	389
Ease of entering from or exit to major highways	7	45	105	216
Others	13	6	6	57

Table 5.1 Survey result - permit purchase decision factors

5.2.10 Question 10: ITS Systems

Question: The following table lists the potential systems which may be combined to improve parking on campus. Select the 3 systems which you prefer to have. Rank them from 1 to 3, with 1 being the most preferred.

This question provided every student participant a list of ITS enabled services for parking and asked the participant to rank the top three choices in order of 1, 2 and 3. The results of the 980 completed responses are listed in Table 5.2. For each ITS enabled service, the weighted sum was calculated and added as the last column in Table 5.2. The top three ITS enabled parking services by participant preference were: (1) online permit sales; (2) flexible parking zone; and (3) lot/zone availability information.

	Definition	First	Second	Third	Weighted Sum
Permit sales	Make permit sales year round and purchase online as easy as buying	293	137	155	1,308
Flexible zone	Allows one permit to park in multiple lots.	248	210	139	1,303
Access control	Stricter control on who can enter the lots.	129	120	83	710
Lot availability information	Display lot availability information to users. For example, on smart phones or display boards.	127	194	153	922
Pay as you use	Pay for only the time you park.	71	113	89	528
Parking spot reservation	Allow users to reserve parking spots prior to arrivals, like reserving a table in a restaurant.	42	62	111	361
Multimodal integration	Provide more transportation options (e.g., bike share, bus, carpool, scooters) that are integrated with parking.	32	67	109	339
Dynamic pricing	Adjust the rate based on congestion level.	32	75	122	368
Others		7	3	20	47

Table 5.2: Survey result - preferred ITS applications

5.2.11 Question 11: Parking Search Effort

Question: in a typical day of last week, after arriving at the UTEP parking lot which you have the permit to park, how do you describe your effort in finding an empty spot?

This question asked every participant to qualitatively describe his/her experience in searching for an empty parking stall (in the permitted lot) on the UTEP campus. There were seven answer choices: six of them corresponded to LOS A to F respectively and one was “did not park on campus”. The brief explanations provided in the survey instrument were:

- A. Very easy: Could find a spot to park immediately
- B. Easy: Could find a spot to park after a short time
- C. Moderate: Could find a spot to park after some time
- D. Difficult: Could find a spot to park after a while
- E. Very difficult: Could find a spot to park after a long time
- F. Extremely difficult: Waiting time is too long, unacceptable

All 1,022 participants responded to this question. Their choices are shown in Figure 5.9.

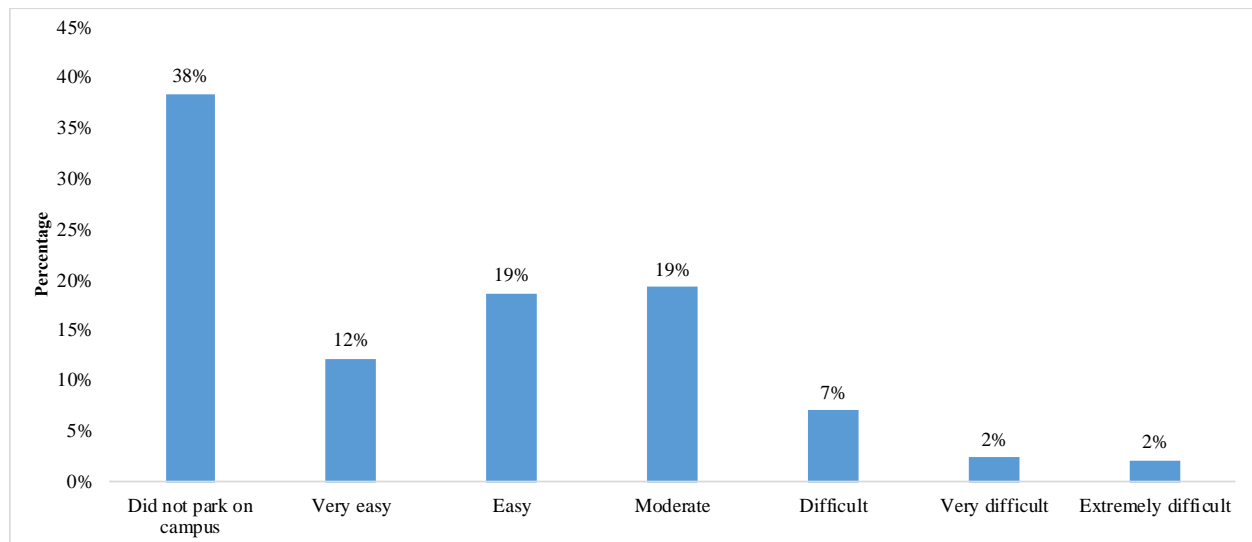


Figure 5.9: Survey result - search effort

5.2.12 Question 12: Parking Search Time and Level of Service

Question: Assuming that the effort to find a parking spot may be described by “A” to “E” Grades, with “A” corresponding to very easy and “E” for very difficult. For each of the grades below, select the value that in your opinion, represents the maximum duration (in minutes) for that grade.

The last question of the survey asked participant to relate LOS in parking with search time. The participant was asked to select the maximum allowable duration (in minutes) for each LOS grade. After removing those incomplete answers and the outliers, the results were plotted in Figure 5.10. The survey findings were used to define the LOS criteria for parking search time (Gurbuz and Cheu, 2020) which are reproduced in the following table.

Description of search effort	LOS	Search time (minutes)
Very easy - Can find an empty parking	A	0 to 2
Easy - Can find an empty parking stall after a short time	B	More than 2 but less than or equal to 4
Moderate - Can find an empty parking stall after some time	C	More than 4 but less than or equal to 7
Difficult - Can find an empty parking stall after a while	D	More than 7 but less than or equal to 10
Very difficult - Can only find an empty parking stall after a long time	E	More than 10 but less than or equal to 15
Extremely difficult - Unacceptable	F	More than 15

Table 5.3: Level of service criteria for parking

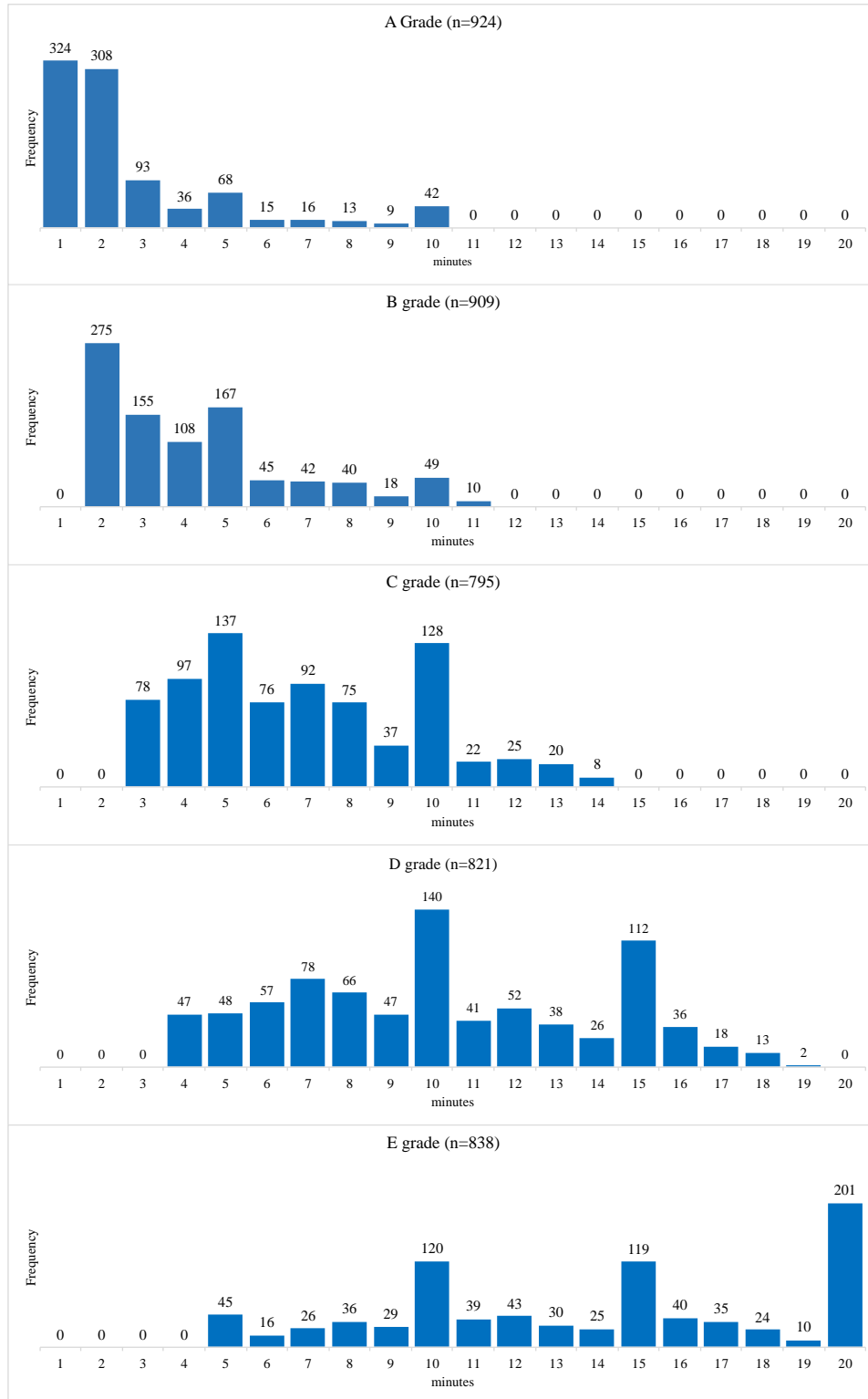


Figure 5.10: Survey result - upper bounds of search time

5.3 Data Validation and Discussion

UTEP's Center for Institutional Evaluation, Research and Planning (CIERP) provided de-identified student records for the entire student population in the Fall 2018 semester. The data provided by CIERP is referred to as the CIERP dataset. Comparable information from the CIERP dataset and the survey sample are listed in Table 5.3. Although the time of the datasets are different, as described in Section 5.1.3, the sample size for representing the entire population of campus and number of permit holders was deemed sufficient. In the Survey dataset, the distribution of student classification by means of undergraduate and graduate levels was very close to the entire UTEP population. The reason for the high rate of full-time students among survey participants might be the timing of the survey. The surveys generally took place during regular school hours (8:00 a.m. to 5:00 p.m.) when most parking issues are faced. Since part-time students generally go to campus after their work (after 5:00 p.m.), the survey demonstrated a bias towards the full-time students. The distribution of the permit types and the areas where students mostly spend their time have very close values in both the CIERP and Survey dataset. Based on all of the above, this Survey dataset was a good representation of the entire population and ready for further model development.

		CIERP Dataset	Survey Dataset
Time of the Dataset		Fall 2018	Spring 2019
Number of students		25,151	1,022
Number of permit holders		9,430	533
Student classification	Freshman	18%	9%
	Sophomore	15%	20%
	Junior	22%	32%
	Senior	30%	27%
	Graduate	15%	12%
Student status	Full-time	61%	86%
	Part-time	39%	14%
Permit type	Blue	40%	40%
	Garage	33%	35%
	Green	15%	15%
	Silver	8%	6%
	Other	4%	4%
Place on campus most of the time	Area 1	5%	11%
	Area 2	9%	6%
	Area 3	14%	16%
	Area 4	19%	16%
	Area 5	24%	20%
	Area 6	29%	31%

Table 5.4: Comparison of UTEP CIERP data and survey data

Section 6 Conclusions, Limitations, and Future Research

6.1 Conclusions

Parking lots are one of the most important infrastructures in highway transportation. Universities are one of the major trip generation/attraction zones that have different types of users (students, faculty, staff, and visitors) with different trip behaviors. Among students, commuter students contribute most of all trips to campus. Commuter students were the focus of this research.

This research was built upon the total (commuter student parking) demand model and base (commuter student parking permit) price model established by Gurbuz and Cheu (2019). In this project, the authors have developed a methodology called the Zoning and Zone Permit Pricing (Z2P2) methodology to set the annual permit prices of individual parking zones. To encourage CPOs to adopt the developed models and methodology, a software tool called SPARKMAN (Smart Parking Management) was developed. Version 1.0 of SPARKMAN was evaluated by six experts from the CPOs at different universities. They provided valuable feedback for future improvements of SPARKMAN. To understand students' trip and parking behaviors on a university campus, a student survey was conducted in the Spring semester of 2019 at The University of Texas at El Paso. A total of 1,022 students participated in this survey and among them 533 have parking permits. The participating students (end-users) were asked to prioritize their preferences among different ITS technologies that can be implemented by university campus parking management. The results revealed the following top three preferences, for which implementation may be facilitated by ITS technologies: (1) an online permit sales system that allows students to buy parking permits at any time; (2) parking permits that allow students to park at any lot based on their class venues on different days of a week; (3) a real-time parking occupancy and navigation system. Finally, the results of the survey were used to develop level of service criteria for parking search time. Threshold values that divide the search time into level of services A to F have been recommended.

6.2 Contributions

Parking is an underserved research topic in transportation. This research has advanced the science of parking management in the following ways:

1. The Z2P2 methodology is believed to be the first scientific approach in setting commuter student parking zones and zone permit prices on university campuses.
2. The survey, with 1,022 student participants, is one of the largest samples ever gathered on university campuses. The survey results have been validated with institutional data. The survey results provided insights into commuter students parking behavior.
3. Through the survey, students' preferences for ITS enable services applied to campus parking management have been obtained.

4. This is the first time the level of service criteria for parking time have been proposed. The proposed level service criteria have potential to be widely used by parking facility owners and operators to evaluate the performance of parking systems.

In addition to the above contributions, the authors have coded the Z2P2 methodology into an easy to use Excel-based add-in and engaged experts from the industry (CPOs) to provide feedbacks.

6.3 Limitations

As in all research projects, the budget, time and manpower constraints had imposed limitations to the conduct of this research. Several limitations are mentioned here so that readers are aware of these when interpreting the results and findings.

1. Although university campuses have four types of users, this research focused on the largest group of users: students.
2. The Z2P2 methodology assumes that the campus core is the destination of all commuter students. The sensitivity of the zone permit price with respect to the location of the campus core is yet to be tested.
3. The survey was conducted on one university campus. The survey results may be localized. With enough resources, surveys should be conducted on campuses across the country.
4. The level of service criteria for parking search time was developed and tested for limited access parking lots. They have yet to be tested for street parking.

These limitations have led to ideas for further research.

6.4 Future Research

As the research topic of parking is still at its infancy, there are many possible directions of research. The authors have identified the following topics as continuations of this project:

- To understand the parking behaviors of faculty, staff, visitors, and visiting students
- To perform sensitivity analysis of the parking permit prices with respect to the location of the campus core
- To modify the level of service criteria for search time to cater to street parking
- To investigate the change in class schedule on the parking demand of commuter students
- To develop a methodology to evaluate the effect of ITS on university campus parking
- To incorporate environmental impact, such as emission, in campus parking policy decisions

The above are just several research topics towards a comprehensive campus parking management solution.

References

- Census. (2017). "American FactFinder." United States Census Bureau, <https://factfinder.census.gov/faces/nav/jsf/pages/community_facts.xhtml?src=bkmk> (Dec. 28, 2019).
- Cheu, R. L., Gurbuz, O., Balal, E., Zhang, M., Gao, H. O., and Zhang, Y. (2018). "Characterization of University Parking System." Final Report, Center for Transportation, Environment & Community Health, Cornell University.
- DDOT. (2018). "Performance-based Parking Pilots." District Department of Transportation, DDOT Services, <<https://ddot.dc.gov/service/performance-based-parking-pilots>> (Dec. 19, 2019).
- FHWA. (2018). "Travel Demand Management." Federal Highway Administration Office of Operations, <http://www.ops.fhwa.dot.gov/aboutus/one_pagers/demand_mgmt.htm> (Sept. 8, 2019).
- Fullerton. (2019). "Student Parking Permit Information". California State University at Fullerton Parking and Transportation Services, <<https://parking.fullerton.edu/documents/Student%20Parking%20Permits.pdf>> (Mar. 20, 2019).
- Gurbuz, O., Jauregui, X., and Cheu, R. L. (2019). "Development of Demand and Pricing Models for University Campus Parking." TRB Annual Meeting, 2019, (No. 19-01174).
- Gurbuz, O., and Cheu, R. L. (2020). "A Survey to Explore Behavior, Intelligent Transportation Systems Needs and Level of Service Expectations for Student Parking at a University Campus." *Transportation Research Record – Journal of the Transportation Research Board*, <https://doi.org/10.1177/0361198119900169>.
- Hess, D. B., Brown, J., and Shoup, D. (2004). "Waiting for the bus." *Journal of Public Transportation*, 7(4), 4.
- IPI. (2018). "2018 Emerging Trends in Parking, Report on a Survey Conducted by the International Parking Institute." International Parking Institute, https://www.parking.org/wp-content/uploads/2018/05/0509_2018_Emerging-Trends_blue_printPages.pdf (Oct. 28, 2019).
- Israel, G.D. (1992). "Determining sample size." *University of Florida Cooperative Extension Service*.
- Jara-Díaz, S. R., and Guevara, C. A. (1999). "On the subjective valuation of travel time savings." *Transportation Planning Methods. Proceedings of Seminar European Transport Conference, 27-29 September 1999*, (Vol. 434).

- Kenney, D. R. (2004). "How to solve campus parking problems without adding more parking." *The Chronicle of Higher Education*, 50(29), B22-B23.
- Kotb, A. O., Shen, Y. C., and Huang, Y. (2017). "Smart parking guidance, monitoring and reservations: a review." *IEEE Intelligent Transportation Systems Magazine*, 9(2), 6-16.
- KU. (2019a). "Commuter Students." The University of Kansas Parking & Transit, <<https://parking.ku.edu/commuters>> (Mar. 20, 2019).
- KU. (2019b). "License Plate Recognition." The University of Kansas Parking & Transit, <<https://parking.ku.edu/license-plate-recognition>> (Mar. 20, 2019).
- LA Express Park. (2018). "Benefits of LA Express Park" <<http://www.laexpresspark.org/about-la-expresspark/benefits-of-la-express-park/>> (Dec. 18, 2019).
- Mackie, P. J., Jara-Diaz, S., and Fowkes, A. S. (2001). "The value of travel time savings in evaluation." *Transportation Research Part E: Logistics and Transportation Review*, 37(2-3), 91-106.
- MIT. (2019). "MIT Parking Permit Rates." Massachusetts Institute of Technology Department of Facilities, <<http://web.mit.edu/facilities/transportation/docs/Parking-Rates-2017-18.pdf>> (Mar. 20, 2019).
- NCES. (2017). "College Navigator." National Center for Educational Statistics, <<https://nces.ed.gov>> (Apr. 20, 2019).
- NMSU. (2019). "Free Parking and Shuttle Service." New Mexico State University Transportation & Parking Services, <<https://park.nmsu.edu>> (Mar. 20, 2019).
- OSU. (2019). "Parking Permits Annual Permits Sales Schedule." Oregon State University Finance and Administration, <<https://transportation.oregonstate.edu/parking/parking-permits>> (Mar. 20, 2019).
- OU. (2019). "Park Free and Ride." University of Oklahoma Parking and Transportation Services, <http://www.ou.edu/parking/Park_at_LNC> (Mar. 20, 2019).
- Pierce, G., and Shoup, D. (2013). "Getting the prices right: an evaluation of pricing parking by demand in San Francisco." *Journal of the American Planning Association*, 79(1), 67-81.
- Prospector. (2019). "Civil engineering student, professor seek to find parking solutions." UTEP Prospector <<https://www.theprospectordaily.com/2019/03/15/civil-engineering-student-professor-seek-to-find-parking-solutions/>> (Mar. 29, 2019)

- QuestionPro. (2019). "Survey software, Free Online Survey Software and Tools." QuestionPro <https://www.questionpro.com/> (Jul. 02, 2019)
- SDOT. (2018). "Paid Parking Rates Reports and Studies." Seattle Department of Transportation, Document Library, <<http://www.seattle.gov/transportation/document-library/reports-and-studies#parking>> (Oct. 19, 2019).
- Shoup, D. (2005). "Parking on a smart campus." *California Policy Options*, 117-149.
- Stanford. (2019). "Introducing Stanford's New Virtual Parking System." Stanford University Parking and Transportation Services, <<https://transportation.stanford.edu/news/introducing-stanfords-new-virtual-parking-system>> (Mar. 20, 2019).
- Teodorović, D., and Lučić, P. (2006). "Intelligent parking systems." *European Journal of Operational Research*, 175(3), 1666-1681.
- UCLA. (2019). "Student Parking Prioritization Process." University of California Los Angeles Transportation, <<https://transportation.ucla.edu/campus-parking/students/student-parking-prioritization-process>> (Mar. 20, 2019).
- UCSD. (2019). "Parking for Freshmen." University of California, San Diego Transportation Services. <<https://transportation.ucsd.edu/parking/first-year.html>> (Mar. 20, 2019).
- UND. (2019). "Parking Permits." University of North Dakota Parking and Transportation, <<http://www1.und.edu/finance-operations/parking-transportation/permits/index.cfm>> (Mar. 20, 2019).
- UNLV. (2019). "Parking Permits." University of Nevada at Las Vegas Parking and Transportation Services, <<https://www.unlv.edu/parking/permits>> (Mar. 20, 2019).
- UNT. (2019). "Parking Information." University of North Texas Transportation Services, <<https://transportation.unt.edu/parking>> (Mar. 20, 2019).
- USDOT. (2016). "Revised Departmental Guidance on Valuation of Travel Time in Economic Analysis." U.S. Department of Transportation Memorandum to Secretarial Officers Modal Administrators, <<https://www.transportation.gov/sites/dot.gov/files/docs/2016%20Revised%20Value%20of%20Travel%20Time%20Guidance.pdf>> (Feb. 15, 2019).
- UVM. (2019). "Transportation at UVM." The University of Vermont Parking and Transportation, <<http://www.uvm.edu/~slife/orientation/opening/?Page=parking.html>> (Mar. 20, 2019).

Vlahogianni, E. I., Kepaptsoglou, K., Tsetos, V., and Karlaftis, M. G. (2016). "A real-time parking prediction system for smart cities." *Journal of Intelligent Transportation Systems*, 20(2), 192-204.

Zhang, X., Yang, H., and Huang, H. J. (2011). "Improving travel efficiency by parking permits distribution and trading." *Transportation Research Part B: Methodological*, 45(7), 1018-1034.

Appendix - Survey Consent and Instrument

The University of Texas at El Paso

Project: SPARKMAN: A Smart Parking Management Tool for University Campuses Information and Consent

Introduction

Dr. Kelvin Cheu, Professor of Civil Engineering at The University of Texas at El Paso (UTEP) is conducting a research project titled “SPARKMAN: A Smart Parking Management Tool for University Campuses”. This objective of this project is to develop a tool called SPARKMAN to assist university parking offices to better manage campus parking. Part of this project includes a survey to collect data to understand students’ travel and parking choices. You have been requested by Dr. Cheu to participate in this survey because you are a UTEP student. The survey consists of 12 questions, which will take approximately 10 minutes to answer. There is no cost or compensation for participating in this survey.

There is no risk associated with your participation in this survey.

Your participation in this survey is voluntary, and you may withdraw your participation at any time.

Confidentiality

You will not be asked to provide any personal identification and confidential information during the survey. The research team plans to survey 500 students. The survey forms will be locked in a cabinet in Dr. Cheu’s laboratory after the answers have been entered into a UTEP approved software. If you answer the online version of this survey, the electronic data will automatically be stored by this UTEP approved software. The electronic data files will be password protected. Only Dr. Cheu and Okan Gurbuz have access to the data. Dr. Cheu and Okan Gurbuz will analyze the data to identify the frequently used factors that contribute to a student’s decisions to buy a parking permit, and the type of permit (location of parking lot). Dr. Cheu will share the aggregated survey findings as teaching materials, present in conferences, publish in scholarly journals, Prospector, and media approved by University Communications. No individual participant will be singled out in the analysis.

Contacts and Questions

If you have any question or feedback concerning with this survey, please feel free to ask Dr. Kelvin Cheu ((915)747-5717, rcheu@utep.edu) or any assistant who is conducting the survey.

Statement of Consent

By writing “Yes” in the space below, you indicate that you have read this information and your questions concerning this survey have been answered. Even after writing “Yes” below in this form, please know that you may withdraw from the research at any time.

I consent to participate in this survey (Please write “Yes” or “No”): _____
Date: _____

1. What is your classification?

- ☐ Freshman
- ☐ Sophomore
- ☐ Junior
- ☐ Senior
- ☐ Graduate

2. What is your student status?

- ☐ Full-time (more than 12 credits for undergraduates, 9 credits for graduates)
- ☐ Part-time (less than 12 credits for undergraduates, 9 credits for graduates)

3. How do you travel to UTEP campus?

- ☐ I live in dormitory / I walk to campus
- ☐ I drive my car (drive alone or give someone a ride)
- ☐ Carpool (get a ride from someone or someone drop me off)
- ☐ I use public transportation (Sun Metro, Brio, streetcar etc.)
- ☐ I ride bicycle
- ☐ I ride motorcycle
- ☐ Others (please specify): _____

4. What type (color) of UTEP parking permit do you have?

- ☐ I do not have a parking permit
- ☐ Remote (green)
- ☐ Perimeter (blue)
- ☐ Silver
- ☐ Garage
- ☐ Others (please specify): _____

5. How early do you come to campus before your first class of the day?

- ☐ 0 to 15 minutes
- ☐ 15 to 30 minutes
- ☐ 30 to 45 minutes
- ☐ 45 minutes to 1 hour
- ☐ More than 1 hour

6. In a typical day last week, how do you go from your parked car, drop off point or bus stop to the final destination (classroom, office, lab etc) on campus?

- ☐ Walking
- ☐ Shuttle bus + walking
- ☐ Bicycle

7. Where do you park your car? Put a mark (circle) on the map or select one of the other alternatives if you do not have a car on campus.

Selection	Alternatives
	I do not drive
	I park in a neighborhood near campus



8. Select the location you stay most of the time while you are on campus? (Just one selection)



9. If you are buying a parking permit right now, select the 3 most important factors that may influence your decision to buy the type of your UTEP parking permit, and rank them from 1 to 3, with 1 being the most preferred. (Select only one 1, one 2, and one 3)

Factors	Importance (1 = most important)
Cost of permit	
Walking time to final destination	
Time to take shuttle bus + walking to final destination	
Protection of car from weather (e.g., shade)	
Ease of entering from or exit to major highways (I-10 or Mesa St.)	
Ease of finding a parking spot	
Others (please specify):	

10. The following table lists the potential systems which may be combined to improve parking on UTEP campus. Select the 3 systems which you prefer to have. Rank them from 1 to 3, with 1 being the most preferred. (Select only one 1, one 2, and one 3)

Potential system	Explanation	Your Rank
Permit sales	Make permit sales year round and purchase as easy as buying concert tickets or booking hotel rooms online.	
Access control	Stricter control on who can enter the lots.	
Flexible zone	Allowed one permit to park in multiple lots.	
Lot availability information	Display lot availability information to users. For example, on smart phones or display boards.	
Pay as you use	Pay for only the time you park.	
Dynamic pricing	Adjust the rate based on congestion level.	
Parking spot reservation	Allow users to reserve parking spots prior to arrivals, like reserve a table in a restaurant.	
Multimodal integration	Provide more transportation options (e.g, bike share, bus, carpool, scooters) that are integrated with parking.	
Others (please specify):		

11. In a typical day of last week, after arriving at the UTEP parking lot which you have the permit to park, how do you describe your effort in finding an empty spot?

- ☐ I did not drive, or I did not park on campus
- ☐ Very easy (could find a spot to park immediately)
- ☐ Easy (could find a spot to park after a short time)
- ☐ Moderate (could find a spot to park after some time)
- ☐ Difficult (could find a spot to park after a while)
- ☐ Very difficult (could find a spot to park after a long time)
- ☐ Extremely difficult (unacceptable)

12. Assuming that the effort to find a parking spot may be described by “A” to “E” Grades, with “A” corresponds to very easy and “E” for very difficult. For each of the grades below, mark the circle that in your opinion, represents the maximum duration (in minutes) for that grade.

Very Easy	Can find a spot to park immediately	A Grade
<div style="display: flex; align-items: center; justify-content: space-between;"> <div style="display: flex; gap: 5px;"> 1234567891011121314151617181920 </div> <div style="text-align: right;">minutes</div> </div>		

Easy	Can find a spot to park after a short time	B Grade
<div style="display: flex; align-items: center; justify-content: space-between;"> <div style="display: flex; gap: 5px;"> 1234567891011121314151617181920 </div> <div style="text-align: right;">minutes</div> </div>		

Moderate	Can find a spot to park after some time	C Grade
<div style="display: flex; align-items: center; justify-content: space-between;"> <div style="display: flex; gap: 5px;"> 1234567891011121314151617181920 </div> <div style="text-align: right;">minutes</div> </div>		

Difficult	Can find a spot after a while	D Grade
<div style="display: flex; align-items: center; justify-content: space-between;"> <div style="display: flex; gap: 5px;"> 1234567891011121314151617181920 </div> <div style="text-align: right;">minutes</div> </div>		

Very difficult	Can find a spot to park after a long time (any time longer than this is unacceptable)	E Grade
<div style="display: flex; align-items: center; justify-content: space-between;"> <div style="display: flex; gap: 5px;"> 1234567891011121314151617181920 </div> <div style="text-align: right;">minutes</div> </div>		