Investigating differences in parking utilization rate: A Case Study at the UTC Chattanooga, Tennessee.

Tejaswini Adari
Engineering Management.
The University of Tennessee at Chattanooga.
Chattanooga, Tennessee, USA
szp533@mocs.utc.edu.

Serkan Varol
Engineering Management.
The University of Tennessee at Chattanooga.
Chattanooga, Tennessee, USA
Serkan-Varol@utc.edu.

Abstract— **Having adequate parking and parking services on university campuses is vital for improving the student experience, reducing traffic congestion, enhancing safety, generating revenue, and increasing accessibility. These enhancements can significantly uplift the built environment of the campus and its surrounding community. Using the University of Tennessee at Chattanooga as the case area, spatial and time series analysis regression models are run to answer this study's question, "Investigating variations in parking utilization rates within the campus," to understand the effect of all the influencing factors on the utilization rates. The study identified the critical factors that impacted the utilization rates. The results of this study can be used by the UTC parking department to address the issues at any given location and strategize better parking management systems on campus.**

Keywords—Parking, lot occupancies, Spatial Analysis, logistic regression, University, Chattanooga

I. INTRODUCTION

Parking is undoubtedly one of the most pervasive and annoying issues affecting American colleges and institutions. Many college students, faculty, and staff would agree with Clark Kerr's words. The former president of the University of California once wrote, "I have sometimes thought of the modern university as a series of individual entrepreneurs held together by a common grievance over parking" (Kerr, 1966, p. 20)[3]. The lack of suitable parking facilities within university campuses can create stress and become a significant issue for students, faculty, and staff, on a daily basis due to difficulty finding parking. This, in turn, can affect their academic and work performance.

Maintaining parking supply and meeting demand within university campuses, especially those located in urban areas, can be a challenge. Limited land availability in these areas makes it difficult to construct new parking facilities. As a result, students and faculty often park in nearby residential areas, causing congestion and frustration for residents. To address these issues, it is important for universities to study and analyze their parking lots to understand the root causes of parking problems and improve their parking management systems.

To this effect, this study employs the case of the University of Tennessee at Chattanooga, as the targeted study area to analyze the factors that influence the parking utilization rate at 90 percent vs 80 percent within the campus. The analysis will involve assessing the relationship between parking lots and nearby buildings using spatial analysis and examining all the factors influencing parking behavior through logistic regression. The study will begin by providing background information on the campus and reviewing relevant literature.

II. BACKGROUND

A) Prior Studies

The Chattanooga Parking Authority (CPA) and River City Company (River City), commissioned a comprehensive study in 2018, of parking in central Chattanooga, that also evaluates the parking characteristics at the UTC campus due to its location in the central Chattanooga area. The study is intended to understand the challenges and opportunities related to parking as the city urban continues to grow [13].

1) UTC Campus Area: Parking Utilization and Demand

UTC's parking plan is developed with the goal of efficiently utilizing all available parking spaces [13, p.103]. The study's primary analysis compared information on supply (parking inventory), levels of use, and expected demand to understand true gaps in parking potential. While "Fig. 1", illustrates the parking use and demand profile, "Fig. 2", demonstrates the estimated future parking demand within the UTC campus area.
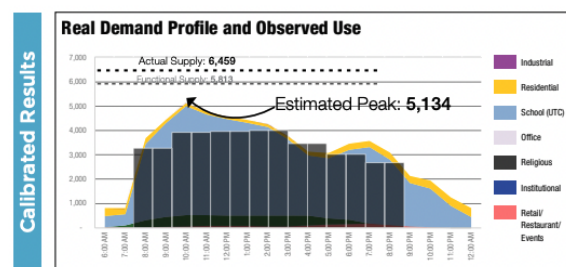

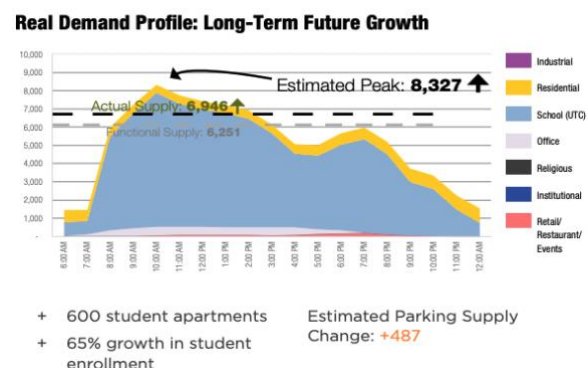Fig. 1. UTC Campus area Parking Utilization and Demand, (*2018*) [13].

Fig. 2. UTC Campus area Parking Utilization and Demand, (*2018*) [13].

2) UTC Campus Area: Key Findings

The University's master plan includes growth to 15,000 students (from its current) in 10 to 15 years. However, the study reports that certain parts of the study area, especially UTC, are expected to grow to levels that will exhaust the current parking supply if the current parking usage increases at the same rate [13]. Additionally based on "Fig. 1 & 2", the demand for parking is projected to exceed its current capacity, resulting in limited parking availability in the area. However, to cope with this demand the study recommends a hike in parking pricing to match demand and also ensure maximum utilization of the available parking spaces.

3) Conclusion

Overall, the previous study has clearly demonstrated the expected peak in parking demand and utilization within the campus, considering the university's expected student growth rate for the next 10 to 15 years. Moreover, the study also stated the need for UTC to reconstruct its parking management practices to ensure maximum parking utilization with the available spaces, instead of spending on building new parking facilities.

B) UTC Campus Information

The University of Tennessee at Chattanooga is a metropolitan university that is spread across 145 acres of land with over 90 buildings including administrative, academic, residential, and athletic facilities on campus. It is an R2 institution with an enrollment of approximately 12000 students and 1075 faculty members. Due to its prime location in the downtown area of Chattanooga, the campus often needs to adjust and update its parking services to meet the parking needs and demands of the university community.

C) Parking Information

The UTC parking services are managed by the university's Parking and Transportation Services Department. The campus has a total of 6117 parking spaces. These spaces are further classified as General, Reserved, Visitor, and Accessible parking lots. The total number of lots and parking spaces for each category of parking lots are summarized in Table.

TABLE 1. UTC PARKING TYPES AND SPACES (FALL 2022)

SL. NO	PARKING TYPE	TOTAL SPACES
1.	Reserved	3167
2.	General	2569
3.	Visitor	211
4.	Accessible	170

In "Fig. 3 and 4", the aerial view of the UTC campus and its parking lots provides a clear representation of the departments located on the campus and their corresponding parking lots. Additionally, in "Fig. 4", the general parking lots are indicated in yellow and the reserved parking lots are indicated in blue for reference.
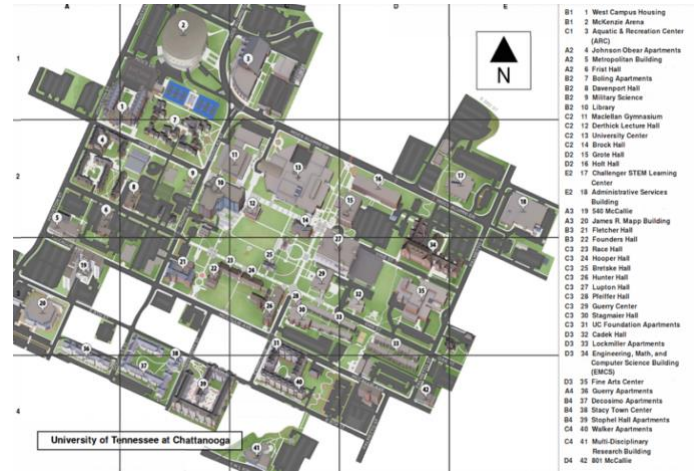

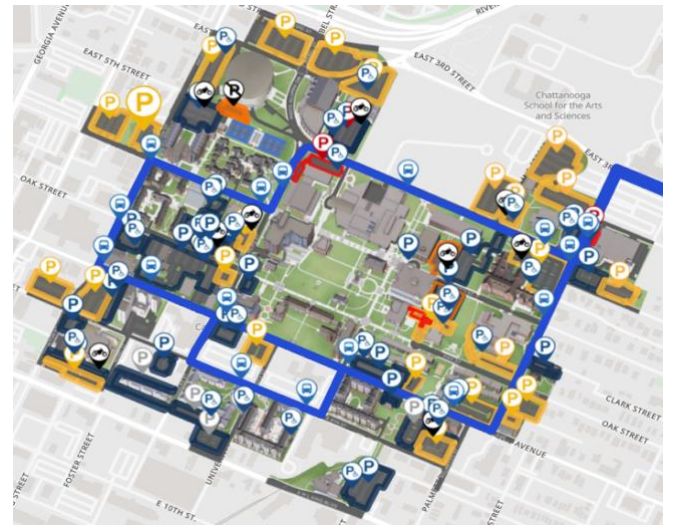Fig. 3. Aerial View of UTC Campus[16]

Fig. 4. Aerial View of Parking Lots[16]

III. METHODOLOGY AND RESULTS

A) Methodology

As a primary higher education institution with its key location and increasing student rate, the campus presents an opportunity to analyze the different factors that affect parking utilization rates- allowing us to derive critical insights into the UTC parking utilization to improve the parking management systems on the campus.

The data used for this project was gathered from several different departments- the UTC Parking Department, The Geographic Information System (GIS) Department, and the Planning, evaluation, and institutional research department. The datasets utilized include the parking Type, lots, university buildings, dorm's physical location (latitude & longitude), and also their occupancies recorded within a week for the Fall Semester for 3 years (2018,2019 & 2022). It also has a record of parking utilization within a particular time frame during the weekdays. Table 2 lists the data attributes and description of each attribute used for the regression.

TABLE 2. VARIABLES DESCRIPTION

SL.NO	VARIABLES	DESCRIPTION
1	Year	Describes the data recorded for 2018,2019 and 2022.
2.	Weekdays	Describes the parking data collected from Monday-Friday.
3.	Lot Type	Provides information about two types of lots: Reserved and General parking lots.
4.	Time	Provides information on the time of recorded parking occupancies for each day. (9:30,12:30.13:30,15:30)
5.	Loc Type	Provides information about the type of buildings within the campus.
6.	Total occupants	Provides data on the total no of occupants within the campus buildings.
7.	Max-find nearest	Provides data on all the blocks that are within 0.11 miles of each parking lot.
8.	90% & 80% Utilization rate	Provides information on all the parking lots at 90% and 80% utilization.

TABLE 3. LOGISTIC REGRESSION MODEL (PARKING UTILIZATION RATE AT 90%)

	Estimate	Std. Error	Z Value	Pr(>|z|)
Intercept	1.325	6.815	1.943	0.05196
Year	-0.065	3.374	-1.934	0.05305
Monday	2.100	2.110	9.949	< 2.2e-16
Thursday	1.803	2.085	8.647	< 2.2e-16
Tuesday	1.972	2.100	9.389	< 2.2e-16
Wednesday	2.079	2.107	9.868	< 2.2e-16
TYPE Reserved	-5.387	2.131	-25.281	< 2.2e-16
11:30:00	0.140	1.631	0.861	0.38902
13:30:00	-0.4467	1.630	-2.740	0.00613
15:30:00	-1.832	1.737	-10.545	< 2.2e-16
X1112	-0.3628	3.893	-9.318	< 2.2e-16
X1113	-0.1024	5.811	-1.762	0.07796
X1114	-0.6237	6.568	-9.495	< 2.2e-16
X1115	-0.1526	1.251	-1.220	0.22245
X1116	1.109	1.143	9.702	< 2.2e-16
X1127	0.8035	8.079	9.944	< 2.2e-16
X1142	-0.3631	2.685	-1.352	0.17625
X1144	1.373	3.395	4.042	5e-05
X1151	-0.9942	5.724	-1.737	0.08239
X1190	-0.3892	2.152	-1.808	0.07053
Dorm Capacity	-0.0007	4.123	-1.877	0.06044
Sum Student Campus	0.0009	1.895	4.977	6.45e-07

B) Regression and Affecting Factor Analysis

To determine the factors affecting the utilization rate the analysis considers the variables related to parking lot conditions and their relation with surrounding building occupancies

The logistic regression was chosen due to the type of variables the model is analyzing. It will allow us to analyze and model the relationship between the independent variables and a binary dependent variable. Here parking Utilization Rate (90% vs. 80%) was chosen as the dependent variable in this model as most of the parking lots have a utilization rate between 80-90 percent. However, different utilization rates can be used to expand this study. For this model, the dependent variable is a binary variable (0 or 1). For the 90% utilization rate model, 1 indicates a utilization rate over 90%, and 0 indicates less than 90%. For the 80% utilization rate model, 1 indicates a utilization rate over 80%, and 0 indicates less than 80%.

The project involves spatial analysis, to locate the parking lots and all the buildings within 0.11 miles with the help of latitude and longitude attributes to understand the parking utilization rate at a particular location. According to Mary S. Smith, P.E., and Thomas A. Butcher, P.E., 0.11 miles is considered the maximum walking distance a person feels comfortable reaching their respective parking lot [8]. Additionally, it is important to conduct a regression analysis to analyze the overall effects of all the variables presented in the dataset.

The regression model revealed important findings regarding the factors that affect the parking utilization rate at 90 percent vs 80 percent. From TABLE 3, It can be determined that the variables that have a p-value less than the significance level of 0.05 are considered statistically significant in predicting the 90% parking utilization Rate. Further, the individual assessment of the significant attributes association and effect on parking Utilization rate can be stated as:

- Year-The coefficient estimate for the variable 'YEAR" is -0.065. This means that for every unit increase in the year, the log odds of achieving a 90% parking Utilization rate decrease by 0.065, holding everything else constant.

- Weekday-The coefficient estimate for the weekday variables (Monday, Tuesday, Wednesday, Thursday) is positive indicating that these variables are positively associated with a 90% parking utilization rate. For example, the coefficient estimate for Monday is 2.100, which means that holding all other variables constant, the

log odds of having a 90% parking utilization rate on Monday are 2.100 higher than on Friday (the reference category).

- Lot Type: The coefficient estimate for the Lot Type variable (Reserved) is -5.387, indicating that holding all other variables constant, the log odds of having a 90% parking utilization rate in a reserved parking lot are 5.387 lower than in a non-reserved lot.

- Time: The coefficient estimates for the Time variables (13:30 and 15:30) are negative, indicating that parking utilization rates are lower at these times compared to 9:30 A.M. For example, the coefficient estimate for 15:30 is -1.832, which means that holding all other variables constant, the log odds of having a 90% parking utilization rate at 15:30:00 are 1.832 lower than at 09:30 A.M.

- Loc Type: The coefficient estimates for the Loc Type variables (1116, 1127, 1144) are positive, indicating that parking utilization rates are higher in these locations compared to the reference location. For example, the coefficient estimate for 1116 is 1.109, which means that holding all other variables constant, the log odds of having a 90% parking utilization rate in location 1116 are 1.109 higher than in the reference location.

- Also, the coefficient estimates for the Loc Type variables (1112, 1114) are negative, indicating that parking utilization rates are lower in these locations compared to the reference location.

- Total campus occupants: The coefficient estimate for the Total Campus Occupants variable is 0.0009, indicating that holding all other variables constant, for every unit increase in total campus occupants, the log odds of achieving a 90% parking Utilization rate increase by 0.0009, holding everything else constant.

Overall, comparing the coefficient estimates of all the predictor variables, it can be stated that 'Weekdays' are the primary influencing factor for the parking utilization rate at 90 percent, followed by 'Loc Type' within the campus. However, we did a utilization analysis for the 80 percent model to see how they differ.

	Estimate	Std.Error	zValue	Pr(>|z|)
Tuesday	1.762	1.944e-01	9.0627	< 2.2e-16
Wednesday	1.823	1.939e-01	9.4040	< 2.2e-16
TYPE Reserved	-4.278	1.774e-01	-24.1163	< 2.2e-16
11:30:00	5.663	1.560e-01	3.6291	0.00028
13:30:00	1.841	1.539e-01	1.1960	0.23169
15:30:00	-1.030	1.550e-01	-6.6406	3.12e-11
X1112	-1.818	3.464e-02	-5.2495	1.52e-07
X1113	-2.386	5.292e-02	-4.5089	1e-05
X1114	-5.775	5.925e-02	-9.7465	< 2.2e-16
X1115	2.972	1.337e-01	2.2230	0.02622
X1116	9.789	1.025e-01	9.5503	< 2.2e-16
X1127	5.600	7.301e-02	7.6702	1.71e-14
X1142	-5.744	2.336e-01	-0.2458	0.80582
X1144	4.287	3.499e-01	0.1225	0.90249
X1151	-7.938	5.274e-01	-1.5052	0.13226
X1190	-1.406	1.944e-01	-0.7234	0.46944
Dorm Capacity	-4.308	3.684e-04	-1.1693	0.24229
Sum Student Campus	9.224	1.675e-04	5.5069	3.65e-08

TABLE 4. LOGISTIC REGRESSION MODEL (PARKING UTILIZATION RATE AT 80%)

	Estimate	Std.Error	zValue	Pr(>|z|)
Intercept	1.268	6.409e+01	1.9786	0.04786
Year	-6.248	3.172e-02	-1.9696	0.04888
Monday	1.773	1.935e-01	9.1666	< 2.2e-16
Thursday	1.434	1.911e-01	7.5070	6.04e-14

The regression model revealed important findings regarding the factors that affect the Parking Utilization Rate at 80 percent. From the above TABLE 4, It can be determined that the variables that have a p-value less than the significance level of 0.05 are considered statistically significant in predicting the 80% parking Utilization Rate. Further, the individual assessment of the significant attributes association and effect on parking Utilization rate can be stated as:

- Year-The coefficient estimate for the variable 'YEAR" is -6.248. This means that for every unit increase in the year, the log odds of achieving an 80% parking Utilization rate decrease by 6.248, holding everything else constant.

- Weekday-The coefficient estimate for the weekday variables (Monday, Tuesday, Wednesday, Thursday) is positive indicating that these variables are positively

associated with the 80% parking utilization rate. For example, the coefficient estimate for Wednesday is 1.823, which means that holding all other variables constant, the log odds of having an 80% parking utilization rate on Wednesday are 1.823 higher than on Friday (the reference category).

- Lot Type: The coefficient estimate for the Lot Type variable (Reserved) is -4.278, indicating that holding all other variables constant, the log odds of having an 80% parking utilization rate in a reserved parking lot are 4.278 lower than in a non-reserved lot.

- Time: The coefficient estimates for the Time variables 15:30:00 is negative, indicating that parking utilization rates are lower at these times compared to the reference time (9:30 am). For example, the coefficient estimate at 15:30 is -1.030, which means that holding all other variables constant, the log odds of having an 80% parking utilization rate at 15:30 are 1.035 lower than at 09:30 a.m.

- Loc Type: The coefficient estimates for the Loc Type variables (1116, 1127, 1115) are positive, indicating that parking utilization rates are higher in these locations compared to the reference location.

  For example, the coefficient estimate for 1116 is 0.97, which means that holding all other variables constant, the log odds of having a 90% parking utilization rate in location 1116 are 0.978 higher than in the reference location.

- Total campus occupants: The coefficient estimate for the Total Campus Occupants variable is 0.0009, indicating that holding all other variables constant, for every unit increase in total campus occupants, the log odds of achieving a 90% parking Utilization rate increase by 0.0009, holding everything else constant.

Overall, by comparing the coefficient estimates of all the predictor variables it can be stated 'Weekdays' are the primary influencing factor for the parking utilization rate at 80 percent, followed by 'Loc type'.

IV. RESULTS

Based on both regression models, the dominant influencing factors for parking utilization are listed below.

- Weekdays (Wednesday) -From the above analysis, it can be observed that out of all the weekdays, the utilization of parking is notably high on Wednesdays followed by 'Mondays' and is also the primary influencing factor at 90 percent and 80 percent parking utilization at UTC.

- Loc Type- Here, the Loc Types denote the categorization of buildings in UTC (Recreation, Residence Halls, and Administration Facilities). The analysis from Table 2 indicated that Loc Type 1144 (Visitor information center) block is the main driver of the 90% parking utilization rate, followed by Loc Type 1116 which includes most of the residence halls. However, in contrast to the 90 percent model, the Loc Type 1144 remained an insignificant factor for the parking utilization rate at 80 percent. Both models clearly demonstrated that Loc Type 1114 has the least impact on the utilization rate. "Fig. 5", provides information on all the block names that influence the parking utilization rates at 90% and 80%.

Building Name	Loc Type	Influence (High-low)
Visitor Information	1144	
Walker Apartments	1116	
Stophel Apartments	1116	
Town Hall	1116	
Lockmiller II	1116	
UC Foundation Apartments	1116	
Guerry Apartments	1116	
Decosimo Apartments	1116	
Lockmiller I	1116	
Stagmaier Hall	1116	
Johnson Obear Apartments	1116	
Human Resources	1127	
James R. Mapp Building	1127	
Founders Hall	1127	
Alumni Affairs	1127	
Administrative Service Building	1127	
Davenport Hall	1127	
Collins Street Office Annex	1127	
Maclellan Gym	1127	
Aquatic and Recreation Center	1115	
McKenzie Arena	1115	
Pfeiffer Hall	1115	
UTC Tennis Courts	1115	
Challenger Field	1115	
Sand Volleyball Courts	1115	
Sports Complex Clubhouse	1115	
Upper Fields	1115	
Lower Fields	1115	
Engel Stadium	1115	
Scrappy Moore Field	1115	
First Baptist Church	1114	
First Baptist Church	1114	
First Church of Christ Scientist	1114	
Christ Episcopal Church	1114	
Catholic Student Center	1114	
The House: University Ministrie	1114	
Danforth Chapel	1114	

Fig. 5. Buildings on campus influence utilization rates at 90% & 80%

- Time- The analysis indicates that the utilization rate greatly impacted at 1:30 PM for the 90% model and at 11:30 AM for the 80% model. These times correspond with the expected duration of the highest utilization rate.

V. CONCLUSION

Based on the findings from the spatial and logistic regression analysis it is recommended that the UTC parking services department must focus on

- The listed blocks in "FIG 5", are primarily driving parking utilization rates on campus and then accordingly plan the parking lot occupancies and future need to manage the on-campus parking services efficiently.

- The weekdays and time slots from the findings impact the utilization rates and use them to plan the parking space allocation accordingly. For example, from both models, Wednesday is observed to have the highest utilization rate, based on it the UTC parking department with further study can consider changing the space allocations based on the supply and need whenever

required, specifically for General and Visitor parking types.

In conclusion, the study identified the most dominant factors affecting the parking utilization rate in the UTC campus and also demonstrated the variables that have the least impact on the utilization rate. The study was able to detect the peak hours, days, and also all the blocks that have impacted the most and least on parking utilization rates at 90% vs 80% in the UTC campus. Additionally, this study can add value for further analysis of the supply and demand of parking on campus. Overall, parking studies within the university campus can help optimize parking management services and improve the overall campus experience.

REFERENCES

[1] A. Mercer, O. Heilicher, E. Schamel and R. Hanch, "Campus parking causes student frustration," Truman Media Network, Feb. 5, 2020. [Online]. Available: https://tmn.truman.edu/blog/news/campus/campus-parking-causes-student-frustration/.

[2] A. Filipovitch and E. F. Boamah, "A systems model for achieving optimum parking efficiency on campus: The case of Minnesota State University," Transportation Research Part D: Transport and Environment, vol. 41, pp. 295-310, Dec. 2015. doi: 10.1016/j.trd.2015.09.006.

[3] D. W. Burr, "Is University Parking a Common Grievance?," Parking Today, Sep. 2011. [Online]. Available: https://www.parkingtoday.com/articledetails.php?id=1072&t=is-university-parking-a-common-grievance.

[4] E. Barata, L. Cruz, and J.-P. Ferreira, "Parking at the UC campus: Problems and solutions," GEMF and Faculdade de Economia, Universidade de Coimbra, Av. Dias da Silva, 165, 3004-512 Coimbra, Portugal, 2011. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0966692311000603

[5] E. A. Narragon, M. I. Dessouky, and R. E. DeVor, "A Probabilistic Model for Analyzing Campus Parking Policies," Operations Research, vol. 22, no. 5, pp. 1025-1039, Sep. - Oct. 1974. doi: 10.1287/opre.22.5.1025.

[6] L. Prevost, "On the College Campus of the Future, Parking May Be a Relic," The New York Times, Sep. 5, 2017. [Online]. Available: https://www.nytimes.com/2017/09/05/business/college-campus-parking.html.

[7] Maleck, Brian, "Data-Driven, Performance-Based Parking Management In a University Setting" (2013). All Theses. 1694. https://tigerprints.clemson.edu/all_theses/1694

[8] M. S. Smith and T. A. Butcher, "How Far Should Parkers Have to Walk?" 2008 [Online]. Available: http://worldcat.org/oclc/3041176.

[9] M. Ezarik, "Perceived Campus Parking Problems and the Factors That Influence Them," Inside Higher Ed, Dec. 14, 2022. [Online]. Available: https://www.insidehighered.com/news/2022/12/14/campus-parking-problems-common-yet-not-universal-infographic.

[10] N. Nadimi, S. Afsharipoor, and A. M. Amiri, "Parking Demand vs Supply: An Optimization-Based Approach at a University Campus," Journal of Advanced Transportation, vol. 2021, Article ID 7457021, pp. 1-15, 2021. doi: 10.1155/2021/7457021

[11] N. Nadimi, S. Afsharipoor, A. Mohammadian Amiri, "Parking Demand vs Supply: An Optimization-Based Approach at a University Campus", *Journal of Advanced Transportation*, vol. 2021, Article ID 7457021, 15 pages, 2021. https://doi.org/10.1155/2021/7457021

[12] S. R. Shook, S. R. Sisodiya, and M. A. McCollough, "University Parking: A Perceived Public Good in a Revenue Constrained Environment," Global Journal of Management and Marketing, vol. 3, no. 1, pp. 41-56, 2019. [Online]. Available: https://www.igbr.org/wp-content/uploads/articles/GJMM_Vol_3_No_1_2019-pgs-41-56.pdf.

[13] Stantec Nelson\Nygaard Consulting Associates Perkins+Will, "Downtown Chattanooga Parking Study," River City Company, Chattanooga Area Regional Transit Authority, Chattanooga Parking Authority, Jan. 2018. [Online]. Available: https://static1.squarespace.com/static/600aee7e0d9165627e3084ba/t/6 0355a014e6b4c2db9ef3835/1614109197920/ChattanoogaParkingStudyReport_JAN2018.pdf.

[14] R. L. Cheu, O. Gurbuz, E. Balal, H. M. Zhang, H. O. Gao, and Y. Zhang, "Characterization of University Parking System," Center for Transportation, Environment, and Community Health, Cornell University, Final Report, Oct. 2. [Online]. Available: https://ecommons.cornell.edu/bitstream/handle/1813/69741/UTEP_YR2_CHEU_FINAL_CHARACTERIZATION4-2j047xf.pdf?sequence=3.

[15] T. Litman, Parking Management: Strategies, Evaluation and Planning, Victoria Transport Policy Institute, 2011. [Online]. Available: http://www.vtpi.org/park_man.pdf.

[16] University of Tennessee at Chattanooga, "UTC maps," [Online]. Available: https://www.utc.edu/sites/default/files/2021-08/utc-central-campus-detailed-buildings-pdf-map-20200730a.pdf.

[17] University of Tennessee at Chattanooga, "UTC building types overview," Explore UTC, [Online]. Available: https://explore.utc.edu/?id=1826#!ce/46605?ct/48771,46605,46600?s/.

[18] W. Riggs, "Dealing with parking issues on an urban campus: The case of UC Berkeley," Department of City and Regional Planning, College of Architecture and Environmental Design, California Polytechnic State University, 1 Grand Avenue, San Luis Obispo, CA 93405, United States, 2014. [Online]. Available: https://doi.org/10.1016/j.cstp.2014.07.002