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April 21, 2020

Antonio M. Calcado

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**Re: Addressing the Parking Chaos on Campus for Commuters regarding the High Parking Violations and Students' Complain.**

Dear Mr. Calcado,

I would like to thank you for attending my presentation which further discussed the issues of the parking chaos on campus for commuters. Parking is a long-term issue affecting both students and faculties in many aspects. According to my research, lack of improvement over the current parking system creates some hidden problems that make it hard to find the available parking space efficiently and also results in the unavoidable payments due to the parking violation. My objective is to improve the current parking system based on the relevant research articles written by scholars who have ideas on how to build new public infrastructure. This point of view aligns with the goal of the Transportation Master Plan under your leadership at the department of institutional planning and operations. Therefore, I would like to introduce my research with the supporting details and existing models of success in solving the parking chaos on campus.

According to the previous financial discourse, commuters on campus wasted five million dollars annually because of the parking violation. Besides, students increasingly complain about the scarcity of parking space and lack of understanding of the area-specific policy. Considering the pieces of evidence that reveal the severity of the parking chaos from two aspects, I think it is crucial to reform the current information delivery method as well as the public infrastructure, which can provide a more efficient and cost-effective way for parking. Studies also show that the parking system can be digitalized by implementing a large scale of embedded systems, which is named as the Internet of Things (IoT). The IoT system is capable of monitoring the occupancy of each parking spot and deliver an optimal routine to the destination. Also, a recent scientific study proved the feasibility of the IoT system on campus by a team at Union College. We can make it better regarding the current chaos on campus.

If you need more information from my side, please let me know anytime at (732)-763-0040 or at ruiming.zhang@rutgers.edu. Thanks again for your time and consideration of this proposal.

Sincerely,

Ruiming Zhang

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**Addressing the Parking Chaos on Campus for Commuters regarding the High Parking Violations and Students' Complain.**

***Promoting the Smart Parking Solution***

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@ https://siskiyou.sou.edu/2015/11/12/campus-parking-its-a-battle/

**Submitted by:**

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**Submitted on:**

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Scientific and Technical Writing

01:355:302:07

Professor Boutin Harry

Project Proposal

**Abstract:**

Searching for parking on campus has always been a thorny issue affecting local transportation and communities. According to the studies, many colleges in the United States shift their concentration on how to optimize the demand rather than building more garages. Based on the high violation rate and complaints from local commuters, Rutgers also face the challenge that the current transportation system cannot satisfy the increasing demand. Research shows that Rutgers issued the highest number of parking tickets compared to the other nine public colleges in New Jersey (Zoppo, 2016). The parking chaos is caused by many reasons across commuters to the policymakers. Studies also claim that some heterogenous parking choice behavior creates wrong guidance, such as walking time and prices (Meng, 2018). The reason why people violate the parking policy is typical because of their intentions for convenience or lack of appropriate assistance. For these reasons, commuters need to be provided with a new information delivery service that can improve the transparency of the area-specific policy for parking.

The goal of this research is to purpose the smart parking solution to resolve the issues of the parking chaos on campus and lower the probability of violating the regulations. A smart parking solution is studied by many scholars and specialists in scientific fields (Barriga, 2019). It aims to build a new public infrastructure that can digitalize the network of every parking spot on campus. With continuous improvements, the platform can provide real-time monitoring of the public transportation system and assist people to find the optimal routine when they search for parking. Rutgers can consider utilizing the resources from this research to recruit experts who can contribute to one of the greatest transformations of the parking system. The following research includes extensive information about the Smart Parking solution as well as deliver a preliminary plan. There is a particular focus on the pertinence to regulate the parking choice behavior by utilizing innovative technologies.

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**Introduction**

The public transportation system on campus connects various facilities with students, staff, faculties, and visitors. Therefore, many universities are facing parking chaos in a different aspect, such as a high violation rate. The cause of the chaotic system is that parking supply cannot meet the increasing demand in each year. The number of commuters is climbing up due to urbanization and needs to receive higher education. The parking issue also leads to severe impacts on the local traffic, lateness for class, and economic loss. The following research will give an overview of the parking choice behaviors and the dependent factors that result in violating regulations.

***Overview of the Transportation at Rutgers University***

According to the annual report published from Institutional Planning and Operation Department at Rutgers University in 2019, the parking service on campus has provided 35,234 parking stalls across four main campuses in the New Brunswick area (2019). Based on the actual demand, the department also issued 141,769 parking permission annually. It reveals that the current parking supply is much lower than the demand from the local community. This annual report claims that 217,868 parking tickets are collected in 2019, which is estimated to be five million dollars. This is the number that also mentioned from a local media (Zoppo, 2016) that the author declared the highest parking violation rate at Rutgers among the other nine public colleges in New Jersey.

The image below visualizes the trend of people who commute on campus during the past six years. The data source is collected from the official Common Dataset released on the Institutional Research and Academic Planning website (2019). It documents the undergraduate students who commute or live off-campus in the New Brunswick region. In 2014, there were only 53% of the undergraduates who commute (2019). However, the number ramps up to 57% in just three years, which shows a rapid increase of the parking demand.

**Figure 1:**

**Percentage of Freshman & Undergraduates who live off campus or commute**

*Source: Common Data Set 2014-2019 Rutgers – New Brunswick*

***Explore Parking Behavior & Root Cause of Violation***

A recent article published from the University of Texas studied student transportation choice behaviors and parking patterns on campus (Gurbuz, 2020). The scholars collected 1022 responses based on different scenarios when people search for parking across campus. The respondents selected the most likely answers in terms of transportation modes, parking location, and Last-mile actions. In order to understand the enforcement level, the team also asked the most important factors that influence the decision to purchase the parking permit. From the research data below, the team at the department of civil engineering analyzed the correlation of the decision factors (2020). It reveals that the most crucial factor is the cost of the permit. One of the common reasons for a parking violation is that the price of the permit is high for students who have low purchasing power. Secondly, the survey tells that the walking time from lot to class building influences the parking choice. Based on a newspaper article written by a student who commutes at Rutgers, she complained about the time loss due to the distance issue between the class building and lot (JACQUELINE, 2017). Therefore, students might look for convenience by parking at the other nearby locations. Thirdly, the ease of finding an available parking stall also impact the parking choice behavior. It needs a consistent perception of the surrounding stalls at the large parking lots, especially during peak hours. Many vehicles compete to search for an empty spot with limited parking supply and then results in conflicts or irrational actions that lead to a violation.

**Figure 2:Permit Purchase Decision Factor based on Transportation Research Record**

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*Source: Survey to Explore Behavior for Student Parking at a University Campus*

Besides, the survey in this study shows that 53% of the respondents had parking permits, which is relevant to the disclosed Common Data Set (2020). In terms of the parking locations, 29% of the respondents parked in a neighborhood street. It reveals that a large part of the community who don’t purchase permit is affecting the local neighborhood and cause parking violation. Additionally, it worsens the local traffic and affects parking supply at the nearby residential area.

The above research concluded the quantified root cause of the violation and parking patterns on campus. In another perspective, the change of policy is also causing unavoidable violation to park on campus. According to a newspaper article written by a Rutgers alumnus, he complained about the information discrepancy of policy for event parking at Johnson Park (Keith, 2019). Because it used to be one of the destined locations for visitors to search for parking. However, Rutgers transferred the ownership of the parking lots at Johnson park to Middlesex County. During the special events and peak hours, we can also perceive that the demand exceeds the parking supply. In the New Brunswick region, the urban area also faces challenges that local communities are been affected by unauthorized vehicles. These types of information are part of the root causes of violation and it turns to be the useful feedback on where to improve the campus parking experience.

Another study of the parking citations from New York University states that the double-parking violation is one of the most common issues in the urban area (Gao, 2017). The researchers collected 10 million parking tickets in different time slots and visualized them into the histogram below. It shows that only 6.3% of the tickets were issued because of double parking in the urban area. However, commercial vehicles contribute 45.2% of the total number of issued tickets (2017). This number reveals the relevant parking problems in the downtown region in New Brunswick. Since the street parking committed to a large part of the on-campus parking in College Ave campus. It can be identified as an alternative solution for commuters when lots are not available. According to the chart, the peak hours of issuing the tickets are around 9:00 am to 13:00 pm where people arrive at the campus and leave for lunch (2017). The data concludes that it’s important to forecast the incoming demand and improve the parking supply. It also drives the need for an intelligent transportation system to allocate parking resources to users accurately and efficiently when traffic is busy.

**Figure 3:**

**Hourly Distribution of all Parking/Double Parking Ticket**

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*Source: Explore the Spatial Dependence of Parking Citation Data (NYU)*

The previous behavior study also analyzed the distribution of the parking search time, which calculates the time when a vehicle enters the garage until finding an empty stall. According to the research, the acceptable search time ranges from 2 to 15 minutes for different parking zones (2017). The reason for the variation is that the quality of the parking facilities determines the productivity of searching. When commuters try to find an empty spot at a large parking lot, it costs more time due to the complex layout. Conclusively, the longtime of searching reveals the true need for the real-time parking lot availability and guidance of an optimized routine. Based on the mentioned root causes of the violation, the research shows that the effectiveness of the information delivery method is low. In order to lower the parking violation, the Department of Public Transportation has to improve the transparency of the area-specific policy regarding the permit information, lot availability, and increasing demand. The data all together provide comprehensive evidence that different choice behaviors lead to a parking violation. Rutgers University can provide an intelligent parking system based on valuable user feedback from this research. More importantly, the objective of the new methodology can be regarded as a tool to cope with the parking congestion problem. Considering the increasing number of people who commute in each year, it’s vital to balance the demand and parking supply while improving the user experience.

**Literature Review**

The dependent decision factors of parking violations are defined based on previous research about parking choice behavior. The following information will talk about the digital transformation of the parking experiences and methodology to lower the parking violation on campus. Therefore, the following section will also introduce a method to improve the visibility for accessing the parking zones remotely and to overcome the barrier of information discrepancy. Additionally, the method will be discussed in terms of the different scientific basis and relevant models of success. It will also make a transition to describe a plan of action that will optimize the public infrastructure and cope with the parking congestion issues.

***Smart Parking Solution based on the Internet-of-things (IoT)***

In the technological prospective study of smart parking solutions, the researchers introduced the concept of the Internet of Things (IoT), which refers to the inter-process communication (IPC) of data among devices and sensors (Barriga, 2019). With the high growth of the hardware and software system, many megacities, such as Los Angles, are deploying the IoT methodology to improve the smartness of public transportation. According to this article, it mentions that the smart parking system will collect data from sensors to broadcast the availability of each parking spot, and then provides a real-time interface to users as well as navigating an optimal routine through software applications. From the picture below, it analyzes the trend of published articles that concentrates on the smart parking lot (2019). The data proves that the popularity of smart parking increased dramatically in the past decade, and a tremendous of scholars are navigating the direction of the technological development and accessibility of the IoT system. It also reveals that the strategy of approaching the traditional parking chaos is becoming mature and well-defined. Therefore, this research will explain more details of the impact over the current public infrastructure, and what is improved from the evolution.

**Figure 4: Distribution of Published Smart Parking Lot Papers per Year**

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*Source: A Literature Review of Smart Parking*

The second part of the study states that search for parking is one of the most important activities, which ramps up to 31% of the ground usage in cities (2019). Also, only 10% of the time is spent on moving while the other part of the time usually is wasted for waiting or stopped. The data reveals that traditional parking results in unavoidable time loss and creating excess gas emission at the same time. Other evidence in this research, claims that vehicles can produce up to 730 tons of carbon dioxide in the urban area, such as Los Angles (2019). It is not only inefficient to search for parking but also harmful to the environment due to air pollution. Therefore, the research drives the demand for a smart system that can resolve the negative social impact and upgrades the old parking mindset.

In another perspective, the external evidence of parking chaos is raising concern for the department of public transportation. Because it needs to forecast the demand of the incoming vehicles during peak hours so as to optimize the parking supply. Also, the parking chaos worsens local traffic and air pollution issues. For the internal evidence of parking violations, commuters will have unnecessary spending on paying the citations. In addition, students will also imitate such behavior to parking for convenience but ignoring the policies on campus. These facts summarize a comprehensive review of the negative impact of parking chaos. Considering the fast growth of smart parking technology, parking congestion problems can be effectively resolved.

The literature review of this research also concludes the most used types of IoT components with the highlight usage trends. In Figure 5, it documents the wireless IoT protocol usage per year from 2011 to 2018. The data shows that smart parking technology is widely deployed and still increasing according to market demand (Barriga, 2019). Also, the paper categorizes the overall evaluation of different electronic components by usage. Thus, if this proposal is selected for deployment, the engineering team will likely select the most relevant sensors based on the project objectives. In Figure 6, the researchers visualized the distribution of the most common sensor type for the system infrastructure, such as camera and ultrasonic. Therefore, the next part of the literature review will discuss the scientific methodologies of different sensor-based solutions and what is the effectiveness of the system for detecting the empty spots as well as the accuracy of data.

**Figure 5: Wireless IoT protocol usage Figure 6: Sensor Type Selection**

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*Source: A Literature Review of Smart Parking*

***Scientific Methodology of the Computer Vision Based Approach***

The study from the University of Washington purposed a smart parking solution that can be built on many platforms and different components (Xiao, 2017). The team researched a potential solution using the camera module and the computer-vision algorithm to detect the vacancy of each parking space. They integrate the camera with microcontrollers to upload pictures on the server, and then determine the occupancy of each slot based on the parked vehicle positions. According to the simulation result on campus, the accuracy of the vision-based technique is around 91% (Xiao, 2017). The researchers claim that the preliminary stage of the platform still needs validation and testing. Because the probability of detecting the parking space depends on the different light intensity, parking layout, and progressive training over the computer algorithms. This vision-based technique proves the feasibility of utilizing a low-cost camera to deliver the occupancy information in real-time for users. If this platform deploys on campus, it will help commuters to easily search for parking. Otherwise, students and faculties will continue to suffer from parking woes and worsen local traffic during peak hours.

**Figure 7: System Architecture of Vision-based IoT Device**

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*Source: Intelligent Platforms & Architecture Lab University of Washington (Xiao, 2017)*

***Scientific Methodology of the Ultrasonic Sensor Based Approach***

Another alternative study, which is purposed by the team at the University of Tenaga Nasional, used different sensor signals to replace the camera-based technique (Singh, 2018). They integrate an ultrasonic sensor with the Graphical User Interface (GUI) that displays the vacancy of parking slots by communicating the database. The improvement is that the ultrasonic sensor can estimate the distance between objects. So, it can return signals when the vehicles parked at the spot. In another perspective, it crosses the barrier of using computer algorithms to analyze the parked vehicle position. The system can simply collect the signals of each parking space and communicate with drivers through the mobile application. Considering the heterogenous parking choice behaviors that research by Tongji University (Meng, 2018), the mobile application can also insert some add-on features from the article, such as GPS location and payment system at the nearby street parking. Because precious study states that search for parking wastes most of the time. If the mobile application can provide a navigation service for commuters to find the nearest available parking zone and the exact location of the spot, the transportation system can be smarter and more efficient. From the conclusion of this sensor-based research. the actual performance of the smart system is reliable through a series of testing (2018), and we can consider the deployment at Rutgers University. It can greatly benefit the community and improve the overall satisfaction level.

**Figure 8: Results of Mobile Application Figure 9: Comparison of Sensor data**

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*Source: IoT based Parking Sensor Network for Smart Campus*

**Plan**

According to a research study at union college, the essential information about the smart parking solution is collected, such as the type of sensors and related software developing knowledge. However, the proposal of this research needs to be approved by the department of transportation and operations at Rutgers. The first step is to review this document as a brief introduction to the current issue of the parking system for commuters. Secondly, we need to recruit the relevant specialists or allocate the existing human resource from other departments, such as the engineers from the Information & Technology side. Next, we need to finalize the project plan if the smart parking solution is approved. It is important that the team can partner with some vendors to provide the electronic components with high quality and low installation cost. Since there are 35,234 parking stalls on campus, which is going to be a huge budget to install the sensors at each parking space (Annual Report, 2019). Then, the team needs to build the cloud infrastructure for the sensors to communicate with the database. In the next step, we need to launch a new mobile application for drivers to access the information about the occupancy of parking spots and the area policies. Lastly, the team will need to perform testing of the software and basic functions. We can continually make improvements to the information delivery method from the smart parking system based on feedback or survey. The plan for the proposal will require a new division under the current department of transportations because it’s a complicated and systematic project. As an engineering student, I think this project will let hundreds of students gain practical experiences in solving the real issue in the community. The department can also hire students across majors who have the related skills set and contribute themselves to the Transportation Master Plan at Rutgers University.

***Phase I – Project Review***

* Apply for the approval from the Department of Public Transportation.
* Revise the project plan and validate the system design of the infrastructure.
* Invite professional consultants for a comprehensive review and a detailed evaluation.

***Phase II – Hardware & Software System Setup***

* Hire specialists for software development and hardware implementations.
* Source the ideal suppliers of the electronic equipment and develop partnerships.
* Perform preliminary testing of the designed system and performance evaluation.

**Figure 10:**

**System Overview of the IoT Platform Device**

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*Source: A Parking Monitoring System for Union College*

***Phase III – Operation Management of the New Smart Parking System***

* Continuous process improvement of the system designs as well as maintenance.
* Coordinate with academic departments and provide relevant job positions for students who need practical training, such as programming.

The first year of deployment will provide sufficient data sources, which will be further analyzed in order to see if the program is lowering the parking chaos. The team can evaluate relevant metrics, such as the number of parking citations per year. If the effectiveness of the project is proven to be high, then this program can be considered as a powerful tool to make the transportation system more intelligent and efficient. We can also invite other universities in New Jersey to expand the program when they encounter the relevant issues.

**Budget**

The following budget is based on a 12-month period. According to the annual report from the Institutional Planning and Operations, there are 35,234 parking stalls on campus (2019). I also researched the market price of the related sensors and microcontrollers. The human expenses include the hourly pay rate for maintenance and the initial development of the mobile application.

* Ultrasonic sensor: $3.95 35,234 pieces = $139,174
* Microcontrollers with camera: $44.95 20 pieces = $899
* Cloud server pay rates: $50 12 months = $600
* Software development: $30 8 hrs. 20 days = $4,800
* System maintenance per year: $20 12 months 80 hrs. = $19,200
* Equipment maintenance per year: $3.95 2000 pieces + $44.95 5 pieces = $8,125
* Electricity consumption: $0.16 per kilo watt 1000 Watt 24 hrs. 365 days = $1,401

Total: $174,199.60

**Figure 11:**

**Cost Estimation of Proposal Budget**

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The above information is based on a rough estimation of what is needed for building the system. However, we can leverage the additional income by acquiring service fees for additional add-on features. A good example is the navigation system that provides optimal routines when searching for parking. People who are not the current student or faculty should purchase the application to access the database. Therefore, the program can increase its profitability by innovating the services. Also, Rutgers can attract third-party advertisements across campuses. This strategy will fulfill both internal and external demands within the community. Conclusively, the smart parking program not only benefits the commuters but also diversify our existing models of business.

**Discussion**

The parking chaos is always a long-term issue that happens across many universities. As we discussed, it not only increases the time of searching for spots but also creates additional air pollution. The frequent citations will also worsen the local traffic and affect the neighborhood parking system if people continue to violate area-specific policies. The results from the official data also revealed the increasing demand for on-campus parking capacity as more and more students chose to drive to colleges. Therefore, the public transportation department needs to take more action by participating in the reform of the existing infrastructure at Rutgers. From a series of studies over the parking choice behavior, we conclude that many factors are affecting people’s decision over parking. The cost of the permit, walking distances, and easiness of searching are all sensitive factors to commuters. If the current system cannot satisfy the diversified demand, the probability of parking violation will still climb up. Therefore, we need to optimize the information delivery method and increase the transparency of parking regulations in real-time.

Considering the introduced model, a smart parking system is strongly advised based on the diversified demand. The reason is that it can provide the availability of each parking stall across campus which will lower the time of search significantly. Also, the operational team can continually make process improvements with add-on features, such as a navigation system. From the previous study, students complain that they found it hard to park in the correct zone due to the complicated time slots as well as authorization. Since the department of public transportation updates the regulation frequently, it drives the demand for better support for guiding people when searching for a parking zone near campus. Besides, we also researched that alumni lack available resources to receive the information. If the smart parking solution deploys on campus, it will resolve the existed issues and makes transportation more intelligent.

As the plan continues to be applied, more and more students will respond to this platform. We can collect sufficient data to analyze if this program is reducing the parking chaos. We can also utilize the specialized workforce at Rutgers because they have a better understanding as one of the communities. If the program deployed successfully, we can also connect other universities to consider this solution for parking chaos. Based on research, more and more universities are facing the challenges of demand management. This will help in the reform to reduce the parking violation.

In the end, I strongly advised your team to review this program proposal. Because we need to collect the results from preliminary testing. Therefore, we can evaluate the new platform and perceive if it creates a better on-campus experience. I also hope you can share some thoughts about the solutions to face the parking issues right now. Please let me know if you have more information required from my side. Thanks for your time and consideration.

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