# SPATIAL AND TEMPORAL CHANGES OF PARKING LOT LAND USE AT SUNY BUFFALO STATE APPLYING UNMANNED HELICOPTER REMOTE SENSING

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**ABSTRACT:** Shortage of on-campus parking space during a school day is one of the major problems for universities in the United States, in particular for those urban campuses. In essence, this is a land use and land use change problem that is impacted by many factors. In this research, we applied unmanned helicopter remote sensing to collect occupational land use changes of student parking lots during the typical school days, such as Monday, Wednesday and Friday or Tuesday and Thursday. Spatial and temporal parking land occupation frequencies were visualized on hourly basis during a typical school day. The field collected student parking lot occupation data was statistically and geographically related to the university class offering time and location database. The research covers spring and fall semesters of 2014. The results show that the highest utilization rates of both student parking lots and classrooms occur in the Tuesday and Thursday afternoons. By contrast, the parking lot competition was not very intense during the morning hours of school days. Imbalances of the parking lot occupations are not only at different times and days, but also at different locations on the campus. Large student parking lots are located in the west side of the campus, while most of class offering buildings are located on the east part of the campus. The only student parking lot at the east side of the campus (lot Y) is always filled with vehicles during the school days. Based on the results of this study, suggestions for more effective on-campus parking management were proposed.

Keywords: unmanned helicopter remote sensing, on-campus parking, spatial and temporal land use change

### **INTRODUCTION**

The City of Buffalo is located at the west part of New York State. It is the second largest city in the state. Current population of the city is around 258,000. Higher education, in particular the public higher education is one of the major sectors of local economic activities nowadays. A total of 14 universities or colleges are located in the metro Buffalo region, and the estimated number of college students studying in these institutions are around 80,000. In the urban localities of large and mid-sized cities worldwide, parking problem has become a significant topic of researches in geography and planning. For instance, the lack of parking spaces and the high parking fee charges in the New York City or Beijing, China are the major problems of these meg-cities. Land use or occupation of on-campus parking lots is one of the most difficult issues that many universities encounter in the United States, in particular at the urban universities. A majority of students at US urban universities select the off-campus living and driving to the campus for classes. This pattern of student life in combination with the time schedule of class offering at the universities intensifies the competitions of parking lots during a school day. It is significant to study the spatial and temporal relationships of class offerings and parking lot occupations on urban university campuses in order to mitigate or resolve the parking lot land use competition problems.

Shortage of on-campus parking space is a common and urgent problem at the US universities. For the campuses that are located in the suburban area, building more parking lots would be an effective solution. However, for the campuses that are located in the urban area optimizing the existing conditions is more important. Analyzing the temporal and spatial pattern of parking and finding the cause of land use competition of this type of parking lots can provide the university valuable information for decision making. Studies of temporal and spatial occupations of parking lots at a university can help the university administrations to effectively utilize both classroom and parking lot resources and better manage the student flow during a school day. The methods of this research can also be generalized to be applied for other universities in the United States in solving the similar problems.

Higher education is one of the major factors influence the economic development of an urban area. Strong higher education institutions in a region would attract many young people to come and study in developing new ideas and new technology. Wendling (2011) indicated that in the United States, parking situation in a university is important enough to become one of the factors either promote or hinder the university development. Recently, more and more researchers focus on the studies of traffic conditions of university campuses and the campus parking policies (Balsas, 2003; Brata, et al., 2011).

Maktav et al. (2005) applied both remote sensing and GIS technologies to conduct urban research of the cities in developing and developed countries. One of the important aspects of remote sensing, in particular applying unmanned helicopter or drone platforms, is to obtain the image data at the times and locations where and when we needed. Researches applying unmanned helicopters or drones can enhance the geographic analysis otherwise might unable to do. For example, Weng (2012) conducted a research of the impermeable surface in the urban areas using the remote sensing images. Hoalst-Pullen et al. (2011) reviewed the trend of remote sensing applications on urban planning studies. In particular, both Weng (2011) and Hoalst-Pullen et al. (2011) addressed the importance of remote sensing using low altitude drone platform on urban studies and planning. Mountrakis et al. (2011) attempted to use support vector machine model to extract and convert remote sensing image data to vector data in the urban areas.

Herwitz, et al. (2004) and Sugiura et al. (2005) applied the unmanned airplane to monitor the crop growing conditions in a large farm to support decision makings on the crop irrigations or fertilizing. Sugiura at al. (2005) conducted corn field vegetation monitoring applying unmanned helicopter remote sensing. The research was able to monitor the growing conditions and condition change of the crop. Xiang and Tian (2011) took further steps to build a low-cost agricultural remote sensing system on the unmanned helicopter platform in order to fulfill the requirements of managing a large area of crop productions.

Chang-chun Li at al. (2011) developed a quick image rectification method for the imaging data collected from an unmanned helicopter platform for earthquake disaster regions. While, Xiang and Tian (2011) created a method to automatically geo-reference the unmanned helicopter images for applications of farm area and agricultural productions. Low altitude unmanned helicopter images were applied to analyze volcanic eruptions in Japan (Kanekoa et al., 2011). The results indicated that this type of remote sensing method is the most effective way for disaster area monitoring. Researchers can not only utilize this method to quantify the magnitude of the disaster, but also the changes of disaster over time.

Remote sensing data collection using an unmanned helicopter or a drone is an emerging new approach of geographic research and technology applications. Sharma et al. (2013) extracted and analyzed the canopy shadows of trees in a forest using the large scale unmanned helicopter images. The major advantage of this approach is that it can collect and analyze a large area in a natural forest locality very quickly and effectively. Great potential exists in applying unmanned low altitude remote sensing platforms for geographic researches or spatial data collections. The objectives of our research are: (1) applying unmanned helicopter remote sensing to collect image data of parking lot land use changes based on hourly time scale during a school day; and (2) analyzing the relationships of spatial and temporal changes of parking lot occupations and the class offering schedule during a regular school day.

The major innovation of this study is to apply unmanned helicopter platform for remote sensing data acquisition at the desired time and location of the researchers at the high image resolution and low altitude. The advantages of this approach are: (1) clear vertical true color (RGB) images can be taken with a high flexibility of time using a helicopter; and (2) aerial imaging using an unmanned helicopter encounters much lower cost than that of buying satellite images. These merits provide a huge convenience and can meet the needs of this research. In addition, attaching different kind of instruments, we can achieve different data acquisition purposes. This new technological innovation can help us obtain a great amount of image data that was unreachable previously. In the future, it can also be integrated with laser scan sensor to build the module of tree-dimensional (3D) data acquisition.

### **METHODS AND APPROACHES**

This study focuses on the data acquisition work using a remote controlled unmanned helicopter. The equipment that we sued for field data collections is DJI Phantom 2 Vision +. A high resolution true color digital camera was attached on the drone. Within 1,000 meter range above the ground, the camera can capture high resolution digital photographs for the parking lots on the campus. Distribution of parking spots on campus at SUNY – Buffalo State is shown in the Table 1. The parking lots that open to the students are A-1, F, G, K, L-1, M, R, Y, Z. A-1and Z lots are actually the parking spaces on the side of the roads, and only provide a few parking spots.

The distribution of the parking lots on campus is imbalanced. Three student parking lots are located at the southwest side of the campus. These are G, a large lot; F, a medium sized one; and K, a small lot. Two parking lots, one large (M) and one medium sized (L-1), are located at the west side of the campus. A large parking lot R is located at the northwest corner of the campus. Only one small parking lot Y is at the east side of the campus.

The name of the lots	Number of positions
A-1	64
F	150
G	643
K	34
L-1	150
М	500
R	500
Y	69
Z	12

Table 1 The number of parking spots at different parking lots.

According to the data provided by the Associate Dean's Office at the School of Natural and Social Sciences, the weekdays can be divided into two groups based on the curriculum arrangement. The characteristic of the university curriculum is that each class is arranged 2 or 3 times a week, and the same class would not be arranged in a row of two days during a week. That means all the courses are scheduled as having class meeting times either on Monday, Wednesday and Friday or on Tuesday and Thursday. A few late afternoon classes are scheduled on Monday and Wednesday only. In this study, the late afternoon classes on Monday and Wednesday were grouped with Monday, Wednesday, and Friday classes in order to keep the dataset simple. The courses arranged in the morning would begin after 8 a.m. and end before the noon. The afternoon classes begin after 1 p.m. and ends before 5 p.m. Since after 4: 30 p.m., students can use faculty and staff parking lots, the parking situation in the evenings was not analyzed in this study. All the buildings that have classrooms are shown in the following image map (Figure 1). Two labeled buildings on this image map (Figure 1) contain large clusters of classrooms. The Classroom Building has many small teaching rooms ranging from 20 to 90 students. The Bulger Communication Center contains large classrooms that often have over 100 student capacities.



Figure 1. The distribution of the buildings on the campus.

The sampling time of aerial survey and image data collections in this research were designed as following (Table 2).

Table 2. The time arrangement of aerial survey.

	M\W\F	T\R
Morning	8:00~9:30 AM	8:00~9:30 AM
Afternoon	1:30~3:00 PM	1:30~3:00 PM

The peak of the traffic flows in each a parking lot appears in 10 minutes before the classes begin. During the class time, the number of vehicles in the parking lot and the parking lot utilization are fairly stable. Data collection was chosen to start after the classes begin. Since the classes last for about one hour and fifteen minutes in maximum, the aerial survey time were controlled within one hour period in order to avoid the possible change time of parking. Two weeks during each of three periods, the beginning of the semester, mid-term and the end of the semester were selected to conduct the aerial survey. In principle, each period of the semester, at least one set of complete information would be collected within the morning or afternoon groups.



Figure 2. Data for one of the parking lot using the video camera carrying helicopter (L-1, February 04, 2014 afternoon surveying time).

Owing to the limitation of the equipment, the digital images of first semester (spring of 2014) were collected as video format. One video was taken in every parking lot. After extracting the image from the video, the total number of the vehicles can be observed from the image frame; and the occupation rate in that parking lot during that time can be calculated. In the fall semester of 2014, a new unmanned helicopter with true color high definition imaging capability was acquired (DJI PHANTOM 2 Vision+, Figure 1). The vertical digital aerial photos can be taken directly through a smart phone enabled flying control system. The image data collection quality and effectiveness increased drastically (Figure 2 and 3).



Figure 3. Data collected during fall semester of 2014 applying DJI PHANTOM 2 Vision+.

The occupation rate of student parking lot during surveying periods of the semester may be different. The hypothesis in this study is that the students may be more actively attending the classes in the beginning and the end weeks during a semester. We expect that the parking lot occupation rates during the mid-term surveying period to be lower than the other two sampling periods. In this research, the statistic t-test was used to test the hypothesis.

The histogram (Figure 4) shows that the average occupation rate of the sampling period of mid-term is lower than the other two sampling periods during the surveying semesters. Homoscedastic t-tests to every pairs of the sampling data were conducted. The p-value of the sampling periods of the mid-semester and semester-end is smaller than 0.05. This suggests that the occupation rates of student parking lot at the mid-semester are significantly lower than that of the end of semesters. Therefore, we might expect the great increase of occupation rate of student parking lots in the end of the semesters.



	F-test	T-test
TEST	(p-value)	(p-value)
B-M	0.297927	0.341328
B-F	0.750491	0.055413
M-F	0.744319	0.039207

Figure 4. Comparison among different survey periods (B – beginning, M- Mid-semester, and F- semester-end) during the two semesters.

Some students prefer to take classes on Tuesdays and Thursdays. Therefore, they can utilize three weekdays to do something else, in particular to have a part-time job. In the meantime, many faculty members would also like to teach the classes on Tuesdays and Thursdays. This kind of preference of choice may cause the possible imbalance of class scheduling and parking utilization during a school week.

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The histogram (Figure 5) shows that the average parking lot occupation rates of Monday, Wednesday and Friday (abbreviation: M) is 0.544, which is lower than the rates of Tuesday and Thursday (abbreviation: T). Homoscedastic t-test of the variance (Figure 5) shows that the p-value is 0.003967, which is smaller than 0.05. The result suggests that we can say the parking lot occupation rate on Monday, Wednesday, and Friday is obviously lower than that of Tuesday and Thursday. Therefore, we may expect more intense competitions of student parking space on Tuesday and Thursday than that of Monday, Wednesday, and Friday.



Figure 5. Comparison among different weekdays.

Similar to the week day patterns of preferred class scheduling during a school week, the students may prefer to take either morning classes or afternoon classes. The histogram (Figure 6) shows that the average parking lot occupation rate of morning (A) time is 0.457, which is lower than the rate of afternoons (P). In order to conduct a valid T- test, we need to make sure that whether the variances of these two groups of data are the same. F-test was applied for testing the variance distributions. The p-value of F-test is 0.0035, which is smaller than 0.05. Therefore, we can say there is a difference of the two sampling data groups. The p-value of the T- test is much smaller than 0.05. That means the parking lot occupation rates of afternoon period is significantly higher than the rate of morning time. It seems we can suggest that most of the students prefer the afternoon classes, and competition of parking space in the afternoon is higher than that in the morning during a school day.



Figure 6. Comparison between morning (A) and afternoon (P) time periods during a school day.

#### **RESULTS AND DISCUSSIONS**

As the results of spatial distribution imbalance of the parking space around the campus, there are significant usage differences both temporal and spatial among student parking lots. The parking lots that are closer to the buildings of the classrooms would encounter high competitions. In the meantime, those parking lots that are far away from the class offering buildings on campus or those are considered have poor public safety insurances would be less interested. In order to verify this assumption, the statistical analysis of one-sided T-test was applied.

Occupation rates of different student parking lots on campus are classified in Figure 7. The category "A" includes those have moderate walking distance to the class offering buildings. These are parking lot F, L, and R, and the average occupation rate during a school day is around 0.5 or 50%. Category "B" parking lots are those having lowest occupation rate and longest walking distance to the class offering buildings. These are parking lot G, K, and M. The characteristics of these parking lots are 1) they are all located on the far west side of the campus; and 2) they are larger than those other parking lots on the east side of the campus. In particular, students parked in the M lot need to cross a major public street (Grant Street) to walk to the class offering buildings. The safety and security concerns of the students are the major issues of this parking lot. Y parking lot is classified into the category "C" with highest occupation rate of almost 1.0 or 100% during a school day. Lot Y is the only student parking lot in the east part of the campus close to most class offering buildings.



Figure 7. Classification of occupation rates during a school day among different parking lots.

In combination of the distribution of class offering at different buildings according the university class scheduling database and the occupation rates of the student parking lots, we applied ArcGIS to make digital maps using the New York State digital orthographic aerial images (Figure 10). In this way, we would be able to visualize the distribution of class offering and parking lot occupation rates both by geographic locations and by time during a school day.

The spatial and temporal relations of class offering locations and the student parking lot occupations are shown in in Figure 8. The symbols of parking lot utilization range from the blue as the lowest to red as the highest. By contrast, the class offering rate in a building is symbolized from the light yellow as the lowest to the dark brown as the highest at the same time period. The highest utilization rates of both student parking lots and classrooms occur in the time period of Tuesday and Thursday afternoon. During this time, a large number of classes are offered in the Classroom Building, the Bulger Communication Center, and the Rockwell Hall. The student parking lots Y, F, and L are either overflowed or reached its capacity (in red symbol on Figure 8). The lowest occupation rate of the parking lots is higher than 60%. It is likely more students would be late in the class during this period owing to competition of parking space, or unwillingly walk long distance based on the parking availability. In contrast, less competition of student parking spaces during the other three time periods, namely Monday, Wednesday, and Friday

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morning and afternoon, and Tuesday and Thursday morning. Two major characteristics exist across the four modeling time periods. These are: 1) Parking lot Y that is located in the east part of the campus and close to class offering buildings is always full no matter how which time period; and 2) large student parking lots that are located at west part of the campus, such as M and G lots, are always among the lowest occupation rates during the school days.



Figure 8. Spatial and temporal distributions of classroom occupations and parking lot land use during different class scheduling school days.

Reading the spatial and temporal models (Figure 8), we recognize that most of the classes are scheduled in the buildings at the east part of the campus, while most student parking space is distributed in the west part of the campus. If a student parks his or her car in the parking lot M, he or she may need to walk around 15 minutes to reach the classroom in the buildings at the east part of campus where most classes take place.

The straightforward solution of the student parking space imbalance on campus is to construct more parking lots at the east part of the campus. In addition to physically increase the land area of parking space, several suggestions are proposed based on the results of this study.

1) Establish a differential parking fee system based on the parking lot locations

The current student parking fee policy is the one charge covering all. This intensifies the competition to the Y lot which is the most favorite parking space that is close to the class offering buildings. Therefore, we would suggest that at least two different types of student parking permits should be issued, namely regular and Y lot priority. Those students would like to park at the lot Y providing the space available should pay a higher parking fee. Students holding a regular parking permit are allowed to park in any student parking lot except Y lot. This way not only we can divert the traffic flow and avoid intense competition of parking space at the Y lot, but also allow students to plan their school time more accurately.

2) Set up a campus wide monitoring system to forecast the real-time parking situation to driving in students In order to keep the students informed for parking situations, a monitoring and broadcasting system on campus is necessary. Developing an "App" for smart phone, and broadcasting the real time parking situation would be a very effective solution. If the information of the situation in each of the parking lots can be sent to the students through smart phone, students can decide where to park before they arrive at campus. That will save time for parking and insure them to be at the classes on time.

3) Build multistory parking garages on the east part of the campus

If the financial situation is suitable, the administration of the university should consider building multistory parking garages on campus, in particular in the east part of the campus where high occupation rate occurs. The number of the parking spaces will be doubled or tripled with same land area this way. For instance, parking lot Y is a suitable location to build a multistory parking garage according the results of this study.

4) Improve the student safety issues on the fringe area of the campus

One of the reasons that students do not like to park in the parking lots located on the west edge the campus is that robberies or sexual assault happened previously in this area. Improvement of safety and security in west part of the campus will increase the parking lot occupation rate at that part of the campus.

## CONCLUSION

In this research, the new technology of unmanned helicopter remote sensing was applied to survey the occupation changes of student parking space on campus. In combination with the class offering database of the university, the occupation rates of the parking lots around the campus were analyzed during school days. The following summarizes the findings of this study.

- 1) The shortage of the parking spaces on campus is not caused by the shortage of land area developed for parking. The major reason is the imbalance of utilization of parking lots both temporally and spatially.
- 2) The temporal imbalance of the parking lots is mainly caused by the preferred class time period of students. The administration of the university can modify this situation by class scheduling.
- 3) The spatial imbalance of the parking situation is mainly caused by the unreasonable distribution of the parking lots on the campus. Under the current situations, the university administration can implement the policy of differentiating student parking fees or implement a real time on campus parking monitoring and broadcasting system to improve the efficiency of parking lot land. This will save student commuting time to classes.

The unmanned helicopter as a new platform of remote sensing data collection was applied in this research. Both advantages and disadvantages of unmanned helicopter or drone were presented. The equipment provides a flexible way to collect image data at the time and location the researchers choosing. It can provide high resolution and large scale spatial imagery data. The equipment can also be applied to monitor the changes over time otherwise it would be impossible. However, the equipment cannot work in the hazardous weather conditions, such as the situations of strong wind blow or snowstorms.

Accounting all these drawbacks of applying drones or unmanned helicopters for remote sensing and large digital data collections, the technology still opens new possibilities and extended our capability of conducting scientific researches. As the development of unmanned flying platform with increased "pay load", many more scientific observation or monitoring sensors can be attached to it to facilitate new discoveries.

## ACKNOWLEDGEMENT

The authors would like to express their sincere thanks to Ms. Chen Liuli Jiang and Ms. Yingyu Zhang for their help of field data collections applying unmanned helicopter remote sensing.

The database of all course offerings with classroom location, time, and student quota were collected from the Associate Dean's Office at the School of Natural and Social Sciences, SUNY – Buffalo State.

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