Optimal Number of Parking Permits to Release at UNC

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Executive Summary

The Parking Services Division of the Department of Public Safety at the University of North Carolina at Chapel Hill is responsible for managing all parking for the university community. During weekday daytime hours, most parking zones on campus require a parking permit. Due to parking space limitations, not everyone on campus can possess a permit. Parking Services must decide how many permits to give out in each lot on campus so as to best serve the university community. Lots frequented by university staff and faculty are overbooked in order to increase utilization. Releasing too few permits leads to a squandering of parking resources, as lots do not fill up during the day. However, too much overbooking leads to situations where lots overflow and permit holders cannot find a spot. Parking Services is interested in finding the optimal number of permits to release in five of the larger lots on campus (Bell Tower Deck, Cardinal Deck, Cobb Deck, Craige Deck, and Jackson Deck) in order to maximize utilization subject to overflowing each lot three or fewer times each year.

Parking Services keeps track of the number of outstanding permits in each lot, and parking officers are occasionally sent to each lot to count the number of full and empty parking spots. By combining these two sets of data, it can be determined what percent of permit holders are present in the lot during a count. Only counts that occurred on school days between the hours of 9AM and 4PM are relevant to determining the number of permits to release. Using these relevant data points and correcting for the time of the count, it is possible to approximate a distribution of the percent of permit holders that will show up during the peak parking time on a given day. The peak parking time is the time of day when the lot is most full and most likely to overflow. This distribution can then be used to determine the optimal number of permits to release, subject to the lot overflowing only two or three times a year.

By the analysis described above, it was determined that the following number of permits should be released for each lot: 837 for Bell Tower, 1939 for Cardinal, 586 for Cobb, 2077 for Craige, and 1052 for Jackson. The analysis was based on two years of data (2008-2009 and 2009-2010 school years), except for Bell Tower, which was newly opened in 2010-2011. It is suggested that 95% of these permits be released at the start of the school year. Empty spot counts should be performed in August and September to ensure that permit holder behavior has not changed significantly. If open spots are available, release the last 5% of permits in October.

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Overview

Parking Services is a division of the Department of Public Safety at the University of North Carolina at Chapel Hill. Parking Services manages all parking for the University community, which represents approximately 40,000 daily trips and 1 million annual visits by students, staff, faculty, event patrons, visitors, and patients at UNC Health Care.

Parking Services operates approximately fifty parking zones on UNC's campus, with the zones ranging in size from a handful of parking spots to thousands of spots. During weekday daytime hours, most parking zones on campus require a parking permit. These permits are distributed by the Parking Services Division to faculty, staff, and students throughout the year. Those parking illegally in spots reserved for permit-holders are subject to receiving a parking ticket and fine.

Parking on campus is limited by the size and number of parking lots. There is a larger demand for parking than the current supply of parking spaces. Parking Services must decide how many permits to allocate to students, faculty, staff, and others demanding parking. At the beginning of each school year, a certain number of permits are distributed to students requesting on-campus parking. Permits are also allocated to the more than 200 departments at UNC based on the size of the department and seniority of its faculty and staff members. When awarded a permit, a student, faculty member, or staff member must purchase the permit for a set price. The revenue that comes from the sale of parking permits is significant, as permits cost hundreds of dollars for the year, and there are approximately 15,000 permits assigned each year.

In many parking zones, Parking Services overbooks the zone by selling more permits than there are parking spots in the zone. The rationale behind this is that those with permits have different personal schedules and will park at different times during the day. So it is rare for all or nearly all permit holders to attempt to park at the same time. By overselling the zone, more permits are distributed and the utilization of the parking zone increases. The danger in overselling zones is that a permit holder will arrive and not be able to park because all parking spots are taken. Parking Services is sympathetic to the plight of this permit holder and attempts to minimize the occurrence of permit holders encountering full parking zones.

Parking Services would like to know the optimal number of permits to release in their larger parking zones. This optimal number will achieve the highest utilization of parking spots in the zone without having permit holders turned away from full lots more than two or three

times a year. The optimal number will vary for each parking zone, and will depend on such issues as the number of parking spots available, the percentage of student resident parkers, the location on campus, and the variety of full-time faculty/staff using the zone.

The lots in question in this study are the Bell Tower Deck, Cardinal Deck, Cobb Deck, Craige Deck, and Jackson Deck. Bell Tower Deck is the newest lot on campus, which opened in the 2010-2011 school year with a capacity of 709 parking spots. It is centrally located near the Bell Tower and Kenan Stadium. Cardinal Deck (capacity 1413), Jackson Deck (capacity 829), and Craige Deck (capacity 1408) are all on the south side of campus, near the hospital. Cobb Deck holds at most 453 cars and is located on the northeast part of campus near Davis Library. Bell Tower, Cardinal, and Jackson Decks serve university employees. Craige and Cobb Decks serve both university employees and students. A map of campus, with parking lots of interest circled, is located in Appendix A.

Traditionally, Parking Services releases an initial number of permits in August that will under-utilize these larger parking zones. After seeing how many more spots could be filled before reaching capacity, more permits are distributed after school has started. In this way, Parking Services increases incrementally toward an ideal number of permits. However, if the optimal number of permits to release were known at the beginning of the year, Parking Services could release that number immediately at the beginning of the year. In this way, more students, faculty, and staff could be granted a permit in the beginning months of the school year, increasing their satisfaction. Parking Services would also pull in more revenue, as it loses revenue when permits are sold midway through the year instead of at the beginning of the year. The permits are pro-rated based on how much of the year has elapsed, so those sold at the beginning of the year bring the most revenue to the department.

This project will provide suggested permit allocations to Parking Services for the five lots listed above. The suggested permit allocations will come with a suggested distribution timetable and warnings about the limitations of this study.

Available Data

Permit Data

Each year, Parking Services distributes permits to students and employees. It keeps a computer record of the transaction, recording the permit number, the parking lot, and the date distributed. Subsequent transactions for that permit holder are also electronically recorded.

Permit holders contact Parking Services if their permit is stolen or lost or if they wish to return a permit they no longer need or use.

For 2008-2009, Parking Services' database recorded the following pieces of information for each permit holder: Permit Number, Type, Lot, Expiration Date, Effective Date, Issue Date, Possession Status, and Possession Status Date. To discover the number of outstanding permits in a given lot on a given day, first isolate the data corresponding to permits in that lot. The relevant pieces of information are then the Expiration Date, Issue Date, Possession Status, and Possession Status Date. There are six possession statuses: Sold, Web, Lost, Stolen, Returned, and Destroyed. The Permit Status Date lists the last date of interaction Parking Services had with the permit holder. If a permit is listed as Sold or Web, the last transaction Parking Services had with that permit holder was when the permit was sold. Web signifies that it was purchased online instead of in person or over the phone. If a permit is listed as Lost or Stolen, the last interaction Parking Services had with that permit holder was to replace his physical permit because it was lost or stolen. Thus, on any given date between the Issue Date or the Effective Date (whichever is later) and the Expiration Date, permits with statuses Sold, Web, Lost, or Stolen are assumed to be active permits. Permits that are Returned are those that have been returned to Parking Services by the permit holder for a partial refund. Permits that are Destroyed are removed from active status by Parking Services for some reason, usually a clerical error during permit distribution. Thus, permits with statuses Returned or Destroyed are only considered to be active between the Issue Date or the Effective Date (whichever is later) and the Possession Status Date. Using this information, the number of outstanding permits in the lot on any given day between August 15, 2008 and May 15, 2009 can be discovered.

The data provided for school year 2009-2010 is similar to 2008-2009, but simpler. There are five data categories: Permit Number, Lot, Issue Date, Returned Date, and Stolen Date. If the permit was never returned or stolen, those two categories are left blank. The permits are assumed to be active from the Issue Date until the Returned Date. If there is no Returned Date, the permits are active until May 15, 2010.

Permit data from two years, 2008-2009 and 2009-2010, is available for Cardinal Deck, Cobb Deck, Craige Deck, and Jackson Deck. Because Bell Tower Deck was newly opened in 2010, special permit data was provided for it. The permit data for Bell Tower runs from July 2010 to March 2011. Its layout is similar to the 2009-2010 data for the other decks.

It is difficult to answer the question "How many permits were released each year in each lot?" because permits were released and returned throughout the year. The number of outstanding active permits in any lot changes as the year progresses. Appendix B gives the number of outstanding permits in each lot for selected dates. The number of outstanding permits in each lot varies month-to-month, but also year-to-year, in some cases significantly. For example, in May 2008 there were 2087 outstanding permits for Craige Deck, while in May 2009 there were 2616 outstanding permits, a difference of over 500 permits.

Open Spot Count Data

Parking Services has a group of officers who, among their other duties, occasionally survey parking lots on campus to count the number of open parking spots. This data is then stored in Parking Services' database. Each open spot count in the database contains the following information: Lot Name, Date of Count, Time of Count, Number of Empty Spots, Officer Name, and any Comments. The Comments are almost exclusively left blank and there is no reason to distinguish among officers, so the Comments and Officer Name fields are ignored for this analysis.

Open spot counts are taken throughout the year. For the purpose of this analysis, however, only days in which students and faculty were present for class or exams are considered. Thus, the first step in cleaning the data is to remove all spot counts taken on weekends, on holidays, and during the summer months between spring exams and the start of the fall semester. School year holidays include Labor Day, University Day, Fall Break, Thanksgiving Recess, Martin Luther King Day, Spring Break, and Good Friday.

The remaining counts that occurred on school days still vary considerably in the time of the count. Counts were taken at all hours of the day. It is reasonable to assume that if a lot is going to fill up on a school day, it will fill up between the hours of 9AM and 4PM. Before that, not enough people have arrived. After that, too many people have gone home for the day. An argument can be made that the counts between 8AM and 9AM provide useful information. However, counts between 8AM and 9AM were much more variable in the number of people present than later counts. Some days, a lot of people would show up early for work and other days the lot was sparsely filled before 9AM. So the decision was made to only retain counts between the hours of 9AM and 4PM for use in analyzing the behavior of permit holders. All other counts were discarded like the counts from weekends, holidays, and summer months.

The remaining counts all occurred during daytime hours on a school weekday. However, there were many days that had multiple counts of the same lot. These counts all provide the same data, namely the behavior of permit holders on one specific day. Often, two parking officers would ride together in counting the number of open spots in a lot, and they would both report the number into the parking database. Similarly, there were many examples where multiple officers would check on the same lot on the same day, but at different times. This may be due to a lack of communication in which lots have been studied that day, or it may be due to an interest in receiving redundant observations to ensure the accuracy of the count on a particular day. Either way, the information is redundant and would skew the analysis if multiple counts on the same day were all given the same weight as a single count on a different day. To remedy this, only one count was retained for each day for each lot. It was decided to retain the count that reported the fewest number of open spots in the lot on that day. This is believed to be the conservative approach, as Parking Services wants to err on the side of releasing too few permits, not too many. Retaining the count with the fewest number of open spots will lead to an analysis that suggests releasing fewer permits than retaining different counts, as will be evident later in this paper.

By the methods described above, at most one open spot count was retained in the relevant data set for each lot on each school day. However, not all lots were surveyed on each day. To see the data points that were retained for analysis in this paper, see Appendix C. There, the relevant open spot counts for Cardinal Deck, Cobb Deck, Craige Deck, and Jackson Deck are reported for years 2008-2009 and 2009-2010. Each data point displays the Lot Name, Date, Time, and Quantity Empty. In addition, the number of outstanding permits on the day of the count is displayed in the last column. For Bell Tower Deck, no spot counts were used in this analysis, so there are no references to Bell Tower Deck in Appendix C.

Analysis

Overview

Using the relevant open spot count data and the number of outstanding permits on the day of each count, the objective is to determine how many permits to release in each lot. To accomplish this, a better understanding of permit holder behavior is necessary. One method to gain this understanding is to determine what percent of permit holders are expected to show up

each day. Specifically, we want to fit a distribution to the percentage of permit holders that are present each day.

Using the percent of permit holders instead of the absolute number of permit holders present is preferred because there are different numbers of outstanding permits in the same lot on different days. It would be meaningless to see that 1200 permit holders showed up to Craige Deck one day and 1400 another day without context of how many permits were outstanding on those days. Thus, the percent of permit holders present during a spot count gives a better measure of permit utilization than the absolute number of permit holders present during a spot count.

Given the number of empty spots present during a count, it is simple to find the number of full spots since the capacity of the lot is known. Dividing the number of full spots by the number of outstanding permits gives the percent of permit holders present during the open spot count. It is possible to take these percentages and fit a statistical distribution to them.

Ideally, each lot should overflow no more than 3 times a year. There are about 150 school days in the fall and spring semesters. Overflowing 3 times out of 150 would be overflowing 2% of all days of interest. With a distribution of the percent of permit holders that will show up each day, it is possible to find the 98th percentile of that distribution. Call the 98th percentile of the distribution X_{98}. 98% of all school days, less than X_{98} percent of permit holders will be present in the lot; that is, only 2% of all school days (3 days a year) will more than X_{98} percent of permit holders be present. Using this, it is possible to determine how many permits to release to only overflow the lot 3 times a year. Release the number of permits so that if X_{98} percent of permit holders show up, the lot is exactly full. In that way, only 2% of days will the lot overflow when a larger percentage of permit holders shows up. If the lot capacity is Z, release $Z \div X_{98}$ permits ($X_{98} < 1$).

So the analysis consists of fitting a distribution to the percent of permit holders present and then reading off the 98th percentile of this distribution. However, there is one difficulty that has not yet been discussed. The open spot counts, from which the percent of permit holders present can be found, occur at varying times between 9AM and 4PM each day. It may not be reasonable to treat a count that occurs at 9AM the same as a count that occurs more toward the

middle of the day, when more permit holders may be present for work. In addition, one is not interested in whether the lot was overflowing at the time of the open spot count. Of interest is whether or not the lot will overflow at *any* time during the day. Therefore, it would be useful to approximate how many permit holders showed up at the peak time on a day when an open spot count occurred, given that the spot count occurred at a certain time and observed a certain number of cars in the lot. A useful correction for the time of the open spot count needs to be developed, to translate from the permit holders present at the time of the count to the approximate number present at the peak time of the day.

Correcting for the Time of the Open Spot Count

To move from the percent of permit holders present during the time of a count to the approximate percent present during the peak time of the day, it is necessary to have an idea of how permit holders come and go from the parking lot as the day progresses. To gain this knowledge, the author decided to observe a parking lot and record the arrival and departure times of cars in that lot. Because most lots have multiple entrances and exits, it was necessary to find a lot where one person could observe all in-flow and out-flow. Bell Tower Lot proved to have this quality, as a single observer can watch all the cars entering and exiting through the sole gate out front.

For two days in March (Wednesday, March 16, 2011 and Thursday, March 17, 2011), the author and a friend, Maria Schwartzman, observed the Bell Tower Deck. At 8AM, a count was taken of the number of cars present in the lot. Then, the arrival and departure times of every entry and exit was recorded from 8AM until 2PM. This data is summarized in Appendix D, with arrival and departure totals for each half hour given. At a first glance, it is clear that the inflow of permit holders is greater than the outflow until around 11:30AM, when the flows even out. Observations were only taken until 2PM due to time constraints of the author. It will be assumed that not much inflow or outflow occurs between 2PM and 4PM, which seems reasonable.

These arrival and departure statistics were used as the basis of a simulation, in order to augment the number of days of data. The simulation was programmed in Matlab. The simulation was run 10,000 times, where each run represented one day from 8AM to 2PM. At 8AM, the number of initial cars in the lot was normally distributed with mean 332 and standard

deviation 15. Arrivals and departures were then simulated according to a time-variant Poisson process, where the rates for each half hour are given in the last column of the table in Appendix D. Actually, all of the above numbers (mean and standard deviation of initial number and arrival/departure rates) were inflated by 10% for reasons that will be discussed in the Bell Tower Lot section below. The number of cars present in the lot at 8:00AM, 8:30AM, 9:00AM, 9:30AM, … , and 2:00PM were recorded. The peak number of cars present during each simulation was also recorded. In this way, for each simulation run, the number present at each half hour interval could be compared to the peak number present. For example, during one simulation run, the number present at 9AM might be 81% of the number present at the peak point during the day. These values are then averaged over 10,000 simulations, with the following results:

	Avg. # Present	% of the Peak	Necessary Multiplicative Time Correction
During the Peak	699.384	1.00	
At 8:00AM	365.076	.522	1.9157
At 8:30AM	472.566	.6767	1.48
At 9:00AM	561.828	.8035	1.2446
At 9:30AM	621.314	.8884	1.1257
At 10:00AM	650.774	.9305	1.0747
At 10:30AM	674.378	.9642	1.0371
At 11:00AM	692.32	.9899	1.0102
At 11:30AM	694.942	.9936	1.0064
At 12:00PM	690.402	.9872	1.013
At 12:30PM	679.388	.9714	1.0294
At 1:00PM	683.516	.9773	1.0232
At 1:30PM	683.138	.9768	1.0238
At 2:00PM	681.314	.9742	1.0265

It is evident that the peak occurs around 11:30AM on average. Before that, people are still arriving to fill the lot. After that, people leave for lunch or for the end of their work day. The third column in the chart shows what percent of the peak number was present at each half hour interval, on average. The last column is 1/(third column), giving the constant that can be multiplied by the count of cars present at that half hour to approximate the number present at the peak time of the day.

These multiplicative time corrections can be applied to the open spot count data to approximate the cars present at the peak time of day. For example, 1137 cars were present during an open spot count of Cardinal Deck on 10/9/2009 at 9:50AM. 9:50AM, when rounded to the nearest half hour, is 10:00AM. Therefore, 1137 can be multiplied by 1.0747 to approximate that there will be 1221.9 cars present at the peak time in Cardinal Deck on 10/9/2009.

This correction relies on the assumption that all decks behave in a similar fashion as the day progresses. While other decks may evolve differently throughout the day, it is believed that the time corrections found via observation of the Bell Tower Lot will be good approximations for the other lots as well. Because observational data was not taken from 2PM to 4PM, the same multiplicative constant that is applied to counts around 2:00PM will be applied to all counts between 2:00PM and 4:00PM.

By multiplying the number present at the time of the count by the proper multiplicative correction factor, the number present at the peak time of day is approximated. Dividing this number by the number of outstanding permits gives the approximate percent of permit holders present at the peak time of day. The time-corrected percent present values for each spot count will not be presented in this paper. To find any specific value, use the following equation, taking values from the tables in Appendix C and the table in this section:

Time-corrected percent present

= (lot capacity − # of empty spots) * multiplicative constant ÷ # of outstanding permits

In the next step, a distribution will be fit to these time-corrected percentage values.

Distributional Fitting

As mentioned in the analysis overview, a distribution will be fit to the percent of permit holders present. The last section described how to correct the percent present for time. A distribution will now be fit to these time-corrected peak percentages present for each lot.

Using EasyFitXL, an add-on for Excel that fits many statistical distributions to the same data, it was determined that a beta distribution fits the empirical distributions of Cardinal Deck,

Cobb Deck, Craige Deck, and Jackson Deck quite well. A beta distribution is a reasonable pick to fit to the time-corrected percent of permit holders present, as the domain of the beta distribution can be viewed as a probability. The percent of permit holders present can also be interpreted as the probability that an individual permit holder will be present. The beta distribution is often used to describe the distribution of an unknown probability value. Because the beta distribution is often used with probabilities and because it fits the empirical data well, it will be used for the fitting of all lots and all years. The distributions were also fit in Matlab, to ensure EasyFitXL's accuracy. The results were the same.

The beta distribution has upper and lower bounds on the values that it can take. In the standard beta distribution, these are 0 and 1. Because no time-corrected percentage values were near 0 or 1, it is reasonable to assign more realistic bounds on the percent of permit holders that will be present at the peak time of the day. The mean and standard deviation of the time-corrected percent present were found. It was decided to set the bound of the beta distribution to be this mean +/- 3 standard deviations. No observed time-corrected percentage values fell outside of these bounds.

A beta distribution was fit to each of the Cardinal Deck, Cobb Deck, Craige Deck, and Jackson Deck time-corrected percentages present: first for 2008-2009 data, then for 2009-2010 data, then for both years combined. Histograms of the data with a beta curve overlaid are shown in Appendix E. Goodness of fits tests are also summarized. While some histograms are not very well fit by a beta curve (notably Cobb Deck data either year and Cardinal Deck 2008-2009 data), the author felt the beta curve fit most distributions well and wanted to use the same type of distribution for all data sets.

Finding the Number of Permits to Release based on the Distributions

With the distributions of Appendix E in hand, it is now time to recommend the number of permits to release for Cardinal Deck, Cobb Deck, Craige Deck, and Jackson Deck. Recall from the Analysis Overview that the 98th percentile of the distribution can be converted into the number of permits that could be released to overflow the lot only two or three times a year. Similarly, the 95th percentile can be converted to the number of permits that could be released to only overflow the lot 5% of all schooldays. The 99.3 percentile can also be found and would

correspond to a number that would overflow the lot only once a year. This would be a more conservative permit release. These levels are reported in each of the following sections, which are broken up by parking lot.

Each section includes three sets of analysis. The first two correspond to the suggested number of permits to release based on one year of open spot count data, either 2008-2009 or 2009-2010. The third set uses both years to reach a conclusion on permit release.

Cardinal Deck

Cardinal Deck has a capacity of 1413 cars. Here is a summary of the two years of data:

2008-2009	2009-2010
95th Percentile: 72.4%	95th Percentile: 71.0%
Permits to Overflow 7X/year: 1953	Permits to Overflow 7X/year: 1990
98th Percentile: 73.3%	98th Percentile: 72.4%
Permits to Overflow 3X/year: 1929	Permits to Overflow 3X/year: 1953
99.3 Percentile: 73.9%	99.3 Percentile: 73.5%
Permits to Overflow 1X/year: 1913	Permits to Overflow 1X/year: 1923
Actual Outstanding Permits on Nov. 1: 1930	Actual Outstanding Permits on 11/1: 1986
Actual Outstanding Permits on Jan. 1: 1925	Actual Outstanding Permits on 1/1: 2024

Both Years
95th Percentile: 71.6%
Permits to Overflow 7X/year: 1974
98th Percentile: 72.9%
Permits to Overflow 3X/year: 1939
99.3 Percentile: 74.0%
Permits to Overflow 1X/year: 1910

For Cardinal Deck, both years are fairly similar and the possible release levels are similar to the actual release levels that occurred in 2008-2009. 2009-2010 released more permits than expected. Because both years are similar, use the suggested permit release values from the Both Years section to choose the number of permits to release. It is suggested that 1939 permits be released, the number of permits coinciding with the amount that the Both Years data suggests will overflow the lot 2% of the time.

Cobb Deck

Cobb Deck has a capacity of 453 cars. Here is a summary of the two years of data:

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2008-2009
95th Percentile: 74.6%
Permits to Overflow 7X/year: 607
98th Percentile: 76.1%
Permits to Overflow 3X/year: 595
99.3 Percentile: 77.4%
Permits to Overflow 1X/year: 585
Actual Outstanding Permits on Nov. 1: 554
Actual Outstanding Permits on Jan. 1: 559

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2009-2010
95th Percentile: 75.0%
Permits to Overflow 7X/year: 604
98th Percentile: 76.8%
Permits to Overflow 3X/year: 590
99.3 Percentile: 78.1%
Permits to Overflow 1X/year: 580
Actual Outstanding Permits on 11/1: 576
Actual Outstanding Permits on 1/1: 585

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Both Years
95th Percentile: 75.6%
Permits to Overflow 7X/year: 599
98th Percentile: 77.3%
Permits to Overflow 3X/year: 586
99.3 Percentile: 78.6%
Permits to Overflow 1X/year: 576

For Cobb Deck, the two years match up nearly identically. The possible release levels are somewhat higher than the actual release levels that occurred. Cobb Deck rarely saw a nearly-full lot in the open spot counts that were taken in 2008-2009 or 2009-2010, even though it has a relatively small capacity. This suggests that Parking Services was overly conservative in its permit releases in these years, and that more permits could have been released. It is suggested that 586 permits be released to the university community for Cobb Deck.

Craige Deck

Craige Deck has a capacity of 1408 cars. Here is a summary of the two years of data:

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2008-2009
95th Percentile: 66.6%
Permits to Overflow 7X/year: 2113
98th Percentile: 67.8%
Permits to Overflow 3X/year: 2077
99.3 Percentile: 68.8%
Permits to Overflow 1X/year: 2048
Actual Outstanding Permits on Nov. 1: 2038
Actual Outstanding Permits on Jan. 1: 2042

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2009-2010
95th Percentile: 60.8%
Permits to Overflow 7X/year: 2314
98th Percentile: 62.2%
Permits to Overflow 3X/year: 2263
99.3 Percentile: 63.4%
Permits to Overflow 1X/year: 2222
Actual Outstanding Permits on 11/1: 2170
Actual Outstanding Permits on 1/1: 2289

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Both Years
95th Percentile: 64.1%
Permits to Overflow 7X/year: 2198
98th Percentile: 65.7%
Permits to Overflow 3X/year: 2144
99.3 Percentile: 67.0%
Permits to Overflow 1X/year: 2101

Craige Deck has the greatest discrepancy between the two years of data. Permit holders were much more likely to show up during the peak time in 2008-2009 than 2009-2010. The actual number of permits released matches up with the possible release levels for each year, but again, the two years do not agree. To err on the side of caution, not knowing how permit holders will react in a new year, it is suggested that the conservative 2008-2009 release levels be followed at the beginning of a new year. If fewer cars are showing up, as in 2009-2010, release more permits. Thus, release the suggested number of permits to overflow the lot 3X/year from the 2008-2009 data: 2077.

Jackson Deck

Jackson Deck has a capacity of 829 cars. Here is a summary of the two years of data:

2008-2009	2009-2010
95th Percentile: 77.5%	95th Percentile: 73.6%
Permits to Overflow 7X/year: 1069	Permits to Overflow 7X/year: 1127
98th Percentile: 78.8%	98th Percentile: 74.9%
Permits to Overflow 3X/year: 1052	Permits to Overflow 3X/year: 1107
99.3 Percentile: 79.8%	99.3 Percentile: 76.0%
Permits to Overflow 1X/year: 1039	Permits to Overflow 1X/year: 1091
Actual Outstanding Permits on Nov. 1: 1042	Actual Outstanding Permits on 11/1: 1137
Actual Outstanding Permits on Jan. 1: 1062	Actual Outstanding Permits on 1/1: 1203

Both Years
95th Percentile: 75.2%
Permits to Overflow 7X/year: 1103
98th Percentile: 76.6%
Permits to Overflow 3X/year: 1082
99.3 Percentile: 77.8%
Permits to Overflow 1X/year: 1066

Jackson Deck has a similar inter-year discrepancy to Craige Deck but to a much smaller extent. Again, permit holders were more likely to show up in 2008-2009 than 2009-2010, for whatever reason. As with Craige Deck, begin by releasing the number of permits that would overflow the

lot 3X/year in 2008-2009: 1052. If the permit holders begin to behave more similarly to 2009-2010 than 2008-2009, more permits will need to be released.

Bell Tower Deck Analysis

As mentioned earlier, Bell Tower Deck was newly constructed on campus for the 2010-2011 school year. Therefore, there are no permit or open spot count records for 2008-2009 or 2009-2010. In addition, there was no spot count data provided for the 2010-2011 school year. Thus, a different approach is necessary to determine the number of permits to release.

The only available behavioral data of parking permit holders that the author possessed is from the observations taken in an effort to correct for the time of open spot counts discussed earlier in the paper. The data was from March 16 and March 17, 2011. By examining the behavior of permit holders in other lots (Cardinal Deck, Cobb Deck, Craige Deck, and Jackson Deck), it becomes apparent that peak attendance levels in March are somewhat lower than the attendance levels in August, September, January, and February. This is probably due to the fact that the high attendance months are at the beginning of each semester, when faculty and employees need to be on campus more often to start the semester off on the right foot. The author, by looking at time series data of time-corrected percentage of permit holders present, surmises that the peak percentage showing up on an average March day is about 5-10% less than the peak percentage showing up during high attendance months. To be conservative, a March-to-peak month multiplicative correction factor of 1.10 should be applied to all March attendance rates, in order to assure that they adequately represent high attendance months. For this reason, in the "Correcting for the Time of the Open Spot Count" section, the initial number in the lot and the arrival/departure rates were all inflated by 10%. This is termed the month-to-month correction, and is believed to be very conservative. Permit holders are no more than 10% more likely to show up at the peak time of day during high attendance months as they are in March.

On March 16 and 17, 2011, there were 881 outstanding permits for Bell Tower Deck. It is possible to create a simulation to assess how often this number of outstanding permits will overflow the 709 spot capacity lot. The simulation uses the same initial number distribution and arrival/departure rates as described in the "Correcting for the Time of the Open Spot Count" section above. Specifically, at 8AM there is a normally distributed number of cars in the lot,

with mean 332 and standard deviation 15. The half-hour arrival and departure rates are given in the last column of Appendix D. All of these numbers are multiplied by 1.10 to apply the month-to-month correction. In 10,000 simulations, the 881 outstanding permit holders overflowed the lot sometime between the hours of 8AM and 2PM 3009 times.

Overflowing 3009 times out of 10,000 is too many. Granted, the month-to-month correction is very large and probably overly conservative. But we need to find a number of permits to release that will overflow the simulated lot only 2% of the time (equivalent to overflowing 2 or 3 times in a school year). In addition to multiplying by the month-to-month correction, let us also multiply the initial number and arrival/departure rates by an outstanding-permit correction. If this second correction is .80, that would mean that there are 80% as many outstanding permits in the simulation as there were on March 16 and 17, and so all rates and the number of initial cars at 8AM should only be 80% as large. For various values of this second correction, run 10,000 simulations and find the largest value such that the simulated lot overflows only 2% of the time (or less).

This largest outstanding-permit correction value is .95. If the initial number in the lot and the arrival/departure rates are multiplied by 1.1 (the month-to-month correction) and then multiplied by .95 (the outstanding-permit correction), the lot will overflow sometime between 8AM and 2PM in 123 out of 10,000 trials (1.23% of the time). Increasing the outstanding-permit correction to .96 causes the lot to overflow 284 times (2.84% of the time). Thus, releasing 881*.95 = 837 permits in August will ensure that the lot overflows no more than 2% of the time, even if permit holder behavior in all months of the school years is similar to their behavior during the high attendance months of August, September, January, and February.

It is thus suggested that Parking Services release 837 permits for Bell Tower Deck. This number is probably too conservative and will result in under-utilization. However, due to the lack of data, it is necessary to be overly conservative. If the lot consistently shows a number of open spots in August and September, it will be safe to release more permits in October. This is because no month, not even January or February, has a higher peak-time attendance rate than August or September.

Assumptions and Limitations of Analysis

This analysis was predicated on the assumption that new permit holders in each lot will behave similarly to those who held permits in 2008-2011. Should new permit holders be less likely to use a parking spot during peak lunchtime hours, the permit release numbers reported here will be too conservative. Should they be more likely to use their permit, these numbers may be too liberal and result in more frequent lots overflows. Thus, it is important that the distribution of employees, staff, and faculty receiving permits in these lots be similar to the distributions in 2008-2011. If a lot that was exclusively university employees is converted to a lot that is shared by employees and students, this analysis will not be applicable.

The methods to find the number of permits to release are believed to be conservative in scope. Only one open spot count was kept for each day for each lot, and that count was the one that reported the most cars as being present. No outliers of high peak-time attendance percentages were removed from the relevant data. When the two available years of data did not agree, the more conservative year was suggested. When analyzing the Bell Tower Lot, a very large month-to-month correction was applied, leading to a lower permit release.

It is true that only two years of data were used in analyzing Cardinal Deck, Cobb Deck, Craige Deck, and Jackson Deck and only two days of detailed data were used in analyzing Bell Tower Deck. However, it is believed that the data collected shows no outliers or unusual behavior that would limit our ability to analyze it.

Conclusions

Cardinal Deck, Cobb Deck, Craige Deck, and Jackson Deck were analyzed by fitting a distribution to the time-corrected percent of permit holders present during open spot counts days in school years 2008-2009 and 2009-2010. If both years gave similar results, the number of permits to release was set to be the number that suggested the lot would overflow 3X/year when analyzing both years of open spot count data together. Both years gave similar results for Cardinal Deck and Cobb Deck. When the two years disagreed, as with Craige Deck and Jackson Deck, the number of permits to release was set to be the number that suggested the lot would overflow 3X/year when analyzing the more conservative year (2008-2009 in both cases). Using

these methods, it is suggested that Parking Services release 1939 permits for Cardinal Deck, 586 permits for Cobb Deck, 2077 permits for Craige Deck, and 1052 permits for Jackson Deck.

To ensure that permit holder behavior has not changed significantly between years, it is suggested that Parking Services release 95% of the above permits in August. If behavior seems similar to past years and permit holders are not showing up more often than expected, release the final 5% of permits in October. Thus, it is suggested to release 1842 permits for Cardinal Deck, 557 for Cobb Deck, 1973 for Craige Deck, and 999 for Jackson Deck in August. Then release 97 more for Cardinal Deck, 29 more for Cobb Deck, 104 more for Craige Deck, and 53 more for Jackson Deck in October, if possible.

For Bell Tower Deck, a simulation model was used that incorporated a month-to-month correction factor and an outstanding-permits correction factor. The simulation found that releasing 837 permits for Bell Tower Deck should be reasonable. Again, release 95% of these permits (795 of them) in August and the remaining 5% (42) in October if permit holder behavior has not changed.

Open Spot Count Advice

From observation of Bell Tower Deck, it was noted that parking lots tend to be most likely to fill up between the hours of 11AM and 2PM. Thus, it is suggested that Parking Services attempt to make more open spot counts during these hours. Open spot counts at other times are acceptable if they are time-corrected to the peak-time attendance. But looking at absolute un-corrected attendance numbers confirm that counts taken earlier than 10AM or later than 3PM are likely to underreport how many cars are really present in the lot on that day. Thus, these early or late counts are of less value than counts taken at peak times. On the other hand, if an abnormal event is happening on campus that would lead to the lot filling up at an unusual time, perform an open spot count at that unusual time.

Appendix A

Map of Campus with Parking Lots of Interest Circled
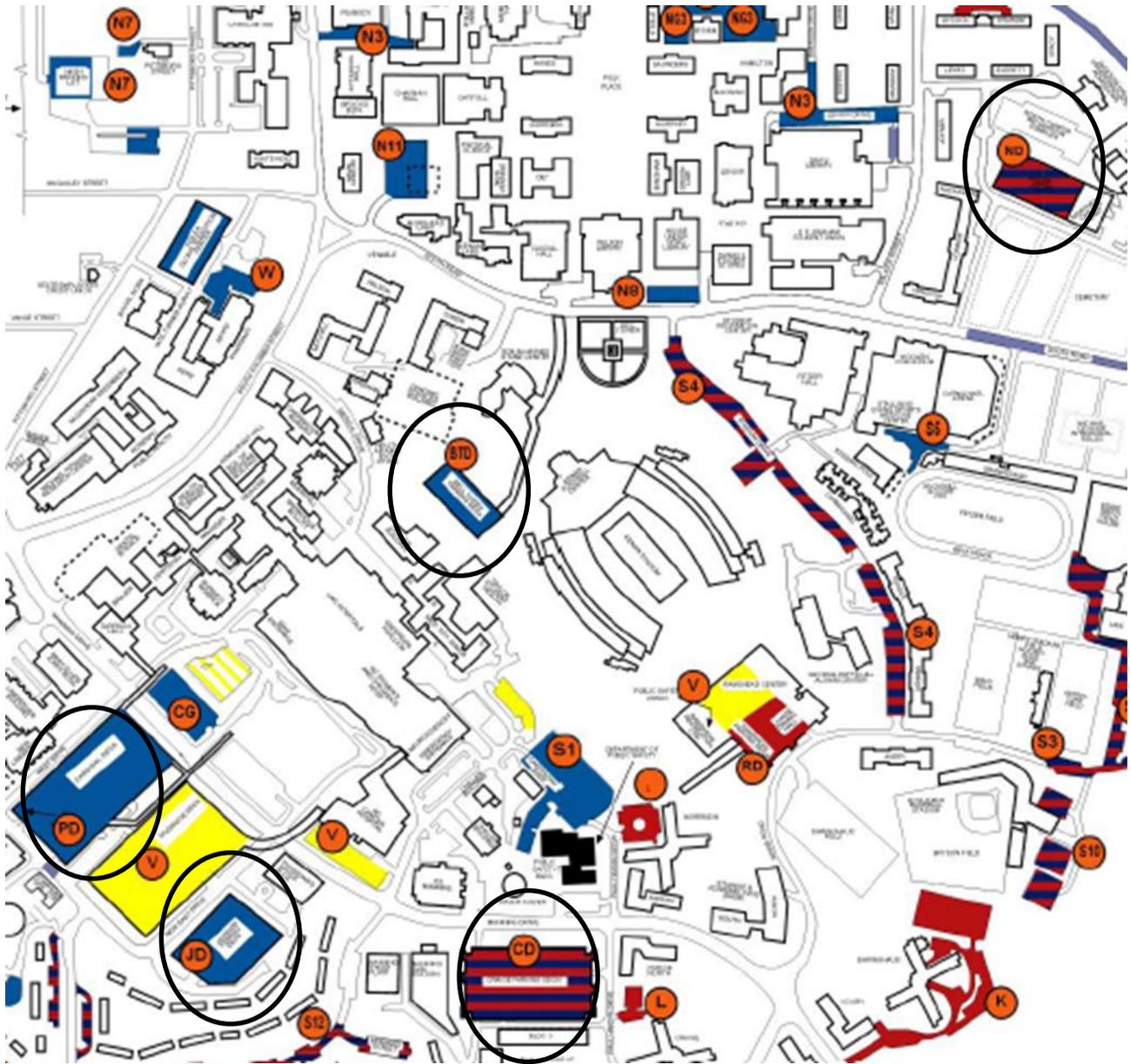
Key:
PD: Cardinal Deck
JD: Jackson Deck
BTD: Bell Tower Deck
CD: Craige Deck
ND: Cobb Deck

Appendix B

Table of outstanding permits in the five parking lots of interest on selected dates

Date	Bell Tower Deck	Cardinal Deck	Cobb Deck	Craige Deck	Jackson Deck
8/15/2008		1900	458	1880	973
9/1/2008		1902	454	1913	972
10/1/2008		1908	521	2024	1011
11/1/2008		1930	554	2038	1042
12/1/2008		1935	560	2044	1062
1/1/2009		1925	559	2042	1062
2/1/2009		1938	566	2050	1064
3/1/2009		1938	580	2028	1072
4/1/2009		1961	581	2087	1099
5/1/2009		1954	617	2087	1102
Date	Bell Tower Deck	Cardinal Deck	Cobb Deck	Craige Deck	Jackson Deck
8/15/2009		1895	425	1722	973
9/1/2009		1921	491	1927	1055
10/1/2009		1951	559	2059	1109
11/1/2009		1986	576	2170	1137
12/1/2009		2011	589	2242	1180
1/1/2010		2024	585	2289	1203
2/1/2010		2039	601	2358	1221
3/1/2010		2050	608	2430	1234
4/1/2010		2076	623	2506	1273
5/1/2010		2085	669	2616	1318
Date	Bell Tower Deck	Cardinal Deck	Cobb Deck	Craige Deck	Jackson Deck
8/15/2010	516				
9/1/2010	574				
10/1/2010	661				
11/1/2010	729				
12/1/2010	764				
1/1/2011	763				
2/1/2011	822				
3/1/2011	861				

Recall that the physical capacities for each lot are: Bell Tower Deck-709, Cardinal Deck-1413, Cobb Deck-453, Craige Deck-1408, and Jackson Deck-829. Note that there is significant variation from month to month and year to year in the actual number of outstanding permits in these five lots.

Appendix C

This appendix shows the open spot count data for the relevant counts retained for analysis. The data is sorted by lot and by year. In addition to the data from the open spot counts, the number of outstanding permits on the day of the count is also displayed.

Cardinal Deck, 2008-2009

Lot Name	Date	Time	Quantity Empty	Outstanding Permits
CARDINAL DECK	9/3/2008	11:31	110	1906
CARDINAL DECK	9/10/2008	11:31	107	1907
CARDINAL DECK	9/15/2008	12:56	180	1907
CARDINAL DECK	10/6/2008	15:23	158	1911
CARDINAL DECK	10/14/2008	14:04	104	1914
CARDINAL DECK	10/15/2008	14:48	123	1914
CARDINAL DECK	10/21/2008	14:08	193	1916
CARDINAL DECK	10/22/2008	13:39	157	1926
CARDINAL DECK	11/7/2008	15:26	143	1930
CARDINAL DECK	2/11/2009	14:39	138	1940
CARDINAL DECK	2/24/2009	12:06	75	1942
CARDINAL DECK	3/25/2009	15:00	172	1955
CARDINAL DECK	3/30/2009	11:30	152	1958
CARDINAL DECK	3/31/2009	13:15	97	1959
CARDINAL DECK	4/1/2009	13:39	95	1961
CARDINAL DECK	4/2/2009	13:52	107	1959
CARDINAL DECK	4/3/2009	13:15	270	1959

Cardinal Deck, 2009-2010

Lot Name	Date Count	Time	Quantity Empty	Outstanding Permits
Cardinal Deck	9/16/2009	11:19	95	1945
Cardinal Deck	10/9/2009	9:50	276	1978
Cardinal Deck	10/12/2009	14:46	181	1979
Cardinal Deck	10/13/2009	14:11	157	1980
Cardinal Deck	10/19/2009	13:51	170	1987
Cardinal Deck	10/20/2009	14:00	139	1988
Cardinal Deck	10/21/2009	10:44	128	1988
Cardinal Deck	10/30/2009	10:38	310	1988
Cardinal Deck	11/3/2009	11:08	84	1990
Cardinal Deck	11/10/2009	10:22	79	1993
Cardinal Deck	11/18/2009	10:06	94	2000
Cardinal Deck	11/20/2009	14:49	312	2001
Cardinal Deck	11/24/2009	13:58	71	2004
Cardinal Deck	12/1/2009	10:05	101	2011
Cardinal Deck	12/2/2009	15:03	109	2013
Cardinal Deck	12/3/2009	15:06	176	2013
Cardinal Deck	12/4/2009	14:51	329	2016
Cardinal Deck	12/9/2009	14:38	198	2015
Cardinal Deck	12/16/2009	11:13	68	2022
Cardinal Deck	1/11/2010	14:31	102	2028
Cardinal Deck	1/13/2010	14:11	21	2028
Cardinal Deck	1/15/2010	11:05	187	2028
Cardinal Deck	1/22/2010	15:04	282	2034
Cardinal Deck	1/25/2010	15:04	148	2036
Cardinal Deck	1/26/2010	10:23	63	2036
Cardinal Deck	1/27/2010	10:47	50	2038
Cardinal Deck	1/29/2010	10:08	193	2038
Cardinal Deck	2/4/2010	10:07	74	2040
Cardinal Deck	2/5/2010	10:22	228	2041
Cardinal Deck	2/8/2010	14:48	106	2044
Cardinal Deck	2/10/2010	14:37	85	2044
Cardinal Deck	2/15/2010	14:48	101	2046
Cardinal Deck	2/16/2010	13:38	44	2047
Cardinal Deck	2/17/2010	10:08	83	2047
Cardinal Deck	2/25/2010	9:55	114	2047
Cardinal Deck	2/26/2010	14:55	290	2049
Cardinal Deck	3/1/2010	10:30	118	2050
Cardinal Deck	3/2/2010	14:15	71	2053
Cardinal Deck	3/4/2010	14:45	151	2055

Cardinal Deck	3/5/2010	14:42	277	2056
Cardinal Deck	3/17/2010	10:20	66	2061
Cardinal Deck	3/22/2010	14:25	72	2065
Cardinal Deck	3/26/2010	14:58	280	2074
Cardinal Deck	3/29/2010	13:49	120	2073
Cardinal Deck	3/30/2010	14:42	195	2073
Cardinal Deck	3/31/2010	14:21	158	2074
Cardinal Deck	4/1/2010	14:16	236	2076
Cardinal Deck	4/8/2010	14:30	174	2079
Cardinal Deck	4/12/2010	14:08	138	2081
Cardinal Deck	4/13/2010	11:25	65	2081
Cardinal Deck	4/19/2010	14:09	117	2081
Cardinal Deck	4/27/2010	14:50	157	2085
Cardinal Deck	4/28/2010	13:45	134	2087
Cardinal Deck	5/6/2010	14:59	220	2091

Cobb Deck 2008-2009

Lot Name	Date	Time	Quantity Empty	Outstanding Permits
COBB DECK	8/21/2008	14:11	145	455
COBB DECK	8/25/2008	9:44	208	454
COBB DECK	8/26/2008	13:55	133	454
COBB DECK	8/28/2008	9:00	236	455
COBB DECK	10/1/2008	11:59	143	521
COBB DECK	10/21/2008	10:11	126	530
COBB DECK	10/22/2008	11:35	106	539
COBB DECK	11/5/2008	9:03	193	554
COBB DECK	11/11/2008	13:38	57	557
COBB DECK	11/12/2008	13:56	63	558
COBB DECK	11/13/2008	14:08	68	558
COBB DECK	11/14/2008	13:37	109	558
COBB DECK	12/8/2008	15:46	117	561
COBB DECK	12/10/2008	9:31	139	562
COBB DECK	1/15/2009	11:59	46	566
COBB DECK	1/27/2009	14:24	56	565
COBB DECK	1/28/2009	11:39	72	566
COBB DECK	2/3/2009	13:12	47	571
COBB DECK	2/12/2009	14:34	59	578
COBB DECK	3/4/2009	14:46	64	583
COBB DECK	3/16/2009	10:34	82	582

Cobb Deck 2009-2010

Lot Name	Date Count	Time	Quantity Empty	Outstanding Permits
Cobb Deck	8/31/2009	11:58	103	487
Cobb Deck	9/3/2009	13:32	107	496
Cobb Deck	9/15/2009	13:19	77	540
Cobb Deck	9/16/2009	14:10	60	545
Cobb Deck	9/21/2009	11:30	81	553
Cobb Deck	9/23/2009	13:58	69	556
Cobb Deck	9/30/2009	13:41	71	559
Cobb Deck	10/1/2009	14:32	80	559
Cobb Deck	10/5/2009	14:51	92	558
Cobb Deck	10/6/2009	11:05	89	558
Cobb Deck	10/7/2009	14:09	63	558
Cobb Deck	10/12/2009	14:55	79	571
Cobb Deck	10/14/2009	11:26	75	574
Cobb Deck	10/20/2009	10:17	93	577
Cobb Deck	10/26/2009	10:45	90	577
Cobb Deck	11/4/2009	14:12	44	577
Cobb Deck	11/10/2009	13:42	59	581
Cobb Deck	11/11/2009	10:01	174	581
Cobb Deck	11/12/2009	14:45	76	582
Cobb Deck	11/19/2009	14:57	85	582
Cobb Deck	11/20/2009	14:49	107	584
Cobb Deck	11/23/2009	10:14	112	585
Cobb Deck	12/7/2009	13:59	53	591
Cobb Deck	12/14/2009	14:32	82	588
Cobb Deck	12/15/2009	15:28	143	587
Cobb Deck	12/16/2009	11:13	101	586
Cobb Deck	1/13/2010	14:30	54	592
Cobb Deck	1/14/2010	13:26	36	592
Cobb Deck	1/20/2010	13:48	39	598
Cobb Deck	1/21/2010	10:01	104	600
Cobb Deck	1/22/2010	13:35	99	599
Cobb Deck	1/25/2010	13:50	48	599
Cobb Deck	1/28/2010	11:26	65	601
Cobb Deck	2/2/2010	13:38	35	602
Cobb Deck	2/3/2010	13:35	47	602
Cobb Deck	2/4/2010	14:20	25	604
Cobb Deck	2/5/2010	10:37	104	604
Cobb Deck	2/8/2010	14:41	43	605
Cobb Deck	2/9/2010	14:03	33	605
Cobb Deck	2/10/2010	14:14	49	605
Cobb Deck	2/15/2010	11:07	67	605
Cobb Deck	2/16/2010	14:39	57	602

Cobb Deck	2/18/2010	14:26	47	602
Cobb Deck	2/22/2010	11:05	57	603
Cobb Deck	2/23/2010	10:05	88	605
Cobb Deck	2/26/2010	13:40	25	608
Cobb Deck	3/4/2010	14:27	48	609
Cobb Deck	3/24/2010	14:17	57	622
Cobb Deck	3/26/2010	14:33	112	624
Cobb Deck	3/29/2010	14:47	59	624
Cobb Deck	3/30/2010	13:38	52	624
Cobb Deck	4/1/2010	15:05	116	623
Cobb Deck	4/6/2010	14:56	60	624
Cobb Deck	4/7/2010	15:15	61	624
Cobb Deck	4/15/2010	14:48	54	623
Cobb Deck	4/20/2010	15:56	104	624
Cobb Deck	4/26/2010	13:33	69	624

Craige Deck 2008-2009

Lot Name	Date	Time	Quantity Empty	Outstanding Permits
CRAIGE DECK	8/20/2008	14:53	303	1934
CRAIGE DECK	9/4/2008	14:11	190	1962
CRAIGE DECK	9/9/2008	11:15	169	1987
CRAIGE DECK	9/11/2008	12:13	160	1995
CRAIGE DECK	9/18/2008	10:43	236	2005
CRAIGE DECK	10/2/2008	14:17	183	2034
CRAIGE DECK	10/7/2008	13:20	140	2050
CRAIGE DECK	10/14/2008	14:15	209	2059
CRAIGE DECK	10/21/2008	14:18	200	2078
CRAIGE DECK	10/22/2008	13:15	159	2083
CRAIGE DECK	10/31/2008	11:38	272	2040
CRAIGE DECK	11/5/2008	11:07	153	2049
CRAIGE DECK	2/3/2009	13:56	20	2070
CRAIGE DECK	2/16/2009	10:54	283	2076
CRAIGE DECK	3/16/2009	14:46	196	2090
CRAIGE DECK	3/31/2009	14:53	150	2078
CRAIGE DECK	4/1/2009	14:02	171	2087
CRAIGE DECK	4/2/2009	14:32	193	2087
CRAIGE DECK	4/3/2009	13:46	351	2076

Craige Deck 2009-2010

Lot Name	Date Count	Time	Quantity Empty	Outstanding Permits
Craige Deck	9/9/2009	15:05	235	1938
Craige Deck	9/16/2009	14:15	190	1983
Craige Deck	9/23/2009	14:33	206	2031
Craige Deck	10/1/2009	14:15	249	2059
Craige Deck	10/5/2009	14:54	265	2055
Craige Deck	10/7/2009	12:08	223	2074
Craige Deck	10/8/2009	14:14	261	2102
Craige Deck	10/13/2009	14:48	181	2111
Craige Deck	10/14/2009	14:55	195	2117
Craige Deck	10/16/2009	15:46	354	2128
Craige Deck	10/19/2009	14:22	170	2136
Craige Deck	10/20/2009	10:19	227	2143
Craige Deck	10/21/2009	10:20	228	2148
Craige Deck	10/28/2009	15:11	184	2170
Craige Deck	11/5/2009	12:53	219	2187
Craige Deck	11/10/2009	10:49	187	2199
Craige Deck	11/11/2009	14:58	177	2201
Craige Deck	11/12/2009	15:38	260	2202
Craige Deck	11/16/2009	14:36	207	2212
Craige Deck	11/20/2009	14:20	336	2219
Craige Deck	12/3/2009	14:39	183	2245
Craige Deck	12/4/2009	15:03	243	2246
Craige Deck	12/14/2009	14:29	253	2263
Craige Deck	12/16/2009	9:21	336	2263
Craige Deck	1/11/2010	14:38	145	2304
Craige Deck	1/14/2010	14:49	170	2315
Craige Deck	1/19/2010	10:03	211	2327
Craige Deck	1/22/2010	13:14	237	2338
Craige Deck	1/26/2010	10:06	201	2348
Craige Deck	1/28/2010	14:28	147	2350
Craige Deck	2/3/2010	10:49	73	2379
Craige Deck	2/4/2010	10:20	259	2384
Craige Deck	2/5/2010	14:29	159	2385
Craige Deck	2/8/2010	14:29	68	2385
Craige Deck	2/11/2010	10:43	173	2390
Craige Deck	2/15/2010	11:18	192	2395
Craige Deck	2/16/2010	14:58	133	2401
Craige Deck	2/17/2010	14:18	112	2403
Craige Deck	2/22/2010	15:03	188	2420
Craige Deck	2/25/2010	14:50	164	2427

Craige Deck	2/26/2010	14:48	306	2426
Craige Deck	3/3/2010	14:08	231	2444
Craige Deck	3/4/2010	14:01	225	2456
Craige Deck	3/18/2010	13:41	209	2468
Craige Deck	3/19/2010	14:02	304	2468
Craige Deck	3/24/2010	15:06	180	2476
Craige Deck	3/29/2010	13:22	233	2483
Craige Deck	3/30/2010	14:58	211	2491
Craige Deck	4/1/2010	14:34	285	2506
Craige Deck	4/8/2010	14:47	267	2524
Craige Deck	4/27/2010	14:32	201	2555
Craige Deck	4/29/2010	13:41	266	2602

Jackson Deck 2008-2009

Lot Name	Date Count	Time	Quantity Empty	Outstanding Permits
JACKSON DECK	8/28/2008	11:49	123	993
JACKSON DECK	9/3/2008	11:05	99	976
JACKSON DECK	9/10/2008	11:08	98	993
JACKSON DECK	9/15/2008	12:13	133	997
JACKSON DECK	10/14/2008	13:51	88	1025
JACKSON DECK	10/15/2008	14:48	174	1025
JACKSON DECK	10/21/2008	13:59	118	1027
JACKSON DECK	10/22/2008	13:53	120	1038
JACKSON DECK	10/28/2008	13:30	49	1041
JACKSON DECK	11/19/2008	10:07	71	1059
JACKSON DECK	12/5/2008	14:41	137	1062
JACKSON DECK	1/13/2009	15:28	87	1071
JACKSON DECK	1/26/2009	13:38	54	1077
JACKSON DECK	2/11/2009	14:14	58	1087
JACKSON DECK	2/24/2009	12:23	64	1092
JACKSON DECK	2/26/2009	9:16	166	1092
JACKSON DECK	3/24/2009	14:47	61	1096
JACKSON DECK	3/25/2009	13:59	33	1096
JACKSON DECK	3/31/2009	12:53	77	1092
JACKSON DECK	4/1/2009	13:23	64	1099
JACKSON DECK	4/2/2009	13:31	94	1097
JACKSON DECK	4/3/2009	13:25	183	1092
JACKSON DECK	4/13/2009	13:35	115	1099
JACKSON DECK	4/15/2009	11:48	77	1099

Jackson Deck 2009-2010

Lot Name	Date Count	Time	Quantity Empty	Outstanding Permits
Jackson Deck	8/27/2009	10:34	62	1040
Jackson Deck	9/9/2009	10:24	51	1070
Jackson Deck	9/16/2009	13:56	44	1093
Jackson Deck	9/22/2009	13:55	39	1098
Jackson Deck	10/1/2009	14:46	89	1109
Jackson Deck	10/2/2009	11:07	105	1110
Jackson Deck	10/5/2009	14:39	89	1108
Jackson Deck	10/9/2009	9:53	125	1113
Jackson Deck	10/12/2009	14:30	90	1115
Jackson Deck	10/13/2009	14:34	40	1114
Jackson Deck	10/19/2009	13:50	72	1124
Jackson Deck	10/20/2009	14:08	47	1126
Jackson Deck	10/21/2009	10:13	67	1126
Jackson Deck	10/30/2009	10:38	119	1137
Jackson Deck	11/9/2009	15:52	145	1149
Jackson Deck	11/10/2009	10:12	34	1151
Jackson Deck	11/18/2009	10:00	61	1151
Jackson Deck	11/19/2009	14:52	64	1153
Jackson Deck	11/20/2009	14:20	148	1153
Jackson Deck	11/24/2009	14:08	77	1172
Jackson Deck	12/1/2009	10:05	33	1180
Jackson Deck	12/2/2009	13:43	22	1179
Jackson Deck	12/4/2009	14:18	114	1180
Jackson Deck	12/9/2009	14:37	55	1179
Jackson Deck	12/16/2009	11:58	40	1180
Jackson Deck	1/11/2010	14:42	34	1214
Jackson Deck	1/13/2010	13:29	7	1216
Jackson Deck	1/15/2010	11:05	54	1216
Jackson Deck	1/19/2010	10:54	23	1216
Jackson Deck	1/20/2010	10:27	22	1219
Jackson Deck	1/21/2010	14:33	29	1221
Jackson Deck	1/22/2010	14:17	70	1220
Jackson Deck	1/25/2010	13:58	16	1220
Jackson Deck	1/26/2010	15:00	28	1222
Jackson Deck	1/27/2010	10:47	9	1221
Jackson Deck	1/29/2010	9:41	68	1221
Jackson Deck	2/3/2010	10:53	1	1227
Jackson Deck	2/4/2010	14:08	5	1230
Jackson Deck	2/5/2010	9:57	98	1230
Jackson Deck	2/9/2010	14:09	3	1230

Jackson Deck	2/10/2010	14:35	25	1229
Jackson Deck	2/15/2010	11:18	21	1230
Jackson Deck	2/16/2010	13:46	10	1229
Jackson Deck	2/17/2010	14:31	27	1229
Jackson Deck	2/18/2010	14:51	39	1234
Jackson Deck	2/19/2010	11:48	52	1234
Jackson Deck	2/24/2010	11:25	14	1236
Jackson Deck	2/25/2010	14:56	51	1235
Jackson Deck	3/1/2010	13:50	34	1234
Jackson Deck	3/3/2010	10:45	55	1243
Jackson Deck	3/4/2010	11:09	37	1241
Jackson Deck	3/5/2010	14:20	7	1240
Jackson Deck	3/17/2010	14:06	18	1251
Jackson Deck	3/23/2010	11:27	27	1259
Jackson Deck	3/25/2010	14:51	40	1263
Jackson Deck	3/26/2010	13:59	101	1265
Jackson Deck	3/29/2010	13:31	72	1265
Jackson Deck	3/30/2010	14:54	101	1264
Jackson Deck	4/1/2010	12:23	98	1273
Jackson Deck	4/8/2010	14:01	59	1276
Jackson Deck	4/12/2010	14:08	40	1277
Jackson Deck	4/19/2010	14:09	24	1280
Jackson Deck	4/27/2010	13:11	26	1283
Jackson Deck	4/28/2010	13:46	34	1285
Jackson Deck	5/5/2010	14:52	54	1333
Jackson Deck	5/6/2010	14:59	91	1337

Appendix D

Observational data from Wednesday, March 16, 2011 and Thursday, March 17, 2011 of the Bell Tower Deck.

	Wednesday March 16	Thursday March 17	Average over 2 Days
Initial @ 8AM	330	334	332
8:01-8:30 Arrivals	100	104	102
8:01-8:30 Departures	6	3	4.5
8:31-9:00 Arrivals	91	78	84.5
8:31-9:00 Departures	4	2	3
9:01-9:30 Arrivals	56	62	59
9:01-9:30 Departures	4	7	5.5
9:31-10:00 Arrivals	37	29	33
9:31-10:00 Departures	4	8	6
10:01-10:30 Arrivals	25	25	25
10:01-10:30 Departures	6	1	3.5
10:31-11:00 Arrivals	26	16	21
10:31-11:00 Departures	4	6	5
11:01-11:30 Arrivals	14	13	13.5
11:01-11:30 Departures	9	13	11
11:31-12:00 Arrivals	13	8	10.5
11:31-12:00 Departures	12	17	14.5
12:01-12:30 Arrivals	10	15	12.5
12:01-12:30 Departures	21	23	22
12:31-1:00 Arrivals	18	13	15.5
12:31-1:00 Departures	12	12	12
1:01-1:30 Arrivals	11	10	10.5
1:01-1:30 Departures	12	11	11.5
1:31-2:00 Arrivals	13	10	11.5
1:31-2:00 Departures	10	16	13

Appendix E

A histogram of time-corrected percentage of permit holders present at the peak time of day is given for Cardinal Deck, Cobb Deck, Craige Deck, and Jackson Deck for 2008-2009 spot counts, 2009-2010 spot counts and a combination of both years. The best fitting beta distribution with bounds at the mean +/- 3 standard deviations is overlaid on the histogram. Kolmogorov-Smirnov (K-S), Anderson-Darling (A-D), and Chi-Squared goodness of fit test results are shown beneath each histogram.

For each histogram, the x-axis is the time-corrected percentage of permit holders present and the y-axis is the percent that fall into the histogram bin.

Cardinal Deck 2008-2009

Bounds [.5967, .7484]. Alpha=1.8541. Beta=2.1663.

Probability Density Function
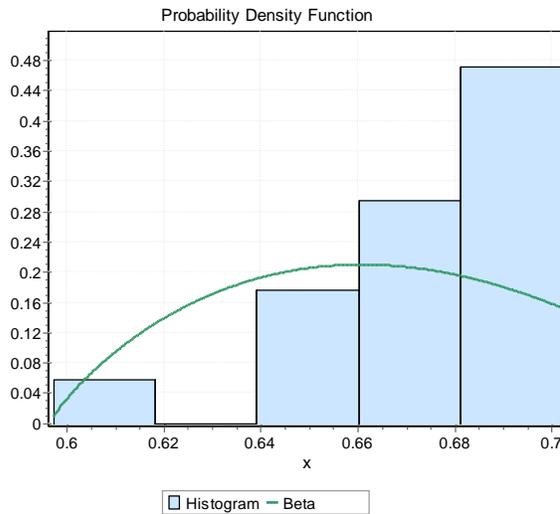
K-S Test: Reject at significance level .2. Do not reject at .1.
A-D Test: Reject at significance level .1. Do not reject at .05.
Chi Squared: Reject at significance level .1. Do not reject at .05.

Cardinal Deck 2009-2010

Bounds [.5135, .7700]. Alpha=4.161. Beta=4.224.
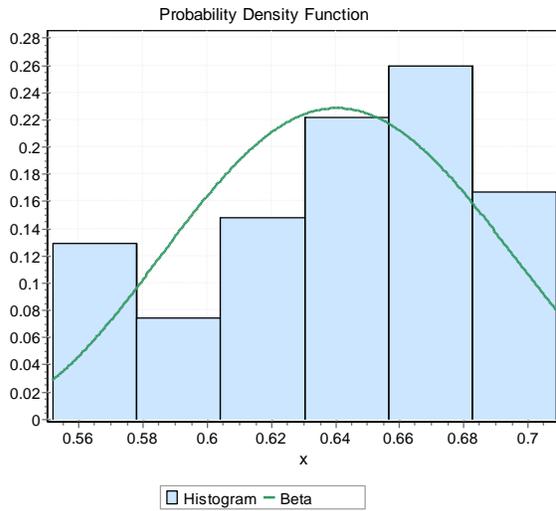
Probability Density Function

K-S Test: Do not reject at significance level .2.
A-D Test: Do not reject at significance level .2.
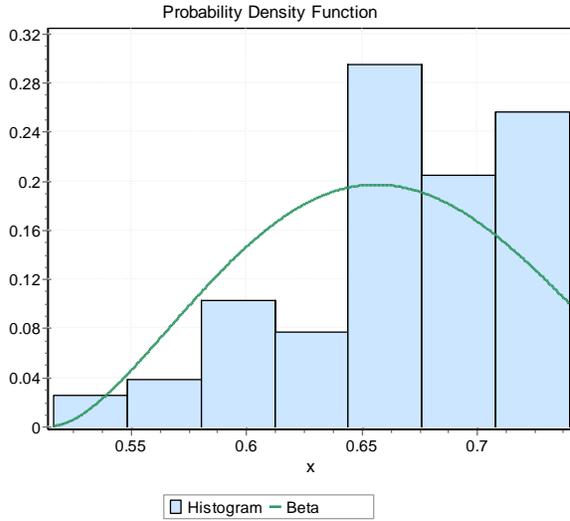Chi Squared: Do not reject at significance level .2.

Cardinal Deck Both Years

Bounds [.5252, .7730]. Alpha = 3.986. Beta=4.0806.

Probability Density Function
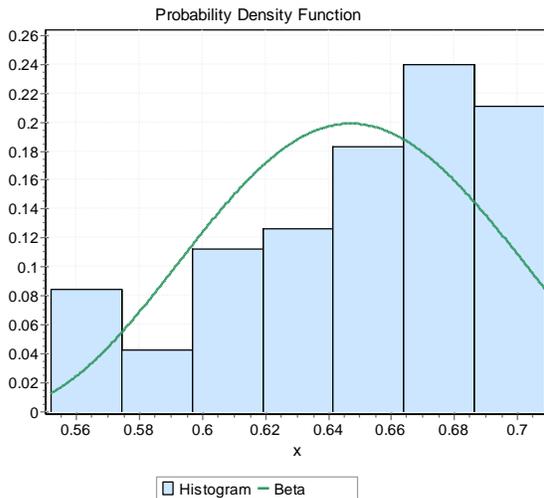
K-S Test: Do not reject at significance level .2.
A-D Test: Reject at significance level .2. Do not reject at .1.
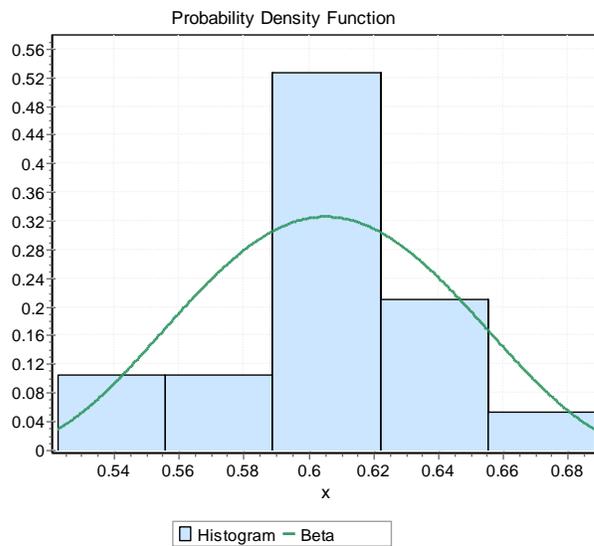Chi Squared: Do not reject at significance level .2.

Cobb Deck 2008-2009

Bounds [.5196, .8182]. Alpha=4.5026. Beta=4.5395.
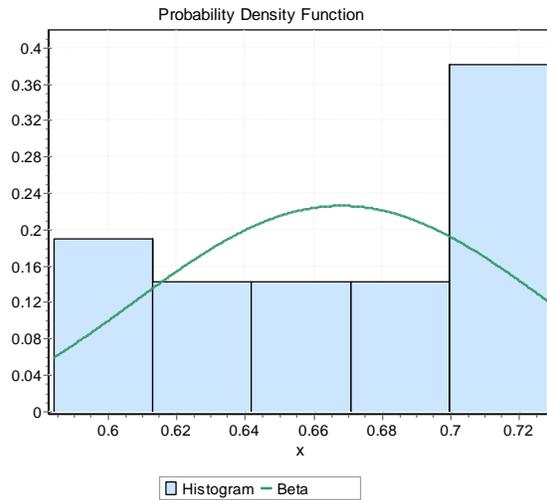
Probability Density Function

K-S Test: Do not reject at significance level .2.
A-D Test: Do not reject at significance level .2.
Chi Squared: Do not reject at significance level .2.

Cobb Deck 2009-2010

Bounds [.5141, .812]. Alpha=2.9998. Beta=3.1903.
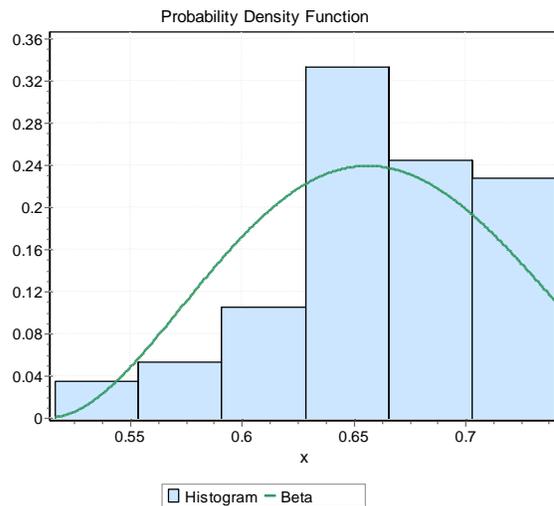
Probability Density Function

K-S Test: Reject at significance level .02. Do not reject at .01.
A-D Test: Reject at significance level .1. Do not reject at .05.
Chi Squared: Do not reject at significance level .2.

Cobb Deck Both Years

Bounds [.5159, .8129]. Alpha=2.6105. Beta=2.8233.

K-S Test: Reject at significance level .02. Do not reject at .01.
A-D Test: Reject at significance level .05. Do not reject at .02.
Chi Squared: Reject at significance level .2. Do not reject at .1.
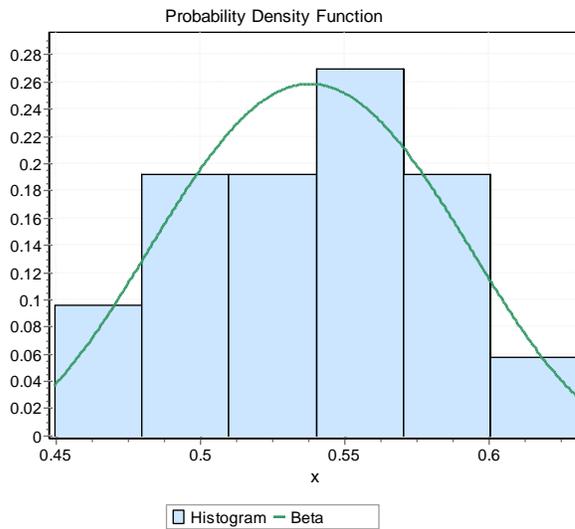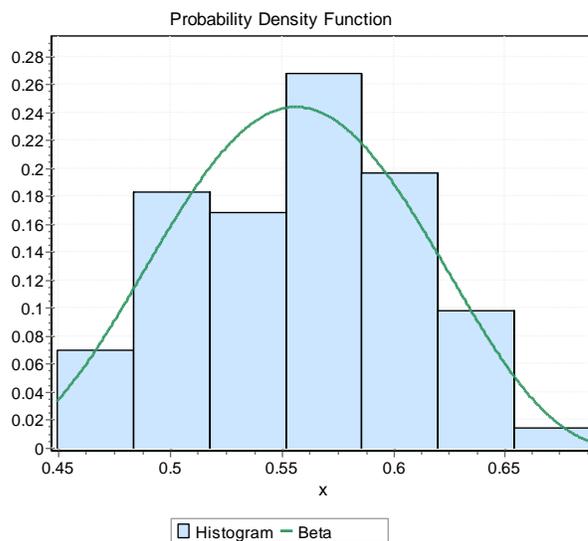
Craige Deck 2008-2009

Bounds [.4974, .7143]. Alpha=3.786. Beta=3.8129.

K-S Test: Do not reject at significance level .2.
A-D Test: Do not reject at significance level .2.
Chi Squared: Do not reject at significance level .2.

Craige Deck 2009-2010

Bounds [.4080, .6686]. Alpha=4.1354. Beta=4.1513.

Probability Density Function

Histogram — Beta

K-S Test: Do not reject at significance level .2.
A-D Test: Do not reject at significance level .2.
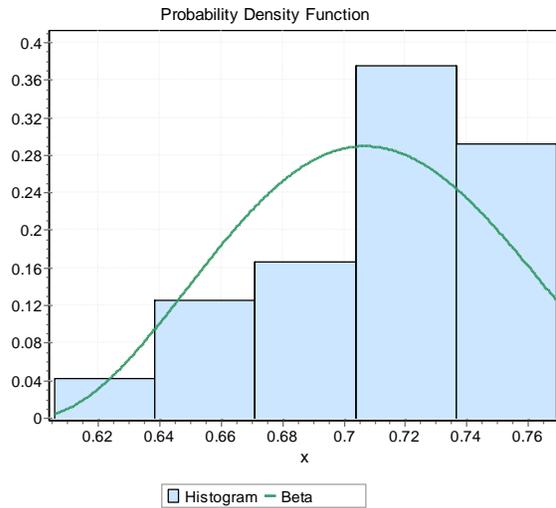Chi Squared: Do not reject at significance level .2.

Craige Deck Both Years

Bounds [.4029, .7099]. Alpha=4.0115. Beta=4.0079

Probability Density Function

Histogram — Beta

K-S Test: Do not reject at significance level .2.
A-D Test: Do not reject at significance level .2.
Chi Squared: Do not reject at significance level .2.
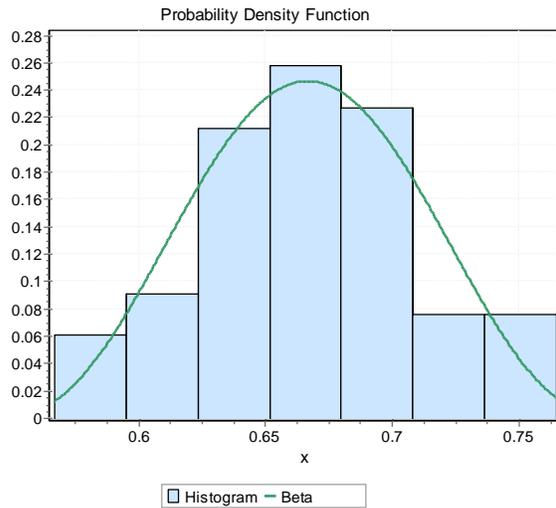
Jackson Deck 2008-2009

Bounds [.5973, .8239]. Alpha=3.3086. Beta=3.4643.

K-S Test: Do not reject at significance level .2.
A-D Test: Do not reject at significance level .2.
Chi Squared: Do not reject at significance level .2.
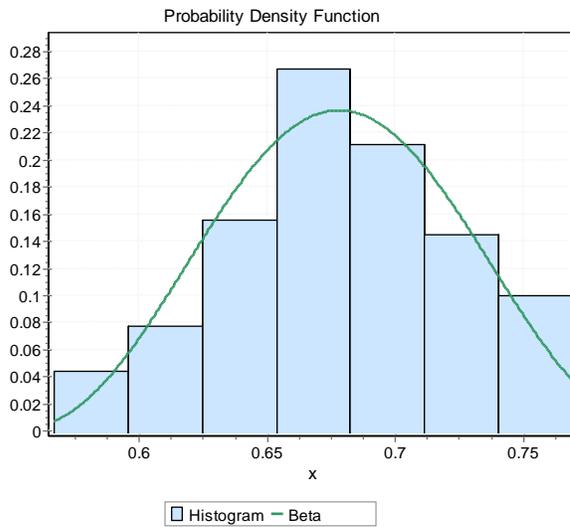
Jackson Deck 2009-2010

Bounds [.5425, .7911]. Alpha=3.9132. Beta=3.9072.

K-S Test: Do not reject at significance level .2.
A-D Test: Do not reject at significance level .2.
Chi Squared: Reject at significance level .2. Do not reject at .1.

Jackson Deck Both Years

Bounds [.5443, .8127]. Alpha=3.9941. Beta=4.0153.

Probability Density Function

K-S Test: Do not reject at significance level .2.
A-D Test: Do not reject at significance level .2.
Chi Squared: Do not reject at significance level .2.