Mail Opt. Team Final Summary Document/Report Structure:

1. Contents of Project's Final Summary (Main Questions and Approaches, Progress
2. Throughout the Semester, etc.)
3. Appendix
4. Bibliography

Main Questions and Approaches

This project started in response to the long wait times first year students encountered at the RPCC mail pickup center. In context of that, our primary goal was to identify aspects of the campus mail distribution process that could be optimized to ultimately shorten waiting times. In pursuing this question, our approach was to maximize our understanding and relevant observations of the campus mail distribution process specific to Cornell, and apply relevant knowledge from statistics and optimization/operations research literature for useful insights on the data and practical solutions we could implement. We obtained these observations by sending groups of members of the student teams to RPCC to record the experiences of the employees working at the service desk, and again to collect data of students who came to collect packages based on the variables we identified as important in understanding the process.

Progress Throughout the Semester

Consulting with Administration

Part of our progress throughout the semester included being able to become better informed of changes to campus mail distribution by setting up weekly meetings in administration– through these meetings, we analyzed data they provided (package retrieval information) and incorporated the tasks they were currently working on, such as figuring out the logistics of implementing Amazon lockers on campus, into our weekly tasks. As an example of tasks we completed directly in response to the questions raised by administration, we performed general research into the functions of Amazon lockers and summarized key points of the process as follows:

1. If items are eligible, shoppers can choose 'Pick-up at Amazon hub' during checkout as their delivery method.
   Packages are delivered directly to lockers by Amazon.
   Customers are emailed once their packages are ready to be picked up.
   Customers are either given a unique code in the email that they input to the locker to be able to retrieve their packages, or access the locker using a smart phone with the amazon shopper app installed.
   Customers can also return packages via the Amazon lockers.

2. Understanding Mailroom Process and Collecting Data

It was important that we understand the current state of the mail process to know what to improve on; therefore, throughout the semester, we made continuous progress in understanding both the workings behind the scenes (what routines the service desk employees go through) as well as data we could collect from the student side (the arrival and departure patterns during certain busy hours in RPCC.) We made progress on this aspect by sending students to observe and document a working shift at RPCC and to record data or student arrival rates and service times. The slide "11/18 Presentation: Behind the Scenes of RPCC" contains the detailed knowledge gained from these observations regarding processing logistics and problems encountered by the service desk employees in RPCC.

Furthermore, we collected a two hour span of mailing center data on a Monday afternoon from 5 pm to 7 pm. Our data is recorded in the google sheet "RPCC StudentArrivalDepatures Data".

Before collecting this observable data, we spent time coming up with a protocol requiring at least two people that would give us relevant insight into the logistics of the queue. Ultimately, we recorded the students' arrival times, departure times, changes in numbers of staff available, service times per request, and the type of service request (e.g. retrieving package vs. retrieving envelope vs. processing netID issue.) One team member recorded items for the left columns A-C of the google sheet primarily related to students' arrival times. Another team member recorded the right side, columns D-G, for students' departure times.

The general procedure the team decided on is as follows:

1. The initial number of students presented in the queue needs to be recorded when the collection starts, and the final number of students in the queue also needs to be recorded when we finish our collection. (For example, our data starts with two students already in the line at 5 pm and ends with twelve students in the line at 7 p.m.)
2. Whenever a student enters the line, person A records down the time. Person A is also responsible for keeping track of any premature departures (i.e. quantity of students that leave the queue prematurely due to any reason.)
3. Whenever a student has their request processed, person B records down the time and notes whether the student was serving by staff #1 or staff #2. Person B also records the time it takes them to get their request fulfilled (the time between when they get to the front of the queue and when they exit the queue)
4. Person B is also responsible for keeping track of the type of the package, e.g. whether it is a package, a key, an envelope, etc.

A screenshot of our RPCC Data Collection Table is in the Appendix at the bottom of the document.

We plan to collect more observable RPCC data in the Spring 2023 semester, particularly around the time students move back in, likely leading to activity levels of the mail centers significantly higher than usual. We have made revisions to our data collection protocols to prepare for these future rounds by changing data precision from minutes to seconds, and by increasing the ease of recording premature departure and accompanied arrival.

3. Analyzing Data and Compiling Solutions

We analyzed the package retrieval data provided by administration as well as the data we collected based on our observations of RPCC. Through our analysis of the package retrieval data, we obtained detailed frequency data that showed us each mailroom's busiest days in the school year. Due to the large volume of frequency graphs for this analysis, they are all listed in the Appendix at the bottom of this document.

We also analyzed the data we collected by observing the queue at RPCC during a busy shift on Monday 5pm-7pm. This gave us insight into the volume and pattern of student arrival and departure activity during busy shifts. Our statistical analysis also includes other values of interest, such as the median for service time, and is shown below.

Data Analysis

Points collected: 115
Range: 0.5 – 7
Median: 1 min
Average: 1.84 min
Shape of distribution: Most of the service times are on the lower end.

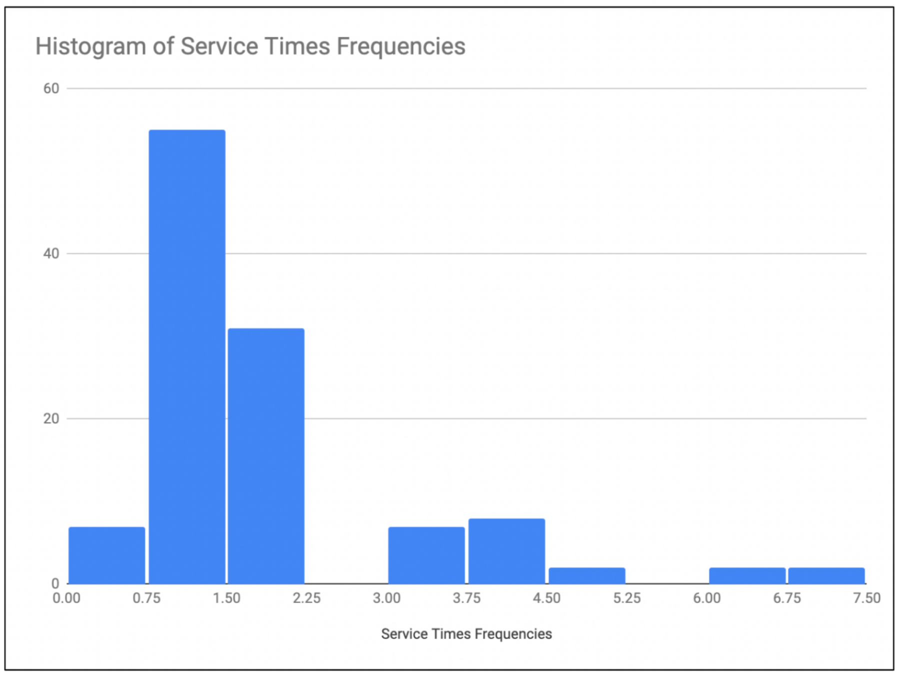


Figure 1. RPCC Data Analysis

4. Programmed Mail Processing Simulation

We currently use the M/M/2 queuing model to compute figures for/model the dynamics of the RPCC mailing center– although as we continue to refine this model, it will need to reflect a more nuanced nature of RPCC (such as accounting for the fact that the number of employees processing service desk request frequently changes.) The team programmed a simulation of this using Python in Google Colab.

In our model, arrival times and amount of service times are generated from an exponentially distributed random variable with mean 1. The simulation accounts for typical operating hours from 8am-10pm. Our model operates using two servers constantly working in parallel; a new student is added to the queue based on randomly generated arrival times, and student requests are processed based on staff availability. The time for their request to be processed is the randomly generated service time. If a staff member is currently serving a student, they are unable to serve the next student in the queue until the time for the request to be processed is over. Once the staff is available again, that staff will begin to serve a new student from the queue, and the cycle repeats.

Our program's functions can be described through three of its functions. The process runs through the function increment_time(), which goes through operating hours and at the end, based on what arrival times have been randomly generated, has created a list of all departure times within 8am - 10pm Monday-Friday business hours. The function service_time() is used to generate the service time. It tells us how long something takes to process. We set its parameter mu=1 and size=10000 (representing an exponentially distributed random variable with mean 1, with a large number 10000 points so that the generated point reflects as random a point as possible from a large graph of the distribution.)

```
def service_time(self):
  return np.random.choice(poisson.rvs(mu=1, size=10000))
```

Figure 2. Service Time function (full simulation is available in the team folder)

Lastly, we have another function process_request() that simulates the employees of the service desk processing requests, which adds to the departure times list when a student's request has been processed. As a result, the model calculates and outputs 1) the average expected number of people in the system and 2) average service time.

```
Average Number of People in System:
1.4588235294117646
Average Service Time:
1.0392609699769053
Arrivals/Hour
61.92857142857143
Customers Served/Hour: 61.857142857142854
```

Figure 3. Sample output of the Queue Simulation

Summary of Knowledge Acquired Regarding Cornell Mail Distribution Process

By sending team members to work in the mailing center, we acquired detailed knowledge regarding mail processing in RPCC. There are five full time staff members as well as 60 student volunteers individually working for 2-6 hour shifts per week. The mailing center handles a large variety of tasks including receiving or sending packages or letters, key issues, and laundry. Packages must be picked up in seven days or will be put on the return shelf on the eighth day.

Packages over 50 pounds are rejected. In a typical week, Mondays are the heaviest day of delivery since most carriers do not operate on Sundays.

We also documented information regarding RPCC's mail labeling system. Letters are separated into different boxes by dorms (High Rise 5, Low Rise 6, etc.) and are sorted by last name. Packages are manually given tags before sorting, including information pertaining to last name, first name, date received, color codes for dates to be sent back if not retrieved in time, and labels indicating package type. On average, 100 packages are processed per hour.

Here are some notable challenges listed by staff workers:

- Email reminders are manually created, not automatically, which decreases time and work efficiency.
- Room changes cause various kinds of coordination problems.
- There are significant amounts of human errors regarding putting packages in the wrong section, accidentally putting it in envelopes, or writing the wrong name on it.
- Improper formatting or content of information on mail causes processing difficulties, with a common issue being not including netID.
- RPCC is understaffed relative to the amount of requests being processed during busy hours.

(Here are detailed slides for more information about the RPCC mail processing: https://docs.google.com/presentation/d/1OFnz9YFNF50_SQcDcDy1CxKe4HQDPhw5JjwR0LOb59A/edit#slide=id.g19143bc6a29_0_25)

Furthermore, a notable component of our understanding of the mail distribution process is that there are some constraints in the changes that can be implemented. For example, RPCC is currently contracted to use the notification software that currently requires manual sending of emails. Also, both our observations and the concerns raised by the RPCC show problems regarding understaffing, but the feasibility of hiring more service desk employees is unknown.

Papers/Books/Course Notes Read and Topics Learned

1. **Papers/Books/Course Notes:**

We looked at details of other colleges' campus mail operations since studying the details and results of real-life implementations could be helpful for us to understand the state-of-art of the mailing processing topic in a wide scope of view. In the google doc "Literature Compilation and Understanding of Mailroom Operations," we summarized sixteen recent papers related to our researched topic (link:https://docs.google.com/document/d/1Rf607HEDAq8bwSzFWJYAkbYf-XW28BMeMBNpVZnOYjI/edit.)

Here, we have highlighted some select papers with relevance to the logistics of campus mailroom operations or optimizing systems with a large variety of variables, cited in the bibliography of the bottom of this document:

1. **Six Sigma Process Improvement for KSU Mailroom[1]:**
   This stood out as a paper documenting attempts at improving operations at a campus mailroom. The publication talks about implementing changes based on Lean Six Sigma – "sort, straighten, standardize, sustain, safety," emphasizing the importance of physically organizing, labeling, and cleaning the mailroom. Notably, before this research was published, KSU already had a self pick-up mail system using a system wherein one would enter a verification code sent by email to get access to a particular item; the locker then automatically opened with the digital screen displaying instructions for location access, and the pickup was then concluded with the receiver's signature. The paper suggested placing lockers into dorm and apartment buildings on campus. However, only the Lean 6s was implemented out of the solutions (no data, but publication stated employees liked the change), and there were no measurable results we could use as data.
2. **Optimization Approaches in the Strategic and Tactical Planning of Networks for Letter, Parcel and Freight Mail[3]:**
   This publication discusses the optimization of cut-off times and time windows within real world distribution networks for letters, parcels, and freight mail (Postal Logistics.) Given its focus on overall (not campus) mail delivery organization, of the four stages described here (Mail collection, Long Haul Transportation, Distribution, and Delivery), the "Distribution" described as where "the final sorting in sequence for the delivery districts takes place" is the most relevant to the campus delivery problem we are focusing on. The core planning involved in the postal distribution network includes the definition of time windows and cut off times such that the system is decomposed into subsystems that can be independently optimized for time/cost minimization. While the paper concentrates more on delivery logistics presumably outside of university control, its ideas can be applied to the campus mail sorting center in that identifying subsystems and specifying time windows (e.g. more specific pick-up time windows) would decrease time cost.
3. **Workforce planning at USPS mail processing and distribution centers using stochastic optimization[4]:**
   This article goes into the analysis of the demand distribution based on historical data, and the development and analysis of the stochastic integer programming model, and is relevant since it helped inform one of our suggestions that the service desk employees are more specialized in terms of types of requests processed (package retrieval vs. other service requests.) This article uses data from a USPS mail processing and distribution center, which is larger in scale than the RPCC Mail Room, but follows the same basic principles and issues that the RPCC Mail Room is having, which is the processing and distribution of packages and letters. The article believes the long run goal would be to optimize the regular workforce by finding workers that are skilled in specific categories

to allow for efficiency, which may be applied to RPCC workers. This article goes into detail about a deterministic model that would solve "a point forecast of demand." It explains the formula it uses to optimize the workforce to make the processing more efficient, as well as cost efficient. Then the article continues to explain its stochastic formulation that can be used to optimize for altering demands based on different demand schedules. These stochastic models are beneficial because they take into account the uncertainty of a problem. However, a limitation of this article in being applied or compared to RPCC operations is that it is modeling for a 24 hour cycle of workers.

2. **Other Topics Learned:**

Queuing Theory: We learned about queuing theory and how the RPCC service desk operations are categorized according to that. Below, the team has highlighted a few relevant concepts learned throughout the semester regarding key aspects of the project.

1. m/m/2 Processes:

The service desk follows the m/m/2 queuing model when two employees are processing service requests in parallel. We learned that by using this model, we could apply formulas based on m/m/s to calculate useful indicators of process efficiency such as the typical expected values for students currently in the system[2] or expected service waiting times.

2. Categories of Queues:

We learned how to categorize queues by the characteristics of their functions; for example, we learned that RPCC services operate as a multi-server model, particularly as a first-come-first-served, multi-queue multi-server model with variable arrival time. The appendix includes a summary compiled by the team regarding this topic (The specific figure is Figure 6. Queuing Theory Understanding.)

<u>Next Steps and Goals:</u>

Goal 1 (Short-Term): Analyzing Mailroom Operations When Spring Semester Starts

When the spring semester starts again in January, the campus administration team collaborating on this project expects to see a high volume of mailroom activity as students return to campus. Since the issues behind mailroom inefficiency arise from a lack of resources– employees, time, etc., analyzing this

Goal 2 (Short-Term): Observing and Optimizing Amazon Locker Implementation– Busy and Typical Operations

Amazon lockers are a new introduction to the campus delivery system. When they are implemented in Spring 2023, we will be able to observe its effects on the campus mail distribution system and potential improvements to factors affecting its effectiveness, such as the locations of the lockers.

Ongoing Work/Long-Term Goals: Refining Queue Simulation and Data, Implementing Suggestions for Mail Distribution Process Improvements

As described in detail in prior sections, much of our ongoing work is related to updates to the campus mail distribution system we will be observing during the Spring 2023 semester. We plan to refine our queue simulation program by implementing the data we collected and will continue collect from RPCC, such as accounting for the characteristic of RPCC that it does not constantly stay as an m/m/2 or m/m/1 queue, but rather commonly changes the number of employees throughout the operation hours. We also plan to collect data covering a greater proportion of the full operation hours such that we can document any patterns within observable trends in employee number occurring relative to the time of day.

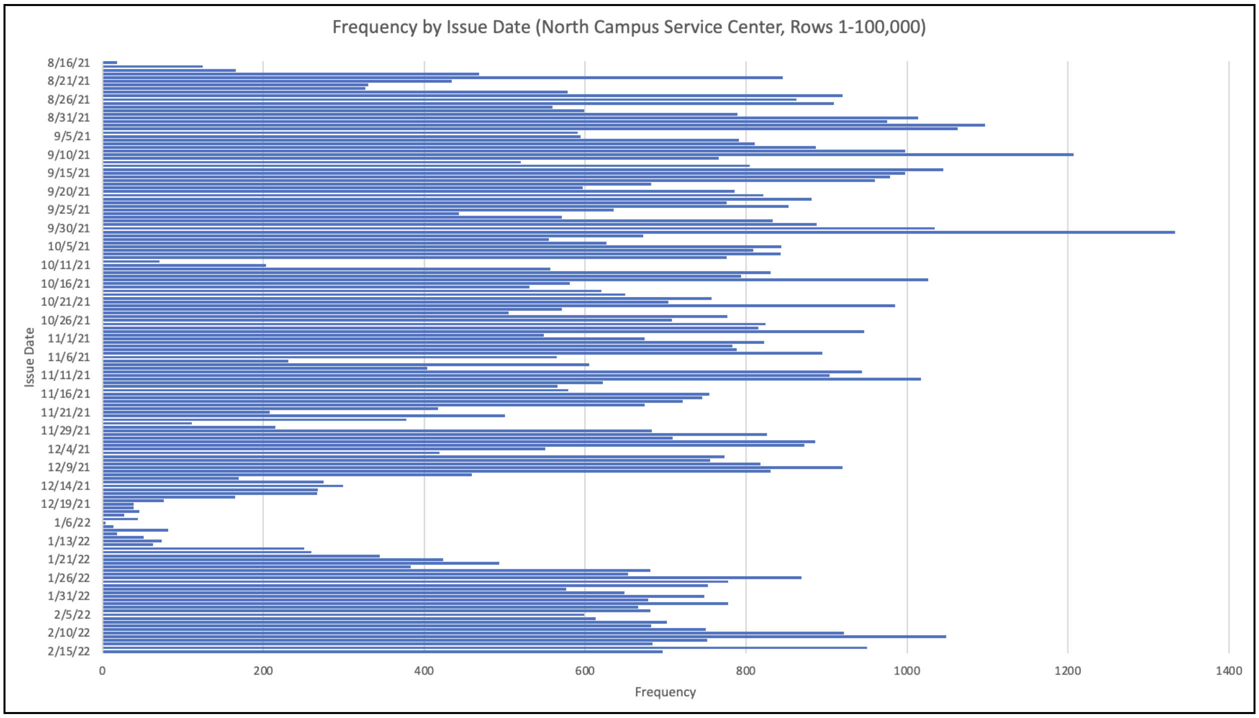
Furthermore, throughout our observations of the RPCC and general campus mail operations throughout the Fall 2022 semester, we noted areas of potential improvements and specific suggestions, such as automating email notifications for mail pickup (the specific suggestions are detailed in prior weekly presentations.) As we continue the project, it is a long-term goal to implement these suggestions where possible.

Another component of our ongoing work is responding to the updates or concerns raised by the campus administration team collaborating on this project, where we will continue to offer our perspectives as students and data analysis/insight where useful.

<u>Avenues Discussed in the Project:</u>

The work done on the project was overall straightforward for this semester, as we focused heavily on collecting knowledge and data on the current operations and state of the campus mail distribution system, then analyzed and modeled the components involved. Therefore, there were ultimately no avenues we were limited in pursuing, as the ongoing data collection and analysis we are interested in performing have become part of our goals to work on in the Spring 2023 semester (listed in prior sections.)

Appendix:



Frequency by Issue Date (North Campus Service Center, Rows 1-100,000)
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8/21/21
8/26/21
8/31/21
9/5/21
9/10/21
9/15/21
9/20/21
9/25/21
9/30/21
10/5/21
10/11/21
10/16/21
10/21/21
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12/19/21
1/6/22
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1/21/22
1/26/22
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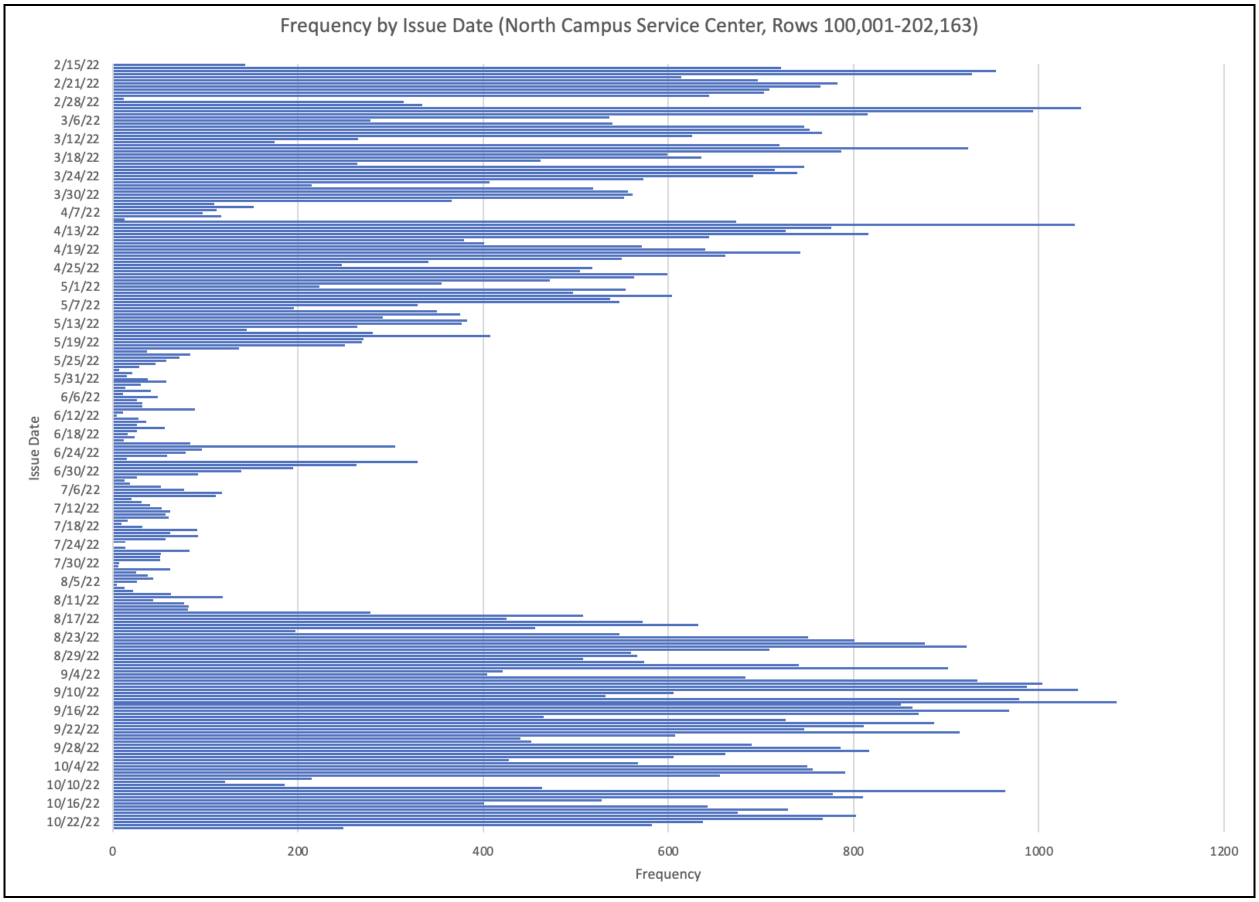
800
1000
1200
1400
Frequency



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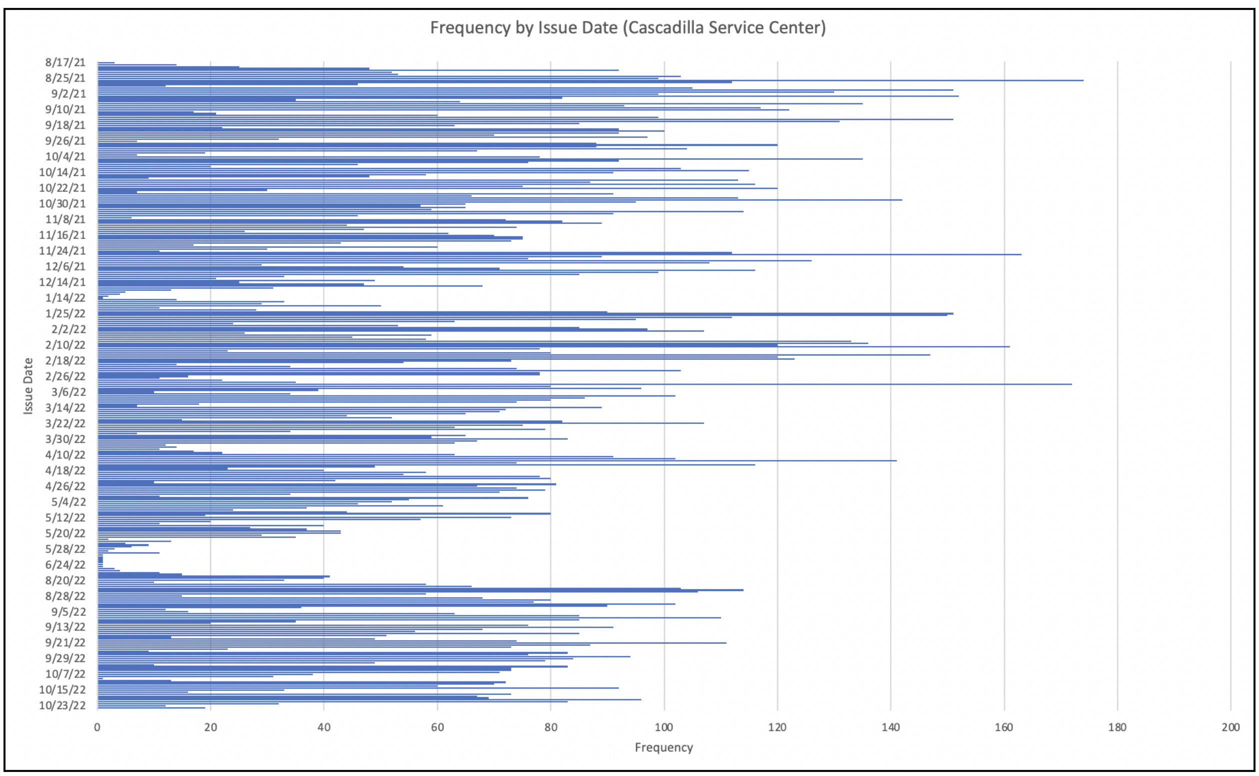
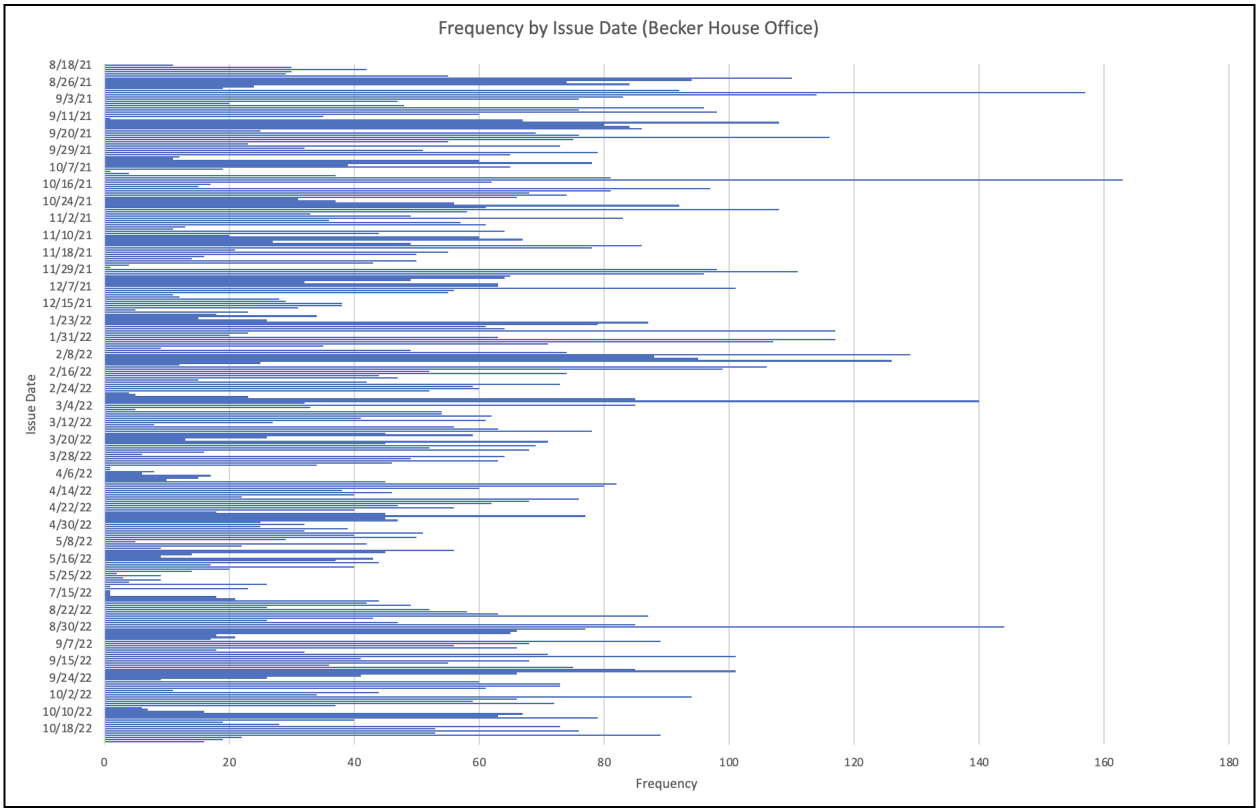
Issue Date
Frequency



Frequency by Issue Date (Cascadilla Service Center)
Issue Date
Frequency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10/16/21
10/24/21
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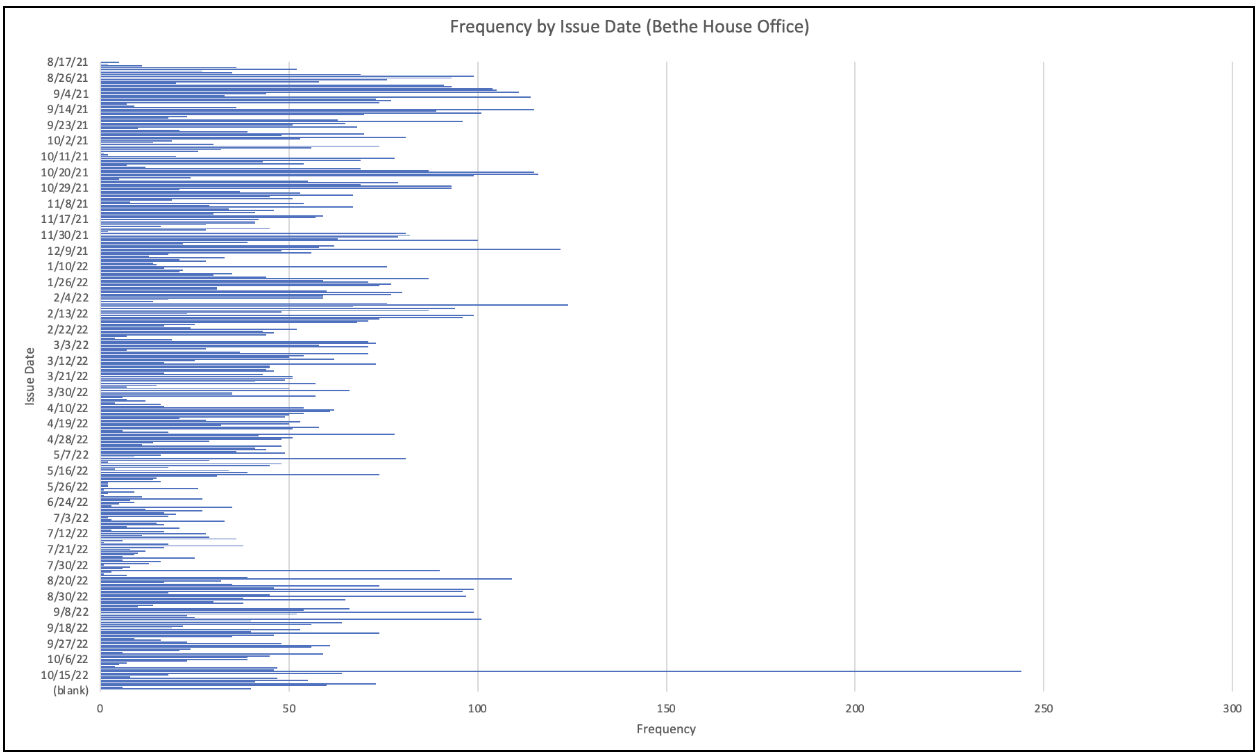
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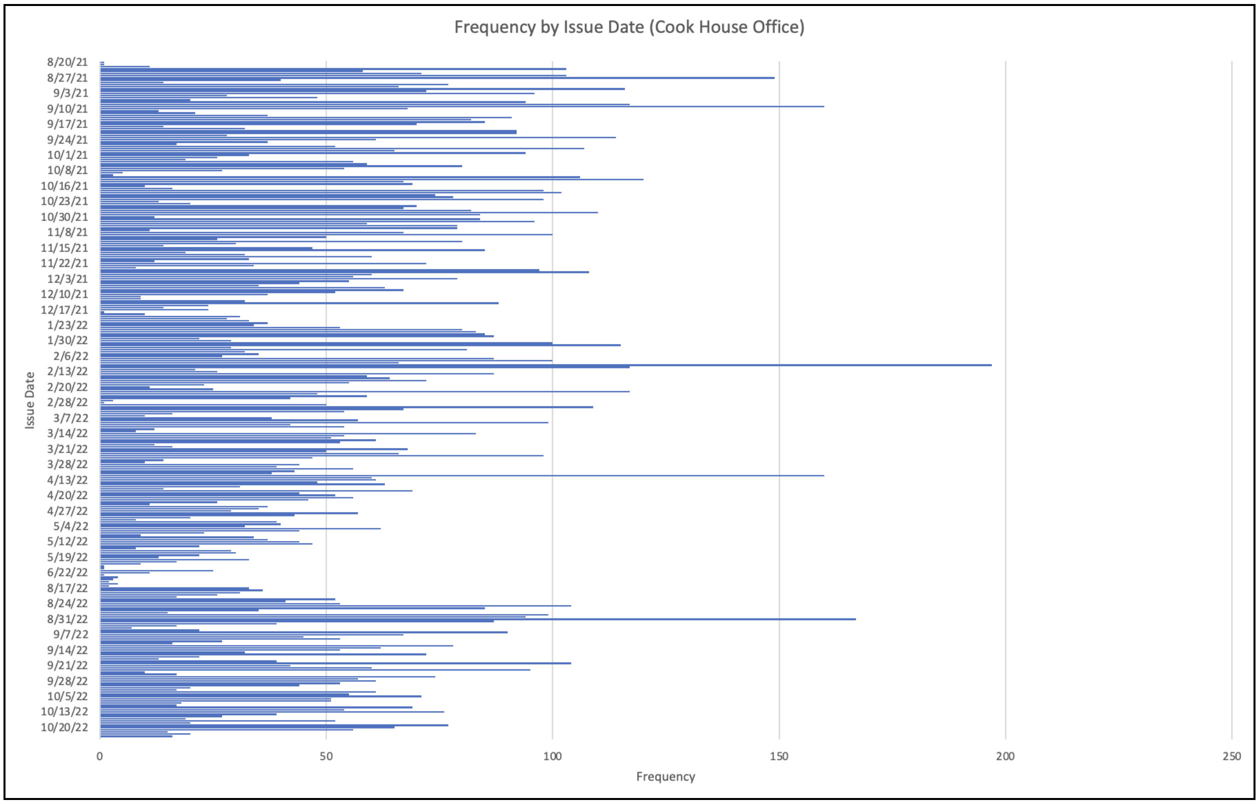

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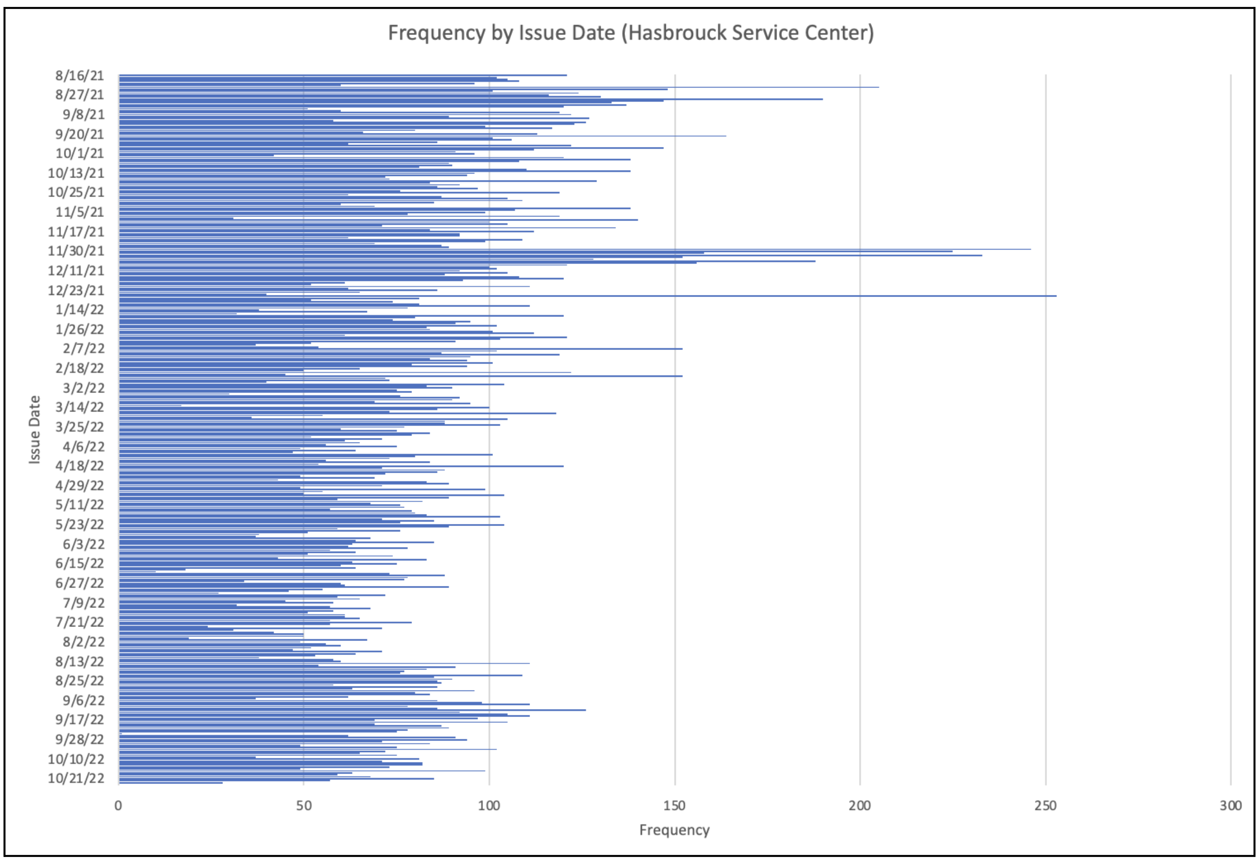

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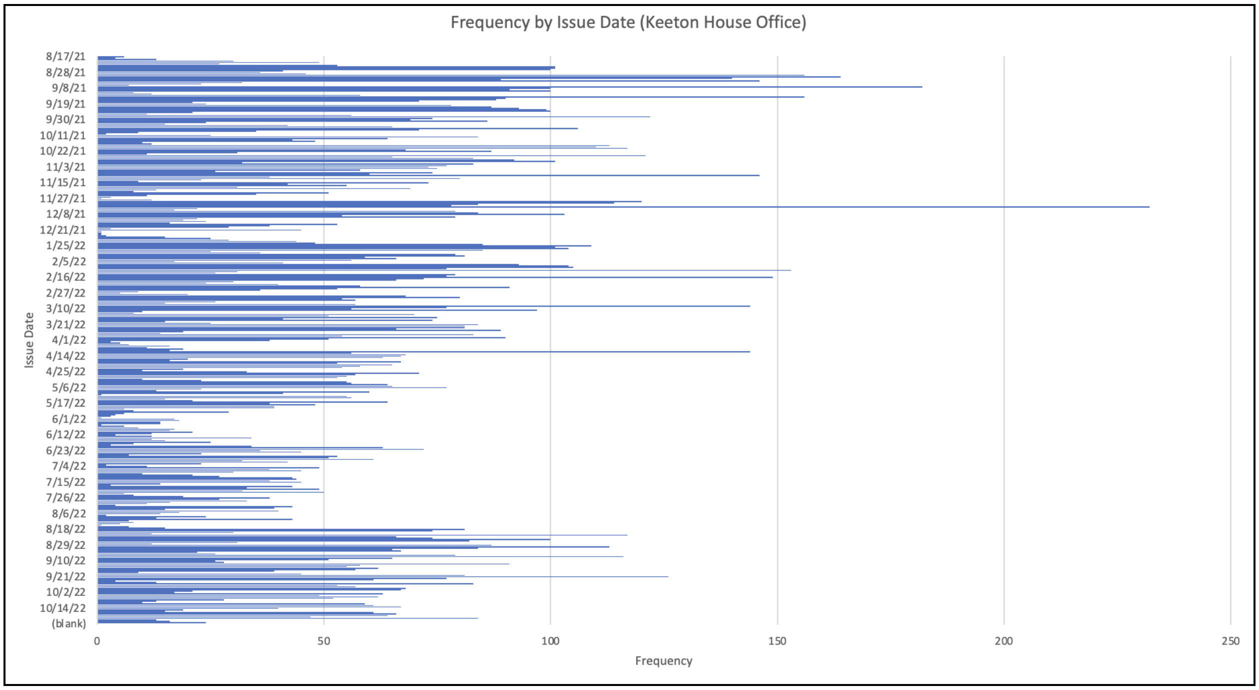

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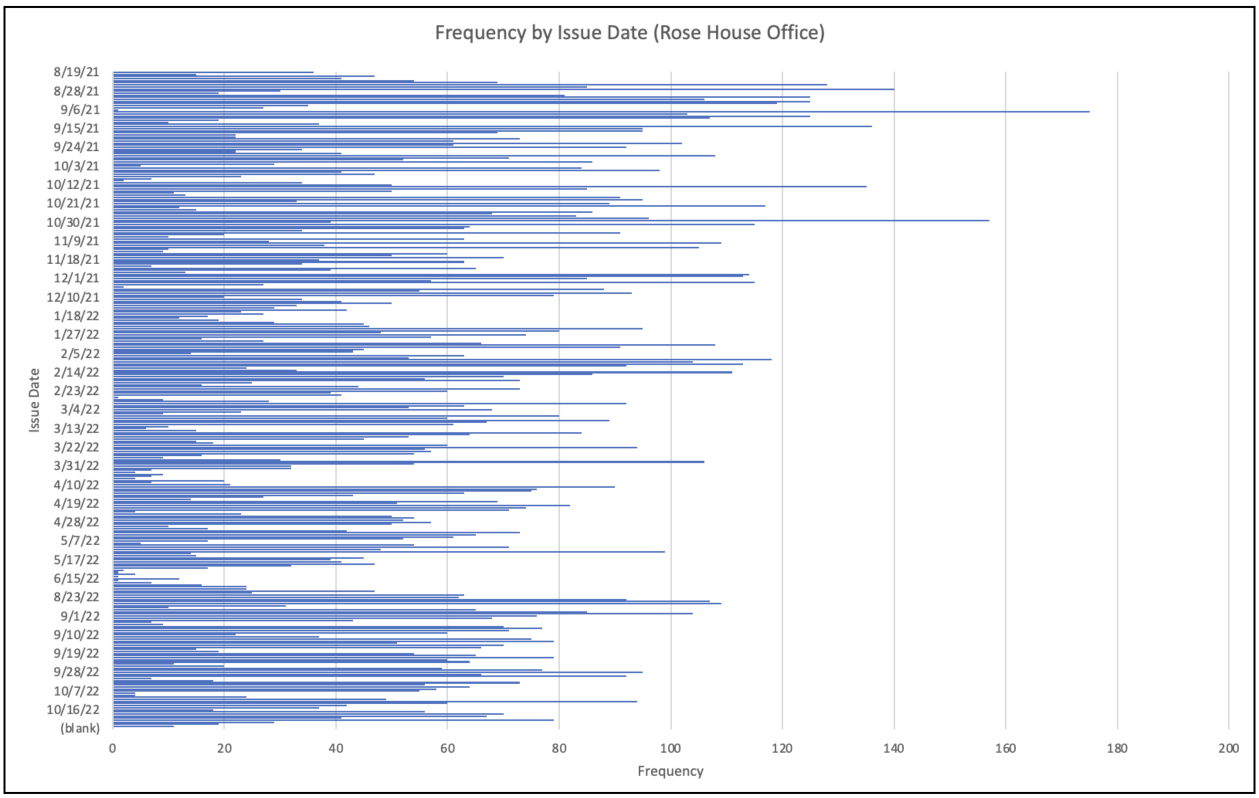
Issue Date
Frequency



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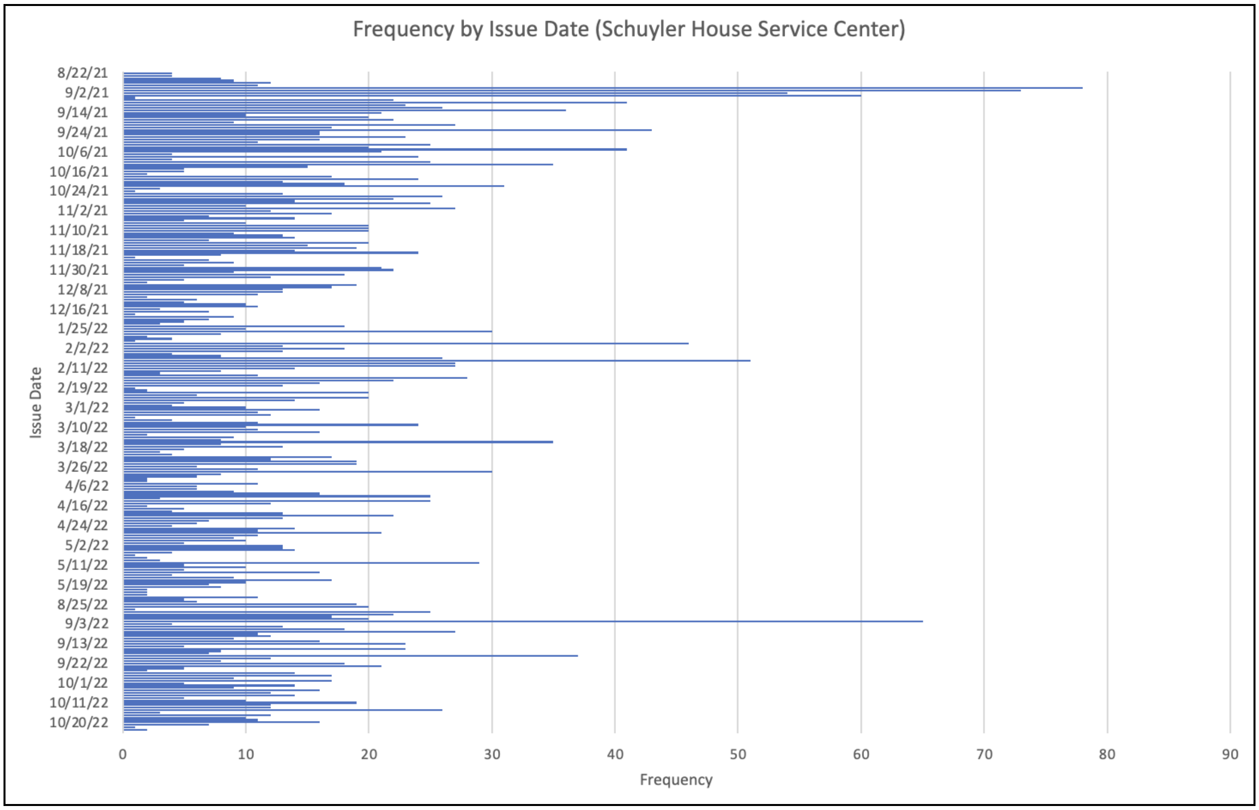
Issue Date
Frequency



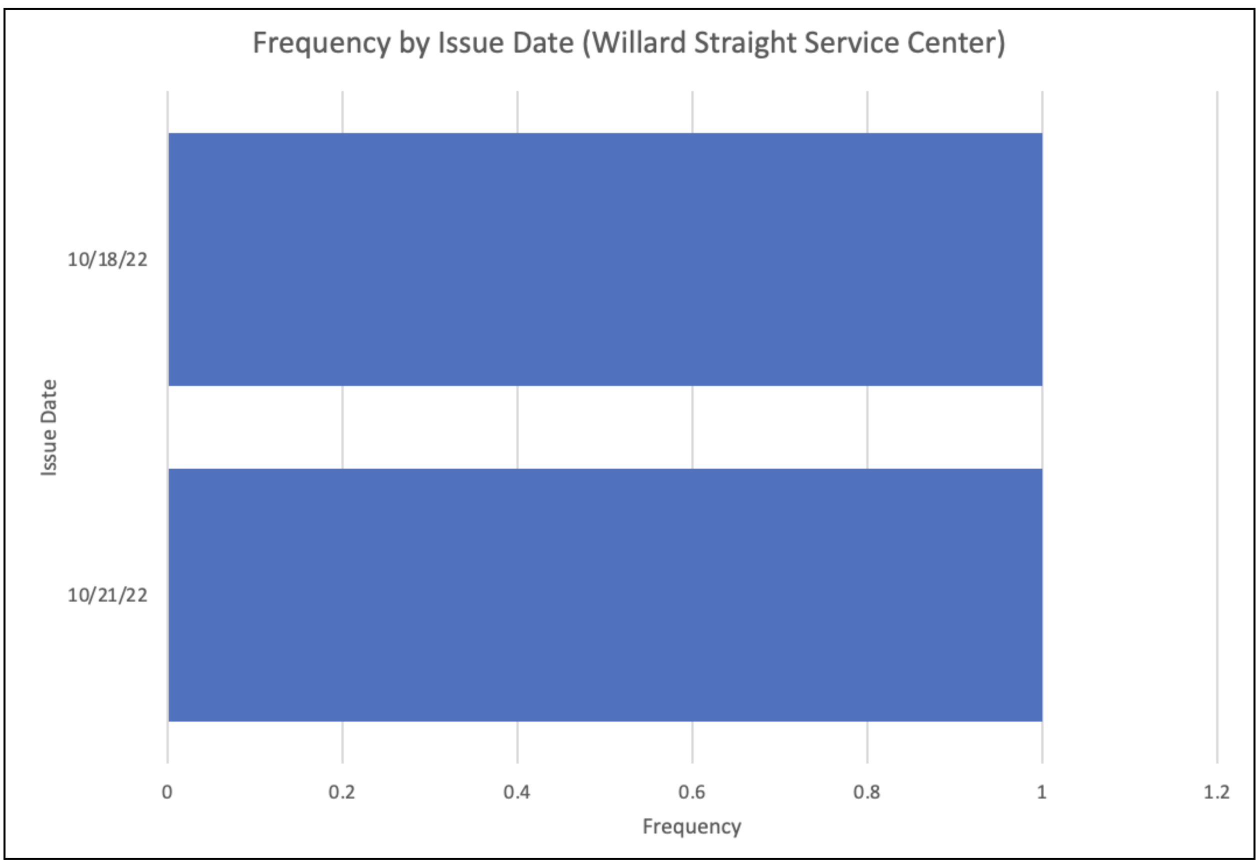


Figure 4. Frequency Graphs of Package Retrieval Data, Sorted by Mailroom

Large packages take more service time						
Nov 28, 2022 (M	5:00pm-7:00pm		*Columns D-G are matched to same student by row, columns A-B are also matched with each other by row			
Arrival Times	Note if there is a staff change (	Premature Depa	Departure Times	X if Employee 1 :	X if Employee 2	Service Times + Service Type (netID vs package vs mail, etc.)
5:02	2 start	5:14	5:02		X	N/A (arrived befo Package
5:04	1	5:23	5:06	X		1 min Package (red envelope)
5:05	1	5:46	5:07	X		1 min Package
5:06	1	5:46	5:07	X		1 min Package
5:06	1	5:51	5:09	X		2 min Package
5:06	2	6:08	5:11	X		2 min Package
5:07	2	6:24	5:12		X	6 min non-Package (maybe netID)
5:08	2	6:25	5:15	X		4 min Package (Thin Envelope Shape)
5:08	2	6:25	5:17		X	5 min Non-Package (looked through binder?)
5:10	2	6:27	5:19	X		4 min Package
5:11	2	6:27	5:20		X	3 min Package
5:12	2	6:27	5:21		X	1 min Thin Envelope
5:13	2	6:30	5:21	X		2 min Thin Envelope
5:13	2	6:35	5:22		X	1 min Package
5:14	2		5:24		X	1 min Package
5:15	2		5:24		X	<1 min Package
5:16	2		5:25	X		4 min Package
5:17	2		5:31	X		6 min Package (looked through binder, seemed to be issues?)
5:18	2		5:32	X		1 min Package
5:18	2		5:35	X		3 min Package
5:19	2		5:37	X		2 min Small Package
5:20	2		5:38	X		1 min Package

Figure 5. RPCC Data Collection Table

Queueing Theory

$$P_o = \text{Prob}\begin{bmatrix}\text{system is} \\ \text{empty (idle)}\end{bmatrix} = 1 - \frac{\lambda}{\mu}$$

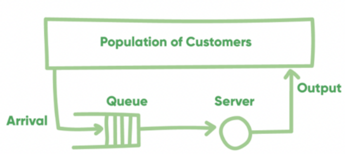
$$L_q = \begin{matrix}\text{average number} \\ \text{in the queue}\end{matrix} = \frac{\lambda^2}{\mu(\mu - \lambda)}$$

$$L = \begin{matrix}\text{average number} \\ \text{in the system}\end{matrix} = \frac{\lambda}{\mu - \lambda}$$

$$W_q = \begin{matrix}\text{average time} \\ \text{in the queue}\end{matrix} = \frac{\lambda}{\mu(\mu - \lambda)}$$

$$W = \begin{matrix}\text{average time} \\ \text{in the system}\end{matrix} = \frac{1}{\mu - \lambda}$$

Note:
λ is the arrival rate.
μ is the service rate.



Single Server Model

- Mu = service rate - the number of people being served per unit time
- Lambda - the mean number of people arriving per unit time

Capacity Utilization = λ/μ

Multipler Server Model

- When there is more people than the service rate per time(mu) you add a parallel server, which creates a multiple server model
- n = number of servers

Capacity Utilization = $\frac{\lambda}{n\mu}$

You are able to increase the capacity utilization by increasing the service rate and the number of servers. This is what we are trying to achieve in the mailroom.

You are also able to increase the service rate by increasing or utilizing the skills of your workers and adding automation.

Queuing Theory Components Applied to Mailroom

1. **Arrival Time**
   a. Arrival time is **variable** because the time of day affects how many people are waiting on line
2. **Service Pattern**
   a. **First come first served**,
      i. The process is meant to be first come first served when waiting in line
   b. Service time is usually a continuous random variable
3. **Service Structure**
   a. **Multiple queue multiple service points (Multiple staff addressing requests) and Single queue single service point**
      i. We think the model will be multiple queue multiple service points because there is usually two lines and multiple workers, but it is not always the case because there is sometimes only one worker leading to there only being one line.

Figure 6. Queuing Theory Understanding

<u>Bibliography</u>

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