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Proposing an Optimized Algorithm for Consolidating Electric-Powered Shared Scooters into Hubs for Efficiently Managing their Charging and Maintenance Operations

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Proposing an optimized algorithm for consolidating electric-powered shared scooters into hubs for efficiently managing their charging and maintenance operations

by

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Abstract

The use of vehicles other than ones containing combustion engines have been adopted significantly over the past few years and the direction it's taking seems to be the future of urban transportation. The hottest vehicle of choice currently is the electric scooter. They are small and portable, fast, and less costly compared to getting in a cab from Lyft or Uber to get around town. The goal of this paper is to make a proposal to drive the creation of a safe, efficient system for these scooters' management. This must be beneficial to all parties involved; the rider, non-riders, and the service provider. My optimization method is an algorithm that demonstrates how a larger fleet of scooters can be collected for charging or maintenance in less distance traveled. This would be possible if small hub locations are introduced for storage. These hubs not only have a great chance of being spotted, but also placed in safer areas, well-lit, and pleasing to make a stop at. It will also help pedestrians to not be obstructed by these vehicles in sidewalks. In my example, I will look at the distance traveled to collect a finite amount of scooters to charge as a charger, often called the hunter. I then compare it to the proposed system's output and see if it can provide an improvement. This will be beneficial for the rider since they can have confidence in charge level at checkout. It can provide the charger a chance to make more income, and if at last, the service provider chooses to take on the responsibility, the benefits are evident.

Acknowledgments

I would like to thank Dr. Robert Chun for his continued support and providing me with the guidance necessary to work on this project. I would like to thank my advisor Dr. Robert Chun and committee members Dr. Teng Moh and Prof. Ahmad Yazdankhah for teaching me the core skills needed to succeed and reviewing my project. And finally, I would like to thank my wife for her patience and support she gave me throughout my school career.

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Chapter 1: Introduction

The use of non-petroleum powered vehicles is advantageous in many different segments of our society for various reasons. Ridesharing vehicles such as bikes and electric scooters have become a convenient method for commuting and at times they are utilized for the last hop to get to the destination. They are reliable and can reduce traffic on surface streets along with greenhouse gases in the atmosphere. With the rise of population in metropolitan areas, and more families moving closer to where their jobs are located, the smartest option to do short distance travel seems to be using a two-wheel vehicle for the ability to maneuver easier on surface streets. Something easy to Hop On and Hop Off, and what's better than a standing scooter. Anyone who can stand and balance their body will be able to ride one of these scooters and the fact some come with a motorized feature makes it more attractive for getting from point A to point B without too much physical effort, leaving you fresh and energized when you reach your destination. With the growing number of companies which are staying competitive to offer such services, there are impacts seen to the general public which are not just limited to the users of such systems. To be specific, the electric scooters are seen many times, left in places where they cause disturbance to pedestrians. In downtown San Jose for example, there are instances of the scooters which are left at a corner allowing the possibility for some other rider to have a fatal impact.

In addition, there are some other aspects of it which can create friction for the general public. For example, they are blocking the business entrance, wheelchair ramps or creating dangerous zones for pedestrians or for passing cars. In some cases, they are dropped off at a spot that is very close to others' personal property. I have personal experience seeing how the negligence could damage some others' property. The injuries they cause to non-riders add up to the reports that, there are as much as 3,300 scooter injuries which took place in the U.S [1]. These are caused by riders who feel their transportation vehicle can bypass many laws.

As this revolution starts, it also will bring many difficulties for others in public places. The future generations will be enduring these scooters a lot more into their cultural behavior. It's best to create a way to control the consumption and rules around it as it scales. The public mass transits for many years have failed to meet goals, so the forefront of expansion in their infrastructure is always welcomed. This could take place with respect to the ratio of population growth in different cities just to create a way to be cost-efficient.

In this study, I will be presenting a model to create smaller hubs, and to help manage their blending process into public spaces. This will help to un-congest our pedestrian walkways or parking lots. These geocoded locations are contained as pick up/drop off spots at the corner of major intersections. Their idea of dock-less carries on in this version to not bottleneck the speed of transaction. To better manage these scooters, we are going to assign scooters to coordination points on the map. My sample data comes from Ford's bike sharing stations located in San Francisco. These coordinates are used for better modeling of this solution to the real world as much as possible, although the locations are further apart than an ideal distance for scooters. In order to address the distance issue, have added more data points to this locations set to mimic hubs. Also, to motivate the more dominant players of the market as they exist today, we put some monetary value behind it since the majority of the scooter rental providers rely on their users to charge up their systems for some Cash value. For any individual who fully charges each unit, a range of $5 - $7 will be paid off by the company as an income to that individual. We will carry the charge attribute of the scooters to be able to determine the most efficient way to gather the alike ones.

Chapter 2: Existing Solutions

2.1 Background

Following the wave of transportation start-ups in recent years such as Uber and Lyft, the new craze has started in the past year towards sharing electric scooters. Their approach was first to just start dropping motorized scooters across city streets without any permission from City officials in order to establish as quickly as possible and keep their niche. Currently one of the biggest players in this domain such as Lime is celebrating its 15th month of operation. They moved into cities like San Francisco without any regulations geared towards them. Officials from cities such a San Francisco have been pressuring them into regulatory operation. To be able to maintain their position, these early pioneers need to stay focused and offer various solutions for problems which they are creating. If they have any missteps in their Operational methods and guidelines, they could be left in the dust by the more established ride-sharing companies such as Uber and Lyft. A company like Bird first introduced it's sharing service in Santa Monica, California; a city which is not nearly as populated as some of the metropolitan areas which they now have presented in. In the beginning, the CEO of Bird, Vander Zanden, had not anticipated the demand to spread out so quickly. To dodge conflict with City officials and to be able to hold a good PR, they proposed a solution to keep scooters from blocking sidewalks and littering the entrance to businesses. One of their methods to keep the scooters, not in use organized was to introduce a concept called micro Park into city streets. Figure 1 shows an example of the micro Park station in Santa Monica. Although it seems like a positive step forward, it's not an ideal way to handle their inventory management since these mini-parks will also take parking spaces away from Cars [2].

Figure 1: Micro-Park concept in Santa Monica by Bird to control placements

2.2 Inventory Management

Currently, none of the scooter-sharing providers have a systematic method with algorithms for placement of these scooters, other than dropping off a fleet of them at busy street corners and watch them spread throughout the city on their own. From that point on, the users are the ones which will migrate the scooters to different geo-locations throughout the town. The only mechanism in place right now is if the provider has a live polling system to track these scooters by GPS locator contact. They are constantly aware of the location and battery charge level and possibly a few other attributes, such as uptime.

To be able to maintain the scooters, they monitor each scooter's battery charge level along with its location from headquarters. Furthermore, to spread the responsibility of charging the battery amongst the general public and to not solely be responsible for ensuring their fleet is operational, they have created a systematic opportunity for anyone looking to get an income out of charging their scooters. They have created a membership system for individuals with some qualification to sign up and take apart in charging up their scooters.

2.3 Scooter Charging Network

The Battery charging network mainly consists of private individuals will go around and collect scooters to charge them. According to NowThis website, Bird scooter collectors who are also called “bird Hunters” could potentially make up to $20. The flat starting value for charging each scooter according to a bird's website is $5 and it will increase depending on how difficult it is to locate the scooter. Typically the bird hunters will take the scooters home and after charging them overnight, need to drop them off as groups of three at dedicated assigned points called “Nests”.

Anytime a monetary incentive is offered without proper regulation in place, it will open up a Pandora box for an opportunist to find ways to take advantage of the system. Though the Bird Hunters could potentially make a lot of money, they also can find themselves in not very pleasant situations. As I did some investigations on the charging at work I came across a Facebook page where bird Chargers created a group. In the pages listings, there were many horrifying stories along with multimedia to support it. Cases of angry Hunters fighting aggressively with one another over Birds to take home for charging. Also, another opportunistic Bird hunter who was categorized as a “gold star charger”, had taken as many as 20 scooters prematurely and kept them in his garage for capturing them later as the bounties increased on those scooters due to the difficulty of locating them by other hunters. Individuals like this could be very aggressive and harmful when approached and called out by others on their behaviors. One hunter was followed by another angry Hunter to her car, who ended up kicking and throwing rocks at her car just because the angry hunter felt what she has taken is his right.

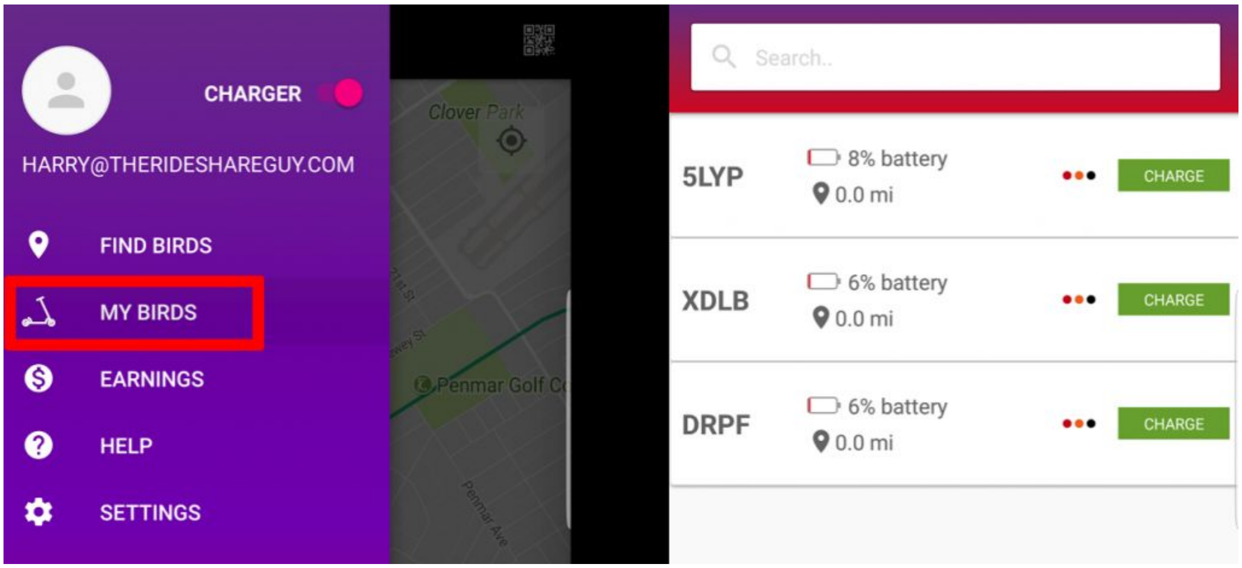

Figure 2: A Bird Chargers' dashboard on Mobile device

While some may argue that this can be an opportunity for many to have an income source, it can also be viewed as the company exploiting the less fortunate. For example, a screenshot taken from a Bird charger's dashboard shows the values are not really flat payout amounts. There have been instances in which payouts were adjusted without any concrete reason. For the money that the scooter sharing companies charge their customers to ride, it would also have to make sense for them to end up with some revenue in their own pockets after the cost of their chargers has been taken into consideration. For Bird, hunters and for Lime, Juicers are essential to their business model but it still leaves some overhead cost.

Currently, these startups are riding on the back of VC’s fundings and they may be more eager to expand their footprint rather than focus on the bottom lines. As they migrate towards becoming a public offering and have shareholders involved in their future decision makings, it’s best to have a look at the numbers and see if it’s really worth for them to outsource their charging tasks. My proposal in this paper can shift their charging tasks to stay in-house by specially dedicated personnel, but a method to collect the scooters with less charge grouped together in fewer trips than going to each station location.

Chapter 3: Problem Statement

Consider a rider who has completed his/her trip and is now ready to release the scooter back into the wild. The one feature that made these scooter services attractive to use was for the rider to use the scooter and then leave it anywhere, once they make it to their final destination. But there has never been a concession on where is a safe place to leave the scooter. Based on Bird's website the recommended location for parking, a scooter is next to bike racks when available. They also suggest to not block the public pathways; however, there is no control over that. This is just a recommendation and no systems on the backend support monitoring this activity. The cities which the services are offered got caught in the middle of the act.

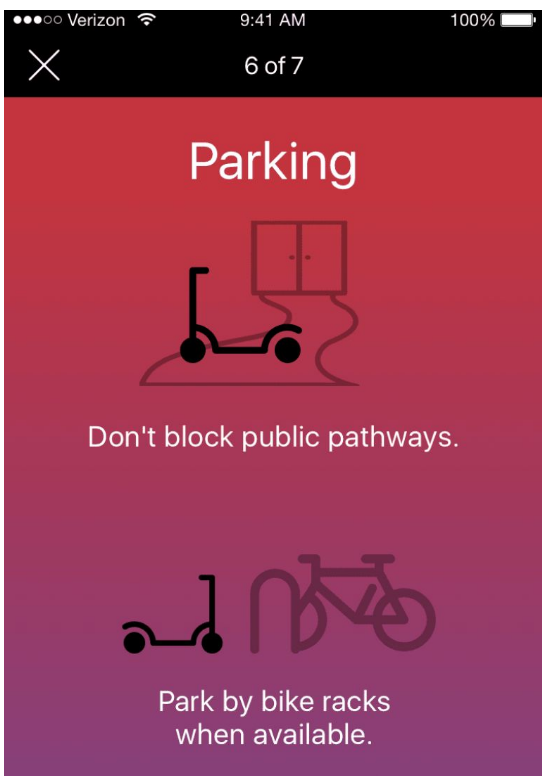

Figure 3: Bird app recommendation for return locations

Back in March, San Francisco witnessed hundreds of electric scooters descended upon its streets overnight. But then in June, the city official ordered their clean-up off the streets after they realized what was happening. Through those times, before the clean-up order was given to vanish them, the residents were puzzled, infatuated by the new discovery to get around the city so cheap. Non-riders where seeing a swarm of these vehicles taking precious spaces away from streets and sidewalks, backed by tech companies which are known for their arrogance over a new idea they put out for adoption. In August, San Francisco announced that it will give only two companies permits to have 625 scooters each in the city streets for one year and only to do testing to collect data. However, this hasn't slowed down any of the scooter sharing companies from expanding their fleet's footprints. Following the path of many ride-sharing Services startups that came to life before them, mini scooter companies lean towards "ask for forgiveness rather than permission" mentality. They continue to raise questions about who is entitled to use the roads and sidewalks, and who should be paying their maintenance costs. According to home guides SF Gate the cost to repair sidewalks in 2013 started at $10.40 Per square foot, bringing the average cost of a small project to around $600. However, major repair costs could spike over $2,000 [3]. Considering that scooters are no longer only kept on the roads, with riders maneuvering back and forth between sidewalks and street weaving through crowds of pedestrians and traffic, there should be some division of costs for sidewalk repairs between those companies as well as the taxpayers.

The most important aspect which this project focuses on is the location placement which these scooters can be picked up and dropped off. To avoid blocking sidewalks, wheelchair ramps, and narrow bottlenecks in sidewalks where other non-moveable obstacles already exist, let's have a look at a proposal to avoid causing problems for non-riders. We do this to also give some incentive for the service providers to invest in the infrastructure to support these mini hubs or as Bird called them in the example above: nests. This will prevent the possibility of leaving scooters in dangerous zones for non-riders and riders themselves.

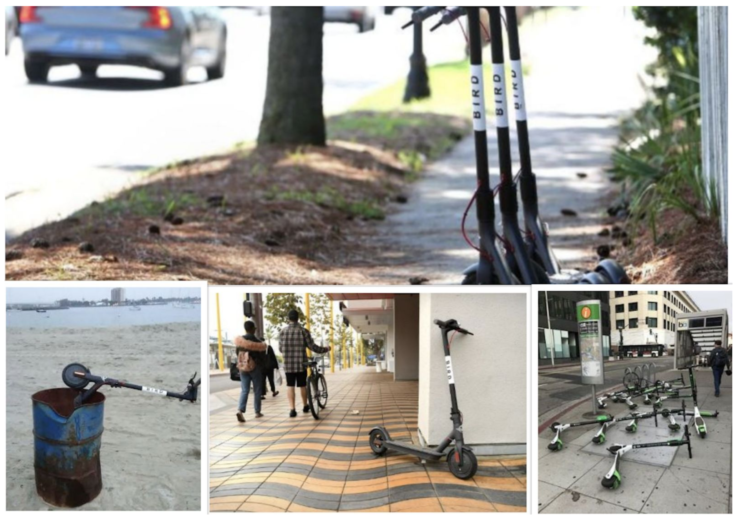

Figure 4: Scooters left in unassigned locations

3.1 Algorithmic approach to distribution and collection

Considering how much money these scooter companies are shelling out for the general public to take apart in charging their scooters, the overhead costs can escalate quickly and surpass the profit lines beyond their making due to their low-cost rental cost. Furthermore, when the task is contracted outside, there are many ethical issues which arise from it. In this research proposal, I will demonstrate a method through the use of algorithms and physical stations as hubs spread throughout the city, which will allow the provider to easily collect the scooters which need charge or maintenance from only a few zones and not traverse throughout all the zones they have scooters in. These few zones at the end of the day have collected all the scooters with their charge depleted, and it will take only a few crew members with a vehicle to be sent out for their collection. My stations are clustered based on their location density and these clusters are taken into account when it comes collection time.

3.2 Sample size and Data

My dataset in this program will include a combination of station locations and Scooters which are initialized at each station to demonstrate the movement of Scooters throughout the regions made of stations. The station locations come from a dataset provided by the For Bike Share company to give a real-life model of geo-located hubs. It has also been expanded by more geo coordinates of intersections in San Francisco which could potentially be station locations for these scooters. The geo-coordinates have been extracted from the dataset and they are being viewed as possible station locations for a scooter-sharing business model to park their scooters at. Although these stations are further apart due to the fact that bikes can travel further and get the end-user to a distant location easier, this model can be interpolated into the scooter-sharing model by creating more stations with close proximity from one another and place those in a proper surface on major intersections or crossroads. Specially when it comes to college campuses where each building should have a hub located within very close proximity.

The Ford stations are concentrated mostly in one region of San Francisco; however, my model can demonstrate what it would be if they were all across the city.

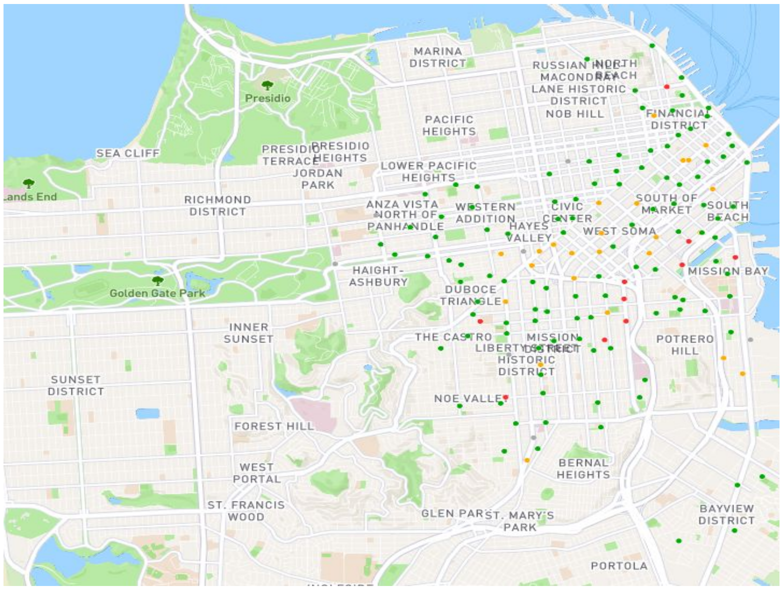

Figure 5: Ford Bike's stations in San Francisco

The model contains 500 unique stations throughout the city, and they will be put through a clustering algorithm based on their geo-location. For this, I use the DBSAN (Density-Based Spatial Clustering of Applications with Noise) method which will group the stations that are within close proximity from each-other together. I have taken this clustering method out of the sklearn library which offers many clustering mechanisms. The constraint criteria used for this grouping is on the distance of two neighboring stations. For the stations to fall within the same cluster, the max distance of points in the same region is considered to be 0.3 mile which is equal to 1,760 feet. This will give us 48 non-overlapping clusters which contain the 500 unique stations in them.

The next phase will contain the assignment of scooters to each of 500 stations. The station capacity for this system is set to be at 10. I will be placing 7 scooters in each station to set up the system. The scooters will be given a unique identifier for better management. Their charge level is going to be randomly assigned to each scooter between 95-100% to give this system a realistic sense of what scooter's will have out there in the real world. For example, not all scooters in the system should start at 100% charge. We will give it a realistic model as it would be at the beginning of a given workday.

3.3 Implementation at a given Iteration

The flow starts with a scooter randomly picked from all the scooters in our system. We have a total number of 3500 scooters distributed throughout our stations in San Francisco. To mimic the action of a scooter that is being used and now becomes free to be put back into the inventory, we take a scooter at random, remove it from the inventory management and treat it as if a rider is using it and is done using it, planning to return it back. The location field of the scooter will be updated with a Latitude and Longitude randomly generated within a geofence of coordinates within San Francisco. This will mimic one that would become free in a real-world scenario and its location for the algorithm is the starting location to then assign a returning location to this scooter based on the desired attributes.

Along with this scooter's location info, I reduce its battery charge attribute by 40 percent to really provide a realistic scenario in which the scooter was used and the charge was consumed. This later will be useful to ensure the grouping is done accordingly. Once the above takes place, I will then search within my 48 clusters to find a matching station in a region close to the rider's location with their battery charge level considered within a threshold to be picked as the ideal location candidate for returning the scooter. It will help drive the metrics when it comes to which stations have the least amount of charge level than others based on the station's average charge level attribute.

Once a request of return comes in, there will be a geocoded location within boundaries of the city of San Francisco randomly generated. I have set up a geofence to be able to randomly pick a location in San Francisco city.

Geo-Fence Boundaries	**Latitude**	**Longitude**
Westmost	37.775316	-122.510990
Eastmost	37.808260	-122.419159
Northmost	37.788232	-122.387852
Southmost	37.702461	-122.455211

Figure 6: The Geo-Fence which the Scooter Location will be generated in

The coordination for destination location is computed based on the logic and it will suggest the preferred station to return the scooter to. This helps to prevent issues with rider negligence which could result in damages to others property. After many iterations, the similarly charged units will be gathered in clusters of stations. Therefore, this leads me to believe that the effort to gather ones with least charge will be minimal and very cost-effective by the provider.

Chapter 4: Design Analysis

4.1 Financial

Based on the sample size that we have, we will take a look at how much each service provider will pay each day to have their scooters charged. The cost has been taken from the average reward that each brand of scooter sharing will give in return for charging their scooter. We have also taken the average number between the flat rate and the full rate of a hard bounty since the reward is higher if the scooter is harder to discover.

	Flat Min Rate	Flat Max Rate	Max Rate	Average Payout Daily
Bird	$ 3.00	$ 5.00	$ 20.00	$ 12.00
Total for Bird(3500)	$ 10,500	$ 17,500	$ 70,000	$ **42,000**

Figure 7: Outsourcing Cost of Charging Scooters daily

One of the advantages of putting this proposal system in place is that it will save the service provider monetary value as well. If they had 6 crew members for collection and they would go out to designated regions to pick up the scooters, it might take them 2 hours to collect. This would leave the total cost of the charging crew considering the minimum wage at $15 per hour at $180. This would be only a fraction of what Bird is paying out to the general public and would avoid raising controversial hunger-games like an interaction between the chargers personnel.

4.2 Security and safety

Proposing publicly available locations for the dockless scooters to be stationed at is an essential practice that needs to be addressed as their population keeps growing. Due to the mentality that "Ask for permission" is followed by these startups, cities missed the hearings that could've taken place by officials to properly regulate their blending into our walkways and streets.

4.3 Station Hubs

After months of painful maneuvering around the side tipped scooters in Santa Monica, there is a shift towards a solution for parking locations dedicated to scooters. Although every precious inch of sidewalk and parking lots count, the overwhelming amount of vehicles left out and about is pushing for some band-aid fixes to be put in.

Figure 8: Santa Monica adopting scooter parking spaces

If the need for such spaces is coming to picture, then what a nicer way to put it into a framework from the start. These spaces need to be accepted into the fabric of our streets. A phenomenon can be introduced by the idea to be guaranteed a scooter when you need one, and for it to be highly charged in one of the designated spaces.

4.4: Public's Vision On This Topic

A study has shown that commuting shorter distances is the essential aspect used to boost scooter sharing. 60% of all transportations in one day, are hops within less than 6 miles. This will allow the scooter to fill the need which Uber and Lyft couldn't expand to. They now have invested, acquired other companies which helps them drive the need and keep it cost effective for the rider. Uber invested $335 million into Lime scooters due to their model. This shows that a huge fund is backing the idea and technology behind it. The application design along with rigid scooters for rental helps the companies to maintain their riders.

4.4.1 Mobile App UX

Given the target user for the application, it is natively designed for mobile. It needs to facilitate easy unlocking and locking. The use of QR code is a popular visually accelerated verification for items with attributes. Lock or unlock and how fast the user can get it through the flow is the key.

Figure 9: Using QR code unique to each scooter

Mobile UX in all apps is very similar. It gives the user the map view to give a sense of proximity distance to each available scooter right away. Almost all the major players in this domain compete over delivering more features with a better user experience. Fig. 10 shows a screenshot of all apps.

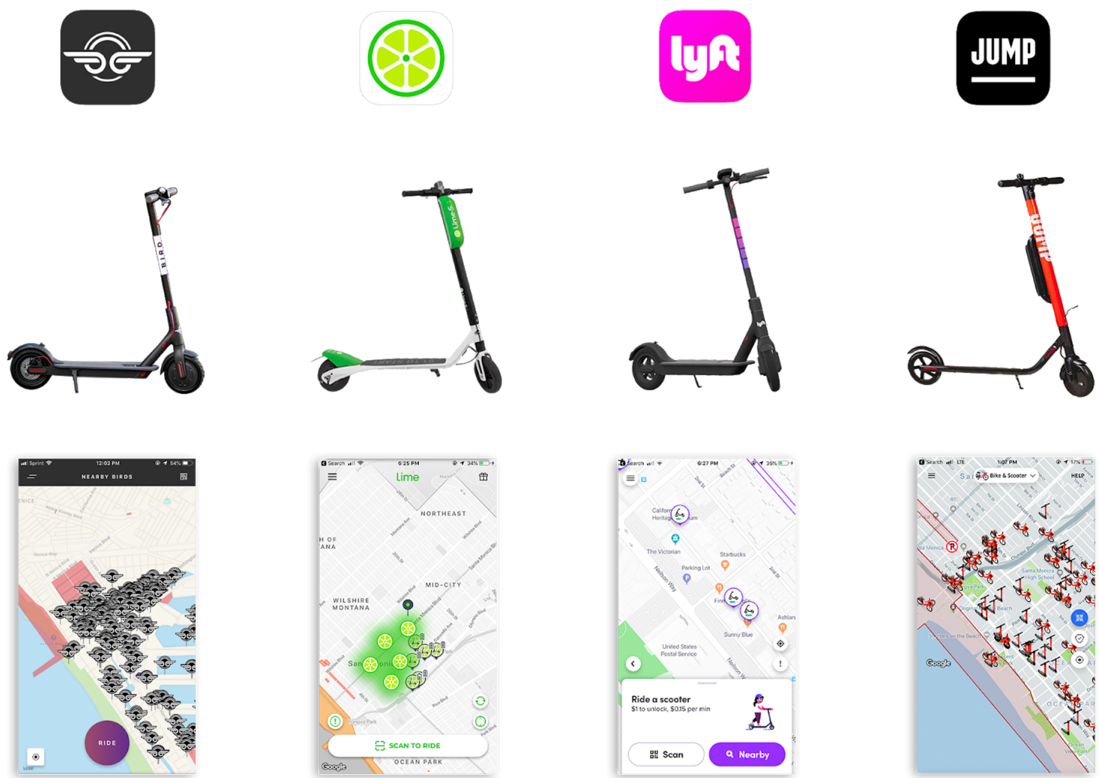

Figure 10: The dashboard of main scooter sharing players

Bird was the first one in the market, but its app is lacking some main features. One of the major ones which will really be advantageous for my proposed solution is the fact that no reservation could be done on a scooter. Once a scooter is identified on the dashboard map, there is no option to hold it before the rider can make it to that scooter. So there is a possibility that the rider will make the trip to the location displayed in the app, but before they can make it there, the scooter is swooped up by another rider. So it leaves no guarantees for a scooter to be available by the time the rider makes it to the pin on the dashboard's map.

4.4.2: Public's Favorability of Scooters

As riders start to get comfortable zooming through crowds and streets, it creates dangerous situations for pedestrians to even walk on sidewalks. The medical community has seen an increase with regards to fatal injuries coming into emergency rooms as a result of scooter accidents. There are still studies to be done on how the public can prevent injuries. It ranges between different cities. This chart shows the public perception of e-scooters in San Francisco which is the lowest, and San Jose sitting third lowest. This is mainly due to the congestion in the streets and the mayhem that scooters will introduce when they are put in the mix. San Francisco already has a battle with Parking and high priced parking lots which makes it both attractive for riders to rely on scooters but dangerous for everyone maneuvering through cars in narrow streets.

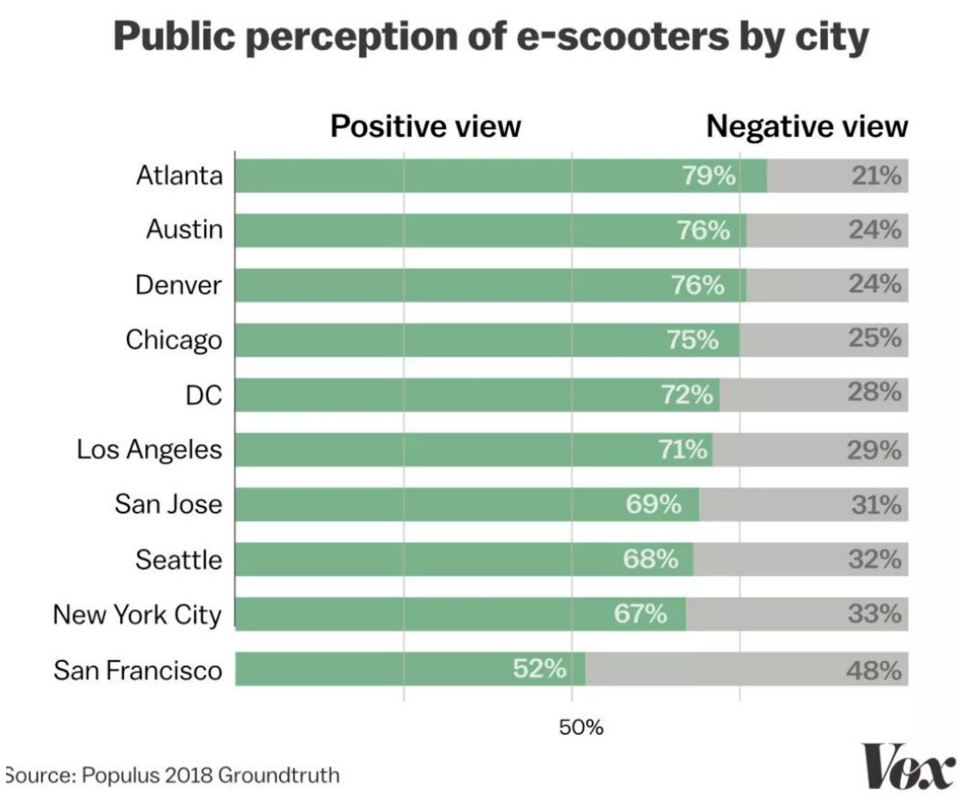

Figure 11: Survey of Public Perception by City

As observed, the larger cities in the country have higher negative views about scooters as well. How they are perceived in these cities is a challenge to solve before we can encompass them into the fabric of the city’s daily commutes.

4.4.3: The Scooter Calling the Cops

Yes, it’s true! Lime scooters will shout at you if it senses that you are fiddling with its core systems. Some have been threatened by calling the cops on them from a speaker on the scooter. Will the scooter actually make the call is unknown. It’s more likely a scare tactic to keep it out of the hands of criminals.

5: Proposed solution

5.1.1 Infrastructure Setup

Most cities are now looking into investing for an infrastructure to support the operation of scooter-sharing companies because these companies for long have dodged the task to provide a solution into organizing their gatherings into hubs. The use of micro-stations is in the works in the city of Santa Monica, CA as a solution to keep the scooters not being used in a designated location. This city is the birthplace for Bird and it experienced an overflow of scooters in its streets without any immediate fix to manage their positioning on roads and parks. The proper placement of these hub networks' location would be an extension of this paper, but having such hubs, is a suggestion for better managing scooters to benefit the needs of both sides. In my proposal, I am relying on existing stations throughout San Francisco which would function as locations these hubs will be placed in the future. Since they will free hosting scooters, there needs to be a larger number up stations to manage shorter distances traveled with a scooter.

In order to get these station hubs clustered into groups, I use DBSCAN which comes from the sklearn library in python along with necessary modules to support it. This library will take an input of vector array or a distance matrix. In my demonstration, I am going to pass it an array of all my coordinations. This array is read from a CSV file which was created by sanitizing the dataset from Ford's bike and extracting only a list of unique combinations to stations. First we cover the python modules which needed to be imported:

```
import pandas as pd
```

```
import numpy as np
from sklearn.cluster import DBSCAN
```

Pandas and numpy modules are the python modules needed to work with large data frames they enable resizing or reshaping the dataset in a meaningful way.

Once I have loaded my coordination list, I will assign a maximum distance between two stations to be considered within the same region. This will need to be passed into DBSCAN to determine how the grouping of the stations will take place. Also an advantage of this type of clustering vs. for instance k-means clustering is that you don't need to pass in the number of desired clusters. Due it's algorithms nature, it will determine for you how many clusters to create based on the required guidelines passed in as parameters. To be able to get some realistic numbers, and manage the clusters easier, I have chosen that distance to be 0.3 mile that equates to 1,760 ft. This means in each of my regions the furthest their stations will be apart is 1,760 feet, and it's placed as the eps(epsilon parameter). Now we can feed this into the DBSCAN clustering:

```
db=DBSCAN(eps=max_distance_of_points_in_same_region, algorithm='ball_tree', min_samples=1, metric='haversine').fit(np.radians(coordination_list))
```

The algorithm for the special clustering is set to ball tree with "haversine" metrics, to perform a calculation based on the great-circle distance between two points. This will take into account the surface shape of the earth and will require the coordinates to be converted to radians for scikit-learn's haversine. This is where we use the Numpy library to convert our coordination vector into radians.

Once we get our db instance which holds the clusters in, I will take a count to find out what's the total number of clusters created based on our request. Then I will give these cluster Ids based on their index in the ndArray that they have been extracted from. Each station is then tagged with it's assigned cluster id to be able to filter out later when assignment time comes.

5.1.2 Fleet of Scooters

There will be no modifications needed for the existing scooters, therefore the companies do not have to change the design or purchase any other versions of the scooter. This is a great motivation for going forward with this proposal since there are no costs involved with replacing an existing fleet of scooters being used. It will only require that companies that work with local governments to focus on creating mini hubs to host the scooters.

5.2: Determining the Return Station

Providing the return station once a rider is done using a scooter is the heart and meat of this solution. Based on the charge level left on the scooter, the rider has been assigned a location to return the scooter to.

The algorithm will compare the charge level and distance to all nearby stations, validate each station's capacity at that given moment to accommodate the returning scooter, and then provide the best station option for the scooter to be returned to.

____If

INVENTORY[select_station_id]['avg_charge_percentage'] < lowest_chrg_level and \

master_5_stations_to_return_to[select_station_id]['distance'] < shortest_distance and

INVENTORY[select_station_id]['qty_present'] != STATION_CAPACTIY:

Once the criteria above are met, the user is prompted to start navigating their way to that station. Having the hub will not only guarantee that when the next rider needs to get a scooter he/she will end up with one, but it will also be a consistent spot that riders can find a scooter at when they need a vehicle.

```
if INVENTORY[select_station_id]['avg_charge_percentage'] < lowest_chrg_level and \
        master_5_stations_to_return_to[select_station_id]['distance'] < shortest_distance and \
        INVENTORY[select_station_id]['qty_present'] != STATION_CAPACTIY:
    lowest_chrg_level = INVENTORY[select_station_id]['avg_charge_percentage']
    _station_id = select_station_id

    #add the bike to this station
    INVENTORY[_station_id]['scooters'].append(free_scooter_object_dict)
    #increase qty
    INVENTORY[_station_id]['qty_present'] += 1
    #re-compute it's average charge
    utils.computer_one_station_average_charge(INVENTORY, _station_id)
```

Figure 12: Heart of the logic

When doing a comparison of a station hosting all scooters, my assignment method will get all the lowest charged scooters in a certain cluster at the end of a business day. This would give the company a chance to only go to those locations and collection them. Currently, both of the top players of the electric-scooter sharing marketplace, S-lime and Bird, pay for the public to charge their vehicles. Both startups that surfaced in the past few years, without any major infrastructures survived. But the benefit of them allowing their users to leave the scooter anywhere leaves the dependency on the general public to charge their vehicles.

5.3 Benefits

The ability to have a dockless system opens up doors for disorganized operation tactics in many cases. With the current system in place, some potential customer can make their way to one of the pins shown in their app's dashboard and then be faced with no scooter in sight. The effort put in by that potential user to get to the location only to find out the scooter was obtained by another rider will result in a hazy user experience.

On the other hand, the problem for the service provider is to ensure that besides the availability of scooters, their performance level should be up to par. There is a manual process involved right now with volunteers who are given directions to better manage the performance. That is, charging these scooters.

Once the final round is gathered, there will be regions with hubs in them where they only contain the scooters with the least amount of charge left in them. In other words at the end of a business day, a company rep could go out only to a few zones and collect all scooters that need charge desperately. They are no longer obligated to travel to each cluster region and collect scooters which are drained in battery charge.

This will avoid the need for building any additional charging infrastructure at the hubs directly, and it can reduce the complex installation of cables and wiring of the hub.

5.4 Additional Features

With this system, there could be additional features implemented also which currently are missing from the mainstream scooter sharing apps out there. For example, Reserve a Scooter is not supported by Bird or Lime, but it would be very beneficial to users to be able to secure their ride for a given time and know that the scooter will be there for them once then need it. If the rider can't make it to the scooter or changes their mind when the time comes when they need it, the rider could be charged a small fee just for holding the scooter reserved and preventing others from using it.

Another feature which is not currently available in the apps, and it can be a great enhancement for the riders experience, is a smarter way to report the battery charge level to the user. What if the user could find out If His scooter's battery life is enough to take him to his destination? None of the current providers have such a feature baked into their business model. A feature which will solely rely on the existing technology at hand. A user could simply enter in their destination address if they wonder whether the next scooter they will pick up will have enough charge to make it there.

6: Data Analysis and results of the proposed solution

6.1 Execution Benefits of The Existing Model

In order to demonstrate improvement this proposal will convey on the overall operating costs and financial benefits, I comb through web seeking data to show how the chargers are currently doing following the existing model. Since this flavor of "gig" economy has come to existence very recently, there hasn't been much data collected by research firms or openly available from the service providers like Bird or Lime. No established data stream exits to outline the potential income vs. out-of-pocket costs associated with doing the diligence of charging these scooters. The blogs and articles that I uncovered, all mentioned that it varies and mainly depends on the aspiration of individual willing to take risks going out to collect these scooters. What they don't mention is that some of the scooters are in dangerous rural areas or sometimes used to lure chargers into dangerous confrontations. I described rouge charges who would hold on to multiple scooters in their garage to increase the bounty and then they will claim them captured just to make more value out of the task. During my explorations, I discovered a blog post on Reddit which a Reddit user by the handle DallasBirdCharger87 had posted an excel sheet of his backlog for collecting and charging Bird Scooters for a period of 22 days. The attributes collected by this user help us create a blase-line, to then compare with the implementation results and measure the improvement done to the process. The raw data is shown in Figure 13 as it was posted online. Figure 14 shows the calculations done to create baseline attributes. The attributes in focus for running this experiment will be on the Miles Drives to hunt scooters and the Number of scooters captured after miles driven. For this, I have taken the Average value of the Miles Flown and the Average number of Scooters that were captured from those drives. Since the value could differ on each scooter based on the bounty that was set on it, we won't take that into consideration as it will not provide a clear data point. Once we determine how many scooters are captured after drives, nonetheless the base payoff value will also assist us to drive an estimation for payouts. This can transpose the monetary value increase in which this proposal will also help drive.

Date (release date)	Miles Flown	Earned	Scooters Charged	$cooter Avg	Time In+Out
7/27/2018	22	10	2	5	
7/28/2018	22	5	1	5	
7/29/2018	37	28.86	4	7.215	
7/31/2018	31	25	5	5	
08/01/2018	25	30.04	4	7.51	
08/02/2018	35	27.38	4	6.845	
8/18/2018	25	40.83	5	8.166	
8/20/2018	25	20.15	2	10.075	
8/21/2018	20	23.09	4	5.7725	
8/21/2018 Lime	0	15	3	5	
8/22/2018	23	37.47	7	5.352857143	
8/23/2018	7	23.2	3	7.733333333	
8/25/2018	5	25	5	5	3
8/26/2018	45	121.08	20	6.054	
8/28/2018	33	68.77	9	7.641111111	2.3
8/29/2018	0.25	32.35	3	10.78333333	0.25
09/05/2018	25	45.6	7	6.514285714	2.25
09/06/2018	35	30	6	6	2.5
09/10/2018	25	75.86	9	8.428888889	2.5
9/16/2018	20	84.75	12		
09/15/2018	30	35.85	5		5

Figure 13. Raw data collected by a Bird Hunter

The two columns in which we will take the average of attributes are Miles Flown, and Scooters Charged.

Miles Flown	Scooters Charged
22	2
22	1
37	4
31	5
25	4
35	4
25	5
25	2
20	4
23	7
7	3
5	5
45	20
33	9
0.25	3
25	7
35	6
25	9
20	12
30	5
24.5125	**5.85**

Figure 14. Averages of Miles Flown & Scooters Charged

With these targeted attributes, we will take a look at the number of scooters that could potentially get captured given the number of Miles that are driven. Our goal will be to show that if the scooter charger collector travels the given miles above how many scooters they will end up collecting and that could translate into the income they could expect from the collection from their route. So our baseline is created around the existing model that our charger will be able to collect on Average 5.8 scooters after driving 24.5 miles.

6.2 Costs Associated With The Existing Model

In this section, it’s best to highlight other costs which every charger will need to factor in when they are calculating their hard earned profits. Aside from the time and the gas to get around for this charging gig, the cost of electricity to charge these scooters should also be considered. As more individuals are onboarding doing such Nonemployer “gig” economy jobs and shy away from payroll employment, it’s best to have panoramic details of what it takes to become a scooter charger.

The electricity cost based on the kilowatt-hour rating that the utility charges are minimal. It will be 7 cents per scooter to charge overnight. The only downfall is that when you first become a charger, the provider will only send you three charges. So you will be limited to the total number of scooters that can be charged at once. Also since most of the scooters will become free after 9 pm on the application and must be placed at a bird nest before 7 am, it’s appropriate to keep track of the capacity each charger can deliver to make the optimum payout.

Another cost which was mentioned previously is handling confrontations that may occur between different chargers as this system is set up to create competition. This can bring out the barbarian in some individuals and be a mechanism for them to release their fury on other chargers they come in contact with, especially if they have shown up to capture what they claim to be theirs. This created a displeasure in the gig for individuals who plan to make this the primary means of making an honest income.

6.3 Setup for Validation

For my implementation, I take a hypothetical scenario where the user is requesting a return location after they have completed their ride in a system where hubs are used for storing scooters when not in use. My algorithm will provide up to five stations within the proximity of the user to choose from. It will also show the distance of each station from where the user is located at. From the final five possible stations to be the potential returning stations, another pass is done and all the station's average scooter charge levels are compared. Out of those, the one with the lowest charge is then determined to be the returning stations. These would be the stations that scooter sharing company's crew will have to visit to pick up all the drained scooters. It could also be the stations which the person doing the charging as a hunter can make a route through and be able to pick up the most scooters which charges have depleted.

To manage the scooter inventory better, the scooters which are cannot be assigned a returning station, are put back in their original source station. Also, the possibility of having all the drained scooters to fall in one station and that station not having any charged scooters has been eliminated by the amount of charged scooters which are placed in each station at the start of the day. During every run, the number of scooters with the lowest charge is recorded in the Station's JSON object and that number has not reached the station's capacity, hence there is no situation in which the entire station is taken up with an entire fleet of dead scooters.

The system will iterate through the entire fleet of 3500 scooters and will highlight stations which contain 3 or more discharged units in them.

6.4 Travel Distance Between Stations:

Once the stations which are holding the most scooters with depleted charge have been highlighted and selected, I determine the distance which a route would take to travel through stations. This is done by calling the Google Distance Matrix included within the Google maps API platform. In order to get a travel distance route, the first station is passed as the source and all the remaining as destinations as a query parameter to the Distance Matrix API. The response body contains details around the time and actual distance it will take to get to each of the destinations. Based on the unit of measurement that is passed into API, the response will contain Imperial or Metric measures. Then extracting the distances between stations and stored in for next step to create a Distance Matrix to display it easier between stations.

6.5 Distance Matrix To Create a Route:

During each run of the simulation, the stations which host the most amount of uncharged units were various distances away from one another. To determine the travel distance between those stations to then be able to compare to the baseline numbers, it's best to create a Matrix of the distances between stations. This table will boast distance in miles for doing hops between stations represented by their ids. Next, a hunter, juicer, or a service provider's charging crew member can create a route just by looking at my distance matrix at a high-level view and determine based on the number miles they wish to travel which stations to visit and in what order. Having a count of the qty_of_low_charge_scooters will help to determine the number of scooter units that will be captured after traveling the route total miles. The rows and column headers display the station IDs for easy mapping of the distance between the stations.

6.6 Results Analysis:

Analyzing the results on every run shows that; based on the stations that are returned containing the most depleted scooters and their travel distance, it can be concluded that the charger can capture more than 5.85 units of scooters by traveling under 24.5 miles. Observing the distance matrix in which all the stations' distances are outlined, a charger can choose a route to get the optimum units. One thing to consider is to add the distance which the charger needs to travel to get to the first station to the total route number. This will create a realistic route and can be compared to baseline. As demonstrated in one iteration in Figure.15, the distances between the stations are 7.1, 2.5, and 5.0 miles. The stations that need to be visited and each hold 3 of the discharged unites are station ids: 447, 332, 488, 491.

If we were to visit all of those stations and collect all 12 scooters, we have traveled a total distance of 14.6 miles (7.1 + 2.5 + 5.0). And this will leave 10.9 of buffer room on mileage which the charger can use to get to the first station and back home.

```
447  qty of low charge scooters : 3
332  qty of low charge scooters : 3
488  qty of low charge scooters : 3
491  qty of low charge scooters : 3
['447', '332', '488', '491']
                           447            332            488            491


            447                           7.1
            332            7.1                           2.5
            488                           2.5                           5.0
            491                                          5.0
```

Figure 15. Route distance to collect scooters from resulting stations

After multiple runs the results show that there is significant improvement from the base line numbers. If we were to create a scooters/miles traveled ratio and determine the improvement rate is always in the positive.

	Miles Traveled	**Scooters Collected**	**Scooter/Mile**	**Improvement**
Baseline	24.5125	5.85	0.238653748	
System in Place	14.6	12	0.821917808	244%
	18.5	12	0.648648649	172%
	9.2	9	0.97826087	310%
	1.3	6	4.615384615	1834%
	5.5	6	1.090909091	357%
	3.6	6	1.666666667	598%
	1.6	6	3.75	1471%
	9.1	9	0.989010989	314%
	6.1	6	0.983606557	312%
	8.4	9	1.071428571	349%
	9.8	6	0.612244898	157%
	28.4	18	0.633802817	166%
	11.3	9	0.796460177	234%
	16	9	0.5625	136%
	14	15	1.071428571	349%
	24.1	12	0.497925311	109%
	24.9	15	0.602409639	152%

6.7 Corner Test Cases To Consider:

In order to make a concrete decision for implementing such a system, there needs to be a counterbalance to the analysis in section 6.6. There are factors which could put our system in a state where it's not always determinant for producing an optimally operational flow.

The first one which will affect the end-user, the rider; what if the station fills up with all depleted scooters and there isn't any with full or enough charge for the next rider to use. This hasn't occurred in this system with 3500 scooters, but as this scales out it's best to keep in mind. A solution for this would be to avoid stations when doing an evaluation for picking them when they have reached one or two fully charged scooters in their overall capacity value. Also to better enhance this, stations which are in rural locations shouldn't be as a part of the recommendation system as a returning station.

These hubs will not provide any protection for the chargers who seek to collect them, however, they are not a location in rural areas off the main pathways. Relying on main intersections and locations which are well lit, well situated in public could avoid some of the dangerous situations that chargers are placed in.

They will also not prevent the vandalism. Since the scooters are meant to be dockless, there will not be any locking mechanism to secure the scooters from vandals. The scooters will continue the need to be tracked by GPS by the service providers.

7: Conclusion And Future Work

7.1 Conclusion

This system is proposed to support and manage the swarming population growth of scooters within our city streets. These scooters have taken away precious surface area from street surfaces, more often seen creating an obstruction for wheelchairs in sidewalks. My goal was to demonstrate a mechanism for gathering all scooters in a scooter sharing system into hubs with the least amount of charge can be located and travel minimum distance for charging collections. This would then help the service provider to send out crew members only to a few hub locations to collect them for charging and maintenance service. Instead of relying on the general public to charge these scooters in a vulgar, competitive battlefield like setting, the charging will be handled only by the service provider. Although the general public is also has seen a major shift to "gig" economy jobs.

Data shows that San Jose, Santa Clara, and Sunnyvale are at the top of the list for cities with a major hike in payroll migration from employment to the Nonemployer or "gig" employment. Between 2012-2014 there has been an increase of 144% in workforce shifting to gig employment, correspondingly a drop of 30% payroll employment [7]. With more individuals electing to make an income from jobs to feel more in control of their day. Be their own boss, and at large, they are contributing to companies. The startups, such as Bird, Lime, and many others that start to surface need to do their due diligence to provide all resources in their power to create a safe, workable environment. This is for their "contract" workers.

This system could also assist the hunters for more efficient collection of scooters from the hubs. The location is consistent every time and takes no time to locate for hunters. It will further increase their bottom line from charging. The higher volume of scooters they can operate on can directly increase their financial rewards to match it.

With planning ahead for better management of the scooter rider sharing expansion into the fabric of our cities, we can benefit by having safe roads for all pedestrians and motor vehicles. Any device that provides means of transportation on a wheel(s) is considered a vehicle and needs to have some operating regulations in order to share the roads with others. To keep the number of injuries from scooter accidents low, and store them properly when not in use out of sidewalk surface area, some standards need to be enforced. Blocking wheelchair access ramps or major walkways can be very detrimental to individuals with disabilities, lowering the quality of enhancement the city has done to improve a disabled person’s lifestyle.

It would really help to have designated hubs for storing the scooters and to provide an incentive to have the scooters be collected from a few hubs once their charge level has depleted. This would encourage the service providers to only visit a few hubs which they can then collect the majority of scooters from that need charge or maintenance. In future works, the possibility could arise if more stations are allocated within the region which the system will span across.

7.2 Future Work

Expansion of this topic for future work can cover the following points. Taking a deeper look into the cost of building hubs for the service providers to evaluate bottom line savings in the long run. How accessible these hubs will be to users and how much space they could potentially give back to sidewalks and pathways. This will paint a bigger picture around benefits for all parties involved so it will be a win, win, win situation.

Also, another advancement that could be combined into this system, is to help the end-user determine whether they can make it to their destination based on the charge level of the scooter at the time of checkout. Once the user enters their destination address, the range is evaluated and it will provide meaningful recommendations to users when they need a scooter to travel to their destination provided in the app.

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