Replacing Payphones in New York City with Wi-Fi Kiosks

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0: ABSTRACT

People use Wi-Fi every day to communicate, complete transactions, find information, or simply entertain themselves; therefore, there is a growing dependency on Wi-Fi accessibility and reliability, especially in highly populated urban environments. With the emergence of data science, Smart Cities around the world are constantly looking for ways to better deliver services to residents and visitors, increase broadband connectivity, and adapt to the needs of the digital age. In this paper, we first analyze a large-scale real-world scenario where Wi-Fi kiosks play a significant role to help people stay connected with one another in New York City, New York. We investigate existing kiosks, like LinkNYC, for their location practicality based on traffic, neighborhood income, usage history, user satisfaction, and other factors. Moreover, we look to replace existing and outdated payphones within New York City with more Wi-Fi kiosks. With many individuals owning handheld mobile devices —like smartphones— with the capabilities to make calls and texts, there is a growing demand for Wi-Fi connection and a dying demand for payphone locations. Instead of having an unnecessary superfluity of payphones that are not often used, our paper finds ways to optimize Wi-Fi reach in the city. We look at Point of Interests, traffic patterns, neighborhood wealth, and other factors to decide the best locations. The evaluation results demonstrate that Wi-Fi kiosks are in high demand and are necessary in Smart Cities, like New York City, to keep people connected in an ever evolving internet world.

1: INTRODUCTION

Nowadays, smart cities like New York City have placed a greater emphasis on working to improve urban efficiency. Since 1905, NYC has installed about 8,000 pay phones on city streets in an effort to improve and better serve the needs of the people at that time.. Since then, with the prevalence and popularity of smartphones and cellular data, many officials have deemed payphones to be obsolete. An initiative began to replace payphones in NYC with more contemporary and useful alternatives, LinkNYC Wi-Fi kiosks. LinkNYC is the first-of-its-kind communications network replacing the city's payphones to build the world's fastest and largest free public Wi-Fi network. Since Mayor Bill de Blasio announced the public launch of LinkNYC in early 2016, more than 1,600 Links are active across all five boroughs, with thousands more set to be deployed over the next several years. The motivation for the shift from payphones to Wi-Fi kiosks is also due to many complaints in neighborhoods where payphones occupy much of the sidewalk space along with the potential to provide more free resources while generating revenue.

So far NYC has planned to install up to 10,000 of the LinkNYC kiosks across all five boroughs to replace the payphones. New York City, however, being the most populated city in the United States, faces many challenges in implementing such an initiative. Due to budgets, resources, as well as crowding and congestion that could result, replacing all of the payphones at once is not feasible, the shift must be gradual. Our goal is to find the most optimal places to begin testing and placing the kiosks first. Once that is done, we can plan to possibly develop a way to use the data from user behavior and clicks to determine where to place the kiosks next based on how much they are being used and what functionalities are being more commonly used in what kinds of areas. For example, kiosks near high tourist areas or subway stations may receive more attention to check subway times and other points of interest.

The LinkNYC kiosks will be free to use and serve as digital screens on street corners that can warn you if the subway is running late, direct you to other forms of transportation, tell you about community events, list daily pollution levels, and ask for your opinion on certain local initiatives. They will more primarily be used for charging smartphones, using fast Wi-Fi, making Internet calls, searching for information about the weather and local restaurants, and can be enhanced to do much more such as obtain user behavior data in the future.

Largely, there is some related work on this topic that we would like to recognize. The first being, the approach used by InLinkUK which is the Wi-Fi kiosks that were added in cities across the UK to replace payphones, similar to what NYC is doing with the LinkNYC kiosks. Another relevant piece of work is research found on obtaining an optimal location for a new retail store utilizing clustering based on available data to find the best ranked "cluster" to place the store. The method used in this research paper is similar to that which we will be using.

Our main contributions can be summarized as follows:

1. Design a greedy approach to select best locations for replacement of payphone booths with Wi-Fi kiosks.
2. Develop an interactive web application for users/authorities to interactively find best locations based on their choice.
3. Provide a set of metrics for evaluations: Crime Complaints, POI, Public Computer Centers and Pedestrian hotspots.
4. Some key insights include:
    a. Positive correlation between number of low income units and number of crime complaints as well as number of pedestrians making our approach ideal for replacement of payphone booths.
    b. Negative correlation between number of low income units and Point of Interests and Public Computer centers.

2: RELATED WORK

In this section, we summarized the previous related works into three areas: 1) methods of replacing the payphones 2) data-driven urban planning, 3) data visual analytics.

Methods of replacing the payphones. The problem of relating to the payphone booths in the urban areas is relatively new in this field. Although there are some existed studies about it, most of them are focused on the features and relations between users and payphone booths.[2] The idea of creating a model to find the optimal locations to begin to replace the existing payphone booths to the smart computer interfaces such as Kiosks is new and can be built upon these features like the demographic of payphone users or the reasons of using public payphone that been researched before.

Data-driven urban planning. With a large amount of data about the city such as human mobility, crime rate, and poverty can be collected nowadays, urban computing has shown an important role in urban planning. There exists a large body of work on the general task of data-driven urban planning such as finding the optimal replacement location for retail stores.[3] However, most of those researches are limited in single city structure and use one single data set to train. In this paper, we focus on providing an optimal way of replacing the payphones in the city gradually using data sets from multiple views.

Data visual analytics. The data visual analytics has a huge body of research and the comparison between results is fundamental in data visualization tasks.[7] There are many methods and approaches when conducting the visual analysis on the data. For example SmartAdP[8] used a dashboard view showing the information and ranking of the billboards. Our work adopted this design with three different function sections and using the greedy algorithm to find the ranking of results based on user's selection.

Figure 1: LinkNYC Kiosk Key Features: 1. Connect to free Wi-Fi. 2. Access city services, maps, and directions from the tablet. 3. Make free phone calls to anywhere in the U.S. 4. Use the red 911 button for an emergency. 5. Charge your device with the USB port. 6. Sleek design to conserve sidewalk space. 7. View announcements and advertisements on the display. [5]

3: MOTIVATION

Our motivation in replacing payphone booths throughout NYC and finding the most optimal locations to begin the replacement with W-Fi kiosks stems from the ideas of improving the accessibility of resources in smart cities and increasing connectivity while also generating revenue for the city of New York.

Current Situation. Statistics have shown that since most people now have cell phones, public payphone usage has fallen by around 90% in the past decade[1]. It was also reported that many payphones are never used at all, and very few earn enough to cover their maintenance costs[1]. The number of calls being made on them have been dropping 20% a year, while the cost of cleaning, replacing broken glass panels, and repairing vandalism on them has risen. This implies that much of the sidewalk space especially at intersections goes to waste in places where the payphones are still present. Currently, the payphones are doing more harm than good if they are being used 90% less and continue to cause unnecessary congestion on sidewalks. Much of this space could be better utilized for senior citizens in wheelchairs and children in strollers while also aiding to alleviate congestion.

Improve Resources. The implementation of LinkNYC Wi-Fi kiosks will aid in overcoming the mentioned issues with the current situation by serving the same purpose while also providing even more amenities. As mentioned earlier, NYC is the most populated city in the United States with a record of 65.2 million tourists in the year 2018[4]. In an effort to better accommodate the needs of these tourists, the LinkNYC kiosks will allow anyone to charge their phones, use Wi-Fi, make Internet calls, search for tourist attractions nearby, look up restaurants, and even let you know about local community events free of charge. The accessibility of these resources can also help to promote connectivity and engagement in local events or businesses. The kiosks also have map and navigation features, a red 911 button in the event of an emergency, and even a headphone jack for privacy when making internet calls.

Generate Revenue. The new Wi-Fi kiosks are funded through advertising, which is what makes it possible to be free to use. Two 55" HD displays on both sides of the kiosk are used to view public service announcements as well as these revenue generating advertisements[5]. The displayed ads will generate funds for the city to share with the companies that design and run the technology. It was estimated that the city of New York will earn more than half a billion dollars in revenue over 12 years from the LinkNYC partnership[6]. With our approach, of making the shift from payphones to Wi-Fi kiosks gradual, we can ensure we are placing them in the most optimal locations to maximize user engagement. Our approach uses clusters to gradually begin the installation of the kiosks in the most optimal locations, and using the information obtained from the novel kiosks, we hope to continue to improve the clustering algorithm to continue to obtain the most optimal locations to install more kiosks based on the datasets used and engagement feedback received.

Future Applications. The LinkNYC kiosks can also be further improved and optimized to be more widely beneficial in the coming years after it's implementation. This is because, each of the Wi-Fi kiosks also have two built-in cameras facing in opposite directions. As of now, the cameras are only used to monitor for vandalism, but if granted permission, the cameras could be used in the future to capture a wide view of the surroundings[6]. Eventually, information from these cameras could also be combined to create real-time data maps useful in future technology, such as self-driving cars[6]. "These technologies provide the architecture that smart cities need to operate, If you use them to collect information about how people are traveling and to detect disruptions, you can react to situations faster and make better decisions." states Joseph Chow, a professor at NYU[6].

4: MAIN DESIGN

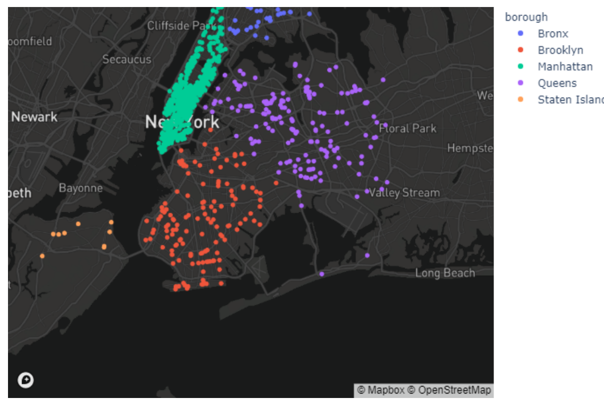

Figure 2: Scatter plot of NYC payphone location on maps by borough: We can see that the density of payphones is highest in Manhattan and least in Staten Island.

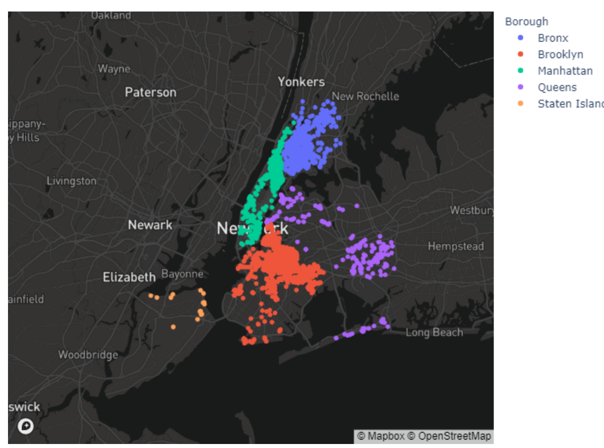

Figure 3: Scatter plot of NYC HPD housing data: We can visualize saturated housing populations in the New York City area.

4.1 - PROBLEM STATEMENT

With limited resources, cities need to identify the most optimal locations in NYC to start replacing Public Pay phone booths with Link NYC Kiosks.

4.2 - DATA SET

The primary data set we are going to use is the "Public Pay Phone Telephone Locations" data set from open NYC. This data set has around 5000 records and 30 features. Some of the features include latitude, longitude, borough, the number of phones in the phone booth, whether the booth is solar powered or not.

We also used NYC Housing data to identify neighborhoods and population densities. We clustered based on the factors to choose and rank locations with highest importance. We used these clusters to find labels for supervised learning algorithms.

We also planned on using additional datasets for considering different constraints that are mentioned in the next section. Due to time constraints, we focused on only a few for in-depth analysis rather than a breadth of lackluster quality.

4.3 - CONSTRAINTS

Considering constraints for such problems is open ended. In this project we aim to consider as many constraints as possible. Some of the initial constraints we are planning to consider are as follows:

Population: Population of a particular borough or a neighborhood or a street can be one of the deciding factors for replacing payphone booths with Wi-Fi kiosks. Those locations with the highest population density should be replaced before less dense areas as one of the main and initial goals for taking decisions is the number of people using phones. For this purpose we have considered the Population data set by NTA(Neighborhood Tabulation Area). We have plotted the population of different neighborhoods in figure 2.

Crime complaints: One of the robust features of linkNYC kiosks is a built in 911 button. So, intuitively it makes more sense to place Wi-Fi kiosks in areas with high crime rate or high complaint rate. This way people in danger/ emergency can make the most use of Wi-Fi kiosks.

Poverty: Another constraint that can serve a good social cause is replacing Wi-Fi in areas that can serve the maximum number of poor people. This step will ensure that people without access to Wi-Fi can make use of freely available Wi-Fi kiosks. We have taken data sets from open NYC data.

Point of Interests: Point of Interests are one of the most busy parts of any city. Additionally, they have people like tourists without access to local cellular networks. So, they can be benefited out of these kiosks for using Wi-Fi to see the city maps, book cabs and communication. It can also serve other people in the area.

Number of Internet connections: Neighborhoods with maximum number of houses without internet connection would benefit out of these Wi-Fi kiosks. Replacing payphones in such areas ensures that the maximum number of people without internet connection can use Wi-Fi from these kiosks.

Other factors: Other factors like number of schools, senior citizen centers etc can be used to investigate if they are potential factors that can be considered for Wi-Fi kiosk replacement.

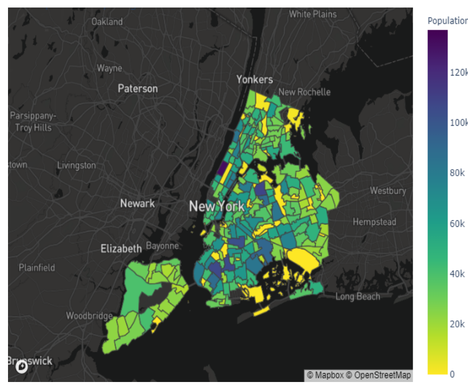

Figure 4: Population of NYC by Neighborhood: The populations according to different neighborhoods have been plotted on a map. Potential areas can be the ones with highest population densities.

4.4 - ALGORITHM

We employed a Greedy Approach algorithm to identify the most optimal locations for Wi-Fi kiosks. Inspired by the SmartADP approach developed by Dongyu Liu [8], we are able to create visual analytics of large-scale population statistics to help select the best locations. This approach creates an interactive visual analytics system that deals with the two major challenges including finding good solutions in a huge solution space and comparing the solutions in a visual and intuitive manner. An interactive framework that integrates a novel visualization-driven data mining model enables urban planners, city governments, and kiosk companies --like LinkNYC-- to effectively and efficiently formulate good candidate solutions.

Our model has the following steps:

1. For every location in a set of payphone locations, we select a radius, for example r = 200 m, and count the number of low income units within the radius r.
2. We then find the location that covers the most low income units.
3. we remove the selected location and units influenced by a location.
4. We will repeat steps 1 through 3 k-times to get k best locations

4.5 LIMITATIONS

Lack of data: One of the biggest obstacles to solving this problem is that data is not available at kiosk level as to how many people have used the kiosk. This could have helped in defining a more robust model with usage per kiosk as target variable to predict. Another problem is setting up a baseline model and evaluation strategies. As this area is relatively unexplored, a lot of research is required to draw parallels between our problem and similar problems from other fields. For example, using retail store placement strategies as a guide. Largely, these obstacles stem from the limited time constraint of this research project. With only a few months to compile relevant data and a disruption to our collaborative abilities due to the COVID-19 pandemic, it proved to be challenging to cover the many ambitious data requirements.

Solution: Since lack of data is restricting our ability to define a strong objective statement, we present a system to generate insights out of the vast data available as we discussed in constraints. This system can help authorities in effective decision making. Also these factors can be used in feature engineering once usage data is available publicly. We also aim to show insights visually. For example, Figure 2 shows how payphones are distributed in different neighborhoods. We believe that if given more time that we would be able to fill some of these data gaps.

Inappropriate Content. Another vulnerability that Wi-Fi kiosks may also face is the control of inappropriate content during usage as well as loitering. To deter users from using the Wi-Fi kiosks for ill-suited means, users will be required to provide their email as well as their phone number along with agreeing to the terms and conditions as a means of acknowledgment and accountability. Another way to control this is when they first started to appear some people were using the LinkNYC kiosks to watch inappropriate videos and blast music. Since then, they have disabled the Internet browser on the kiosks' tablets in September 2016 in exchange for curated content on devices and have received very few complaints since[6].

4.6 - INTERACTIVE DESIGN

The users are desired to know the optimal solutions using the power of computational devices. However, the large number of locations creates a high number of search spaces when seeking the optimal solutions. Therefore, an user interactive design is necessary to provide users the optimal solutions they are looking for.

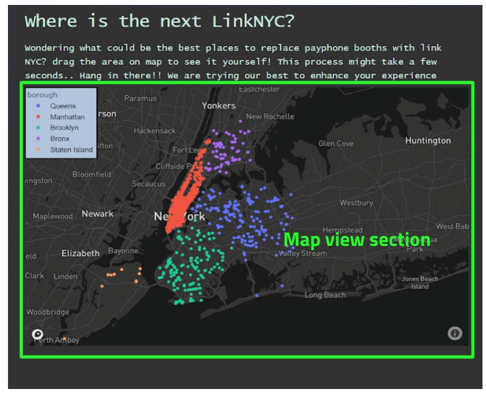

Figure 5: Map View Section of the web application.

Map View. The map-centered exploratory approach is very common in making decisions with multiple constraints. Therefore, we provide a map view that shows the location of the payphone booths in NYC. The users can interact with the map by selecting the area containing the payphone booth they want as figure 5. This enables users to specify the target area as an input to the computing device. The results of those optimal locations will also appear in this map view section straightforwardly to help users make their decision.

Figure 6: Parameter Selection and Result View Section of the web application.

Parameter & Result Section. The parameter selection section allows the users to select the number of k-top results and the radius r as figure 6 red area. The users can adjust those parameters in realtime and see the difference between results. The result view section will show the number of low-income units for the locations in the selected area to present users a clear reason why the results are optimal as figure 6 blue area.

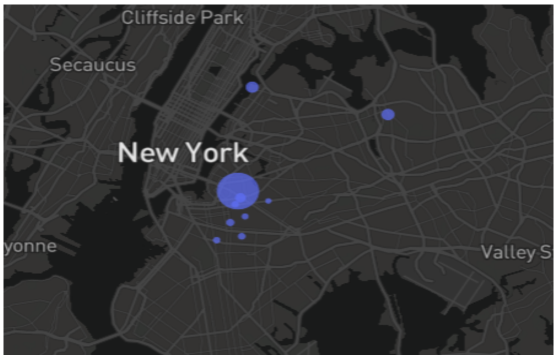

Figure 7: Top 10 selected locations based on greedy approach. Size of point represents the number of low income units within 200 m radius.

5: EVALUATION

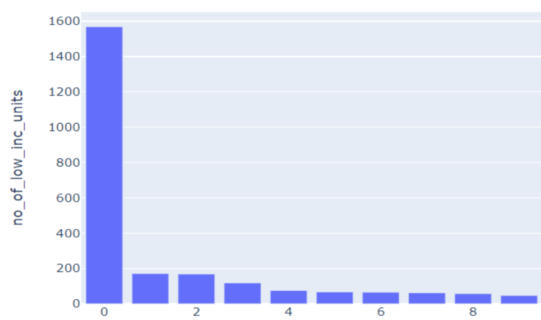

Figure 8: Number of low income units for top 10 locations with r = 200

As discussed in the previous sections, one of the biggest obstacles is lack of the usage data of LinkNYC kiosks to predict which location is better over others. We come up with novel methods to test if our suggestions are feasible or not. We have used various factors to compare different suggestions and based on the requirements of authorities and targeted groups of people, we can establish which locations are most suitable for Wi-Fi Kiosk Placement. Figure 8 shows the number of low income units for top 10 locations picked by greedy method.

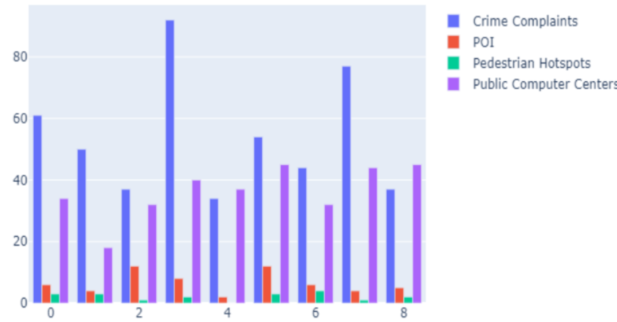

Figure 9: Number of crime complaints, Points of Interest, Pedestrian Hotspots and Public Computer Centers for top 10 locations.

After coming up with suggestions, we decide to use four metrics to display for authorities/users to choose the best locations. If the target of replacing Wi-Fi kiosks is to facilitate areas with a high crime rate, the number of crime complaints can be used as a metric. Similarly, Pedestrian hotspots can be considered as a metric to facilitate maximum number of pedestrians.

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Factor considered	**Correlation**
Crime Complaints	**0.134396**
POI	**-0.030925**
Pedestrian Hotspots	**0.261588**
Public Computer centers	**-0.172378**

Table 1: Correlations between number of low income units and various factors for top 10 locations.

Table 1 shows the correlation between the number of low income units and various factors. Positive correlation between the number of low income units and crime complaints may suggest that the security in such neighborhoods is compromised and those locations make good candidates for Wi-Fi kiosk placement. Similarly, the number of low income units has positive correlation with proximity to pedestrian hotspots (places with high pedestrian activity) implying that Wi-Fi would reach a large number of pedestrians. On the other hand, we see negative correlations with the number of points of interest and public computer centers. Such correlations are obvious given the fact that POIs and computer centers are usually located in affluent neighborhoods, it would be more beneficial to place Wi-Fi kiosks in areas with fewer public computer centers nearby.

Poverty: We can also consider factors such as poverty to select locations to reach lower income communities, whereas fast Wi-Fi may be less prevalent in homes. However, areas of high poverty may be less beneficial for the companies trying to advertise and promote more nonessential or expensive products on the kiosk.

Population Density: Areas with higher population density have a greater probability of receiving more attention and usefulness for these kiosks as well as advertisement exposure.

Points of Interest: Locations with the highest number of POIs nearby or POIs like sightseeing locations may be optimal locations to provide more resources for visitors not familiar with the area as well as obtaining maximum usage and advertisement exposure.

Crime Data: Providing emergency features in areas of high crime may be beneficial since one of the functions for Link-NYC is emergency call.

Other Factors: Other factors to be considered are areas with a high number of schools, senior citizen centers, etc.

6: CONCLUSION

As there continues to be a greater dependency on Wi-Fi connectivity rather than payphone booths with the growing trend of mobile device users —in part due to the popularity and usability of smartphones, we see that Smart Cities need to begin to look at Wi-Fi kiosks as a means to address the shift in demand. This paper provides a useful alternative and plan to better serve people with disabilities and families with strollers by conserving that unused sidewalk space and provide more innovative amenities instead.

In this paper, we looked at LinkNYC Wi-Fi kiosks to better provide these resources. Along with the advertisements that keep Link NYC's services 100% free for users and are estimated to earn more than half a billion dollars in revenue over 12 years for the city of New York, the digital displays feature useful and enriching content —including community board meeting updates, real-time transit, weather information, daily pollution levels, public safety announcements, phone charging ports, and more. The screens are also used for emergency messaging, for instance, in an extreme weather event like a hurricane or to dial 911. In many ways, these kiosks keep people well-informed and connected with one another through various mediums of communication.

Finding the most optimal locations to begin replacing these phone booths with the Wi-Fi kiosks is an important challenge to consider. Due to budgets and resources as well as crowding and congestion that can be caused by replacing them all at once, the shift to install up to 10,000 of the kiosks across all five boroughs had to be gradual by finding the most optimal places to begin testing/placing the kiosks first.

The major contributions of our work include:

1. Designed a greedy approach to select best locations for replacement of payphone booths with Wi-Fi kiosks.
2. Developed an interactive web application for users/authorities to interactively find best locations based on their choice.
3. Provided a set of metrics for evaluations: Crime Complaints, POI, Public Computer Centers and Pedestrian hotspots.
4. Some key insights include:
   a. Positive correlation between number of low income units and number of crime complaints as well as number of pedestrians making our approach ideal for replacement of payphone booths.
   b. Negative correlation between number of low income units and Point of Interests and Public Computer centers.

Limitations Discussed: Throughout our implementation of this project however, there were some technical and misuse limitations that we addressed. One of the major limitations discussed in this paper include lack of usage statistics of existing Wi-Fi kiosks to quantitatively evaluate the approach.

Potential Future Work - Implementing More Data: As discussed earlier, if the usage statistics of current kiosks are available, a stronger evaluation strategy can be proposed. All the factors discussed in our work like the number of low income units, crime data , pedestrian count, population density, poverty data, socio-economic factors can be used as features in a supervised learning model. This problem can be implemented as a Classification as well as Regression problem. Unsupervised learning techniques like clustering can be employed to find various clusters of locations.

Potential Future Work - Real Time Mapping: Another future implementation that can be incorporated into the Wi-Fi kiosks is the use of the two built-in cameras, which face in opposite directions, potentially yielding views up and down the street. As of right now, they only monitor vandalism and do not use facial recognition technology or track people's movement through the city. However, if they were to use facial recognition in the future, they would aid in better protecting the city and detecting suspects as well as their trail in related crimes. This is another contributing factor to why the crime rate in areas could be an important factor for the future to consider placing the kiosks. The cameras could also be used to capture a nearly 360° view of each Link's surroundings. As stated earlier in the paper, this view as well as sensors could be combined to create real-time data maps that might be useful for emerging technologies such as self-driving cars as well as help generate more revenue for NYC by providing this data to other companies or platforms.

Large cities around the world are looking for methods such as these to improve how they deliver services to the public, increase broadband connectivity, and adapt to the needs of the digital age. Many aspiring Smart Cities are looking to New York City and their Wi-Fi kiosk network, in particular LinkNYC, as a model to improve urban efficiency.

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CONTRIBUTIONS

1. Ranjitha Korrapati: Worked on the web application, visualizations, and evaluation using python / dash / plotly. Worked on the Google Slides. Presented during the midterm presentation.
2. Calvin Kuo: Worked on the abstract, introduction, algorithm, limitations, and conclusion. Worked on the Google Slides. Presented during the final presentation for the title, introduction and design slides.
3. Shengtao Lin: Worked on the related works and interactive design. Worked on the Google Slides. Presented in the final presentation for the app design / demo, evaluation, and conclusion slides.
4. Chaand Patel: Worked on the abstract, introduction, motivation, limitations, and conclusion parts of the paper. Worked on the Google Slides. Worked on finding relevant open sourced data sets for the project. Presented during the midterm presentation.