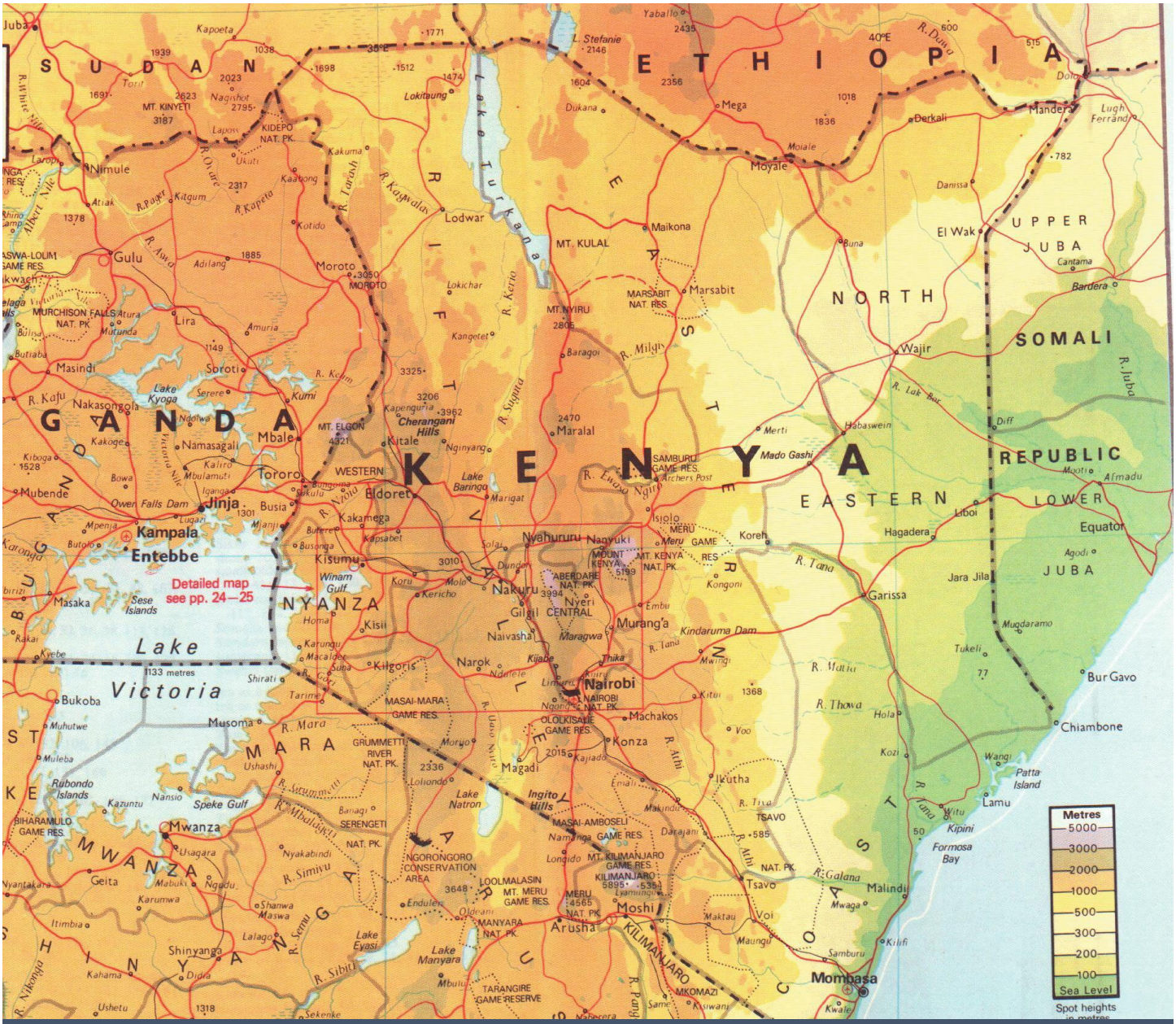

Capstone Project

Neighborhoods Characteristics of Innovation Hubs and Technology Centers in Kenya

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6/25/20

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Tables and Figures

1. Introduction

1.1 Background

As if you heard the term “Silicon Havannah”, Kenya’s ICT services sector is thriving in recent years, with a growth rate of 8% per annum, which contributes as the fastest growing economic factor of the country(Akamanzi, et al., 2016). In fact, more specifically, the tech hubs are performing as drivers of innovation, social change, and economic opportunity within and beyond the African continent (De Beer, et al., 2016). As indicated by International Trade Centre, “Technology(innovation) hubs have emerged across Africa to serve as start-up creators and tech community builders” (2019). They are playing a more and more important role in the culture of innovation through supporting business development, community creation and local capacity building, promoting the extension of local innovation ecosystem and enhancing the linkage between governments, local markets and large groups(Akamanzi, et al., 2016).

1.2 Problem Introduction

This capstone project is aimed to explore the neighborhoods characteristics around the tech-hub centers in Kenya (i.e. innovation hubs and technology centers as latest recorded) , to further understand the fast development of the “Silicon Havannah” phenomenon, from a geographical perspective.

1.3 Stakeholders

This capstone project mainly faces to academic institutions, think tanks and NGOs, trying to provide some rough analysis results for their convenience of further research and discussion.

Regarding with wider range stakeholders, characterized based on the concept of open innovation and collaboration (Chirchietti, 2017), an innovation lab is not only established structure to assist young people in reaching their entrepreneurial potential (De Bastion, 2013) , but also a nexus point of local start-up community, investors, academia, technology companies and wider private sectors(Chirchietti, 2017), involving local governments and big more network operators (Haikin, 2018). Therefore, in this case, this capstone project is also expected to help with any discussion approach initialized by the large groups of stakeholders mentioned above.

2. Data

2.1 Data Description

The primary data used for this capstone project is the geodata “Infrastructure/Collection of Innovation Hubs and Technology Centers in Kenya” from Kenya Open Data (referred to as “Innovation Data” in this report), including the types, location, target market information of the existing recorded innovation hubs and technology centers in Kenya.

Secondly, Foursquare API is used here to explore geographical information of the surrounding venues of the innovation hubs and technology centers as mentioned above.

The data origins are listed in the table below.

2.2 Data Source

Table 1 Data source

Data Name	Form	Source
Infrastructure/Collection of Innovation Hubs and Technology Centers in Kenya (“Innovation Data”)	GeoJson	https://www.opendata.go.ke/datasets/infrastructure-collection-of-innovation-hubs-and-technology-centers-in-kenya
Foursquare	API Query	https://foursquare.com/

2.3 Data Usage

For the “Innovation Data”, firstly, it will be downloaded from the website and delivered to the panda dataframe which contains several categories of hubs’ detailed information:

1) ‘Type’: technology hubs and programs, venue funds or web portal.

2) ‘Name’: the names of the hubs such as “iHub”, “Naliab” etc.

3) ‘County_Location’: this category indicates the administrative location of the innovation hubs and technology centers in Kenya (i.e. county name).

4) ‘Target Market’: the targeted market sectors of the hubs.

5) ‘Latitude and Longitude’: It presents the geographical coordinates of a certain hub (web portal hubs have no location information).

The created dataset will be grouped with different categories as described above for initial analysis while the details will be discussed in the exploratory data analysis part. NAN values will be dropped for the convenience of further analysis.

The coordinates information of “innovation data” will be utilized jointly with the Foursquare API Query. Requests would be sent to return venue information in need. In this case, it refers to the venue information of tech-hub neighborhoods, which will be illustrated in the neighborhoods exploration part.

3. Methodology

3.1 Exploratory Data Analysis

Upon obtaining the dataframe containing tech-hubs’ information (table head shown in Table 1), some initial exploration can be conducted to find out the basic conditions of the innovation hubs and technology centers in Kenya.

Table 2 Table head of "Innovation Data" (Panda dataframe)

	Type	Name	County_Location	Target_Market	Latitude	Longitude
0	Technology Hubs and Programs	Ihub	Nairobi	ICT	-1.298752	36.790795
1	Technology Hubs and Programs	Nailab	Nairobi	ICT	-1.299116	36.790860
2	Technology Hubs and Programs	Lakehub	Kisumu	ICT	-0.108192	34.748901
3	Technology Hubs and Programs	Chandaria Business Center/Kenyatta university	Kiambu	All sectors	-1.182003	36.936359
4	Technology Hubs and Programs	Empty Hub	Bungoma	ICT	0.566012	34.559121

3.1.1 Hub types

Firstly, the dataframe is grouped by the category 'Type', and then Python Matplotlib Bar Chart is used here to visualize the counts of different hub types in Kenya. From the chart below, it is indicated that the primary tech-hub type in Kenya is physically established technology hubs and programs. There are other targeted as 'Venture funds' and the lefts are web portals.

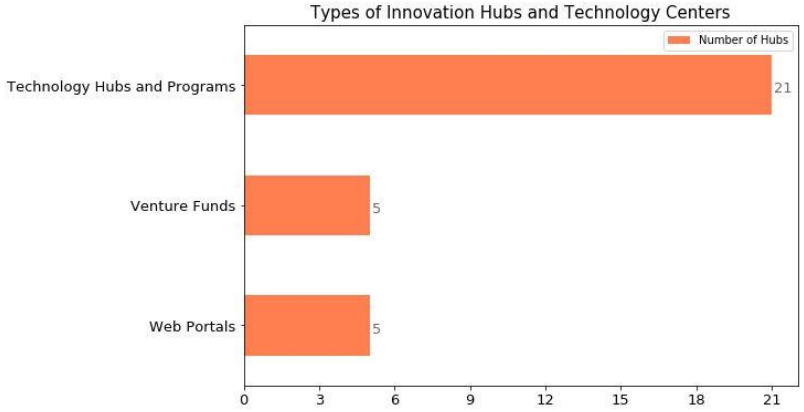

Figure 1 Types of Innovation hubs and Technology Centers

3.1.2 Target Markets

Then, the dataframe is regrouped by different sectors of markets the hubs target at as Figure 2.

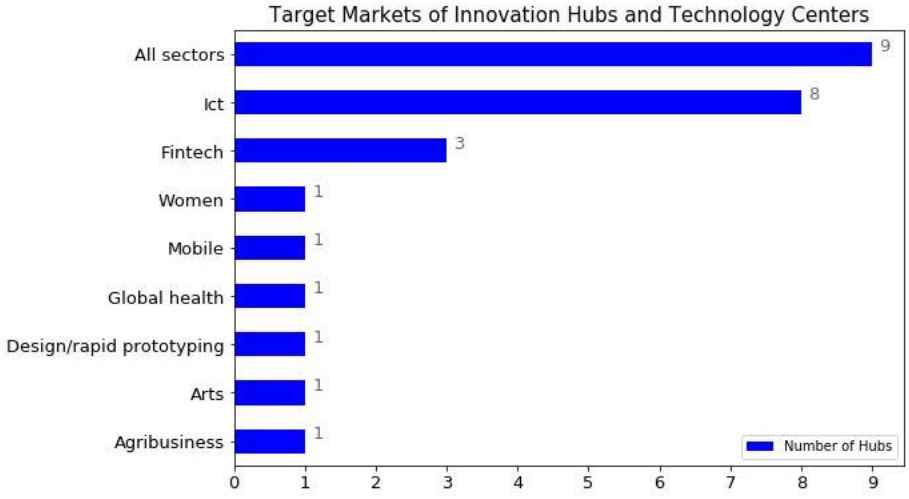

Figure 2 Target Markets of Innovation Hubs and Technology Centers

A certain number of hubs have broad target markets as “All sectors”, referring to the feature of “Hybrid organizations”. According to Littlewood and Kiyumbu (2018), “Hybridity”, in varying form, is an important characteristic of hubs in Kenya. Followed by are “ICT” and “Fintech” as the major target markets. The other sectors include ‘Woman’, ‘Mobile’, ‘Global Health’, ‘Design/rapid prototyping’, ‘Arts’ and ‘Agribussiness’. As a matter of fact, mobile technology and digital payments have contributed a lot to Kenya’s fast-growing ICT services (Akamanzi, et al., 2016).

3.1.3 County Location

According to the World Bank, the Kenya government early committed to establishing hubs in each of its 47 counties (Kelly, 2014). It is shown in the below chart that that as recorded by the “Innovation Data”, at least 7 counties including Kiambu, Taita taveta, Nyeri, Mombasa, Kisumu, Bungoma and Nairobi city are equipped with innovation hubs or technology centers.

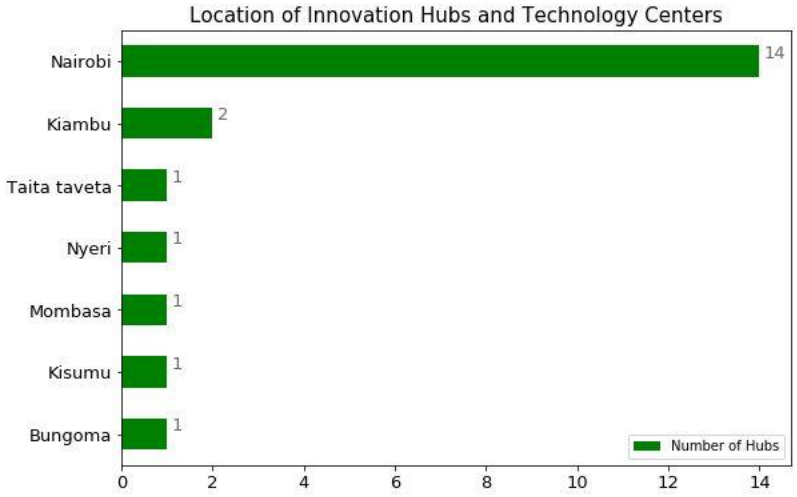

Figure 3 Location of Innovation Hubs and Technology Centers

Python Folium Map is used here to present the geographical locations of the hubs through utilizing the coordinates provided by “Innovation Data”.

Figure 4 Hub locations

It is clearly indicated that most hubs are gathered in Nairobi City in both the Bar chart and the Folium Map. As the capital of the country, Nairobi becomes the “heat center” of tech entrepreneurship support infrastructures shown in the heat map in Figure 3 (The GeoJson of Kenya Boroughs is applied in blue line).

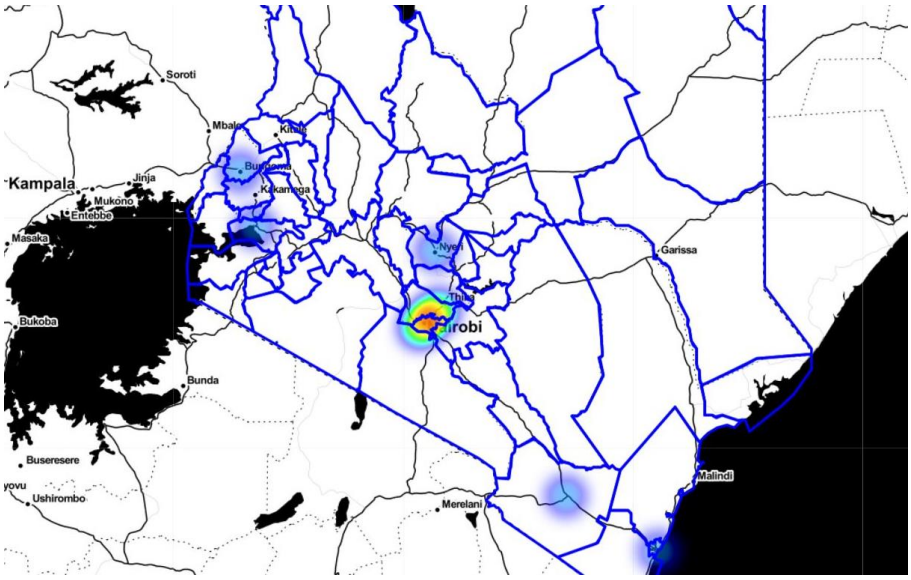

Figure 5 Heatmap of tech-hubs within Kenya Boroughs

3.2 Neighborhoods Exploration

Since all hub locations are confirmed, it is the turn to explore the surrounding neighborhoods of the tech centroids utilizing Foursquare API in response to the primary project problem.

Step 1: Explore the neighborhoods around the hubs

Here a function called “Get Nearby Venues” is created. The names of the hubs, latitudes, longitudes are taken as inputs to the function. The API request URL is formed with Foursquare credentials, the above parameters, along with explore radius of 800 meters and explore limit of 150. “Get Nearby Venues” is applied with the request URL while the returned venues are delivered to a new dataframe named as “Kenya_venues” (Table 3).

Table 3 Venue categories returned (Kenya_venues table head)

	Name	Neighborhood Latitude	Neighborhood Longitude	Venue	Venue Latitude	Venue Longitude	Venue Category
0	Ihub	-1.298752	36.790795	Pete's Burrito Shop	-1.298586	36.790762	Burrito Place
1	Ihub	-1.298752	36.790795	Soiree Garden Restaurant	-1.297648	36.791483	Sports Bar
2	Ihub	-1.298752	36.790795	Debonairs Pizza Ngong Road	-1.299768	36.790409	Pizza Place
3	Ihub	-1.298752	36.790795	Newscafe Vibe	-1.294755	36.787473	Lounge
4	Ihub	-1.298752	36.790795	Kesh Kesh	-1.292535	36.789639	Café

After grouping the venues by hub names (Table 4), 91 unique venue categories are counted for all the venues returned.

Table 4 Venues grouped (Table head)

Name	Neighborhood Latitude	Neighborhood Longitude	Venue	Venue Latitude	Venue Longitude	Venue Category
Akirachix	61	61	61	61	61	61
C4D lab(UoN)	39	39	39	39	39	39
Chandaria Business Center/Kenyatta university	6	6	6	6	6	6
Dedan Kimathi University Innovation and Incubation Centre (DeHUB)	2	2	2	2	2	2
E4impact-Tangaza College	5	5	5	5	5	5
Empty Hub	8	8	8	8	8	8

Step 2: Analyze the neighborhoods

Through One Hot Encoding applying to all the venue categories, the frequency of the venue categories for each hub can be calculated as presented in Table 5.

Table 5 Frequency grouping using One Hot Encoding

	Name	African Restaurant	Art Gallery	Arts & Crafts Store	Arts & Entertainment	Asian Restaurant	BBQ Joint	Bakery	Bar	Baseball Field	Bed & Breakfast	Beer Garden	Boarding House	Bookstore	Burger Joint	Burrito Place	Bus Station	Bus Stop	Café	Child Care Service	Chinese Restaurant
0	Akirachix	0.032787	0.016393	0.0	0.0	0.0	0.016393	0.032787	0.098361	0.000000	0.016393	0.0	0.000000	0.032787	0.032787	0.032787	0.0	0.0	0.049180	0.0	0.016393
1	C4D lab(UoN)	0.000000	0.000000	0.0	0.0	0.0	0.000000	0.051282	0.000000	0.000000	0.000000	0.0	0.025641	0.000000	0.000000	0.000000	0.0	0.0	0.051282	0.0	0.051282
2	Chandaria Business Center/Kenyatta university	0.000000	0.000000	0.0	0.0	0.0	0.000000	0.000000	0.000000	0.166667	0.000000	0.0	0.000000	0.000000	0.000000	0.000000	0.0	0.0	0.000000	0.0	0.000000
3	Dedan Kimathi University Innovation and Incuba...	1.000000	0.000000	0.0	0.0	0.0	0.000000	0.000000	0.000000	0.000000	0.000000	0.0	0.000000	0.000000	0.000000	0.000000	0.0	0.0	0.000000	0.0	0.000000
4	E4impact-Tangaza College	0.000000	0.000000	0.2	0.0	0.0	0.000000	0.000000	0.000000	0.000000	0.000000	0.0	0.000000	0.000000	0.000000	0.000000	0.2	0.0	0.000000	0.0	0.000000

Based on that, the most common venues can be filtered through frequency sorting. Table 6 shows the table head of 1~10th most common venues for each hub (This table is merged with the original 'Innovation Data' Table).

Table 6 1~10th most common venues for hubs (merged)

	Type	Name	County_Location	Target_Market	Latitude	Longitude	Cluster Labels	1st Most Common Venue	2nd Most Common Venue	3rd Most Common Venue	4th Most Common Venue	5th Most Common Venue	6th Most Common Venue	7th Most Common Venue	8th Most Common Venue	9th Most Common Venue	10th Most Common Venue
0	Technology Hubs and Programs	Ihub	Nairobi	ICT	-1.298752	36.790795	0	Bar	Hotel	Coffee Shop	Lounge	Café	Shopping Mall	Shoe Store	Diner	Nightclub	Pizza Place
1	Technology Hubs and Programs	Nailab	Nairobi	ICT	-1.299116	36.790860	0	Hotel	Bar	Coffee Shop	Lounge	Shopping Mall	Shoe Store	Diner	Nightclub	Pizza Place	Café
2	Technology Hubs and Programs	Lakehub	Kisumu	ICT	-0.108192	34.748901	0	Shopping Mall	Hotel	Office	Bar	Lounge	Diner	Chinese Restaurant	Hotel Bar	Coffee Shop	Gas Station
3	Technology Hubs and Programs	Chandaria Business Center/Kenyatta university	Kiambu	All sectors	-1.182003	36.936359	0	Coffee Shop	Gym	Park	Skating Rink	Baseball Field	Pool	Grocery Store	Fast Food Restaurant	Deli / Bodega	Historic Site
4	Technology Hubs and Programs	Empty Hub	Bungoma	ICT	0.566012	34.559121	2	African Restaurant	Nightclub	Department Store	Grocery Store	Hotel Bar	Thai Restaurant	Food Court	Deli / Bodega	Vineyard	Diner

3.3 Machine Learning Application

As described above, the most common venues are obtained through neighborhoods exploration steps. In this section, machine learning technique is applied to cluster the neighborhoods based on the venue frequency features in Table 5. K-means clustering, one of the simplest and popular unsupervised machine learning algorithms is utilized, clustering data points with certain similarities with a fixed K.

3.3.1 Find the Best K

Through calculating with the cost function, the plot below (Figure 6) is made to illustrate the relationship of K value and Squared Errors. Using the elbow rule, the point of elbow is the most optimal value of choosing K, which makes the best K as 3.

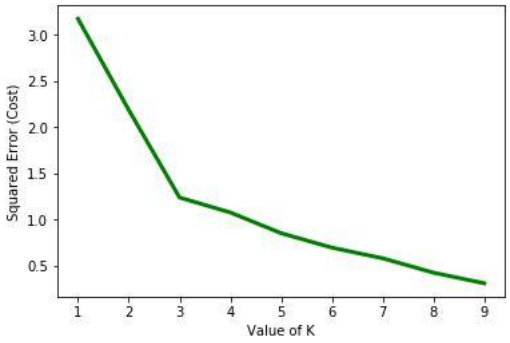

Figure 6 Plot of K value and Squared Error

3.3.2 K-means Clustering

Therefore, the number of clusters is set as 3. The cluster labels are generated after running the k-means clustering algorithm. Those labels are added back to the hubs data while merging with the 1~10 most common venues table (Table 7).

Table 7 Cluster labels (merged)

	Type	Name	County_Location	Target_Market	Latitude	Longitude	Cluster Labels	1st Most Common Venue	2nd Most Common Venue	3rd Most Common Venue	4th Most Common Venue	5th Most Common Venue	6th Most Common Venue	7th Most Common Venue	8th Most Common Venue	9th Most Common Venue	10th Most Common Venue
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1	Technology Hubs and Programs	Nailab	Nairobi	ICT	-1.299116	36.790860	0	Hotel	Bar	Coffee Shop	Lounge	Shopping Mall	Shoe Store	Diner	Nightclub	Pizza Place	Café
2	Technology Hubs and Programs	Lakehub	Kisumu	ICT	-0.108192	34.748901	0	Shopping Mall	Hotel	Office	Bar	Lounge	Diner	Chinese Restaurant	Hotel Bar	Coffee Shop	Gas Station
3	Technology Hubs and Programs	Chandaria Business Center/Kenyatta university	Kiambu	All sectors	-1.182003	36.936359	0	Coffee Shop	Gym	Park	Skating Rink	Baseball Field	Pool	Grocery Store	Fast Food Restaurant	Deli / Bodega	Historic Site
4	Technology Hubs and Programs	Empty Hub	Bungoma	ICT	0.566012	34.559121	2	African Restaurant	Nightclub	Department Store	Grocery Store	Hotel Bar	Thai Restaurant	Food Court	Deli / Bodega	Vineyard	Diner

Figure 7 K-means clustering visualization

To visualize the clustering results, the collections are labeled with different colors, with red, purple and light blue representing clusters 1~3, as presented in Figure 7.

4. Results

The clustered results are obtained to form the dataframes for each clusters (Table 8~10).

Table 8 Cluster 1(Table head)

	Name	Latitude	Longitude	Cluster Labels	1st Most Common Venue	2nd Most Common Venue	3rd Most Common Venue	4th Most Common Venue	5th Most Common Venue	6th Most Common Venue	7th Most Common Venue	8th Most Common Venue	9th Most Common Venue	10th Most Common Venue
0	Ihub	-1.298752	36.790795	0	Bar	Hotel	Coffee Shop	Lounge	Café	Shopping Mall	Shoe Store	Diner	Nightclub	Pizza Place
1	Nailab	-1.299116	36.790860	0	Hotel	Bar	Coffee Shop	Lounge	Shopping Mall	Shoe Store	Diner	Nightclub	Pizza Place	Café
2	Lakehub	-0.108192	34.748901	0	Shopping Mall	Hotel	Office	Bar	Lounge	Diner	Chinese Restaurant	Hotel Bar	Coffee Shop	Gas Station
3	Chandaria Business Center/Kenyatta university	-1.182003	36.936359	0	Coffee Shop	Gym	Park	Skating Rink	Baseball Field	Pool	Grocery Store	Fast Food Restaurant	Deli / Bodega	Historic Site
5	Sotehub	-3.397310	38.555934	0	Hotel	Asian Restaurant	Lounge	Nightclub	African Restaurant	Arts & Entertainment	Gas Station	Eastern European Restaurant	Ethiopian Restaurant	Arts & Crafts Store

As can be seen from Table 8, hubs in cluster 1 owns common venues like ‘Bar’, ‘Hotel’, ‘Shopping mall’, ‘Coffee Shop’ etc., indicating strong urban characteristics, like city center, business zone or other well developed areas.

Table 9 Cluster 2

	Name	Latitude	Longitude	Cluster Labels	1st Most Common Venue	2nd Most Common Venue	3rd Most Common Venue	4th Most Common Venue	5th Most Common Venue	6th Most Common Venue	7th Most Common Venue	8th Most Common Venue	9th Most Common Venue	10th Most Common Venue
7	Nairobi Industrial Park(JKUAT)	-1.093634	37.011659	1	Hostel	Convenience Store	Department Store	Diner	Dumpling Restaurant	Eastern European Restaurant	Ethiopian Restaurant	Fast Food Restaurant	Flower Shop	Food Court

While cluster 2 in Table 9 has only one hub point included, which is the ‘Nairobi Industrial Park’, and it is surrounded by various restaurants and stores, indicating the characteristic of independent technology zone away from the city center.

Table 10 Cluster 3

	Name	Latitude	Longitude	Cluster Labels	1st Most Common Venue	2nd Most Common Venue	3rd Most Common Venue	4th Most Common Venue	5th Most Common Venue	6th Most Common Venue	7th Most Common Venue	8th Most Common Venue	9th Most Common Venue	10th Most Common Venue
4	Empty Hub	0.566012	34.559121	2	African Restaurant	Nightclub	Department Store	Grocery Store	Hotel Bar	Thai Restaurant	Food Court	Deli / Bodega	Vineyard	Diner
16	Dedan Kimathi University Innovation and Incuba...	-0.397222	36.961085	2	African Restaurant	Convenience Store	Department Store	Diner	Dumpling Restaurant	Eastern European Restaurant	Ethiopian Restaurant	Fast Food Restaurant	Flower Shop	Food Court

In Table 10, hub points of cluster 3 are described as hybrid innovation zone with neighborhoods covering different functions of eating, living and entertainment, which may refer to mature community in unique counties.

Hence, we define the 3 clusters as following:

Table 11 Cluster Classification

Cluster 1	Urban Gatherings
Cluster 2	Independent Technology Zone
Cluster 3	Innovative Community

5. Discussion

5.1 Observations

From Figure 8~10, the locations of Cluster 1 are enlarged for observing convenience.

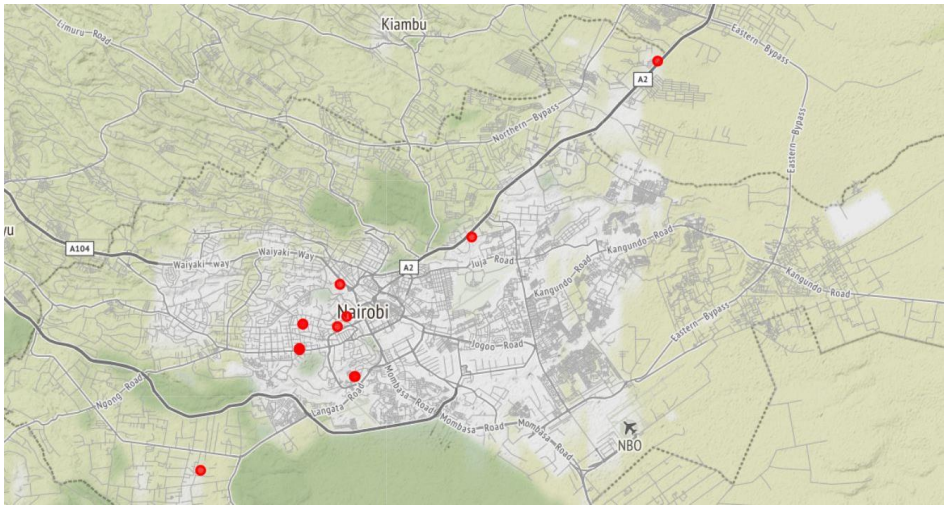

Figure 8 Cluster 1 zoom in (a)

Figure 9 Cluster 1 zoom in (b)

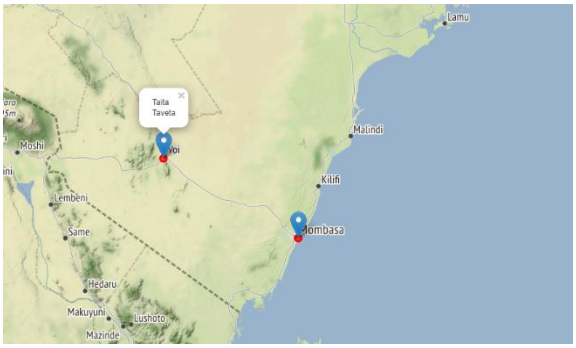

Figure 10 Cluster 1 zoom in (c)

As can be found in the figures, Cluster 1 (in red points) mainly gathered in Nairobi city with an extreme high density (Figure 8), which proves the classification of “Urban gatherings” for Cluster 1 in the results part. Besides, the Cluster 1 also contains hub points in Kisumu, Mombasa and Taita Taveta. The urban characteristics appear in hub points Taita Taveta may benefit from the existence of Taita Taveta University. Lakehub in Kisumu is close to Great Lakes University Of Kisumu and Kisumu Innovation Center. Mombasa has competitive innovation ecosystem while the SwahiliBox is well known.

By creating a Bar Plot for the 1st common venues of Cluster 1 (Figure 11), it is indicated that hotels and bars are the dominant venue categories around the “Urban Hubs”, which creates enough public space for communication within digital entrepreneurs, investors, researchers and other groups.

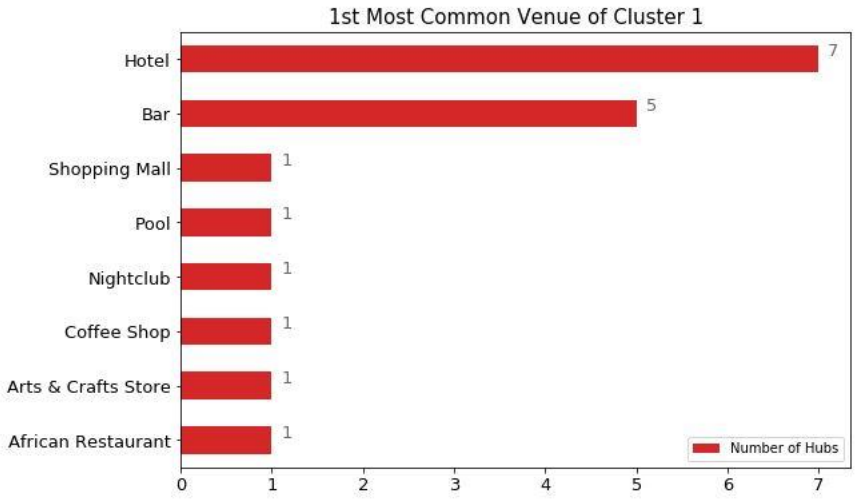

Figure 11 1st common venue of Cluster 1

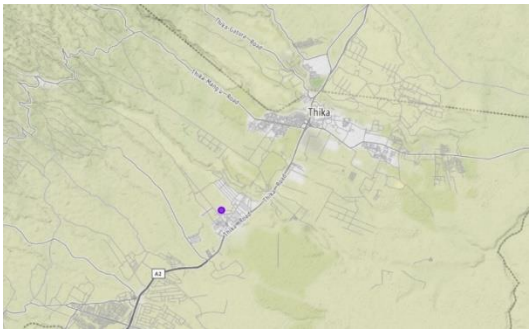

Figure 12 Cluster 2 zoom in

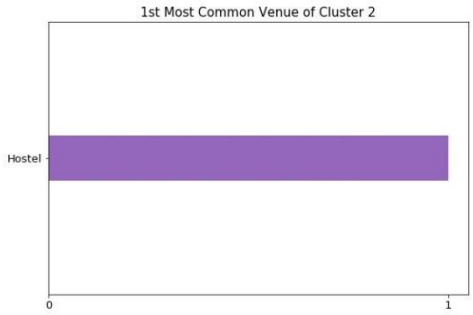

Figure 13 1st most common venue of Cluster 2

Figure 12 is the hub point of Cluster 2, as discussed in results part, this cluster has only one data point which is Nairobi Industral Park (JKUAT) in Kiambu. It is an independent technology zone filled with innovative enterprises and research institutions. The 1st most common venue here, hostel (Figure 13), providing enough accommodations for the motivated groups here.

Figure 15 Cluster 3 zoom in

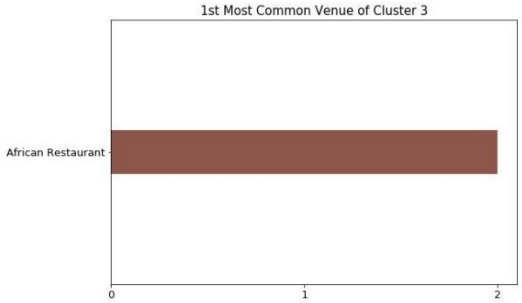

Figure 14 1st most common venue of Cluster 3

The last cluster, cluster 3, one in Nyeri with the famous Dedan Kimathi University of Technology, one in Bungoma which is an agriculture-based county. They are both surrounded by local restaurants, Africa Restaurant, as the 1st most common venue.

5.2 Recommendations

According to the World Bank report (Kelly, 2016), “Innovation”, “Efficiency” and “Inclusion” are the three major factors effecting digital development. Well adapted neighborhoods under the consideration of these factors can accelerate the sustainable development of tech-hub centroids.

1. Connectivity plays a vital role in innovation and collaboration (Da Cunha and Selada, 2009), hence clustering environment would contribute a lot to the technology ecosystem. Nairobi city is densely distributed with the tech hubs while the other counties still have a long way to reach mature clustering environment. It is recommended that the academic institutions, think tanks and NGOs make further analysis on how to get urban-rural linked in developing innovation connectivity.
2. In the “Urban Characterized” hub points, it is recommend to make research on how to fulfill the existing structures to improve efficiency through pushing forward the establishment of four zones utilizing the existing neighborhoods: business zone, commercial zone, knowledge zone and assembly zone (Kelly, 2016).
3. For the independent hub points or hub points located in agriculture-based counties, researches can be conducted on how to introduce investors or funders of diversified sectors to inspire innovation and inclusion. Thoughts can also be put on expanding the function of the existing neighborhood infrastructures such as universities and colleges.

5.3 Limitations

There are some limitations in this capstone project that are necessary to be listed:

1. The original dataset may not be a completed recording of all the existing innovation hubs and technology centers in Kenya.
2. Web portals are all dropped because of NAN values of coordinates information, which could have some influence on the analysis.
3. The distribution of hub points is quite unevenly (most gathered in Nairobi city, close to each other), which may not prove it is a good clustering.
4. When utilizing Foursquare API, the original venues returned may not be sufficient. For example, when the explore radius down to a smaller value, like 500 or 600 meters, no venues are returned for ‘Nairobi Industrial Park (JKUAT)’.
5. Due to the limited time and effort, there is a lack of tacit knowledge when conducting this capstone project, which is quite important in understanding the local conditions.

6. Conclusion

This capstone project conducted initial analysis for neighborhoods characteristics of innovation hubs and technology centers in Kenya through exploratory data analysis with open geodata. By utilizing Foursquare API and applying K-means clustering, one of the unsupervised machine

learning algorithms, venues around tech-hub centroids are returned and the hub points are clustered into three clusters. The major cluster is in Nairobi, which is the capital of the country. The other two clusters are distributed in several counties but usually located close to innovation-encouraged infrastructures like universities and industrial park. Recommendations are made to promote research on enhancing the urban-rural linkage in innovation connectivity, pushing forward the establishment of diversified zones utilizing the existing neighborhoods, increasing the function of the existing neighborhood infrastructures, in order to support forming sustainable technology development environment featured with innovation, efficiency and inclusion.

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