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Water Quality Assessment in Smart Cities in India

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by

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First, I would like to thank and pray for Allah for blessing me and giving me the power to continue my studying with my first baby born and getting high grades in all subjects and hopefully my capstone too. Secondly, I would like to thank my husband Sultan for supporting me in my studying journey. Thirdly, I would like to thank Dr. Vandana for helping me and showing me the directions that I can take to reach my final capstone project in the best way. In addition, I would like to thank Dr. Sanjay Modak for his support and guidance. This project allows me to explore and learn more about India country, specially about the water monitoring.

Abstract

This research aims at assessing the quality of water in India for the case of the 100 smart cities initiative in 2015 (Hoelscher, 2015) and propose which cities are eligible for the smart city design. K-mean and Hierarchical clustering techniques are used to divide 614 water monitoring locations in India into 6 different clusters and WHO water quality parameters are used as reference to suggest eligibility of each monitoring location for becoming a smart city. Results of this study can help planners to speed up the process of assessment and take necessary actions to enhance the water quality. The information is collected from Water Quality Database from the Central Pollution Control Board (CPCB) website as all the updated data is available on the website. The version used for this research paper is from 2021 which is the latest data as of today which will allow me to get the related result to be used in the future. In this report I used SPSS for the data analysis to specifically do both clustering techniques which are K-mean and Hierarchical clustering technique.

Keywords: India smart cities initiative, water quality, SPSS statics, monitoring water and WHO (World Health Organization).

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Chapter 1. Introduction

1.1 Background Information

Nowadays, the idea of smart city initiative is trending around the world and every country is trying to beat the top in advanced technologies and transforming its cities to a smart city. India is one of those countries that is going toward this goal of having most of the cities in India to be a smart city. To be eligible to this goal, the water quality should be as strong as the infrastructure of a smart city. Insufficient access to a clean water leads to spread of diseases and country's economy will be affected as its residents are not getting clean water for daily use which is also affecting the goal of being a smart city.

In this paper, previous papers of India smart city initiative, water scarcity, water pollution, smart water monitoring and different clustering technique has been studied and summarized in the literature review section to allow the understanding of the problem and implement the analysis needed concerning the water quality for smart cities and state the cities in India that are eligible for this initiative by assessing the water quality.

More discussions about analyzing the water quality of smart city are conducted which is the core of this paper. An analysis is conducted on an existing data of cities in India where it has been compared with the values of WHO (World Health Organization) to make sure it is meeting the standard values of smart city. Two clustering techniques has been used to divide the different monitoring locations in India to different clusters based on their water quality parameters.

In addition, the paper ends with a recommendation section where I summarized the main points for future work and for the urban planners to consider in their water monitoring studies as analyzing the data is the very first step toward having a good solution in any problem. All the sources are mentioned in the references section at the end and the appendix section shows all the cities of the initiative of India's smart city.

1.2 Project Goals

Cities around the world are going toward being a smart city and India is one of the countries that have proposed this idea and have selected some of its cities to be a smart city. Our focus in this report is the water quality, where assessing the water quality is the very first step of having a clean drinkable and livable water.

The prime minister of India has the vision to convert 100 cities of India to “Smart City”. Quality of water assessment is an important criterion of selection process to assign any city under the title of “Smart City”. In this report I suggested whether those are suitable and eligible to be a smart city or not and show which cities in India can be a smart city from the water quality assessing other than the declared ones.

The project studies different water parameters and compare the values with WHO parameters to check whether it fall in the same category of drinkable water or not. Mainly, water monitoring locations in India are used as those are the source of data in this project.

K-mean and Hierarchical clustering methods are used to define the number of clusters and to compare the standard water parameters settled by WHO with each monitoring location in India to divide them into different clusters.

Research question:

To assess the water quality suitability for the proposed cities to nominate them under smart city category.

1.3 Aims and Objectives

The aim behind this project is to suggest the different clusters of smart city initiative in India based on their water quality and to show the eligible cities to be a smart city.

Objectives:

- ✓ To assess water quality in India's cities
- ✓ To cluster cities in different clusters based on the water quality
- ✓ To know which monitoring locations of cities are eligible to be known as a smart city based on the water quality

1.4 Research Methodology

The assessment of water quality is initiated by collecting existing data from the list of smart cities in India's mission. The data is gathered, descried, explored, and verified to fed them into the clustering techniques. Clustering techniques has been used to divide the monitoring locations of cities into different clusters and then comparing the clusters characteristics from WHO prescribed conditions. Based on results, monitoring locations of cities will be divided into different groups. Number of clustering groups will be found from clustering technique known as Hierarchical clustering technique. The result of the Hierarchical cluster will then be used as an input or will fed into the K-mean clustering technique which will divide the different monitoring location based on their parameters. The water quality criteria that are followed are declared by World Health Organization are shown in the following page in table 1. The following step is assessed whether the quality of water in those monitoring locations are applicable to meet the criteria of drinkable water of WHO. SPSS is used to do processing of the data and apply clustering techniques that are mentioned earlier.

Table 1.WHO water quality parameters (Organization, 2021)

Parameter	Maximum value set	Minimum value set	Median
Aluminum	0.5 mg/l	0.03 mg/l	0.2 mg/l
Ammonium	3 mg NH_4/l	0.05 mg NH_4/l	0.5 mg NH_4/l
Chloride	1000	20	250
Iron	2 mg/l	0.1 mg/l	0.3 mg/l
pH Maximum	pH 10.5	pH 8	pH 8.5
pH Minimum	pH 7	pH 5	pH 6.5
Nitrite (as NO2 −)	3.3 mg/l	0.003 mg/l	0.5 mg/l
Nitrate (as NO3 −)	75 mg/l	40 mg/l	50 mg/l
Dissolved oxygen	8 mg/l	4 mg/l	6 mg/l
Temperature	35 °C	15 °C	25 °C
Conductivity	2700 µS/cm	1700 µS/cm	2500 µS/cm
Sodium	400 mg/l	100 mg/l	200 mg/l
Sulfate	800 mg/l	50 mg/l	250 mg/l
Turbidity	25 NTU	0.3 NTU	5 NTU
Zinc	15 mg/l	1 mg/l	5 mg/l

1.5 Limitations of the Study

As India is very huge country with many cities, the water quality data should be available more widely and open to the public for the best result of assessing water quality. The opposite was here as not all cities of India has its water information available to study.

The first limitation of the study was lack of data for the other cities than the studied ones as there are a lot more to study, explore and suggest.

The second limitation was that there are no continues updates on smart cities mission of India from 2015 which was an obstacle also as it is part of important information that could be used to improve this paper to see the updates of smart cities and whether those cities continue to have the same mission of being a smart city or not.

At the end, mainly all the limitation are surrounded around lack of data of open sources and for future references and studies it is better for a person to be in India physically to explore and get information by going to the place itself and ask experts living in India about the data and information as I believe that there are a lot of confidential information that cannot be easily published in the internet for the public.

Chapter 2. Literature Review

2.1 Introduction

This literature review outlines the most important ideas discussed in some of the research papers about India's smart city initiative, water scarcity in some countries and its root causes, water challenges around the world, poor water management and water monitoring solution.

Moreover, a deep study of India's smart city initiative allows me to understand the criteria of being a smart city. Water scarcity papers shows that a lot of countries around the world are suffering from the issue and in the future, it will affect more countries as well. Poor water management is one of the main reasons of wasting water, knowing how to manage water recourses is very important aspect in smart cities. Water monitoring solutions are found for those poor water management using smart techniques that will save water and all reusing the water.

The study of water quality for smart cities of India will allows me to state whether those are suitable to be a smart city or not. In addition, I have studied the different type of clustering techniques so I can choose the best technique for this project be checking the available data and considering the details of which data analysis program can fit the data and can give the best results. Applying my knowledge to the data I got benefited me to conclude the study by addressing the eligibility of being a smart city from the water monitoring locations data that I have.

2.2 Literature Review

2.2.1 Smart city initiative of India:

The Modi government launched the Smart Cities Mission in June 2015, the article “India's Smart Cities Mission” is discussing the mission is proposed to be in more than 100 cities in India (Hoelscher, 2015). As statistics shows, 1 in every 3 Indians are living in urban area where it shows that India is going toward urbanization and moving toward smart cities initiative. The mission is a new opportunity for urban planners in India and for the State where it is a starting point of innovating and being creative to the city and to find new solutions the existing problems.

Recently, smart cities concept has been evolving around the world and cities are challenging each other to propose the best ideas about smart and sustainable city. The paper “Smart Cities in India: Features, Policies, Current Status, and Challenges” proposes the smart city definition based on 3 things which are the core of the smart city (Nallapaneni Manoj Kumar, Sonali Goel, Pradeep Kumar Mallick , 2018). In addition, the paper mainly discusses the concept of smart city in India and focusing on topics such as: present status, challenges, and features of smart cities in India.

The paper “Impact of sustainable design on India’s smart cities development” (Iram Akhtar, 2021) is talking about the idea of smart city is to integrate the ICT with some smart components connected together to improve the performance and operations in the city and to make life easier for people. India country has the vision of making more than 100 cities a smart city with technologies such as smart meters, renewable energy generation and smart buildings. The paper also summarizes the idea around the development of the hybrid energy system in smart city and its economics side.

According to “100 New Smart Cities” paper, India country has been considered as 10^{th} largest economy in the world which made the minister thinking of having 100 smart cities in the country. The paper is also focusing in the smart (Somayya Madakam, 2015) cities essence and its conceptual views from different practitioners. Moreover, the article is also talking about the 6 dimensions of smart cities and finally the paper is considering the question of “How to set up 100 New Smart Cities in India” which made the research very interesting.

2.2.2 Water scarcity issue has been a challenge for many countries worldwide:

According to "Global assessment of water challenges under uncertainty in water scarcity projections" paper, water scarcity is worldwide problem, and it is so critical for the environment, and it also has the main goal of why people are going toward water extraction during the last century and until today. Moreover, the climate and social changes are becoming an issue nowadays and increasing the water scarcity. In addition, the paper also took a probabilistic approach to assess and measure the global water scarcity projections following 2 methods which are: Shared Socioeconomic Pathways (SSPs) and Representative Con-centration Pathways (RCPs) and talks about changes in the uncertain range of the expected water scarcity condition (P. Greve, 2018). Finally, the authors developed a general decision-making framework to enhance policymaking.

The importance of water can be shown in how it is taking a large aspect of a humans' body where it is more than two-thirds of the human body; where the brain itself is made up of 95% of water, blood is 82% water, and lungs are 90%water (Moustafa Khalifa, 2018). The article "The Importance of Clean Water" discuss the number of people drinking unsafe water worldwide which are around two billion people, and it is very huge number. In addition, it talks about the number of prevalence, the importance of clean water and how the issue of unclean water affects the public health.

The paper "China 's water scarcity" discuss the water scarcity in China as China has been facing it seriously and especially in the north side of China as there is an insufficient local water resources and a poor water quality because of the pollution and this is causing 2 problems which are: serious impacts on the society and serious impacts on the environment. The paper theme is to provide an overview idea of China's water scarcity attempting to understand the water recourse issues that will affect the sustainable development in China (Jiang, 2009). In addition, the shortage of water and poor-quality water have a huge effect on food security, economic development, and quality of life in China. Nevertheless, the paper also summarizes how reduced quality of available water affect the country and analyzes water resource management issues that need to be addressed.

The article “Water Issue in Egypt: Resources, Pollution and Protection Endeavors” discuss the case of Egypt country where is has been listed among the top 10 countries that are threatened by water scarcity by 2025 as the high increase of the population of Egypt country. The main source of the water resources in Egypt is the Nile River which took about 97% of the total water resources (Hussein I. Abdel-Shafy, 2002), while the rest of resources comes for winter rain and non-renewable ground water aquifers. The main issue of the polluted water in Egypt in the Nile River is the industrial waste as about 350 industries are discharging their sewage-water in the river (Hussein I. Abdel-Shafy, 2002). The paper mainly studies the water issues in 2 perspective which are: water quality and man-made water pollution problems in Egypt country.

The paper “Deep Challenges for China’s war on water pollution “discuss the pollution crisis of water and complied nitrate data in groundwater for both shallow and deep groundwater for 52 systems in China (Dongmei Han, 2016). The Nitrate pollution in China has an exceeding level referring to the US EPA’s maximum contaminant level. There was a comprehensive plan released in China in 2015 which is The Water Pollution Prevention and Control Action Plan aiming to attempting pollution of ground and surface water as those are recognized as most severely degraded natural resources in China and as one of the most heavily polluted water sources worldwide (Dongmei Han, 2016). In addition, despite the improved ways of provisioning clean water, in China it is estimated that more than 200 million people are struggling to get safe water and still use the unsafe water sources.

2.2.3 Different water monitoring techniques has been applied for the water quality issues using IoT:

According to “IoT based Smart Water Quality Monitoring System” article, the Smart Water Quality Monitoring System is used to get continues water condition measurement of 4 physical parameters which are the following: temperature, pH, electric conductivity, and turbidity properties. To measure those parameters, 4 sensors are connected to Arduino and the data are extracted from the sensors (Monira Mukta, 2019). An application in .NET platform offers a comparison of the given data with the standard values worldwide and based on the result obtained,

the Smart Water Quality Monitoring System will analyze the data and classify whether it is drinkable water or not.

Water is one of the most important things in human life as it is one of the essential needs for human to survive. In the paper “Smart water quality monitoring system with cost-effective using IoT”, sensors nowadays are more effective as they can be connected through Wi-Fi and exchange and interact through IoT (Sathish Pasika, 2020). IoT also has the capability to address environmental issues such as water quality monitoring. The article shows a Water Quality Monitoring (WQM) system which is used to monitor the drinking water quality using IoT and it is cost effective and uses very efficient system. The system is using several sensors to measure different parameters such as pH, the turbidity, level of water in the tank, temperature, and humidity and fed them into the Microcontroller to process them using IoT based Think Speak application.

According to “Smart Water Monitoring System using IoT” article, water is very important in our daily life, at the same time water pollution is one of the biggest problems around the world (Gowthamy J, 2018). To make sure that the water is safe for drinking and for other supplies such as agricultural, water monitoring should be used. The article shows a low-cost design system for water real time monitoring of both quantity and quality using IoT. Some sensors are used with an Arduino controller to measure the data and they are connected to the WI-FI to process and analyze the data.

As the population is increasing as well as the urbanization, cities are welling and must transform to smart cities using IoT. Water quality is very important aspect of smart city mission, the paper “Framework for a smart water management system in the context of smart city initiatives in India” (Mohammed Shahanas.Ka, Dr.Bagavathi Sivakumar , 2016) has discussed a smart water monitoring system for the seek of smart water management. The sudden change in climate change and the population increase made the water issues to reach its peak, from the quality, quantity, and value of water. Currently, the issue in India is that the data collected for the water is being done manually and this paper shows how they are trying to provide IoT solution to convert everything digitally. The solution will include the following: sensors to collect water level from tanks, Arduino and Raspberry Pi to transmit to a server, web interface to visualize data and finally using Ubidots cloud platform. In addition, SMS message and email will be used.

2.2.4 Water in smart cities:

Smart water grid helps in solving challenges as water shortage, climate change and sustainable water resources management according to “Development of an integrated smart water grid model as a portfolio of climate smart cities” paper (Kim, 2018). In addition, the paper is discussing a brand-new method to describe the methodology between technology, resource management, and sustainable water infrastructure. A huge number of companies are keeping track of their footprint and looking forward for a sustainable environment. The smart water grid is a combination of water and Information and communication technology which is for sustainable, smart, and responsive water resource management which includes distribution and production.

Future decade will probably utilize the digital data in a very productive way. 5G network has already launched which has dramatically changed the way of transferring the data between users and machines. IoT technology has already been popular nowadays, according to the paper “DIGITALIZED WATER AND SMART CITIES”, IoT connections will reach 3.5 billion by the end of 2023 (Paska, 2018), an example of the IoT connection nowadays is the autonomous vehicles that we are hearing of a lot nowadays and some companies around the world has already launched their autonomous vehicles. Moving on to water and digitized water, water is a requirement living, but sometimes it can also be harmful such as heavy rainfall and floods. Access to a clean water is the target of humans as there are only 2.5 % fresh water in earth (Paska, 2018). Hence, this makes an issue for accessing clean water and solutions must be found. Today, collecting water data is either manually or very costly using technology, the paper “DIGITALIZED WATER AND SMART CITIES”, describe 2 solutions of water using the ICT which are: rain data collection through telecommunication network which is basically done using microwave signals and water quality monitoring based on digitization and IoT.

The increasement of water demand has been taking into consideration when planning a smart city as it is considered a challenge. Ensuring a safe access to clean water resources is also a challenge when talking about smart water monitoring solutions such as sensor nodes in the water pipes. The paper “Smart Water Grids for Smart Cities: a Sustainable Prototype Demonstrator”, shows a prototype demonstrator of smart water metering infrastructure which is self-powered and working

at 169 MHz (Leonardo Gabrielli, Mirco Pizzichini, Susanna Spinsante, Stefano Squartini, 2023). The prototype design of the powering circuit is based on the innovative use of microturbine enabled energy.

The paper "Smart Water Management System" is trying to solve the issue of the current situation of water distribution system which is the manual valve and replacing them with electronic valves. The management of those valves are going to be though mobile application and can prevent a lot of water wastage (Prof. Vinod, 2017). Providing people with safe water is very challenging and analysis the water and get use of the data is very important and the more important thing is how to smartly manage those resources. Smart water management is playing a major role in transformation of cities into smart cities for developing countries and will increase the economic growth of the country as well as the wealth of its citizens.

2.2.5 Clustering techniques:

Grouping and clustering objects are very important to recognize different categories and treat them differently. An example of clustering is clearly shown in hospitals; where the patients of the same

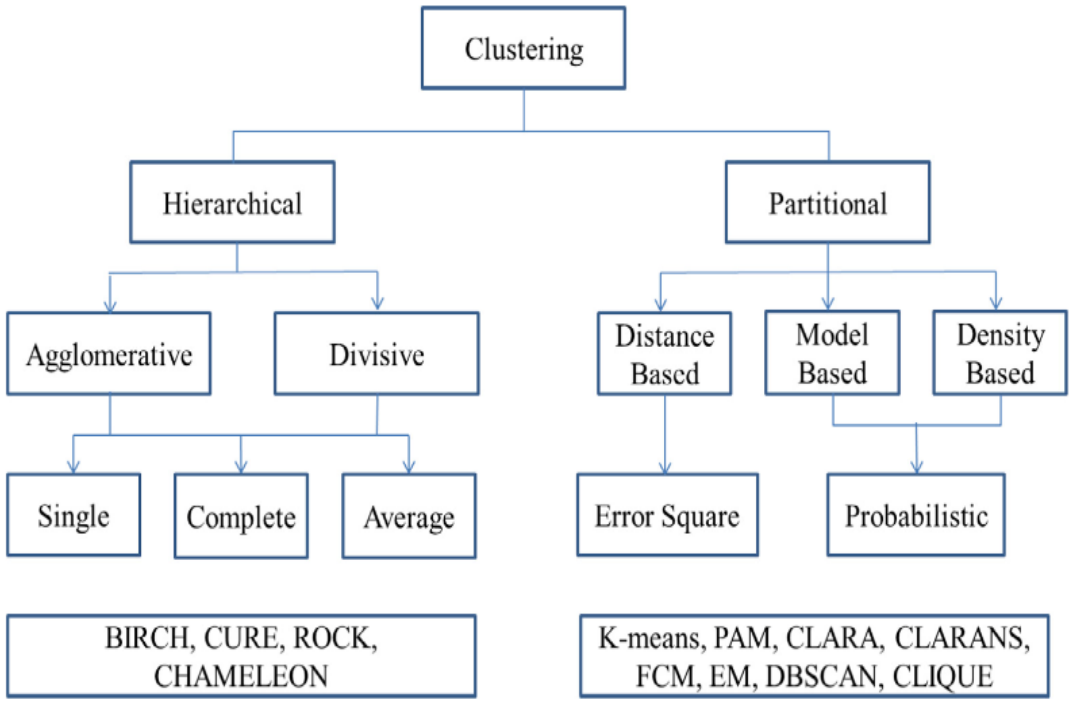
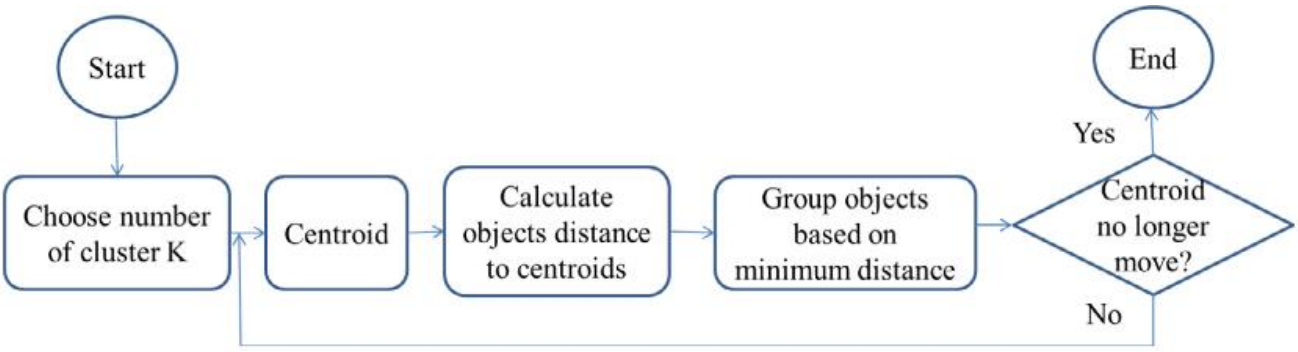


Figure 1. Taxonomy of clustering approaches

symptoms are group together and categorized to have the same disease and treated the same while others of different symptoms are grouped under different disease. Mainly, this technique is used to label groups so they can be identified clearly. According to "A review of clustering techniques and developments "paper (Amit Saxena, 2017), there are 2 types of clustering: Hierarchical and Partitional as shown in Figure 1.

K-means is a clustering technique, and it is one of the best-known clustering algorithms and it is the best technique that suit this project. The procedure is by getting a dataset and number of clusters, k; defied by the user and must define k centroids for each cluster. Then the distance will



be measured between a data point and the cluster centroids to find the minimum distance and group it accordingly. The figure below shows how the algorithm works:

Figure 2. Flow diagram of k-means algorithm

Clustering techniques are used widely in so many sectors and this technique helps a lot to divide the different groups based on their parameters. There are so many different clustering methods and each of them are used for a specific purpose. Importance sampling methods are commonly used in signal processing methods for approximating statistical moments of random variables by a set of weighted samples (Vıctor Elvira, Luca Martino, David Luengo). K-mean is one of them and it is simple and fast clustering method which is used widely. A detailed explanation about k-mean is in the report of "Review on determining number of Cluster in K-Means Clustering" (Trupti M. Kodinariya).

Main points of the Literature Review:

- Smart city initiative of India.
- Water scarcity issue has been a challenge for many countries worldwide.
- Water monitoring solution techniques for water quality issues using IoT.
- Water in smart cities.
- Types of clustering techniques and which one fits my project.

Chapter 3. Project Description

3.1 Project description

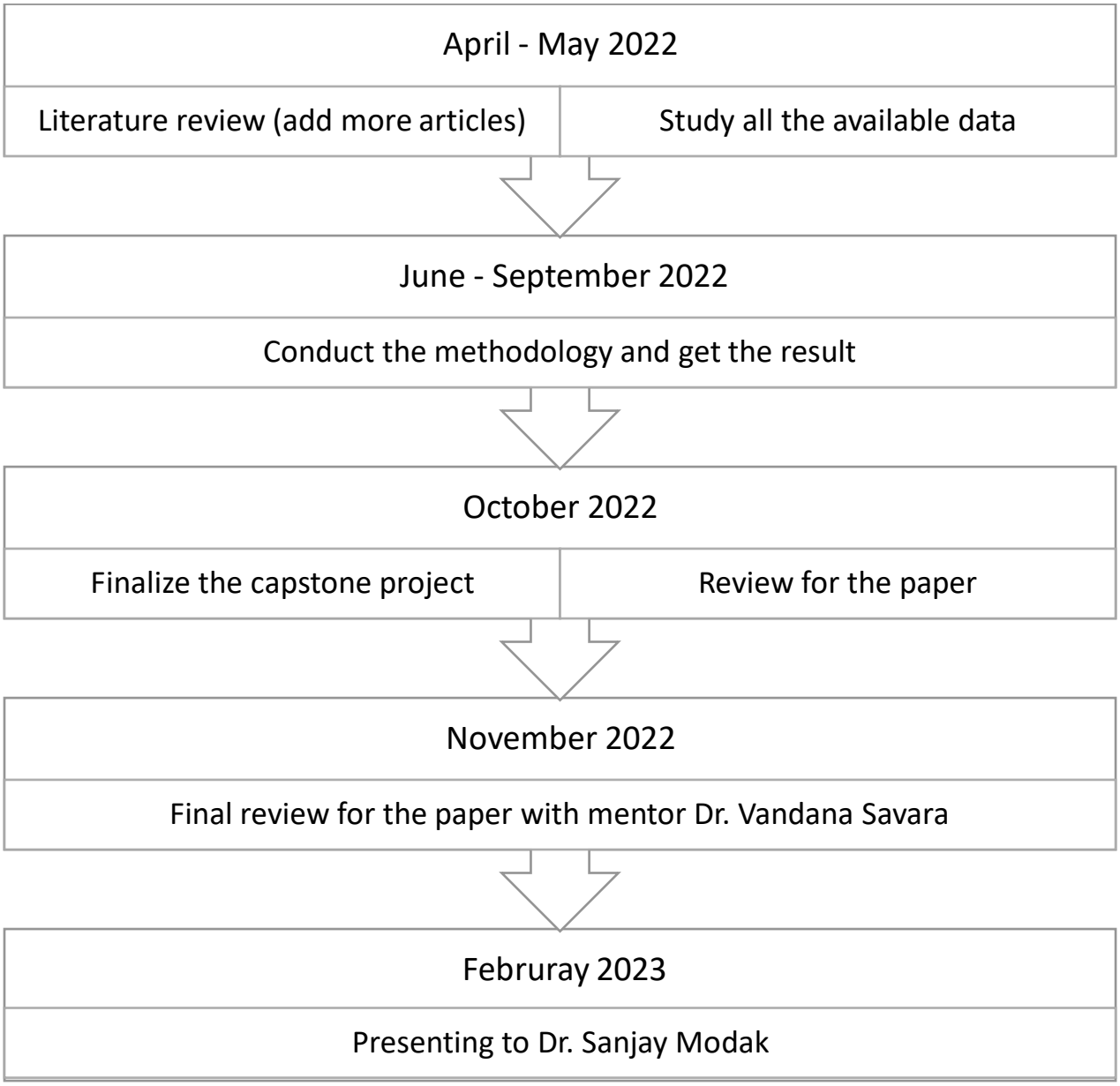
India is one of the countries that has the mission of taking its cities to be a smart city. To reach this goal, the water quality base must be as strong as the technology of the city and never discard its importance. Insufficient access to a clean water leads to spread of diseases and country's economy will be affected as its residents are not getting clean water for daily use which is also affectng the goal of being a smart city. The standard of drinkable and livable water in given by WHO and published online for any refence for smart cities.

My focus on this report is to do water quality assessing, where assessing the water is the very first step of having a clean drinkable water. The prime minister of India has the vision to convert 100 cities of India to "Smart Cities". Quality of water assessment will be an important criterion of selection process to assign any city under the title of "Smart City". In this report, I suggested whether those are suitable and eligible to be a smart city or not.

Two clustering techniques have been used to cluster the monitoring locations data into different groups. Hierarchical cluster is the first technique to get the number of clusters using built in function in SPSS analysis software by visually analyze the graph. The second technique is K mean clustering method where it is used to compare the standard parameters settled by WHO with each of smart city water parameters in India to cluster different cities to different clusters. By getting all the data needed, a graph is plotted to visualize the final result where only two clusters out of six are very close to WHO parameters, meaning those two have a very good water parameters that meets the stranded of drinkable and livable water.

By getting the results of this project, urban planners and specially for smart city planners, would be able to see how it is important to follow the WHO water parameters to define the smart cities water quality as not all the cities are eligible of being a smart city for the water quality perspective. In addition, India has the initiative of converting 100 cities into smart cities but not all the cities have water data available as an open source which was lack in this report.

Project Timeline:



Project resources and budget estimate:

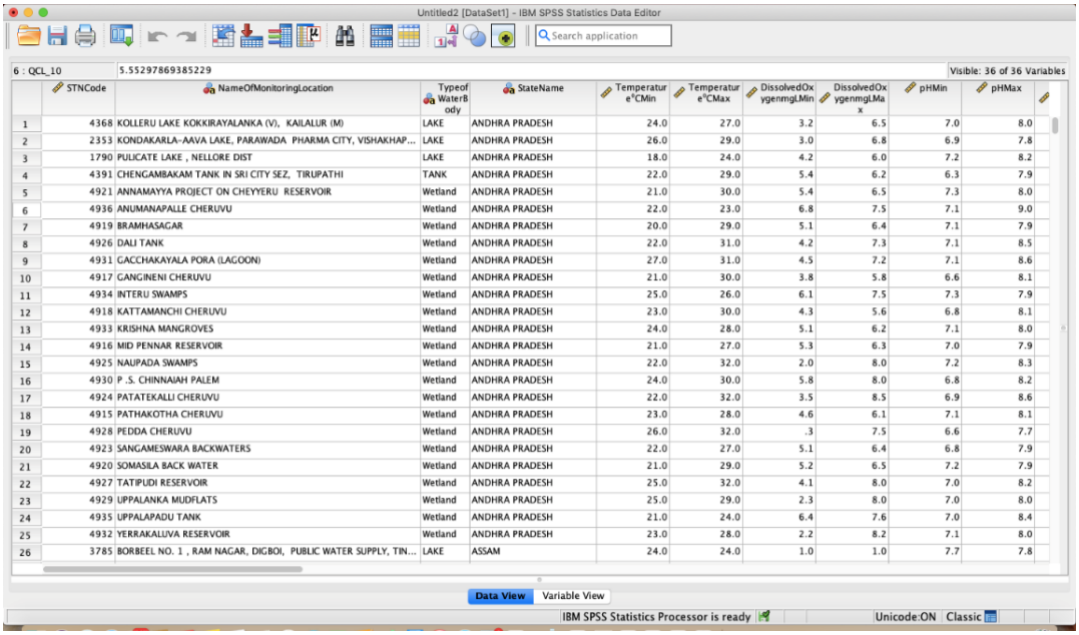
The main resources of the project are Central Pollution Control Board (CPCB) and World Health Organization (WHO), where CPCB has the data of existing water quality in India where it can be analyzed and processed and in WHO website, the values of acceptable drinkable water were found to compare it with the water data of smart city mission of India. I analyzed the data using SSPS which is an analytics software. Moreover, there is no budget associated with the project as everything is available online in the open sources I mentioned.

Chapter 4. Data Analysis

4.1 Data analysis

Hierarchical clustering helped me to determine the number of clusters that I can use and gave me a brief idea of the data before starting the k-means clustering. By getting the Hierarchical clustering graph, I processed to do the k-means cluster and interpreted the result. By combining Hierarchical clustering and k-means clustering, I had a great combination that helped me to determine the similarly and differently data in the clusters. Below I'm explaining the details of the data analysis process and result.

Step 1: Firstly, I imported the data I have from excel to SPSS Statistics data editor and identify the main parameters of the data and label each of them.



	STNCode	NameOfMonitoringLocation	TypeofWaterBody	StateName	TemperatureCMin	TemperatureCMax	DissolvedOxygenmgLMin	DissolvedOxygenmgLMax	pHMin	pHMax
1	4368	KOLLERU LAKE KOKKIRAYALANKA (V), KAILALUR (M)	LAKE	ANDHRA PRADESH	24.0	27.0	3.2	6.5	7.0	8.0
2	2353	KONDAKARLA-AAVA LAKE, PARAWADA PHARMA CITY, VISHAKHAP...	LAKE	ANDHRA PRADESH	26.0	29.0	3.0	6.8	6.9	7.8
3	1790	PULICATE LAKE , NELLORE DIST	LAKE	ANDHRA PRADESH	18.0	24.0	4.2	6.0	7.2	8.2
4	4391	CHENGAMBAKAM TANK IN SRI CITY SEZ, TIRUPATHI	TANK	ANDHRA PRADESH	22.0	29.0	5.4	6.2	6.3	7.9
5	4921	ANNAMAYYA PROJECT ON CHEYYERU RESERVOIR	Wetland	ANDHRA PRADESH	21.0	30.0	5.4	6.5	7.3	8.0
6	4936	ANUMANAPALLE CHERUVU	Wetland	ANDHRA PRADESH	22.0	23.0	6.8	7.5	7.1	9.0
7	4919	BRAMHASAGAR	Wetland	ANDHRA PRADESH	20.0	29.0	5.1	6.4	7.1	7.9
8	4926	DALI TANK	Wetland	ANDHRA PRADESH	22.0	31.0	4.2	7.3	7.1	8.5
9	4931	GACCHAKAYALA PORA (LAGOON)	Wetland	ANDHRA PRADESH	27.0	31.0	4.5	7.2	7.1	8.6
10	4917	GANGINENI CHERUVU	Wetland	ANDHRA PRADESH	21.0	30.0	3.8	5.8	6.6	8.1
11	4934	INTERU SWAMPS	Wetland	ANDHRA PRADESH	25.0	26.0	6.1	7.5	7.3	7.9
12	4918	KATTAMANCHI CHERUVU	Wetland	ANDHRA PRADESH	23.0	30.0	4.3	5.6	6.8	8.1
13	4933	KRISHNA MANGROVES	Wetland	ANDHRA PRADESH	24.0	28.0	5.1	6.2	7.1	8.0
14	4916	MID PENNAR RESERVOIR	Wetland	ANDHRA PRADESH	21.0	27.0	5.3	6.3	7.0	7.9
15	4925	NAUPADA SWAMPS	Wetland	ANDHRA PRADESH	22.0	32.0	2.0	8.0	7.2	8.3
16	4930	P .S. CHINNAIAH PALEM	Wetland	ANDHRA PRADESH	24.0	30.0	5.8	8.0	6.8	8.2
17	4924	PATATEKALLI CHERUVU	Wetland	ANDHRA PRADESH	22.0	32.0	3.5	8.5	6.9	8.6
18	4915	PATHAKOTHA CHERUVU	Wetland	ANDHRA PRADESH	23.0	28.0	4.6	6.1	7.1	8.1
19	4928	PEDDA CHERUVU	Wetland	ANDHRA PRADESH	26.0	32.0	.3	7.5	6.6	7.7
20	4923	SANGAMESWARA BACKWATERS	Wetland	ANDHRA PRADESH	22.0	27.0	5.1	6.4	6.8	7.9
21	4920	SOMASILA BACK WATER	Wetland	ANDHRA PRADESH	21.0	29.0	5.2	6.5	7.2	7.9
22	4927	TATIPUDI RESERVOIR	Wetland	ANDHRA PRADESH	25.0	32.0	4.1	8.0	7.0	8.2
23	4929	UPPALANKA MUDFLATS	Wetland	ANDHRA PRADESH	25.0	29.0	2.3	8.0	7.0	8.0
24	4935	UPPALAPADU TANK	Wetland	ANDHRA PRADESH	21.0	24.0	6.4	7.6	7.0	8.4
25	4932	YERRAKALUVA RESERVOIR	Wetland	ANDHRA PRADESH	23.0	28.0	2.2	8.2	7.1	8.0
26	3785	BORBEEL NO. 1 , RAM NAGAR, DIGBOI, PUBLIC WATER SUPPLY, TIN...	LAKE	ASSAM	24.0	24.0	1.0	1.0	7.7	7.8

Figure 3. Importing the data from Excel to SPSS

Step 2: After importing the data, I analyzed the data using Hierarchical Cluster Analysis built-in function to have a better visualization of the data and to determine number of clusters that the water quality data has.

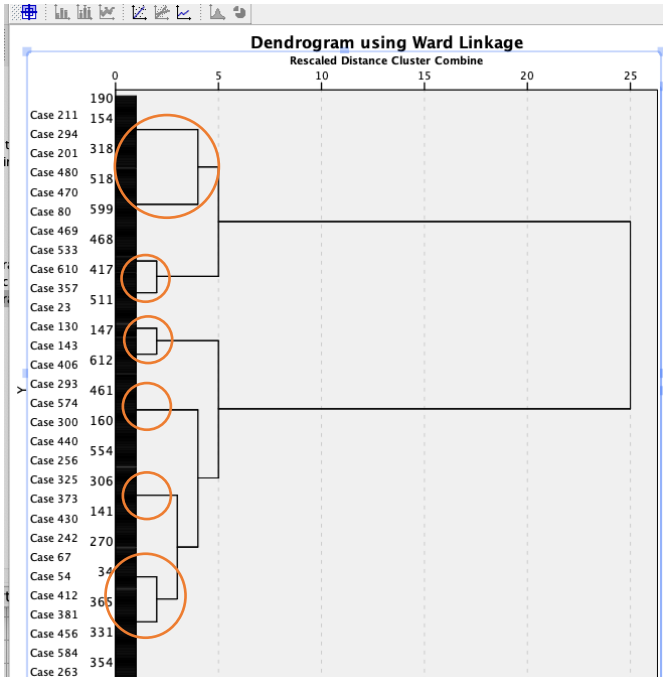


Figure 4. Hierarchical Cluster Analysis (Determine number of clusters)

Step 3: By getting the number of clusters to be used (which is 6), I used it as an input to k-means Cluster Analysis for classification and interpretation.

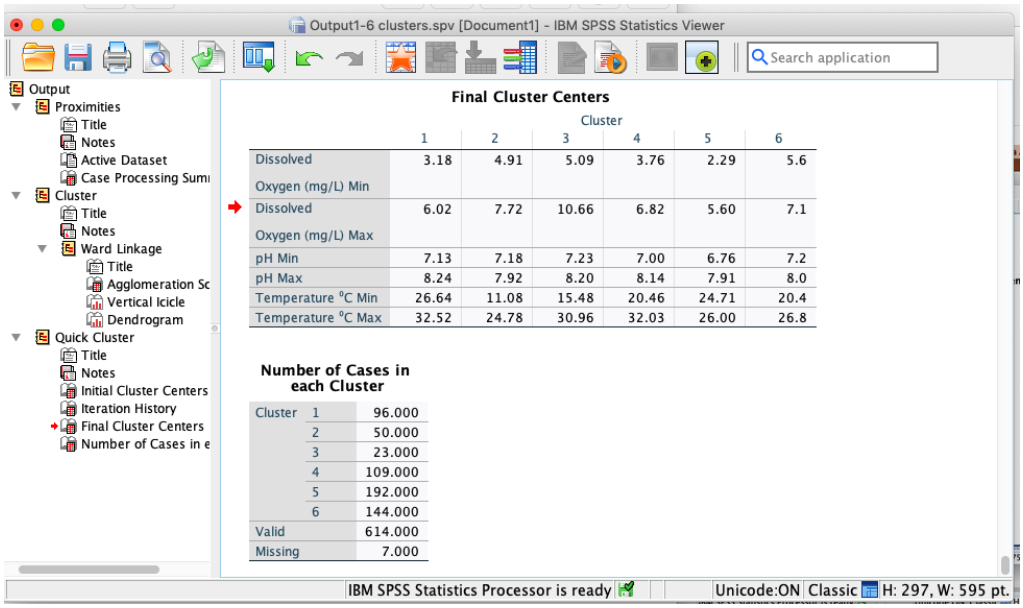


Figure 5. k-means clustering analysis result

Step 4: In this step, I took the result of the k-means clustering and added the WHO parameters which is in the table 2 below for the comprising and getting the final result.

Table 2. Result of clustering with WHO parameters

Cluster	Temperature ºC Min	Temperature ºC Max	Dissolved Oxygen (mg/L) Min	Dissolved Oxygen (mg/L) Max	pH Min	pH Max	count
1	26.6	32.5	3.2	6	7.1	8.2	96
2	11.1	24.8	4.9	7.7	7.2	7.9	59
3	15.5	31	5.1	10.7	7.2	8.2	23
4	20.5	32	3.8	6.8	7	8.1	109
5	24.7	26	2.3	5.6	6.8	7.9	192
6	20.4	26.8	5.6	7.1	7.2	8	144
WHO	15	35	4	8	6.5	8.5	

Step 5: Finally, I plotted the 6 clusters with the WHO in 3D model (shown in Figure 6 below) to better visualize the result. I used 3 parameters only which are the Max of Temperature, Dissolved Oxygen, and pH parameters to plot the 3D model.

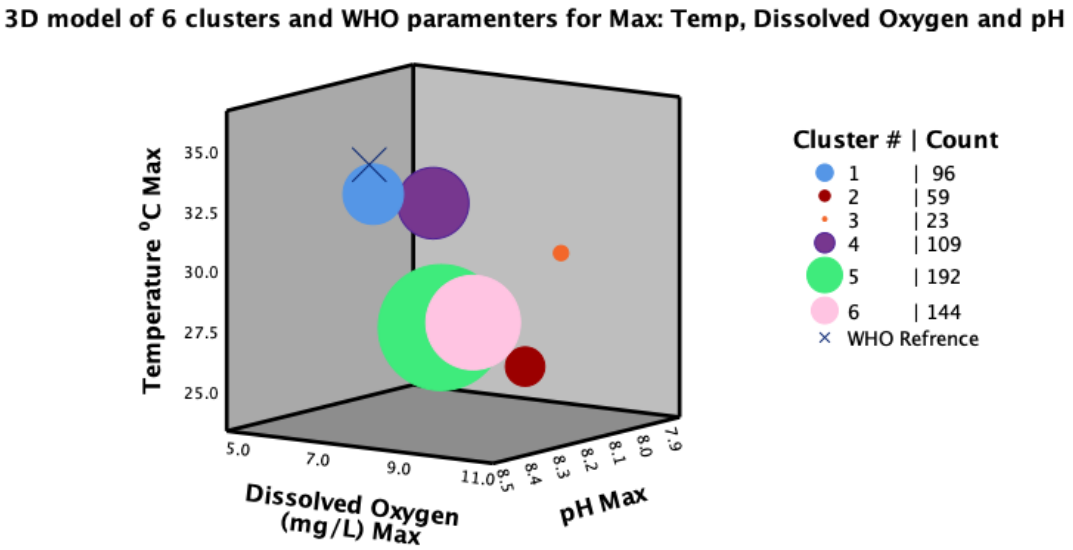


Figure 6. 3D model of the result

After visualizing the 3D model of the result, I can clearly conclude that there are two clusters which are very close to the WHO reference parameters, and we can say now that the cities within the two clusters are eligible to be in the smart city vision from the water quality point of view.

Table 3 below shows the state name with the different clusters divided based on the Max of Temperature, Dissolved Oxygen, and pH parameters and the count indicates number of monitoring locations in each state. A total of 614 monitoring locations were conducted in the data analysis clustering.

Table 3. States\ Cluster division count

State Name \ Cluster Number	1	2	3	4	5	6	Total
Andhra Pradesh	3			7	6	9	25
Assam	3			27	3	12	45
Bihar			5				5
Chandigarh			1				1
Chhattisgarh	1			1			2
Delhi	3						3
Goa	9						9
Gujarat	13			4	2	2	21
Haryana				1			1
Himachal Pradesh		5					5
Jammu & Kashmir		24	2				26
Jammu & Kashmir		4					4
Jharkhand			2	1	1	2	6
Karnataka	6			7	120	32	165
Kerala	5			2	3	8	18
Lakshadweep	1						1
Madhya Pradesh		1	5	10		17	33
Madhya Pradesh			1				1
Manipur						18	18
Meghalaya		6				1	7
Mizoram		1	1	1		1	4
Nagaland				2			2
Odisha	4	1	2	7		1	15
Puducherry	3						3
Punjab			3				3
Rajasthan	1	1		4	1	13	20
Tamil Nadu	5		1	2		1	9
Telangana	39			22	56	8	125
Tripura				5		13	18
Uttar Pradesh						4	4
Uttarakhand		2					2
West Bengal		5		6		2	13
Total	**96**	**50**	**23**	**109**	**192**	**144**	**614**

Table below (Table 4), shows the shortlisted States within cluster 1 and 4 which as mentioned before are the closest clusters to the WHO references which makes the water quality assessing for those states are eligible for smart city initiative.

Table 4. State\ Cluster division for clusters 1 and 4

State Name \ Cluster Number	1	4	Total
Andhra Pradesh	3	7	10
Assam	3	27	30
Chhattisgarh	1	1	2
Delhi	3		3
Goa	9		9
Gujarat	13	4	17
Haryana		1	1
Jharkhand		1	1
Karnataka	6	7	13
Kerala	5	2	7
Lakshadweep	1		1
Madhya Pradesh		10	10
Mizoram		1	1
Nagaland		2	2
Odisha	4	7	11
Puducherry	3		3
Rajasthan	1	4	5
Tamil Nadu	5	2	7
Telangana	39	22	61
Tripura		5	5
West Bengal		6	6
Total	**96**	**109**	**205**

Table 5 shows the monitoring locations of the smart cities initiative and the cluster they are categorized to, showing all clusters from 1 to 6.

Table 5. Smart City name from the initiative \ Cluster division

City Name \ Cluster Number	1	2	3	4	5	6	Total
Ahmedabad	3						3
Amravati			1				1
Bengaluru					4		4
Bhopal				3			3
Bilaspur		1					1
Chandigarh			1				1
Guwahati				6			6
Indore						5	5
Jabalpur						6	6
Jaipur				1			1
Jhansi						1	1
Kochi	1						1
Muzaffarpur			1				1
Patna		1					1
Rajkot	1					1	2
Rampur					1		1
Salem				1			1
Shillong		1					1
Srinagar		1					1
Surat				1		1	2
Udaipur						8	8
Grand Total	**5**	**4**	**3**	**12**	**5**	**22**	**51**

The cities that are declared to be a smart city in India and are applicable with the WHO parameters which are clusters 1 and 4 are shown below. A total of 8 cities out of 21 cities are eligible for the smart city initiative as per their water quality.

Table 6. Smart City Name from the initiative\ Cluster division for clusters 1 and 4

City Name \ Cluster Number	1	4	Total
Ahmedabad	3		3
Bhopal		3	3
Guwahati		6	6
Jaipur		1	1
Kochi	1		1
Rajkot	1		1
Salem		1	1
Surat		1	1
Grand Total	**5**	**12**	**17**

Chapter 5. Conclusion

5.1 Conclusion

India's population is increasing day by day and more people are going toward urbanization, therefore, having a high-water quality for drinking and living must be considered very importantly. Smart city initiative of India illustrates the idea of how the minister wanted to transform 100 cities toward the future.

The discussions in the literature review were about the smart city initiative of India, water scarcity issue has been a challenge for many countries worldwide, water monitoring solution techniques for water quality issues using IoT and finally types of clustering techniques and which one fits my project.

Moreover, the data analysis was done on 614 different monitoring locations in 23 states in India. Using Hierarchical and k-means Cluster Analysis techniques, I got the number of clusters that I can use and the best to fit my data. After analyzing data, 21 cities of the smart city mission were considered in the study and after comparing the water quality data of WHO reference parameters, we got 8 cities only that has the best water quality and eligible to be a smart city.

5.2 Project Deliverables

The focus in this report was to do water quality assessing of the smart city initiative of the prime minister of India. In this report, I suggested whether those are suitable and eligible to be a smart city or not. I used two clustering techniques to cluster the monitoring locations data into different clusters and compare the parameters with the standard parameters settled by WHO using SPSS analysis program. By getting all the data needed, a graph was plotted to visualize the final result where only two clusters out of six are very close to WHO parameters, meaning those two are having the water parameters that meets stranded of drinkable and livable water. By getting the results of this project, urban planners and specially for smart city planners, would be able to see how it is important to follow the WHO water parameters to define the smart cities water quality as not all the cities are eligible of being a smart city for the water quality perspective.

5.3 Recommendations

By the end of my report, I recommend each country to fully understand how to state whether a city is applicable to be a smart city or not from the perspective of water quality as it is very important factor for living in a wealthy city as creatures. India has declared that 100 cities will be in the initiative of smart cities but after analyzing the data, I found that only 8/21 (as of the limitation of data) are having acceptable condition of water quality referring to WHO organization parameters. So, not all cities are applicable to the initiative and urban planning leaders must be careful about the water quality in cities as they are an important factor of smart city and suitability initiatives.

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Appendix

Following are the cities which being declared to be smart city in India:

Port Blair	Belagavi	Jaipur
Visakhapatnam	Shivamogga	Udaipur
Tirupati	Hubballi Dharwad	Kota
Kakinada	Tumakuru	Ajmer
Amaravati	Davangere	Namchi
Pasighat	Bengaluru	Gangtok
Guwahati	Kochi	Tiruchirapalli
Muzaffarpur	Trivandrum	Tirunelveli
Bhagalpur	Kavaratti	Dindigul
Biharsharif	Bhopal	Thanjavur
Patna	Indore	Tiruppur
Chandigarh	Jabalpur	Salem
Raipur	Gwalior	Vellore
Bilaspur	Sagar	Coimbatore
Naya Raipur	Satna Ujjain	Madurai
Diu Dadra & Nagar	Nashik	Erode
Haveli	Thane	Thoothukudi
Silvassa	Greater Mumbai	Chennai
New Delhi	Amravati	Greater Hyderabad
Municipal Council	Solapur	Greater Warangal
Panaji	Nagpur	Karimnagar
Gandhinagar	Kalyan-Dombivali	Agartala
Ahmedabad	Aurangabad	Moradabad
Surat	Pune	Aligarh
Vadodara	Pimpri chinchwad	Saharanpur
Rajkot	Imphal	Bareilly
Dahod	Shillong	Jhansi
Karnal	Aizawl	Kanpur
Faridabad	Kohima	Prayagraj
Dharamshala	Bhubaneshwar	Lucknow
Shimla	Raurkela	Varanasi
Srinagar	Oulgaret	Ghaziabad
Jammu	Ludhiana	Agra
Ranchi	Jalandhar	Rampur
Mangaluru	Amritsar	Dehradun

Smart cities included in the analysis Water data used:

Smart city name	Number of monitoring locations
Guwahati	6
Muzaffarpur	1
Patna	1
Chandigarh	1
Bilaspur	1
Ahmedabad	3
Surat	2
Rajkot	2
Srinagar	1
Bengaluru	4
Kochi	1
Bhopal	3
Indore	5
Jabalpur	6
Amravati	1
Shillong	1
Jaipur	1
Udaipur	8
Salem	1
Jhansi	1
Rampur	1