Visualization of Dengue Cases in Singapore

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I. Introduction / problem statement

Dengue (also known as break-bone fever) is a disease that affects humans and is caused by a mosquito-carried virus (World Health Organization, 2023). The virus, more specifically, is called dengue virus (DENV) and it is mostly the dark-colored Aedes *aegypti* mosquitoes that humans get infected by. Not all people that get infected by dengue show any symptoms or just get mild symptoms, but those who do typically experience high fever, severe headaches, or vomiting. The majority of infected people get better after a week, but some might be unfortunate and develop severe dengue which in that case they need hospital care. Typical symptoms of severe dengue involve rapid breathing, blood in vomit or stool, or worst case, even death. Individuals that have gotten infected before, infants and/or expectant mothers have an increased risk of developing severe dengue.

The World Health Organization (2023) states that there were 5.2 million reported cases of dengue worldwide in 2019, which showcases that dengue is a global burden. Additionally the numbers do not show the real picture because of either misdiagnosing or under-reporting, as many cases are asymptomatic or mild and self-managed as stated before. Estimates suggest there are 390 million dengue infections annually, with 96 million showing clinical symptoms. Furthermore, approximately 3.9 billion people are at risk of dengue infection. The risks primarily reside in Africa, the Americas, the Eastern Mediterranean, South-East Asia and the Western Pacific. Asia is the most infected region with the bulk of the global burden, accounting for about 70% of cases (World Health Organization, 2023). However, dengue is also spreading to new regions such as Europe, which might develop to be a future concern as climate change is prominent.

II. Motivation

Singapore's tropical climate provides the perfect breeding ground for Aedes mosquitoes. Consequently, the country is highly prone to dengue outbreaks. In 2020, at the height of the COVID-19 pandemic, dengue claimed more lives than the pandemic that had instilled widespread fear, resulting in 32 fatalities. (Khalik, 2020)

Controlling the spread of dengue is crucial to preventing epidemics and safeguarding public health. This concern extends beyond health alone; dengue outbreaks can strain healthcare systems, impact productivity, and affect the overall well-being of the population. Therefore, monitoring and addressing dengue cases is vital to curbing its impact on both health and society.

Utilizing data visualization techniques to depict the historical progression of dengue cases within Singapore enables its citizens to gain a clearer understanding of the virus's transmission rate and its geographical spread across the country. Furthermore, it underscores the significance of personal protection through mosquito repellents, emphasizing the importance of safeguarding oneself against disease and mosquito exposure. Singaporean citizens are the primary target users in this context, but further stakeholders that benefit from data visualization techniques revolve around government health agencies, healthcare professionals and policymakers.

III. Literature review

In 2016, Singapore launched a project named Project Wolbachia (Dzeviatau et al., 2022) in an attempt to curb the population of the Aedes aegypti mosquito, also known as the yellow fever mosquito. Male Aedes aegypti were infected with the Wolbachia bacteria and released around cities and neighborhoods to mate with females, resulting in the production of eggs that do not hatch and subsequently reducing the population of the Aedes mosquitoes..

By 2023, the project had successfully decreased the population of the Aedes mosquito by more than 90% in major residential areas such as Tampines, Yishun and Choa Chu Kang. Additionally, dengue cases have also decreased by over 88% for the areas which have not been covered by the project. The National Environment Agency (NEA) has plans to continue the expansion of the project to more areas in the coming years.

Recently, in a report by The Straits Times on September 27, there has been an increase in the number of dengue cases, with 330 cases reported between September 10 and September 16, up from 198 cases reported in August 13 to August 19. The warmer months have resulted in the increase of dengue transmission in Singapore as the Aedes mosquito develops and multiplies quickly during this period.

NEA's main webpage provides an overview of the dengue clusters in Singapore. It also shows the areas with higher density of the Aedes mosquito and where the hotspots are. However, we felt that more visualizations can be done to help people to better understand the information shown.

What we as a group deemed as lacking in the current environment of data visualization when it comes to dengue in Singapore will be further elaborated here. We identified that we currently have no predictability of potential outbreaks and therefore; our main goal of this project is to provide people with a clearer understanding of dengue occurrences, how a dengue cluster can spread and the extent of its severity. This will be done by various means of visualizations.

To understand and reach our goal of this project, we first have to look into various factors that correlate with the rising outbreaks. The report by The Straits Times hints that months with warmer temperatures is a factor leading to higher transmission of dengue in Singapore as a consequence of Aedes mosquitoes population increasing during those months. In this report we are going to further analyze how temperature affects higher transmission of dengue, as well as other linking factors such as rainfall to possibly uncover trends and patterns. Moreover, we want to explore other visualizations to further broaden our understanding about dengue in Singapore as previously stated.

IV. Datasets

The Singapore Dengue dataset, compiled by Team SGCharts from data provided by the National Environmental Agency (NEA), spans a five-year period, running from May 2015 to November 2020. The dataset is collected twice a week and comprises of number of dengue cases, street address, geographic coordinates (latitude and longitude), cluster number, number of cases within onset in the last two weeks, total cases in cluster, date (YYMMDD format), and month number. Initially existing as a PDF, the dataset was transformed into CSV files for convenient access. Upon download, the dataset is presented as a compressed file containing 257 individual CSV files, each delineating dengue clusters for specific dates. While the dataset is not perfect since the conversion from PDF may cause dirty data such as wrong, misspelled, or duplicate addresses, our team is planning to clean it so that it becomes usable for visualization. The link to the website is the following: https://outbreak.sgcharts.com/data.

Given that the dataset solely offers address details, longitude, and latitude as geographical indicators, our team resorted to the GIS Map website to procure a spatial file delineating the subzone boundaries of Singapore. Specifically, Singapore's Urban Redevelopment Authority (URA) divides the city into 323 subzones, each typically centered around pivotal points like neighborhood or commercial centers. Acquired in the GEOJSON format, this file would enable us to later map the dengue cluster locations onto the most granular spatial unit within Singapore.

In addition, we acquired a dataset about Singapore's weather, from Kaggle. The data itself was obtained from Meterological Services Singapore, but has been combined from 2014 to 2020 for the locations of Ang Mo Kio, Changi and Tuas South respectively. The reason was these 3 locations contained the least amount of missing data, compared to all other locations. The dataset contains fields like station, year, month, day, maximum, minimum and average temperature, rainfall and wind speeds. The link to the dataset is https://www.kaggle.com/datasets/cyanaspect/singapore-weather?select=angmokio.csv

With these datasets, our team will:

- Analyze the trend of dengue in Singapore over the years
- Discover dengue clusters in Singapore and how severe they are, whether they have recovered, gotten worse over the years, etc
- See if there is correlation between dengue and factors such as weather, etc
- Evaluate the effectiveness of project Wolbachia in suppressing the number of dengue cases

V. Tools and resources used

To effectively visualize the data on dengue cases in Singapore, Tableau will be our tool of choice. Its ease of use and wide range of features make it the perfect tool to analyze geographical data. The dataset provides essential information on the number of cases for specific locations all around Singapore; Tableau allows us to cross-reference this large volume of information to make valuable observations and pinpoint the exact location of outbreaks through accurate geospatial mapping. Furthermore, Tableau's interactive dashboard feature allows for real-time data visualization, simplifying the complex reasons behind dengue clusters and their increase in specific periods of time.

For the purposes of data manipulation and cleaning, we opted to use python with pandas to conduct exploratory data analysis (EDA). For minor changes, we made the edits in the csv file directly. We understand that there are other tools, like Tableau Prep that could help us to achieve the same goals. However, we chose python with pandas over Tableau Prep as we have experience learning and using it in the Analytics Foundation course, and we are not familiar with Tableau Prep. In the interest of time and to ensure that we spend adequate time on visualizations rather than cleaning data, we stick to the tools that we are familiar with, instead of learning new ones.

VI. TASKS

In our comprehensive visual analytics project focusing on dengue cases in Singapore, our team will employ a multi-level approach to gain valuable insights and create data visualizations that are both informative and useful.

Geospatial analysis is a fundamental aspect of our project, as it allows us to map the locations of dengue cases across Singapore. This analysis is essential for several reasons. It enables targeted resource allocation, directing medical resources and preventive measures to areas with the highest risk of outbreaks. By identifying clusters and hotspots of dengue occurrences, it provides crucial epidemiological insights into the spread and potential causes of the disease. This knowledge helps in predicting outbreaks and implementing proactive measures such as mosquito control and public health awareness campaigns. Analyzing the spatial distribution of dengue cases informs public health policies, contributing to more effective strategies for disease prevention and control. Moreover, this data visualization raises community awareness by highlighting prevalent risks in specific areas, encouraging individuals to take personal preventative measures to combat the spread of the disease.

In conjunction with geospatial analysis, our team will conduct temporal analysis by analyzing the trend of dengue in Singapore over the years. This temporal dimension is crucial for assessing the effectiveness of control measures and for predicting future outbreaks. It enables us to track the progression of cases over time, identifying trends, seasonality, and notable fluctuations. Temporal analysis is indispensable for understanding the long-term patterns and dynamics of dengue in the region.

Cluster analysis is another vital aspect of our project. It allows us to examine the severity of dengue clusters, their evolution over time, and whether they have gotten better or worsened. This analysis helps uncover the underlying factors contributing to the formation and persistence of these clusters. Such insights are valuable for decision-makers in developing targeted strategies to contain the disease.

Correlation analysis will then focus on exploring the potential relationships between dengue cases and environmental factors, such as temperature and rainfall in Singapore. As the transmission of dengue is directly influenced by these environmental factors, visualizing the correlation between them is imperative. It confirms hypotheses and identifies critical trends, like dengue peaking in August, one of the hottest months with the least rainfall. Discovering such patterns will empower authorities to better understand and coordinate efforts to combat dengue effectively, especially in a changing climate.

We will also conduct recent cases analysis to understand the dynamics of new dengue cases and visualize their characteristics. By doing so, we gain insights into the demographics, geographic distribution, and emerging trends in recent cases. Visualizations created in Tableau will illustrate the characteristics of these cases, making it easier to communicate our findings to a wider audience.

Finally, we will explore the total cases across the years in Tampines and Yishun to see how Project Wolbachia has impacted dengue cases in those regions. We will dive deeper into each phase of the implementation process to understand whether the project was successful in decreasing the number of dengue cases. This visualization will allow us to gain a better understanding of how effective dengue control measures are compared to the Wolbachia method.

Through these various analytical approaches, our project aims to provide a comprehensive and actionable understanding of dengue in Singapore, supporting public health policies and strategies to combat the disease effectively. These analyses and visualizations will not only benefit Singapore but also serve as a valuable model for similar studies in regions grappling with dengue and other vector-borne diseases.

VII. Method

Unfortunately, real life datasets often come in formats that may not be suitable for analysis immediately and may be missing data. Hence, in order to create the visualizations that we want, we have to process and clean the data. The dengue dataset spans from May 2015 to November 2020, collected biweekly, with each CSV file representing biweekly data. However, having data scattered across numerous files poses a challenge in terms of accessibility and manipulation for visualization purposes. To consolidate the 257 CSV data files, we initiated the process by creating a dedicated folder on the Desktop and organizing all the CSV files within. Then, accessing the computer terminal, we directed our working directory and employed a command line to merge all these files into a single, comprehensive CSV file.

Furthermore, the "date" feature format is non-standard, in YYMMDD, making it challenging for Tableau to recognize it as a date. Instead of devising a calculated field to convert this data format to a recognizable one within the software, we opted to directly alter it in the combined CSV file. This process retained the original format in one column while introducing a new column, "Date Modified," to hold the date in YYYYMMDD format. We did this as we needed the date to be used as a common column for joining or creating relationships between datasets, and Tableau cannot join on calculated fields. This was done using the concatenate function in csv. E.g. if the date is 150703 in the "H" column, the formula =CONCATENATE("20", LEFT(H2, 2), MID(H2, 3, 2), RIGHT(H2, 2)) adds 20 in front of the existing date value. We simply used ctrl and mouse click to drag and apply the formula for all the rows.

In addition, the Singapore weather dataset was split according to the three locations; Ang Mo Kio, Changi and Tuas South. Each of these files also had missing temperature and rainfall data in some years. Thus, we had to use python with pandas to clean it. We conducted exploratory data analysis (EDA) by loading the csv files onto a Jupyter Notebook, getting the data type and structure of the dataset, seeing if there is missing data and summary statistics with methods such as .info() and .describe(). Then, for each year with missing temperature or rainfall data, we constructed a histogram using the .hist() method to see the distribution of temperature and rainfall data points, in order to determine an appropriate method to fill the missing data. For example, if the distribution is symmetric, we would get the mean of the data points and use it to fill the missing cells. If the distribution was skewed, we would use the median. We decided to clean each year's data individually instead of getting the average or median of all the years combined in case of any seasonal variations or year specific trends. This is to ensure that our data is accurate and reliable. Once cleaning for the 3 files were done, we took the temperature and rainfall columns of the 3 files and averaged it out in another csv file. This would represent the mean temperature and rainfall across the 3 locations. We also modified the date format to match the Dengue dataset's date format so that we can create joins/relationships in Tableau.

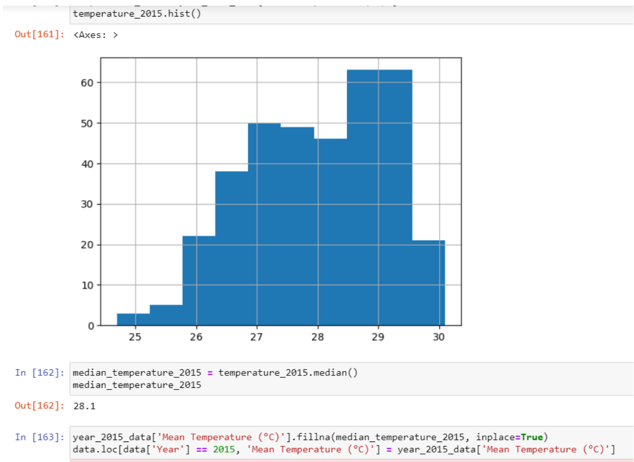

Figure 1: Distribution of temperature data in 2015 using a histogram, and code to clean the data

As the dengue data was captured on a biweekly basis and the weather data on a daily basis, we created a relationship between the dengue and weather dataset in Tableau instead of using a join. This is to prevent the weather dataset from losing precious data points if it were to join with the dengue dataset, due to the difference in collection frequency. Preserving the data points allows us to paint a more accurate picture of the situation.

To create the set of dates required to display the impact of the Wolbachia Project in Tampines and Yishun, we created a location set to group the two regions together using the dengue dataset we have. Then, we combined the data for the different dates ranging from Phase 1 to Phase 5 by creating a calculated field to group the dengue cases for each Phase of the project together. The issue we faced with this method was being unable to find the right code required to group the dates together. We had to sift through many different methods online to find what we needed.

Similarly, we used Tableau to attach the GEOJSON spatial file to the processed main dataset. This involved a join operation that intersected the "Geometry" field from the subzone boundaries file and a join calculation using the MAKEPOINT function with the "longitude" and "latitude" attributes. The primary challenge was the limited geographical information in the original dataset. Initially, the map presented dengue cases as circles, leading to a cluttered and unclear visual for users. Incorporating subzone boundaries into the dataset enabled the creation of a more illustrative, filled map. This updated visualization provides an easier way to discern areas with higher case numbers via tooltips and color mapping.

VIII. VISUAL ANALYSIS RESULTS AND DISCUSSIONS

First, our geographical visualization illustrates the total cases recorded from July 2015 to November 2020, utilizing a diverging color scheme to indicate case density. (Figure 1) The color gradient ranges from green, indicating the lowest occurrence, to red, representing the highest. Although a sequential colormap may seem better due to numerical data, we opted for a diverging colormap due to the typical association of red with danger and green with safety. This makes it intuitive: regions marked in red indicate a higher number of cases, prompting the need for increased precautions. Hovering the cursor over different subregions reveals specific case details such as pin numbers and names.

The results indicate a higher prevalence of dengue cases in Singapore's East and North regions. Particularly, clustering is observed predominantly in Geylang in the Central region, followed by Bedok in the East, Serangoon in the North-East, and Woodlands in the North.

This observation aligns with established research backed by the National Environmental Agency (NEA), which indicates that higher dengue transmission rates occur in densely populated, urban areas. Conversely, the western region of Singapore, being more forested and with a lower human population density, exhibits fewer cases, making it a less conducive environment for the epidemic vector.

In addition, Dr. Borame Sue Lee Dickens, a senior research fellow at the NUS Saw Swee Hock School of Public Health, highlighted that the architecture of older buildings in Singapore offers ample opportunities for the accumulation of small pools of water. These buildings often exhibit more crevices due to wear and tear, along with now-defunct design elements that create environments conducive to mosquito breeding. For instance, the holes in buildings originally intended for bamboo poles, used for hanging laundry outside windows in high-rise flats, are potential breeding sites for mosquitoes. In our map visualization, we observed that regions like Geylang are notably susceptible to dengue outbreaks, which correlates with the previously mentioned reason in relation to the presence of older buildings in these areas.

Consequently, inhabitants residing in regions highlighted as red or orange on the map should exercise additional caution and place greater emphasis on personal protection.

Additionally, the Singaporean government should focus its resources and disease control efforts on these areas to prevent and reduce dengue.

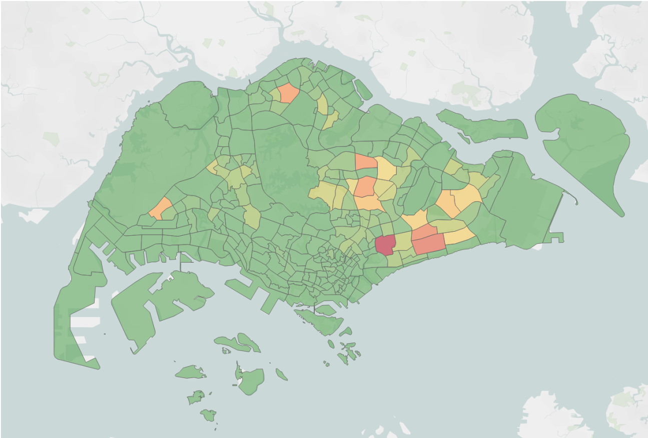

Figure 2: Geospatial Analysis of Dengue Cases in Singapore

Secondly, we wanted to take a closer look at the temporal aspect of dengue cases. These two visualizations allow us to observe the evolution of dengue cases and of the total number of clusters through the years.

Firstly, we created a combined chart displaying the number of clusters for each year as bars as well as a line representing the total number of dengue cases through the years, between 2015 and 2020.

Then we wanted to take a closer look at the variations of dengue numbers across shorter periods of time. We created a square mark visualization with a green-to-red color scheme, representing the level of dengue cases, for each month. For example; in the month of December 2016, which is colored in green, only 194 cases were declared whereas in December 2020 there were 9777 cases. The corresponding square is therefore colored in red.

We created these 2 visualizations with the aim to identify potential patterns in the progression of dengue cases over time such as trends, seasonality or any notable fluctuations. Our analysis revealed a drastic drop in dengue cases between 2016 and 2017, which can be explained by the success of project Wolbachia which, launched in 2016. The number of cases remained relatively low in 2018, but picked up strongly again in 2019 and 2020, partly because these years were on average warmer and more humid than the previous. However, the main reason is the strong correlation between dengue cases and the covid 19 pandemic. Indeed, most mosquito bites happen at home and with the high number of people having to work from home due to health guidelines ; the risk of being bitten by the mosquitoes that carry the disease highly increased.

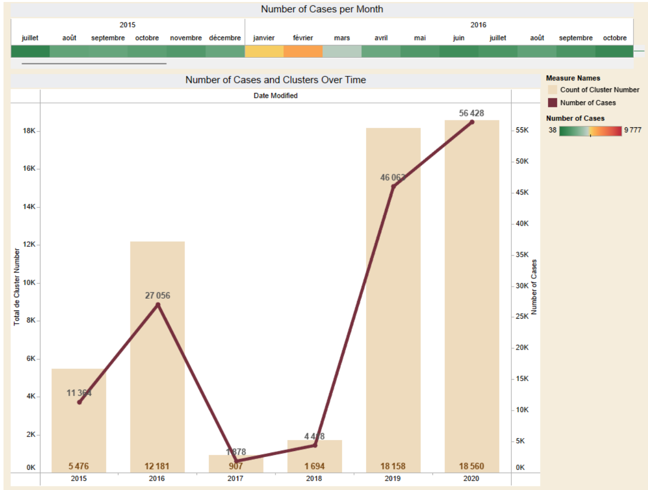

Figure 3: Bar and Line Chart of Number of Cases and Clusters Over Time

Looking at the Dengue, Temperature and Rainfall chart, it appears that the month of August has the most dengue cases and it is the 2nd hottest month with an average temperature of 28.7 degrees celsius, just behind May at 28.9 degrees celsius. August also has the least amount of rainfall, along with February. One would assume that both temperature and rainfall have a positive correlation with the number of dengue cases, and the more rainfall the better as it creates more or enhances the mosquito breeding sites. With more aedes mosquitos being bred, it would increase the risk and transmission of dengue, which would increase the number of cases. However, according to the National Center for Biology Information (NCBI), excess rainfall can flush out the mosquito breeding sites and destroy them, but also create new sites as well (Benedum et al. 2018). The risk of dengue also increases when temperature goes up to 29 degrees celsius, but decreases afterwards. Hence, we observe that in November and December where the temperature is the coolest at around 27.5 degrees celsius and with the most rainfall of all the months, they have the least amount of dengue cases. As rainfall starts to decrease in January, the dengue cases rise.

This is just our observation and there are likely many other factors, such as humidity, mosquito population at a point in time, whether precautionary measures such as clearing stagnant water are taken, time lag between the change in temperature and rainfall between the months that can influence the transmission of dengue. However, these data are not feasible or impossible to collect, hence we make do with temperature and rainfall data.

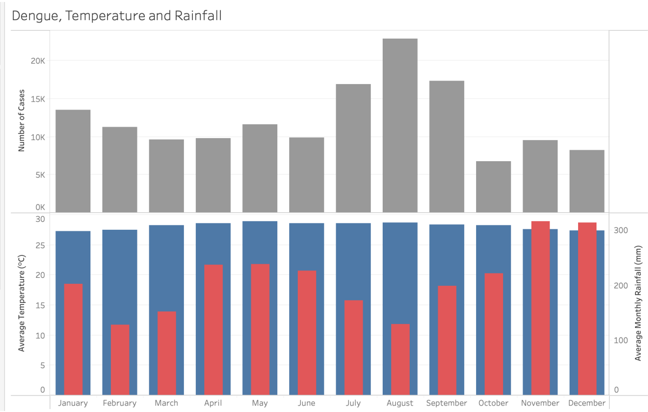

Figure 4: Dual Axis Bar Chart of Dengue, Temperature, and Rainfall

Lastly, the final visualization displays the dengue case trends in Tampines and Yishun regions over the years. Specifically, it highlights a phase of Project Wolbachia focusing on areas with prior dengue outbreaks and high Aedes mosquito populations. Notably, the orange area corresponds to Phase 1 of the project which took place from October 2016 to January 2017. A closer examination reveals the monthly case counts. An evident drop in cases is observed in Yishun. As Phase 1 concluded, there was a noted reduction of over 50% in the Aedes mosquito populations in the release sites. However, in the upcoming phases, the trend might not look quite the same as Phase 1.

In Phase 2, beginning from April 2018 to January 2019, they improved their release methods and achieved >70-80% suppression of the Aedes mosquito population in the release sites. However, the cases in Yishun have spiked back up between August and October of 2018. While they were able to decrease the population of Aedes mosquitoes, the number of dengue cases were still rising in the region.

In Phase 3, beginning from Feb 2019 to October 2019 they achieved >90% suppression of the Aedes mosquito population in the study sites. However, cases in Tampines increase significantly during this testing period. Similarly to Phase 2 of the study, a decrease in the population of the Aedes mosquitoes did not necessarily mean that there would be a decrease in the number of dengue cases.

Phase 4 & 5, beginning from November 2019 to July 2020 and onwards, Tampines continues to maintain a high level of dengue cases despite the decrease in Aedes population in the area. As a result, while the project conducted by NEA had been able to steadily decrease the population of Aedes mosquitoes, they might be targeting the wrong areas to release the mosquitoes as the total cases per month in the region were still very high.

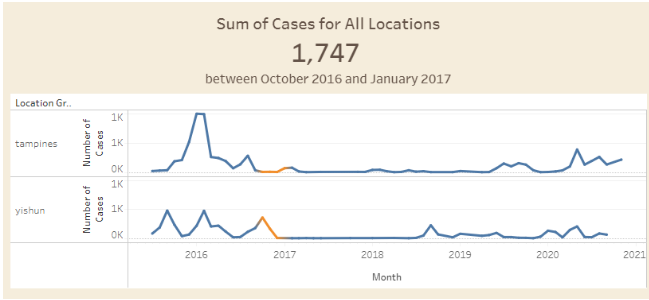

Figure 5: Line Chart of Number of Cases in Tampines and Yishun over the years

IX. DEMO OF VISUAL ANALYTICS SYSTEM

X. PROJECT MILESTONES

To analyze the data on dengue cases in Singapore, our team will go through the following steps:

A. *Collect and clean the data* : to initiate the project, our team will make sure that each csv file constituting this dataset is well structured and relevant so that the data is uniform and ready for analysis.

B. *Gain basic insights* : explore the data in Tableau to have a first overview of patterns and correlations in dengue cases.

C. *Visualization* : map dengue cases as a foundation for our analysis and display the distribution of cases by location. Then proceed with a temporal analysis to investigate potential seasonality and track dengue trends. Finally, deeply analyze clusters and identify the factors that contribute to their formation. After going through each of these aspects, we can overlap them on charts to have a better understanding of the matter.

D. *Dashboard creation* : display the different maps and graphical representations created and add interactive features to have a clear and accessible visualization.

E. *Report observations* : draw conclusions from the dashboard to deliver our findings on the evolution of dengue cases in Singapore, along with the factors and attributes which influence and explain it.

V. CONCLUSION AND FUTURE WORK

In our visualization, our study highlighted significant findings about dengue cases in Singapore. The densely populated urban areas in the east have a higher incidence of dengue. Excessive rainfall plays a crucial role in reducing mosquito breeding sites and, subsequently, dengue cases. Interestingly, reducing the Aedes mosquito population doesn't consistently decrease dengue cases in the region.

Our dataset covers the period between 2015 and 2020. Examining longer-term trends can enhance our understanding of how climate change and urban development impact dengue transmission.

Developing advanced predictive models that incorporate the variables utilized in this study can aid in establishing early warning systems and targeted interventions to reduce dengue cases in Singapore.

In our future efforts, integrating D3.js into our visual analysis reports can significantly enhance our data representation and storytelling. By incorporating D3.js, we can elevate the interactive and dynamic elements within our visualizations. This library allows for the creation of compelling, real-time graphics, charts, and maps that respond to user interactions. Its use can contribute to clearer communication of complex data patterns, making the presentation more engaging and comprehensible to a wider audience. D3.js also enables the generation of more flexible and customizable visualizations, empowering us to adapt and modify the graphics efficiently based on the evolving data needs and analytical requirements. Its implementation aligns with modern visualization practices, ensuring that our reports remain at the forefront of conveying insights from data.

Furthermore, the dashboard requires additional visualizations to explore the relationship between dengue cases and Singapore's population density, as well as the correlation between building age and the incidence of cases. These would serve to augment the existing findings and discussions in our geospatial analysis, offering viewers clearer insights into the subject matter.

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