IMMIGRATION SCENARIOS IN CANADA

A Choice That Will Define Our Future

COLLABORATIVE PROJECT FINAL REPORT | ID# 1925

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ABSTRACT

"Century Initiative envisions a Canada at scale, with 100 million people in 2100 working together to achieve our shared potential. We see a Canada that's a global leader, celebrating ambition and innovation, fully leveraging its talent and diversity, and offering an example to the world of broadly shared prosperity." This vision statement from the Century Initiative website inspired us, Collaborative Project Group 1925 (CPG1925), to create new web-based tools to illustrate what Canada would look like with 100 million inhabitants. The new tools are based on a previous tool found on the Century Initiative website, with data obtained from Statistic Canada's 2016 census and projections obtained directly from Century Initiative. Population and GDP figures have now been associated with smaller enumeration units in order to illustrate projected changes under 3 different immigration scenarios: 0 Immigration, Status Quo, and 100 Million. The re-developed tools include various interactive components to allow the user to navigate the projected landscape and view various statistics associated with the queried population scenario, in a variety of ways. One tool uses 3D to illustrate changes and another shows population density changes by colour in a choropleth map. The results complement and expand upon the current tool's illustrative capacities by showing an example of where future Canadians might live, and how this future population would affect the country's Gross Domestic Product (GDP). The tools could be updated with future data from a future census, future projections, or more specific information regarding local areas, as this data becomes available.

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1.0 INTRODUCTION

1.1 PROJECT BACKGROUND

Based upon current low birth rate calculations, Canada's future generations are on track to inherit a country with a declining population which will directly result in a country with a decreased Gross Domestic Product (GDP). Century Initiative is a non-profit organization looking towards increasing Canada's population to 100 Million unified by diversity and prosperity. It is their hope that by driving national discourse on strategic population growth and stimulating change through coordinated action and thought leadership, Canadians can build a prosperous, bold and dynamic future (Century Initiative, 2019).

1.2 PREVIOUS WORK DONE

In 2016, Century Initiative launched an online tool for Canadians that visualized the benefits of immigration in relation to GDP. This initial tool, titled 3 Scenarios for Canada, illustrates a rising or falling GDP bar chart on the background of a map of Canada. Users may select from one of three immigration scenarios, and a projected year's values. The three immigration scenarios are *Scenario 1*: Zero Immigration Scenario, *Scenario 2*: Status Quo Immigration Scenario, and *Scenario 3*: Hundred Million Scenario. Essentially, these scenarios represent three immigration scenarios and their theoretical influence on Canada's GDP. Canada under a 'Zero Immigration Scenario' would suffer a severe decline in GDP growth, while under the highest immigration scenario, Canada would benefit from a substantial increase in GDP growth.

In addition to selecting the Immigration Scenario, users may select one of five years to visualize the projection for that year under the selected scenario. The tool begins with base values derived from Statistics Canada's 2016 census and increases (with the exception of the first year interval) by twenty-five years. The year intervals following the 2016 base year are 2025, 2050, 2075, 2100.

1.3 CLIENT INFORMATION

In 2019, A Burton Cartography (ABC) and CPG1925, through Fleming College's, Frost Campus, APST62-2019 course, partnered with Century Initiative to build upon their tool. The primary point of contact was Yohana Mebrahtu. The primary method of contact was through her professional email yohana.mebrahtu@centuryinitiative.ca. The organization is located at #1710-2 Bloor Street West, Toronto, Ontario M4W3E2.

1.4 PROBLEM DEFINITION

At the project's onset, Century Initiative expressed an interest in expanding the tool to incorporate more interactivity within smaller divisions of Canada. It was proposed that Canada be illustrated at three different levels, Federal, Provincial and major metropolitan. These study areas are exhibited in **Appendix C: Figure 1 and Figure 2**. It was a necessity that the combination of population in comparison to GDP be maintained, so it was determined that the population would be represented through a typical chloropleth style cartographic rendering, and the GDP would be represented in the third dimension. The user will be able to zoom in to view the varying study areas of Canada. The tool will begin on Canada and gradually transition from the Federal view, to the Provincial view and lastly to the major metropolitan areas.

Century Initiate outlined a few parameters for the anticipated tool. It was requested that

- The tool maintains the current functionality of allowing the user to select from the three scenarios, also allowing the user to select either the base year, or from four projections.
- Due to the structure of the organization, the tool must be provided to the organization at no-cost.
- The tool must be adaptable for integration into the organization's website, ideally structured as an independent block of code that may be placed onto the existing tool's host web page.

1.5 OBJECTIVE - PURPOSE

The overarching goal of the project is to redevelop Century Initiative's 3 Scenarios for Canada tool. The redeveloped tool with enable a broad range of potential users to visualize the benefits associated with an increased population derived from high immigration quotas. From here on in, Century Initiative will be referred to as the Client.

Our primary ambition is to utilize an interactive web-based map which will illustrate Canada at varying zoom levels in the 3rd dimension. As an example, imagine a map of Canada. In this map, each province is coloured a slightly different colour which represents the population. Now envision the province rising in accordance with the Province's contribution to Canada's total GDP. Years and scenarios will remain available for the users to select and will appear as a slider for year selection and radio buttons for scenario selection.

External restrictions limit certain aspects of the project. The project must be supplied to the Client at no-cost. This criteria is met with Mapbox's exclusive opportunity for non-profit organizations to host maps through Mapbox services at no cost. This enables the Client's users to not only access the new tool, but also enables the Client to host documents and files externally. By removing the need to host GeoJSON files on the server by hosting the files through Mapbox's vector Tileset, the Client can expect very few costs associated with the tool. The only fee incurement that the Client will notice may be a small hosting fee for an additional HTML, CSS, JS, and JSON files. It should also be anticipated that final product may not undergo any future revisions as in-house staff are limited and the organization lacks any permanent, full time information technologists. This means the tool must undergo rigorous QA/QC testing prior to release.

1.6B OBJECTIVE - SPECIFIC

Specifically, the project will meet 5 criteria established by the faculty on which a grading strategy may be applied to. The project will meet 5 elements of the 6 course requirements. These are specified below in an annotated format:

1. Data Acquisition and Pre-Processing.

   Due to Century Initiatives inability to provide the original data, the authors must source the data independently.

2. Database Design and Processing

   Data will be amalgamated and processed with the correct formulas to project federal, provincial and metropolitan data correctly and stroed in relative file formats that the Client may access, alter, and employ as needed.

3. Web Technology

   Through the use of Mapbox's feature services and APIs, the author will publish the map online, making it accessible for wide range of users to interact with the final tool. These APIs, JavaScript libraries and feature services will enable a multitude of options and visualizations to occur. In-house web development techniques will be employed to utilize HTML, CSS, JSON, and JS files. This will all be provided for no cost to the client.

4. Programing and Customization

   Customization will be obtained through considerable use of JavaScript. It will be necessary to create additional JavaScript functions to manipulate data for use within MapBox's Libraries. The customization will frame the essential functions needed for the Client to utilize the new tool.

5. Visualization.

   Through the programed customizations, the final product's visualization will effectively communicate the Client's main objective: promoting more immigration through an illustrated GDP increase based upon an increased population.

1.7 LITERATURE REVIEW

The following sources of information proved invaluable during the development of the final product. As such, the sources are annotated below to provide a foundation on which the reader may form an understanding of not only the tool, but also some of the more intricate functions, tools and scripts that will be discussed throughout the report. The reviews are situated in a logical order.

1.7.1[B] CENTURY INITIATIVE: 3 SCENARIOS FOR CANADA (CENTURY INITIATIVE, 2016)

Century Initiative's current tool to exhibit population growth in comparison to GDP. This tool enables users to select from three scenarios which range from a no immigration policy, to our current immigration policy, and a high scenario where Canada's population reaches 100 Million inhabitants by year 2100. These statistics have been derived from professional mathematicians and cannot be reproduced by the authors of the report. The original formula has been created centered around the Cobbs-Douglas Economic formula. These scenarios values have been derived from two sources, primarily the Conference Board of Canada's publication in 2016 (Conference Board, 2016) which highlights various demographic milestones (cited under Conference Board of Canada, 2016) under the 'Status Quo Scenario' and 100 Million Scenario. The tertiary milestone, Zero Immigration Scenario has been obtained from the United Nations report of global demographic projections, published in 2015 (United Nations, 2015). Although both reports detail alternative immigration scenarios, it is only of interest to focus on the primary three scenarios outline. A view of the Century Initiative's current tool can be found in **Appendix A: Figure 1. Century Initiative's current tool.**

1.7.2[B] VECTOR TILES (MAPBOX, 2019) AND MANAGING LARGE DATA FILES FOR MAPBOX STUDIO WITH TIPPECANOE (MAPBOX, 2019)

This document provides an opportunity to better understand the use of vector tiles versus GeoJSON. Mapbox has integrated a repository into each Mapbox member's account that enables developers to host their GeoJSON files online. This enables the end-user to experience faster transitions through less loading time. Vector tiles are similar to image tiles for web mapping, however, are customizable and easier to upload. Through a simple drag and drop function, GeoJSON becomes a vector tile service, referred to as a Tileset. This enables the developer to quickly apply changes or add new data with ease. All Tilesets have a replace function, which is the root of the services ability to enable quick changes to data visualization. Vector Tilesets are drawn into a map by setting the source prior to the addition to the Mapbox layer. Both of those functions are drawn using Mapbox's library and are not modifiable.

What is not mentioned through the documentation of Mapbox's Vector Tiles, and Tilesets, is that data must be 5 Mb or smaller for uploads. This is problematic in the sense that larger GeoJSON files are not uploadable. A work around can be found using Tippecanoe. Best run from a Linux command line, such as a command terminal in Ubuntu 16.04 Xenial Xerus. The developer can compress and convert large GeoJSON files into a Mapbox Tileset (.mbtiles file), and upload into the Mapbox Studio's Tileset repository. This allows the developer to upload files as large as 25 GB which is a considerable difference from 5 Mb.

1.7.3[B] EXTRUDE POLYGONS FOR 3D INDOOR MAPPING (MAPBOX, 2019)

This tutorial provided the base on which we would illustrate the rise and fall of Canada's GDP per enumeration unit. Although originally created for 3D building mapping, it was adapted to correlate to just polygons. The tutorial itself underlines the ease in which, through well thought out attribute fields, a web developer can create a multitude of effects. Firstly, the use of a number field, the developer can assign the field to represent the height of the polygon. Although unstated within the tutorial, this numerical field MUST be an integer. This was discovered by the author to be an unrecognized component of the Mapbox's JavaScript library that will not represent fractional, REAL numbers from being represented on the web. Secondly, a developer can assign a colour field within the attributes table of the GeoJSON to visualize the polygon. This visualization technique was substituted for an alternate visualization technique that was implemented into the root of Mapbox's JavaScript function of 3D extrusions. This will be outlined in *Create a gradient line using an expression*. Lastly, through this tutorial, it is illustrated that a developer may also control the opacity of the extruded polygons through the fractional use of 1, and the developer may set the base height to the extruded polygons.

1.7.4[B] CREATE A GRADIENT LINE USING AN EXPRESSION (MAPBOX, 2019)

This tutorial illustrates the application of a color ramp on a line. This was adapted to polygons. The premise of the tutorial illustrates that a variable can be assigned to a colour for visualization. This can then be paired with an expression that extracts the selected features properties assigned to a numerical field within the GeoJSON. This field can be either real or integer, which is unstated. It was determined by the author that whole, rounded numbers were cleaner and easier to categorize. The function illustrated within this tutorial draws from an interpolate function that groups numbers together dependent on the range in which they fall into. For a comparable example, population can be classified into intervals of 100-1000,1001-etc, in which each field will be visualized differently dependent and the developer's selection of colours positioned within the PAINT function of Mapbox's .addlayer script.

1.7.5[B] DOUGHNUT & PIE JAVASCRIPT CHARTS (CHART.JS, 2019) AND DISPLAY A POPUP ON CLICK (MAPBOX, 2019).

This JavaScript library enables web developers to create quick charts and graphs. For this project's purpose, the Doughnut and Pie chart library was used. Data can be hard-coded into this function and is quickly visualized upon the loading of the website. This structure was mirrored and embedded within the Mapbox's popup function. Additionally, the Chart.JS Doughnut Chart function was modified to draw selected features attributes, in particular the selected feature's GDP. This adaptation of dynamic data implemented into a traditionally static field is relatively revolutionary and no documentation exists on this application of data and script. In addition to drawing from dynamically gathered data, the modified function also matches corresponding data based upon the user's selection that draws auxiliary data from JSON. This relates to an inadequacy from Mapbox's .getqueriedfeatures function. Due to the inexistence of documentation on this complicated function, filters have been implemented within the Chart.JS script to sort data based upon user selected features.

1.7.6[B] MAPBOX STUDIO MANUAL (MAPBOX, 2019)

This manual provides an introduction to Mapbox's Studio. The manual also hosts external links to more resources for more specific applications of the Studio, however the manual serves as the base to this feature. With every Mapbox account, a Studio is available to developers. This service enables the customization of basemap features and is useful to not only set basemap features to specific colours outlined by clients, but also enables developers to filter what is visualized in the final product. The Mapbox feature service Datasets allows for developers to create and edit GeoJSON through a web browser setting. The Tileset feature service converts datasets into vector tiles, and may be drawn upon utilizing account specfic URLs, which vary from Tileset to Tileset. These Tilesets may also be loaded into the Studio application to enable more customized basemaps.

2.0 METHODOLOGY

2.0 JASON & LUCAS' METHODOLOGY

This section of the report details how the results that our subgroup of the collaborative project was achieved and highlights the intermediary results that were produced. Table 1 in Appendix B shows the task list used to create our final results.

2.0B METHODOLOGY INTRODUCTION

In order to fulfill the course's required elements, a modified waterfall workflow diagram was created to help map the anticipated processes. **Figure 1: Workflow Diagram (Burton, 2019)** illustrated below outlines the elements met, with supporting examples of the utilities incorporated into each element. Following the workflow diagram, a detailed analysis of each main element will be found.

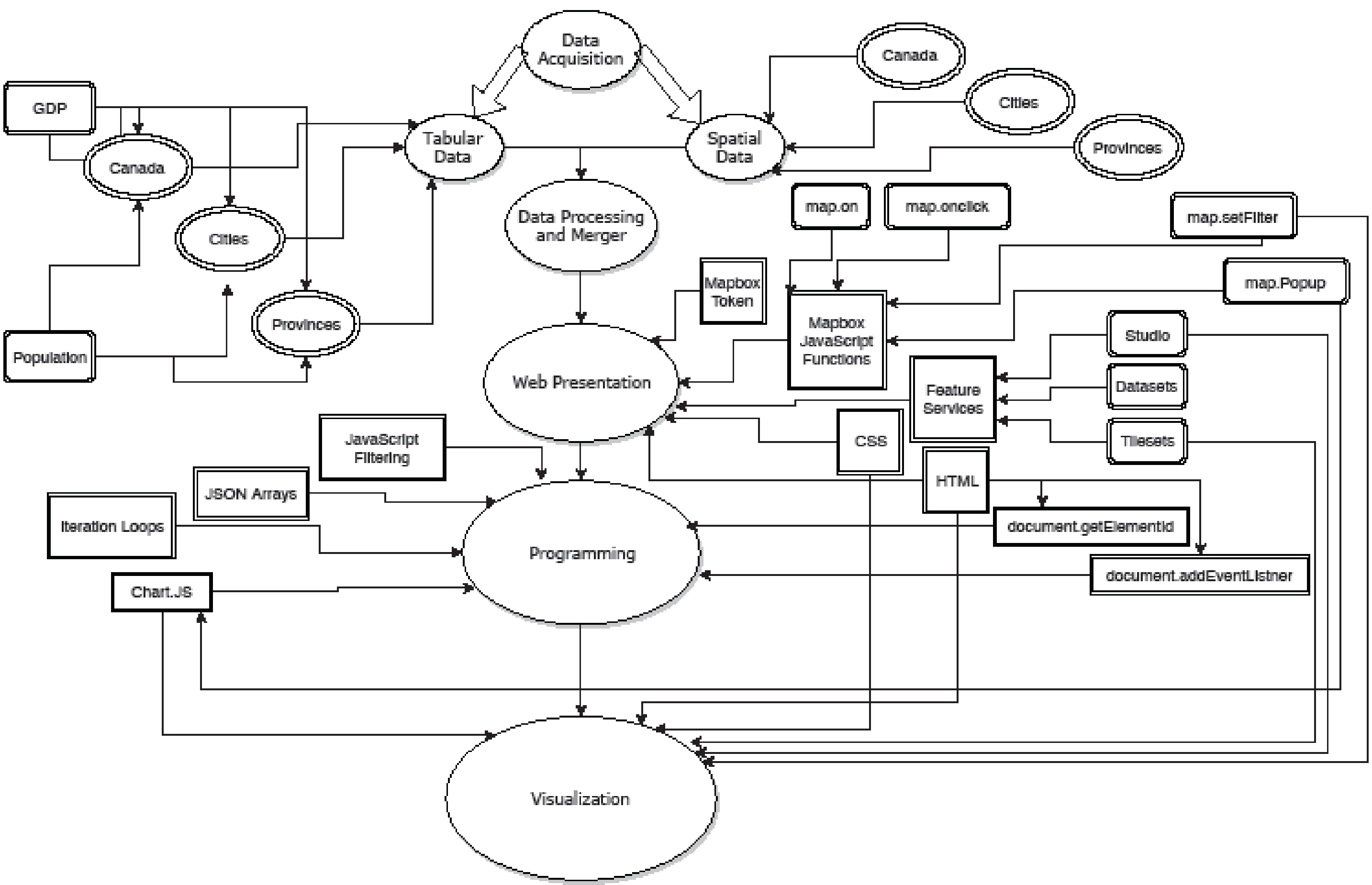

Figure 1: Workflow Diagram (Burton, 2019).

2.1 DATA ACQUISITION & PREPROCESSING METHODOLOGY

2.1.1 DATA ACQUISITION

Upon initiation of this project, all base data was acquired from Statistics Canada. This includes all spatial and tabular data. The tabular data were several excel spreadsheets holding population and GDP data for provinces and census subdivisions of Canada for the year 2016. Spatial data consists of a shapefile that displays all of Canada's census subdivisions as of 2016 and another that displays the Provinces. All unnecessary fields were stripped from the shapefile. This left an object ID, shape field, census subdivision ID, census subdivision name, and shape area.

2.1.2 DATA PREPROCESSING

For each of the 5162 census subdivisions 12 fields had to be added to hold predicted population values for each of the years of interests (2025, 2050, 2075, and 2100). In addition, another 12 fields had to be added to hold data for the population density of the years of interest. For the field creation, each were populated using values generated with the formula capabilities within Excel, using growth rates presented on the Century Initiative's website. Provincial data was manipulated in a similar manner using Excel and predictive rates presented by Statistics Canada, combined with the research presented by Century Initiative.

2.1.1^{B} DATA ACQUISITION AND PRE-PROCESSING METHODOLOGY

Upon project commencement, it was determined that data acquisition consists of two main components: acquiring tabular data and acquiring spatial data. Tabular Data consists of 2016 baseline projection statistics and all population and GDP data for each feature type (Cities, Provinces, Country), whereas Spatial Data acquisition specifically consisted of obtaining the spatial boundary files needed for our final visualization. The details for the data acquisition process follow below.

2.1.1^{B} TABULAR DATA

Base Line Projection Figures

From Century Initiative's original tool, projection figures have been obtained for the application of a more detailed analysis of Canada. The original tool illustrated Canada's growth in population and GDP through 3 scenarios which are called the Zero Immigration Scenario, Status Quo Immigration Scenario, and the 100 Million [population] by 2100 Scenario. These scenarios each start at the year 2016 and illustrate Canada's Population and GDP at years 2025, 2050, 2075, and 2100 is respect to the selected immigration scenario. Averages based off the change from year to year were transcribed as source data. Due to the complexity of the original tool's economic formula, generalized statistics derived from the tool were applied to the federal, provincial and municipal data collected, as per the permission of the Client. The transcribed baseline projections were retained in Microsoft Excel and are saved under the 1925B_Source_Data file name. Upon completion of transcription, data underwent a QA/QC check to ensure that data was recorded correctly. This data has been included in this report and can be found in **Appendix D, Table 1.**

GDP Data

Baseline GDP data was obtained from two sources. 2016 provincial and federal GDP data was downloaded from Statistics Canada. Following the data obtainment, the files were converted from .csv to .xlsx. Proceeding the conversion, data was reviewed, and all unnecessary fields were removed from the source data files. This data has been included in this report and can be found in **Appendix D, Table 2.** Metropolitan GDP data was obtained from Statistica. This data was not available for download and required to be transcribed from the website. This was due to the website's policy on creating an account to download their data. Data for 28 cities was obtained. These records were retained with Microsoft Excel. This data has been included in this report and can be found in **Appendix D, Table 3.** Upon completion of transcription or obtainment through download, data underwent a QA/QC check to ensure that data was recorded correctly.

Population Data

Baseline population data was obtained from two main sources. 2016 provincial and federal population data was downloaded from Statistics Canada. These files were obtained as .csv file formats and were converted to .xlsx format. The data was subsequently examined, and all unnecessary fields were removed to enable efficient use of the data. Data was also checked for quality assurance purposes to ensure no records were missing. This data has been included in this report and can be found in **Appendix D, Table 4**. Metropolitan population data was sourced from TodoCanada, a web-based statistics service. This data was unavailable for download, and therefor was transcribed to the project's excel source data file. Upon completion of transcription, data underwent a QA/QC check to ensure that data was recorded correctly. This data has been included in this report and can be found in **Appendix D, Table 5.**

2.1.2[B] SPATIAL DATA

Spatial data files, known as shapefiles, were to be sourced from Natural Earth, a web-based vector and raster shapefile hosting service. Four shapefiles were obtained, at the scale 1:10m, from the cultural file accessed through the website's "Downloads" link. These four shapefiles were 1. Admin 0 – [global] Countries; 2. Admin 1 – [global] States, Provinces; 3. Urban Areas; and 4. Populated Places. More details regarding these files can be found in **Appendix D, Table 6.** These items were obtained in the WGS84-Web Mercator projection, and remained as such for the duration of the data pre-processing.

2.2 DATABASE DESIGN AND PROCESSING METHODOLOGY

2.2.1 MICROSOFT ACCESS DATABASE

Upon completion of the data manipulation phase, all created tables were compiled into a single Microsoft Access database for safe storage. The database currently holds 13 tables and over 5,000 records. Each table contains data for either the provinces or census subdivisions. The data consists of ID's, census subdivision name, provincial name, population, GDP, population density, area, and growth factors based on the scenario they are associated with.

2.2.2 GEODATABASE

A geodatabase was created to hold the original shapefiles (provincial and census subdivisions), a copy of each table that holds predictive values for population growth, and a toolbox that holds the models used to conduct each join and shapefile export.

2.2.3 SPATIAL AND TABULAR DATA JOINING/AUTOMATION

Following the manipulation of the tabular data and its compilation into a single database, it was exported into single csv files. These files were then joined to the census subdivision shapefile and a provincial shapefile using a model created in ArcMap using the model builder. The model joined the tabular and spatial data based on census subdivision ID numbers and based off the province's name. After joining, the model created new feature layers for each year and scenario (low immigration, medium immigration, and high immigration). These feature layers were then exported and saved as shapefiles for later application.

2.2.1^{B} TABULAR DATA

2.2.1.1^{B} Master Database

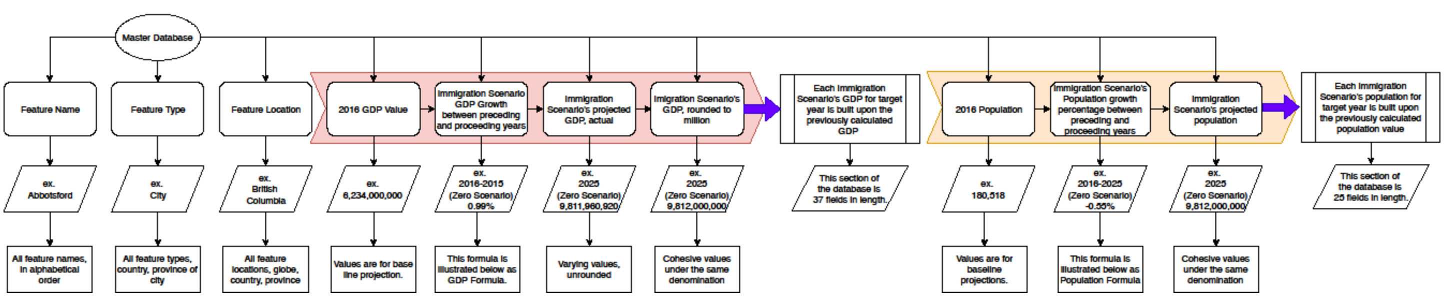

Figure 2: Master Database Structure Diagram(Burton, 2019.) A larger illustration is available in Appendix E: Figure 1.

The primary purpose of the Master Database is to retain all calculations. Microsoft Excel was used. Firstly, all locations are compiled into alphabetical order. Location names were altered to be better paired to their corresponding shapefile. This manual process entailed reviewing the shapefile names and deleting any accents and ensuring spelling was unified. Following the name heading, 64 additional headings were created. These included a feature location; feature type; baseline population and GDP data. The GDP related headings created were four fields per scenario, per year, for growth as a percentage, calculated GDP, and rounded GDP. The fields created for population were four headings per scenario per year growth as a percentage and actual population. A view of the first row is illustrated below to obtain a better understanding of the naming convention and colouring scheme. Names were highlighted in yellow, while the feature type and location are in grey. Baseline data was highlighted to be blue and the scenarios ranged from orange, yellow or green for either *Scenario 1,2* or *3* (as outlined in the introduction).

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	NAME	Type	Feature Location	GDP 2016	Zero Immigration GDP Growth Precentage 2016-2015	Zero Immigration GDP 2025	Zero Immigration GDP 2025 rounded to Million	Zero Immigration GDP Growth Precentage 2025-2050	Zero Immigration GDP 2050	Zero Immigration GDP 2050 rounded to Million	Zero Immigration GDP Growth Precentage 2050-2075	Zero Immigration GDP 2075	Zero Immigration GDP 2075 rounded to Million	Zero Immigration GDP Growth Precentage 2075-2100	Zero Immigration GDP 2100	Zero Immigration GDP 2100 rounded to Million	Status Quo GDP Growth Precentage 2016-2025	Status Qu 202

Figure 3: Master Database Headings Exemplar.

Based upon the name field, baseline data was then joined to its respective GDP and Population data column. This join, due to multiple source locations, was done manually through copying and pasting data into correct fields. Data was then reviewed for errors and continuity. It was noted that various sources provided data in multiple formats, such as precise integers and rounded integers. All GDP data was rounded to a similar denominator to retain consistency among the data figures.

The second core process of the master database data processing stems from creation of the projection fields for Canada, the provinces and the metropolitan areas. This is categorized into two different methods of projection, one for GDP and one for Population. For GDP projections, the immigration scenario's growth percentage was imported first. Then utilizing Microsoft Excel's =FV() formula, 2016 baseline GDP data was compounded and calculated for the next year interval. For example, the formula for Abbotsford's GDP in 2025 under the Zero Immigration Scenario is as follows:

=fv(E2 ,9, 0, -D2)

Figure 4: GDP Compounding Interest Excel Formula.

Where the **rate (0.99%)**, "E2" in red, is compounded by the **total number of payment periods (9 Years)**, "9" in blue, multiplied by **the payment made each period (0)**, "0" in green, multiplied by the **present value of future payments, inversed (- 6,234,000,000)**, "-D2" in yellow.

This GDP formula was used for all GDP projections, however the **total number of payment periods** changed from 9 years for the 2025 interval to 25 years for 2050, 2075, 2100 year intervals. This is because the difference in years between the base year (2016) and the first-year interval (2025) is nine years apart, whereas the other intervals are evenly distributed at intervals of 25 years.

For the population projections, 2016 baseline population data was multiplied by the averaged population growth percentage and added upon itself. For example, if we were to calculate Abbotsford's total population in 2025 under the Zero Immigration Scenario, the formula would be as follows.

```
=sum( AO2 * AP2 + AO2 )
```

Figure 5: Population Projection Excel Formula.

Where the first value is **2016 baseline population (180,518)**, "AO2" in yellow, multiplied by the **growth percentage (-0.55%)**, "AP2" in red, added to the original number, **2016 baseline population (180,518)**, "AO2" in yellow.

Once the first record's formulas were created, populating the entire table was an easy task. Using Excel's ability to drag formulas down through columns, the whole table automatically calculated all record fields. A detailed examination was conducted to ensure that all values were being derived from the correct fields to ensure accuracy. As a note, each calculated number was used to calculate the next projection. This formula system was easier to integrate rather than continuously working from the baseline numbers. For example, this would mean that Abbotsford's population would be the total of 2050's population multiplied by the growth percentage between the two-year classes, and then added back onto itself.

Also to note, the creation of two fields is included in this database. This data is attributed to the author's pre-existing general knowledge of Canadian geography. These fields detail the location's primary location as well as the type of location, for example, Abbotsford's location is in British Columbia, and Abbotsford is a City. These two fields will enable the developers to filter results based upon type and location during the web development process of the project, discussed in section 2.4.1[B]. The total amount of fields in the master database is 2,795.

2.2.1.2B Attribute Database

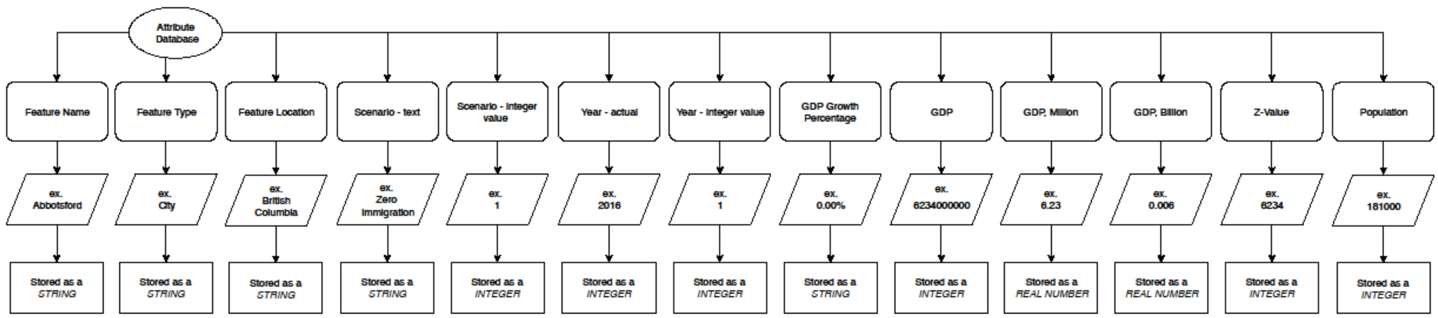

Figure 6: Attribute Database Structure Diagram (Burton, 2019). A larger illustration is located in Appendix E: Figure 2.

The attribute table has two variations. Firstly, the creation of the attribute table has been conducted with the utilization of Microsoft Excel, as a .csv. The fields included in the attributes database was kept to the bare minimum. Each scenario and each year were separated, with fields for **Location Name**, **Location Type**, **Feature Location**, **Scenario** (string), **Scenario** (integer), **Actual Year** (integer), **Year ID** (single digit integer), **Population**, rounded to the nearest thousand (integer), **GDP interest per annum** (string), **GDP total**, rounded to million (integer), GDP control (**z-value**)(Integer), **GDP in Billions**, rounded to the 10 million (real number), and **GDP in Trillions** rounded to billion. These field enable the developer to harness certain forms of the attributes during the Programming and Customization stage. These items were simply copied and pasted into the correct table from the master database and subsequently double checked for accuracy. Each table was saved as Att(Scenario)(Year), example Att11 for Attributes related to scenario 1 (Zero Immigration Scenario), Year 1 (2016 baseline data).

Once the attribute database was created, it was converted from an .xlsx to a .csv, and then exported to Microsoft Access to be saved as an .mdb in preparation to join with the spatial data files.

An additional step was taken to convert the .csv used to convert to the .mdb. This was to create a JSON file from the attributes and was done by uploading the .csv to the JSON converter (CSVJSON.com, 2019) and then saving the output to the project's filing structure.

2.2.2B SPATIAL DATA

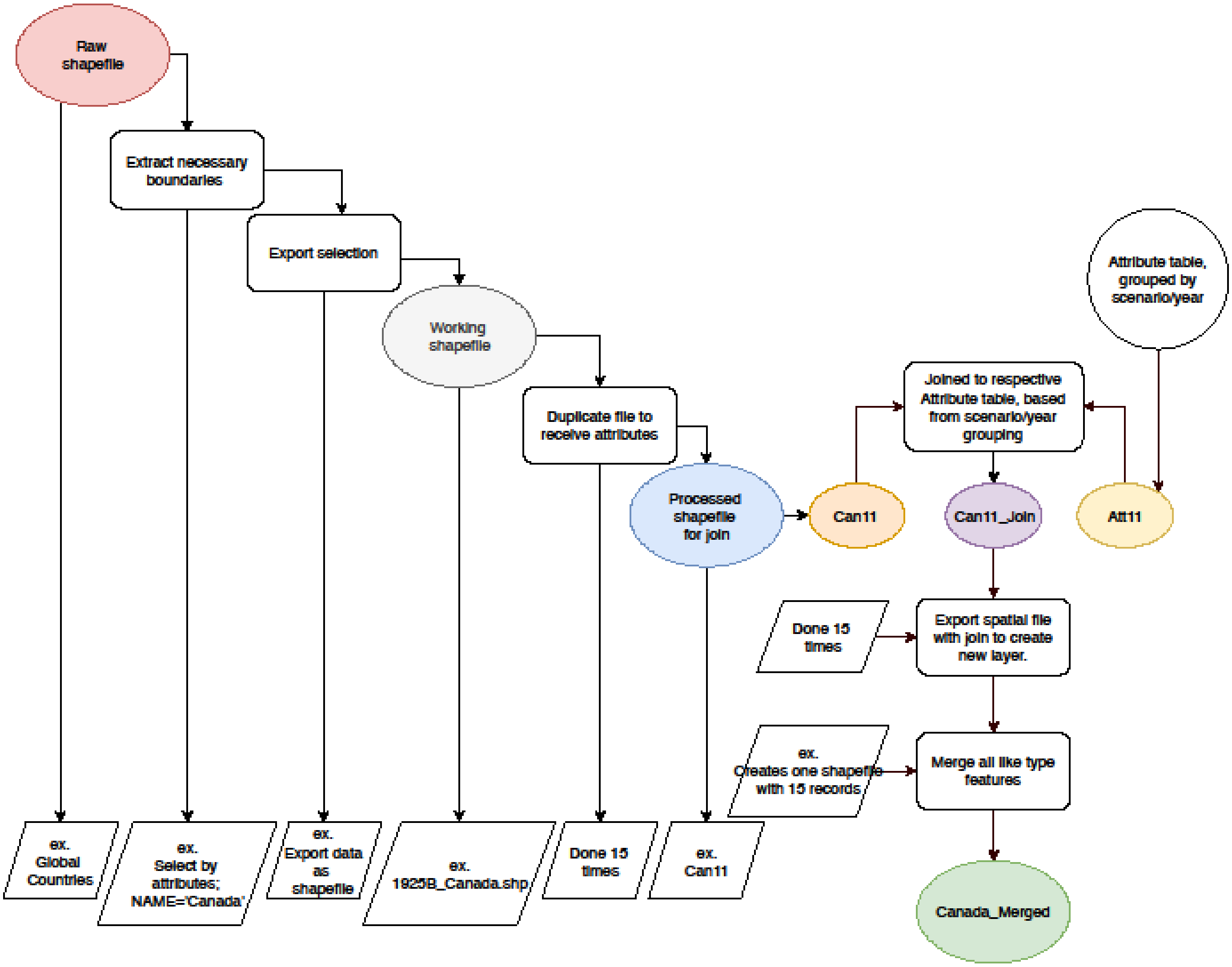

Figure 7: Shapefile Manipulation Flow Diagram (Burton, 2019).

First, from the world countries shapefile, Canada was selected by attribute and saved as its own, separate shapefile. The formula for selecting Canada was as follows: [Name]='Canada'. Secondly, from the Provinces and States world shapefile, provinces were queried through select by location, with all provinces and territories included within the boundary of Canada ascertained from the first selection. The selected provinces and territories were then exported as a separate shapefile. Lastly, snapping the global cities point shapefile to the global metropolitan areas enabled the developers to access metropolitan names for matching purposes later in the process. Cities were then selected within Canada through the Select by Location tool, and then exported as an individual, working shapefile. Following the creation of a working city shapefile, Canadian cities were selected by names that matched city names from the tabular data. This was done using Select by Attributes, and for example, followed this equation: [Name]='Toronto'. Then the cities were once again exported and saved as selected Canadian cities.

Once the primary boundary files for each zoom level had been ascertained, each shapefile was duplicated fifteen times, with each shapefile retaining an abbreviated feature type name, followed by the scenario then year. This was easiest done through ArcCatalog. The total number of each shapefiles needed for each feature type is 15. This is to correspond with the attribute tables that have been prepared to be joined. For example, the shapefile that will contain Canada's attributes for scenario 1, year 1 (Zero Immigration Scenario in 2016, the base year) would be titled Can11. The total number of shapefiles is 45 (15 Country, 15 Provinces, 15 Cities).

The final step in spatial data processing was to merge the tabular and spatial data. As mentioned above, two databases were utilized towards the production of the project's final solution. It was here where the Attributes Database was joined with the shapefiles duplicated 15 times in the above step. First, the country, province, and city shapefiles, categorized by scenario and year, were uploaded to ArcMap. Following that importation, the 15 attribute data tables were imported as .MDBs. Once the data was compiled in the ArcMap table of contents, each grouping of shapefiles was joined with the corresponding attribute table. For example, all [type](scenario)(year) like Canada-1-1 or Province-1-1 shapefiles were merged with AttributeTable-1-1.

Upon population of the attribute table for each feature type/scenario/year, all the like feature types were merged using ArcMap's Merger tool. This combined all 15 shapefiles with the same boundaries into one shapefile. This results in 3 main shapefiles representing Canada, the provinces and cities for all scenarios and years.

After the creation of the three primary shapefiles, Quantum GIS 3.6 (QGIS) was used to convert the shapefiles into GeoJSON. This is done through right-clicking the shapefile within QGIS and selecting 'Save As', where the developer is then able to select the location and file format desired.

At this point, the GeoJSON must be opened in a code editor. Line four must be deleted as coordinate declaration is no longer supported in the Mapbox Feature services. This line references the CRS, which is included in all QGIS GeoJSON files.

Once the GeoJSON is structured correctly, it is now prepared to be processed once more, this time processing the files through Tippecanoe. To summarize the literature review above that discussed Vector Tiles and Managing large data files for Mapbox, GeoJSON must be less than 5Mb for upload. Conversion allows for a substantial file size increase and a prompt conversion to the Mapbox Tileset file format.

2.3 WEB DEVELOPMENT/PRESENTATION METHODOLOGY

2.3.1 CREATION OF GEOJSON

Using QGIS each shapefile was exported to a GeoJson file to allow for its integration with Leaflet and MapBox. The CRS used was EPSG: 4326 – WGS 84 and a coordinate precision of 5. Each shapefile had to be inspected before its conversion to ensure all population, population density, and GDP fields were held in number type fields in order to be properly used later. Once GeoJson were exported using QGIS they had to be compressed from their original size of 144MB to roughly 5MB each. This was done using mapshaper.org and its simplification tool. The GeoJson were simplified to a setting of 2.5% and then re-exported for further processing.

2.3.2 JS VARIABLE CREATION

Each of the GeoJson files was then converted, using Notepad++, into a JS variable so the field data could be parsed using JavaScript and the interactive Web App. Again, fields had to be inspected to ensure that population, population density, and GDP were still held as number values.

2.3.3 HTML/CSS

The barebones website was created using HTML and CSS. A grayscale base map was added to the website using Leaflet.js built in options and crossover with MapBox. Constraints were applied to ensure the user is not able to scroll the map away from North America. In addition, a set fixed initial zoom was applied to also ensure the user would not be able to zoom out passed a certain extent.

2.3.4 JAVASCRIPT CREATION

JavaScript was applied to allow for the user to select which population growth scenario and year they would like to view in a choropleth display of the data. JavaScript was also applied to create a styling function to each layer that is selected to appear. The colouring function is applied to the population density field. Therefore, the field had to be a number value or else the function would not be able to properly work. The JavaScript also allows for an info window to be populated with various information about the census subdivision that the user clicks on. Such information included population density, census subdivision name, and population.

2.3.1[B] WEB PRESENTATION

Included in a Mapbox subscription is the use of their API key, referred to as a Mapbox Token. This token enables the map to be hosted and projected online and is comparable to a Google Maps API Key. Also included in a Mapbox account is the ability to draw from their JavaScript libraries. This enables the use of functions like adding a map layer (map.addLayer), adding a map source (map.addSource), locating a feature's attributes at mouse location (clickPopup.setLngLat), clicking on a map's feature (map.on[click],[mouseenter],[mouseleave]), creating a pop-up (map.Popup), and filtering features based upon zoom level and user selection (map.setFilter). These functions are hosted through Mapbox, and are accessed upon successful application of the Mapbox Token. The incorporation of these Mapbox JavaScript libraries, and their placement within the JavaScript file, is outlined within the Programing and Customization Methodology.

Further in the methodology discussion, visualization techniques will be disseminated. It should be noted that with Mapbox's feature services, the Tileset service is the repository for GeoJSON. Furthermore, Mapbox's Studio service enables developers to adjust basemap properties, zoom levels, labels, map center, pitch, bearing and much more. These items are unique to Mapbox Studio and pertain primarily to visualization, however these services are tied to the application of web technology implemented in the final product's presentation and are not associated with the developer's unique JavaScript script for the final tool.

The final product's functionality lies rooted within the HTML. The primary HTML document hosts the script that enables the user to select the desired scenario and year to be rendered through the tool. This script is tied into the project's JavaScript file, which will be outlined in depth during the Programming Methodology section. Also found within the HTML document is the framework for the legend and is also further discussed in the Visualization Methodology section. CSS is also employed to enable various stylings, but also prevents all three legends from loading simultaneously on page access.

2.4 PROGRAMMING AND CUSTOMIZATION METHODOLOGY

2.4.1[B] PROGRAMMING AND CUSTOMIZATION

Through the extensive use of JavaScript, this element of the project is the most complex. Through the following paragraphs, it should be noted that references and relations will be drawn upon from both the preceding, and proceeding, methodology sections.

Upon loading the HTML, a series of JavaScript functions begin to execute. The first series of events relates to loading the map. The main JavaScript file begins with accessing the Mapbox token, which relies upon the implemented web technology outlined earlier in the methodology discussion. Following the validation of the Mapbox Token, a container to hold the map is created which will hold the cartographic visualization. This is accessed used through a Mapbox specific function. After the introduction of the map container, parameters must be set. The function requires 8 parameters to be defined. The first parameter is the name of the container, and for the final solution this was named ‘map’. Next, the style is set, drawing from a style contained in the account holder’s Studio. This is drawn from a customized URL and will render the basemap. For more about basemap design and application, please review the Visualization methodology discussion. Following the style of the map, the center of the map, followed by the minimum zoom, zoom intervals, pitch, bearing and maximum bounds of the map are all defined. Proceeding the initial map definition function, two variables are set to hold alternate zoom thresholds for the varying levels of zoom.

The second function to occur upon validation of the token is Mapbox’s map.on(load). These events occur in order and ensure the map and relevant vector tiles are drawn correctly. Prior adding the map’s source, four variables are set which enable the user to filter between scenarios and years via the HTML code. A ‘year’ and ‘scenario’ variable are both set to ‘1’ to ensure the map loads the vector tiles associated with scenario one, year one. Then two more variables, ‘filterYear’ and ‘filterScenario’ are set draw from the vector tile’s attributes and will later match attributes to data selected by the user. For the time being, these filter variables are set to match the initial ‘year’ and ‘scenario’ set above.

The next series of events to occur following the declaration of the variables is adding the source of the vector tiles. This function is attribute to Mapbox. As mentioned earlier in the report, these vector tiles are converted GeoJson files specific to Mapbox’s feature Tileset service. The source is titled in accordance with the developers naming convention. The two parameters required for this function are type, set to vector, and the customized URL, set to the corresponding vector Tileset. This function is repeated three times as the federal, provincial, and metropolitan sources must be added to the map individually.

The next event to occur is the addition of the vector tiles as a layer draped over the basemap. The function requires a few parameters and enables a multitude of customizations. The parameters for the customization options will be introduced here but will be discussed further in the Visualization methodology portion of the report. The first parameter is the ID name and is set as a string. The ID parameter was determined to reflect the layer, for example Canada's vector Tileset was set to 'Canada', whereas the provinces was set to 'Province', and cities as 'City'. Following the 'id' parameter, a source layer must be cited. This is related to the function above that added the vector Tileset's customized URL. The layer within the vector Tileset is called in as the 'sourcelayer'. A maximum and minimum zoom level parameter can be determined for this layer's visibility. The type of feature manipulation is explicitly determined prior to the commencement of the effects. For all loaded vector Tileset, this parameter was set to 'fill-extrusion'. A filter parameter is included in this function, and for the purposes of this project, each filter followed the same principal formula which was ['==', 'is(Layer ID), true]. The next parameter of the function is the feature colour, feature opacity, feature height and feature base, which will be outlined in the Visualization methodology, and discussed in the Visualization Results.

The next two events that occur retrieve information from the HTML script in which the user selects the scenario and year to be rendered. This is done through the document.getElementId portion of the function and is followed by either ('slider') or ('buttons') to represent which HTML element the values will be drawn from. This is then followed by adding an event listener and assigning the selected value as the input value. This done with .addEventListener JavaScript function. The function continues by declaring a variable which equals the parsed value from the event listener, as an integer. Following the conversion of the value from a string to an integer, the filtered year is set using a Mapbox expression where the filtered variable equals a number that matches the retrieved value from the GeoJSON (Tileset) objects. The map is then set in accordance with the filter, and this is done using a filter combination expression. First a filter variable is set defining what it will contain. The variable is then defined as equaling all objects, in a specified layer, equal the variable parsed from above. For example, if the user selects the Zero Immigration Scenario button via HTML page, the script will then match all GeoJSON/Tileset areas that have a scenario that matches the user's selection. This function and loop are employed for both the year selection, and scenario selection.

Following the filtering, the map is refreshed and visible to the user. If the user selects (left clicks) on a visualized polygon, a click event occurs. This click opens a pop-up. Before the pop-up appears, auxiliary information is retrieved through the JSON array. The JSON array is filtered through a custom filter that returns specific objects that match the selected year and scenario. An additional filter is included to filter only the correct feature types needed for the upcoming data analysis. Proceeding the creation of a variable array dependent on the queried values, two variables are declared and set to allow the second customized array loop created for the project. For every item in the array filtered above, a name is drawn, and the rounded GDP is drawn. This is our comparison figures referred to shortly.

A chart function is now implemented and is assigned the following function. From the mouse click, the Chart.JS library gets the location of the click through a .getElementById function, and then assigns the chart a name. The chart's parameters are fulfilled and these range between the type of chart (doughnut), the data for the labels, the datasets for the GDP comparison, the colours to visualize the chart, and a few configurable options such as legend display and chart title. The configurable options are adjusted per event at each zoom level.

The pop-up's location is set to the clicked event. The latitude and longitude of the event are gathered through a .setLngLat event. The HTML is then instructed to display the selected polygon's name, drawn dynamically through the GeoJSON, and then to display the chart. This is then added to the map.

The last two functions set the user's cursor to a pointer when it is located above a selectable polygon, and then when the cursor is removed from a selective area, returns to a regular arrow. This is done with a simple map.on(cursor location, layer Id, and then a .getCanvas().style.cursor script. The script then repeats in the above manner to satisfy all three zoom levels incorporated in the final product.

2.5 VISUALIZATION AND FINAL PRESENTATION METHODOLOGY

2.5.1 VISULIZATION

Choropleth maps have been created in ArcMap in order to have something printed for presentations, including the open house on June 21, 2019.

2.5.1B VISUALIZATION

The underlying basemap visualization of the final solution stems from the use of Mapbox Studio and its associated features. The original information exhibited in the provided basemap template, such as countries, states/provinces, oceans, roads, airports and more (which appeared as points, polygons, lines, and labels) were removed. To create the labels, a point Dataset was created for the country, provinces, and cities. These points were placed in the relative center of the polygons to be labelled. The Dataset's attributes were populated with location names, as well as any abbreviations. These labels were then fully customized to appear, and disappear, depending on the varying zoom at which the tool is viewed at. The colours used for labels were derived from the Client's website, and a red (#d40000) was used for Canada's capital, and appears a bit larger than the surrounding labels. The red hue will be referred to as the project's main red colour as it has been used multiple times during the creation of the project. The provincial capitals, as well as other cities, were sized logically, and a blue hue from the Client's site was used (#4c94d6). This blue hue has been repeated throughout the visualization and will be referred to as the main blue colour. The font type used for the labels was Bariol Bold, and the labels have varying white halos around them. The pitch, bearing, bounding box, and map center were all set through the Studio application. The Canadian border and provincial boundaries Tilesets were imported to the Studio as line features, providing an outline of the study area on the base map. These lines were colour using the main blue colour and vary thicknesses and opacity slightly to differentiate between the provincial boundaries and the federal boundary. The Canadian country Tileset was added a second time as a polygon type layer and has been shaded a light red derived from the main red colour. This provides a subtle background in which the study area may be enhanced and focused upon.

Population for each zoom level/Tileset was derived from a JavaScript function where data has been interpolated from the Tileset. Values for interpolation were obtained through data analysis. It was determined that nine population classes would be used for each zoom level. The largest overall value for the feature type was subtracted from the lowest overall value, and the remaining value was divided by eight. This provided equal intervals of population increase in which the feature will visualized. For example, if Canada had a lowest population value of 1, and a highest value of 9, then 9 – 1 -> 8/8 = 1. Therefore, the population would be classified into intervals of increase by 1. The classification values are then assigned a corresponding value of colour, and the JavaScript function interpolates the colour in a linear structure. The colours used for the visualization of the feature type were all derived from the main red colour, with slightly darker or lighter shades of the main colour used to represent an increase, or decrease, in population. The opacity of the polygons was set to 50%, while remaining grounded at a base level set at 0. The height of the polygons, which illustrates the GDP was derived from the total GDP for the study area. These values vary in an attempt to limit the extrusion height and retain the study area within the boundary of the tool. Labels were customized to be above certain polygons and were done on a logical scale. For example, provincial names are on provinces, whereas city labels are not brought above the polygons until the cities are in view.

Upon interaction with the tool, a doughnut chart appears. This is drawn through a Chart.JS JavaScript function tied to Mapbox's pop-up event function. The chart draws information from two sources, the first being the selected element presented through Mapbox, and the other being corresponding auxiliary data to better illustrate some figures. For example, if Canada is selected, all the provinces' GDP totals are present to illustrate Canada's GDP composition, while if a city is selected, the city's GDP contribution to its corresponding province's GDP is compared. These colours are primarily green and has been sourced from the Client's existing logo.

The legend of the tool displays the colour ramp, which is programmed into a CSS class. As the user scrolls in and out of the map, the values change in response to the feature being viewed. For example, if Canada is displayed, a population range from 18 million to a 100 million is displays whereas when the user zooms into the provinces, a population range from 19 hundred to 39 million is displayed. This alleviates the need for multiple legends and keeps all the information contained in a recognizable location for user ease. The legend also allows the user to select the scenario and the year to be rendered.

3.0 PROJECT RESULTS

3.1 DATA ACQUISITION, DATABASE DESIGN AND PROCESSING

Figures 2 and 3 in Appendix A show our geodatabase and Access database that hold our spatial and tabular data. There is crossover between the two databases and their tabular data. This was to ensure our data was backed up in case of any corruption or accidents that might happen which would result in data loss. The Access database consists of 13 tables and over 5,000 records. The geodatabase consists of these tables as well as the boundary files used to display the census subdivisions.

3.1B DATA ACQUISITION AND PRE-PROCESSING RESULTS

The data acquired for the final solution has been sourced from open access data files that had no limited use clause. The final count of tabular data sources was five. The spatial data source was minimal, at one, with four shapefiles. All the sources met the clients need in the sense that the sources were free to access and use the data as necessary.

3.2 SPATIAL AND TABULAR DATA JOINING/AUTOMATION

Figures 4 in Appendix A displays the successful model constructed for data automation and use in ArcMap. The model uses the Join Tool, Make Feature Layer Tool, and Export to Shapefile tool. Each Feature created is associated with one growth scenario and one time period of interest. Figure 5 in Appendix A shows an example of the data stored in the exported shapefiles. 13 shapefiles were created. That is one shapefile for each year and each scenario of population growth.

3.2 B DATABASE DESIGN AND PROCESSING RESULTS

Tabular data in the master database follows no specific adherence to string or numerical values. The Attribute Database contains static values unrelated to the equations used in the master database. This ensured that strings, integers and real numbers were represented in the final product correctly. A few additional rounded fields were included in the Attribute Database to represent GDP by million, billion and trillion.

Spatial data was selected in accordance with the desired study areas. Upon completion of the spatial boundary collection, the attributes were joined. This process was exaggerated due to the need for each scenario/year to be joined with a singular shapefile. This is due to the author's inability to visualize a more efficient manner in which one boundary may have multiple attributes. The individually joined spatial files were then merged to create overlapping boundaries of similar features with the corresponding attributes. This provided the developer of the final product with the ability to store like features together and access the attributes through GeoJSON.

The attributes were also exported as JSON due to the structure of Mapbox specific function's lack of capabilities. It will be noted further in the Results discussion that manipulation and querying from JSON is more efficient then GeoJSON retrieval. A view of the Master Database is illustrated below, with the Abbotsford location's 2016 to 2025 GDP growth formula for the Zero Scenario highlighted in the selected cell.

F2 =FV(E2,9,0,-D2)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	NAME	Type	Feature Location	GDP 2016	Zero Immigration GDP Growth Precentage 2016-2015	Zero Immigration GDP 2025	Zero Immigration GDP 2025 rounded to Million	Zero Immigration GDP Growth Precentage 2025-2050	Zero Immigration GDP 2050	Zero Immigration GDP 2050 rounded to Million	Zero Immigration GDP Growth Precentage 2050-2075	Zero Immigration GDP 2075	Zero Immigration GDP 2075 rounded to Million	Zero Immigration GDP Growth Precentage 2075-2100	Zero Immigration GDP 2100	Zero Immigration GDP 2100 rounded to Million	Status Quo GDP Growth Precentage 2016-2025	Status Qu 202
2	Abbotsford-Mission	City	British Columbia	6,234,000,000	0.99%	6,811,960,920	6,812,000,000	0.42%	7,564,453,781	7,564,000,000	0.30%	8,152,689,442	8,153,000,000	0.21%	8,591,667,325	8,592,000,000	1.69%	7,248,
3	Alberta	Province	Canada	301,711,000,000	0.99%	329,682,954,929	329,683,000,000	0.42%	366,101,847,107	366,102,000,000	0.30%	394,571,075,452	394,571,000,000	0.21%	415,816,576,863	415,817,000,000	1.69%	350,828,
4	British Columbia	Province	Canada	263,978,000,000	0.99%	288,451,687,464	288,452,000,000	0.42%	320,315,909,581	320,316,000,000	0.30%	345,224,679,762	345,225,000,000	0.21%	363,813,146,776	363,813,000,000	1.69%	306,953,
5	Calgary	City	Alberta	113,151,000,000	0.99%	123,641,352,265	123,641,000,000	0.42%	137,299,568,468	137,300,000,000	0.30%	147,976,413,715	147,976,000,000	0.21%	155,944,136,901	155,944,000,000	1.69%	131,571,
6	Canada	Country	World	2,023,824,000,000	0.99%	2,211,454,924,007	2,211,455,000,000	0.42%	2,455,746,408,382	2,455,746,000,000	0.30%	2,646,712,954,470	2,646,713,000,000	0.21%	2,789,224,018,522	2,789,224,000,000	1.69%	2,353,298,
7	Edmonton	City	Alberta	84,382,000,000	0.99%	92,205,146,988	92,205,000,000	0.42%	102,390,718,478	102,391,000,000	0.30%	110,352,942,017	110,353,000,000	0.21%	116,294,846,356	116,295,000,000	1.69%	98,119,
8	Halifax	City	Nova Scotia	18,358,000,000	0.99%	20,059,990,145	20,060,000,000	0.42%	22,275,945,223	22,276,000,000	0.30%	24,008,192,619	24,008,000,000	0.21%	25,300,902,911	25,301,000,000	1.69%	21,346,
9	Hamilton	City	Ontario	28,631,000,000	0.99%	31,285,411,147	31,285,000,000	0.42%	34,741,398,174	34,741,000,000	0.30%	37,442,998,304	37,443,000,000	0.21%	39,459,099,642	39,459,000,000	1.69%	33,292,
10	Kingston	City	Ontario	7,419,000,000	0.99%	8,106,823,558	8,107,000,000	0.42%	9,002,355,246	9,002,000,000	0.30%	9,702,406,637	9,702,000,000	0.21%	10,224,828,342	10,225,000,000	1.69%	8,626,
11	Kitchener-Cambridge-Waterloo	City	Ontario	26,513,000,000	0.99%	28,971,049,064	28,971,000,000	0.42%	32,171,376,822	32,171,000,000	0.30%	34,673,124,028	34,673,000,000	0.21%	36,540,082,736	36,540,000,000	1.69%	30,829,
12	London	City	Ontario	21,071,000,000	0.99%	23,024,515,325	23,025,000,000	0.42%	25,567,950,855	25,568,000,000	0.30%	27,556,194,938	27,556,000,000	0.21%	29,039,945,813	29,040,000,000	1.69%	24,501,
13	Manitoba	Province	Canada	67,391,000,000	0.99%	73,638,892,900	73,639,000,000	0.42%	81,773,516,969	81,774,000,000	0.30%	88,132,482,229	88,132,000,000	0.21%	92,877,935,943	92,878,000,000	1.69%	78,362,
14	Moncton	City	New Brunswick	6,526,000,000	0.99%	7,131,032,557	7,131,000,000	0.42%	7,918,772,117	7,919,000,000	0.30%	8,534,560,684	8,535,000,000	0.21%	8,994,100,250	8,994,000,000	1.69%	7,588,
15	Montreal	City	Quebec	169,931,000,000	0.99%	185,685,487,815	185,685,000,000	0.42%	206,197,496,879	206,197,000,000	0.30%	222,232,061,220	222,232,000,000	0.21%	234,198,046,219	234,198,000,000	1.69%	197,595,
	New Brunswick	Province		34,593,000,000	0.99%	37,800,154,651	37,800,000,000	0.42%	41,975,801,999	41,976,000,000	0.30%	45,239,972,070	45,240,000,000	0.21%	47,675,897,940	47,676,000,000	1.69%	40,224,

Master Sheet

Ready

Figure 8: Master Database View.

3.3 WEB DEVELOPMENT

Figure 6 in Appendix A shows a screen capture of the finished web application that was completed. It was constructed using Leaflet.js and Mapbox. The web application displays the population and population density for Canadian Census Subdivisions based off the users desired choice of growth scenario and time period.

3.3 [B] WEB TECHNOLOGY RESULTS

Through the use of Mapbox's feature services and APIs, the developer was able to host and render the map online. These APIs, JavaScript libraries and feature services will enable a multitude of options and visualizations. In-house web development techniques was employed to utilize HTML, CSS, JSON, and JS files. Over all, the final solution was succesfully accessed through Mapbox API's. The Mapbox Token utilied is visualized below in **Figure 9**, while the incorporation of the Mapbox Token is illustrated in **Figure 10**

```
var mbkey = 'pk.eyJ1IjoicmV4MTMiLCJhIjoiY2p2em9rcGh3MDJpbDQ4b2QyNmFmMjFzMyJ9.aeseiTnVarMkVM
```

Figure 9: Mapbox Token Illustration.

```
// MapBox Token loaded here
mapboxgl.accessToken = mbkey;

var bounds = [
    [-170,41], // Southwest coordinates
    [-30, 90]  // Northeast coordinates
    ];

// Map is created, defined with loading parameters
var map = new mapboxgl.Map({
    container: 'map',
    style: 'mapbox://styles/rex13/cjwhx7qoa0ivy1dqxqho71m94',
    center: [ -98.357977,  60.093385 ],
    minZoom: 2.75,
    zoom: 2.75,
    pitch: 90,
    bearing: 0,
    maxBounds: bounds // Sets bounds as max
    });

// Zoom threshold is set
var zoomThreshold1 = 3;
var zoomThreshold2 = 3.5;



// Load the map
map.on('load', function() {
```

Figure 10: Use of Mapbox Token in script.

3.4 B PROGRAMING AND CUSTOMIZATION RESULTS

The programming and customization of the final product required substantial testing, re-writing, QA/QC protocols and very exact attention paid to structure and spelling. Many issues encountered through the process of scripting the tool stemmed from misspelled variables, functions placed in illogical order, and inappropriate use of expressions. Due to the lack of Mapbox documentation on particular expressions, such as filtering and returning queried features, a JSON array was utilized as a secondary source of information. Matching selected features attributes to JSON attributes was employed as a quick fix to Mapbox's inadequacies. The final script will enable the Client to place the code directly into their existing web space, which is in line with the needs of the Client. A view of the script can be seen below in which the Canada feature layer is added to the map and successfully extruded and painted.

```
// Adding Country layer from tileset
map.addLayer({
    // Defining the ID of the layer
    'id': 'Country',
    // Linking to the map source, defined above in map.addSource
    'source': 'CanCountry',
    // Calling in the correct layer from the defined tileset
    'source-layer': 'Canada',
    // Setting the max zoom to zoom threshold
    'maxzoom': zoomThreshold1,
    //defining the effects to be applied to the polygons derived from tileset source
    'type': 'fill-extrusion',
    // Applying the paint to the function to the visible polygons
    'paint': {
        // Defines the extruded polygons colour
        'fill-extrusion-color': [
            // Obtains data from attirbutes in tileset, creates smooth results between inpu
            'interpolate',
            // Interpolates between defined stops below, stops below and starts above defin
            ['linear'],
            // Retrieving population from tileset attributes
            ['get', 'POP'],
            // Defining the intervals, assigns colour gradient to intervals
            18867000, '#F7D0D0',
            29017000, '#F3B9B9',
            39167000, '#EB8B8B',
            49317000, '#E35C5C',
            59467000, '#DB2E2E',
            69617000, '#D40000',
            79767000, '#AE0000',
            89917000, '#870000',
            100067000, '#610000'
            ],
        // Defines extruded polygon's opacity (transparency)
        'fill-extrusion-opacity': 0.5,
        // Defines the extruded polygon's height, based off of the GDP control set in the a
        'fill-extrusion-height': ['get', 'GDPcontrol'],
        // Defines the base of the extruded polygons, set to the top of the basemap
        'fill-extrusion-base': 0,
    },
    'filter': ['all', filterYear, filterScenario]
}, 'PROV-SM-LABELS');
```

Figure 11: Example of loading a layer through JavaScript.

3.5B VISUALIZATION RESULTS

Customization of the basemap through Mapbox Studio was tedious and relatively undocumented in terms of specific customization. Through extensive trial and error, it was found that label properties could be retained from the complimentary basemaps provided and applied to the specific boundaries and labels needed for the final presentation. It was interesting to note that the application of a label on a Tileset resulted in labels being duplicated throughout the polygon. This relates to the fact that Mapbox places a label for each polygon for each tile rendered. A work around was created through the use of the creation of a simple point layer that allowed each point to represent the position and attributes of each label needed.

Colour choices were derived from the Client's logo in anticipation of creating unity between the final product and the Client's main website.

A z-value to represent the height of the projected GDP values per feature was obtained by the refinement of the actual GDP projected for the scenario/year. These values, generally speaking, were obtained by removing the actual GDP's last 6 digits, which is essentially GDP per million. This value must be an integer and real numbers were not accepted in the function due to constraints through the Mapbox library.

Classification levels for population were derived from subtracting the lowest population per feature by the largest and divided by eight. This enabled the use of 9 classes for population visualization A final view of the final solution, with a selected feature provincial of Alberta is shown in **Figure 12**, and a view of the metropolitan area of Windsor is shown in comparison along side southern Ontario, seen in **Figure 13**.

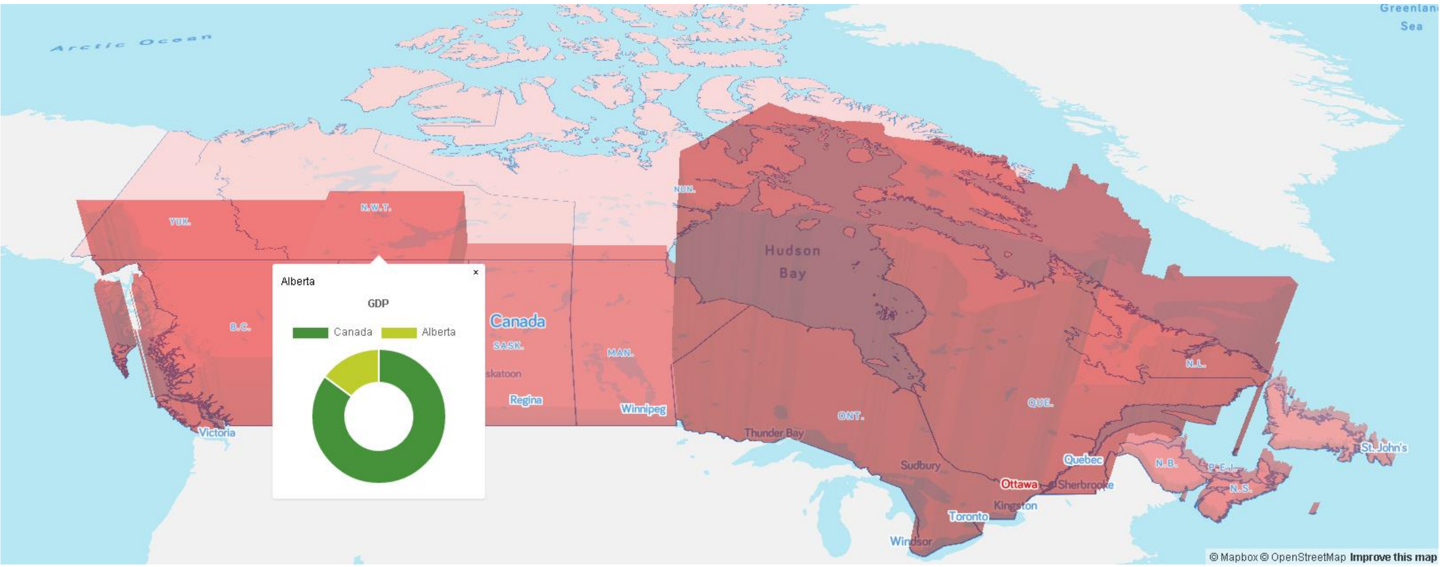

Figure 12: Final product, provincial view, with chart.

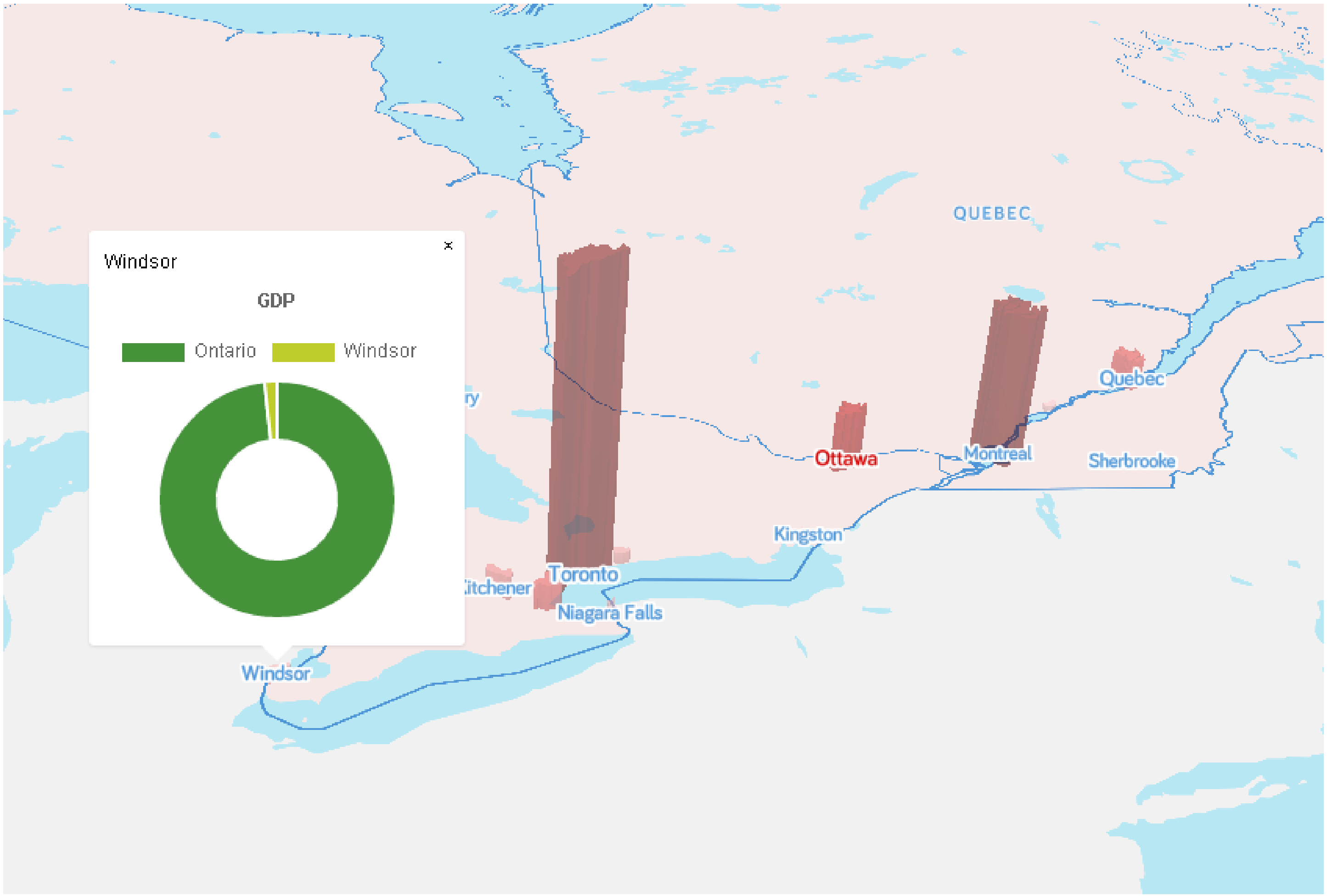

Figure 13: Final product, metropolitan view, with chart.

4.0 OBJECTIVE CONCLUSION

4.1 DATA ACQUISITION AND PRE-PROCESSING CONCLUSION

4.1.1[B] DATA ACQUISITION AND PRE-PROCESSING SUMMARY

Tabular data acquisition entails the collection and retainment of pertinent non-spatial data. Primarily numerically based integers, a few string based data fields were also recorded. All data used in the final tool was sourced from sources that had no associated costs. Tabular data used was open access with no limitations for use. It should be noted that the data collected was created by the data's host organization, and subsequently, may become subject to use restrictions in the future. After the data was obtained, it underwent a review process to ensure accuracy and data structure. Spatial files from Natural Earth had no stated limitations on use and were also ideal to satisfy the needs of the client. Some inaccuracy may be observed due to the rounding employed in the preprocessing.

4.1.2[B] LIMITATIONS OF DATA ACQUISITION AND PRE-PROCESSING

The foremost limitation of the tool is the data used. Due to the nature of the mathematical formula used in the original tool, the new tool uses generalized statistics. These generalized statistics were derived from the original tool by calculating the growth percentages between each year interval for both population and GDP. It would be desired, prior to publication of the tool, to consult with a professional economist to ascertain the validity of the statistics projected through the tool. Furthermore, the tool is limited to 26 major metropolitan areas. This is detrimental to the analysis of the data in minute aspects, such as by townships, smaller cities, or even census divisions.

4.1.3[B] RECOMMENDATIONS ON DATA ACQUISITION AND PRE-PROCESSING

In addition to vetting the statistics through a certified mathematician and/or economist, it is recommended that the tool be updated upon publication of the next census data. This would provide for a current tool that better reflects the country as it stands in the present day.

4.2 DATABASE DESIGN AND PROCESSING CONCLUSION

4.2.1[B] DATABASE DESIGN AND PROCESSING SUMMARY

Data was amalgamated and processed with the initial tool's formulas to project federal, provincial and metropolitan data. This process will also undergo a QA/QC process to ensure accurate data analysis.

Following the acquisition of all relevant data, certain data management techniques will need to be implemented.

Two databases were necessary in the creation of the final solution. A master database was created to enable efficient data population, which was automated using Excel specific formulas. The master database is structured in such a way that in the event of a tool revamp or update, only the original baseline figures need to be replaced and all the additional projection figures will update accordingly. Due to the structure of data obtained through these calculations, it was necessary to create a second database that contained only relevant data needed for web presentation. This second database is referred to as the attribute database and is detailed proceeding the master database's description.

To create the master database of tabular data, multiple processes were undertaken. It is desired that all information be combined and correctly compounded to represent the figures to be used in the analysis. This database was hosted through Microsoft Excel as this program enabled the authors share and work collectively through a shared document online. Furthermore, it became quick and easy to preform analysis through the program and therefor it was determined this program would host the data permanently.

Data was amalgamated and processed employing the formulas (derived from the Client's original tool) to project federal, provincial and metropolitan population and GDP data correctly. This process also underwent a QA/QC process to ensure accurate data analysis. It was noted that upon the attempt of uploading data whose cells contained expressions was unacceptable for the final presentation. Hence the creation of the Attribute Database. This was done through copying the master database's values and pasting them as VALUES ONLY into the attribute database which resulted in static values.

It was noted that many data sources provided the data in multiple formats, such as actual GDP from Statistics Canada and rounded (to the nearest million) for metropolitan GDP data from Statistica and Todo. The data was formulated to all be rounded to a like denominator.

Spatial data was not generalized therefore the data has remained with the raw boundaries provided from the source's organization.

4.2.2[B] LIMITATIONS OF DATABASE DESIGN AND PROCESSING

The master database was limited in functionality after processing the initial formulas, and was unsuitable for web presentation.

4.2.3[B] RECOMMENDATIONS ON DATABASE DESIGN AND PROCESSING

The master database could be re-worked to incorporate the web values as well which would allow for a more efficient data structure. This would need to be done by a data management professional.

4.3 WEB TECHNOLOGY CONCLUSION

4.3.1[B] WEB TECHNOLOGY SUMMARY

The course's web development element is fulfilled through the use of HTML and CSS, with the addition and utilization of Mapbox's libraries and feature services. Although based upon JavaScript, the libraries provided through a Mapbox account are not owned by the developer. Through the use of Mapbox's feature services and APIs, the final solution was published online, making it accessible for wide range of users to interact with the final tool. These APIs, JavaScript libraries, and feature services will enable a multitude of options and visualizations to occur.

4.3.2[B] LIMITATIONS OF WEB TECHNOLOGY

If Mapbox decided to alter or remove any of their JavaScript libraries the tool's functionality will be put into jeopardy. This would be unavoidable but is possible to be managed through future support of the project from a professional with reasonable JavaScript and web development understanding.

4.3.3[B] RECOMMENDATIONS ON WEB TECHNOLOGY

Recommendations stem from the use of the Mapbox platform, in which if the opportunity presented itself, the author would consider contributing notes and accessory documentation on specific functions that does not currently exist. This would benefit future developers and be beneficial to the entire web GIS development community. These notes range from how-to documentation, which would relate to combining specific Mapbox functions with visualization techniques, to providing information reference material to adjusting, calling, and working with GeoJSON/Tilesets/Datasets and JSON file formats within JavaScript. In addition to the substantial need for better Mapbox documentation for new features and scripts being incorporated through their API's, current documentation should be expanded to better reflect the parameters which need to be fulfilled to execute their functions and events. This specifically would include use integers rather than real numbers in obtaining a z-value for extruded features.

4.4 PROGRAMMING AND CUSTOMIZATION CONCLUSION

4.4.1[B] PROGRAMMING AND CUSTOMIZATION SUMMARY

Customization requirements was obtained through considerable use of JavaScript. It was necessary to create additional JavaScript functions to manipulate data for use within MapBox's Libraries. The employment of additional JavaScript functions and loops enabled more efficient data retrieval.

4.4.1[B] LIMITATIONS OF PROGRAMMING AND CUSTOMIZATION

It may be difficult for a novice programmer to interpret the tool. The script has extensive commenting however these comments only provide so much knowledge.

4.4.3[B] RECOMMENDATIONS ON PROGRAMMING AND CUSTOMIZATION

Any developer that chooses to revamp the tool must have substantial knowledge regarding JavaScript programming. If the tool is revamped, it could be disseminated into smaller files to ensure that various functions lie externally from the document to ensure the tool's script does not become too cluttered with repetitive lines of code.

4.5 VISUALIZATION SUMMARY

4.5.1[B] VISUALIZATION SUMMARY

Through the programed customizations, the final product's visualization will effectively communicate the Client's main objective: promoting more immigration through an illustrated GDP increase based upon an increased population. The combined use of Mapbox Studio's basemap, in addition to the specifically created JavaScript enables the final product's users to gain an insightful perspective into the benefits of a higher population while illustrating a higher GDP.

4.5.2[B] LIMITATIONS OF VISUALIZATION

The final solution is only available in English. This is detrimental to dismantling language barriers and enabling open access to the tool, especially considering the purpose of the tool in relation to immigration. The colour choice of the tool also prevents those with colour impairment from properly navigating the solution.

4.5.3[B] RECOMMENDATIONS ON VISUALIZATION

The tool should be updated to at least utilization Canada's second official language, French. Much of the content is numeric and having a translated version would be accessible given adequate time and resources.

Colour values should be altered to be friendlier towards individuals experiencing visual limitations such as colour blindness. Height (z-values) may also be altered in the event the tool displays information outside of the viewport.

5.0 PROJECT CONCLUSION

5.1 PROJECT BENEFITS

The benefits of a modernized tool that exhibits the potential prosperity of Canada are evident. Potentially used by policy makers, current and future leaders of Canada can gain a glimpse into the benefits of increased immigration and the direct result this has on their home province and possibly their residential metropolitan area. Members of Parliament's constituents can use the tool to visualize the impact that new and increased immigration policies would have on their province. Immigrants themselves can view the tool to better understand the positive impact their contribution has to the betterment of Canada. The tool is accessible to all age classes, races, creeds, genders and persons with disabilities. The tool stands strong along with the deep-rooted multicultural image Canada has created on the global stage. The impact and benefits of the tool far exceed the author's brief explanation on its benefits.

5.2 PROJECT SUMMARY

As an outstanding leader in promoting a prosperous and diversified Canada, Century Initiative aims to sway public opinion on ratifying immigration quotas. It is argued that with a larger population, Canada's GDP will also increase benefiting all Canadians. It is unfortunate that traditional repopulation methods are declining, as illustrated through The Conference Board of Canada's report which outlines Canada's decreasing birthrate, yet with a unified goal of increasing Canada's total population to a 100 million inhabitants by the end of the century, Canadians' will reap the rewards of having a substantially larger GDP. This bold objective is further substantiated through the use of a tool on Century Initiative's site which allows the user to visualize the effects of a high population in comparison to GDP over a variety of scenarios. However, it has been tasked to the author of the report to improve this tool. As the world around us continues to grow and we seek answers, explanations and a better understanding of the world around us, interactive web-based cartographic renderings are a staple in the transmission of information. Therefore, it was proposed that a more interactive tool replace the current tool. The anticipated new tool would be one that combines all the elements of the original tool, such as selecting an immigration scenario and a projected year, but also incorporates more detail in regards to where people will live and how each province and major city will contribute to the overall prosperity of the country.

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APPENDICES

APPENDIX A

FIGURE 1: Century Initiative's current tool.

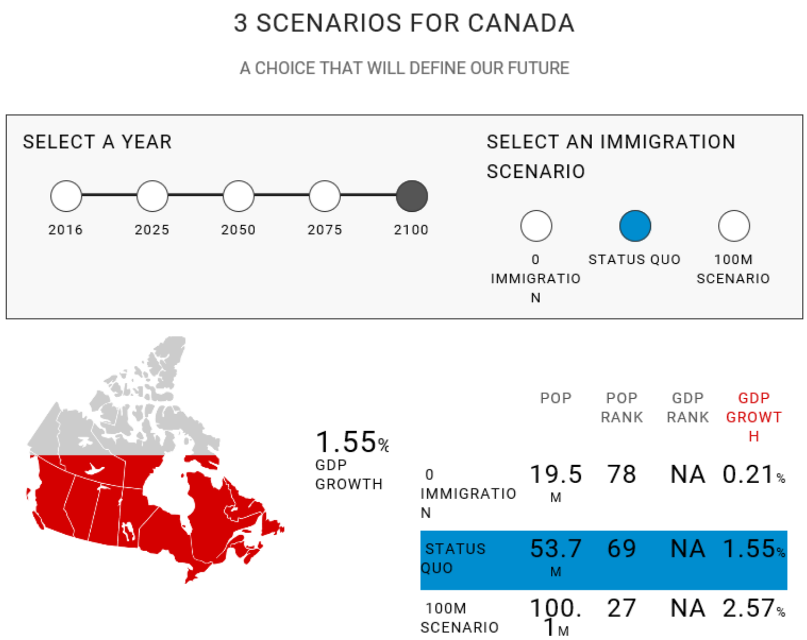


Figure 2: The geodatabase created to hold all shapefiles, tables, and models for data analysis in ArcMap.

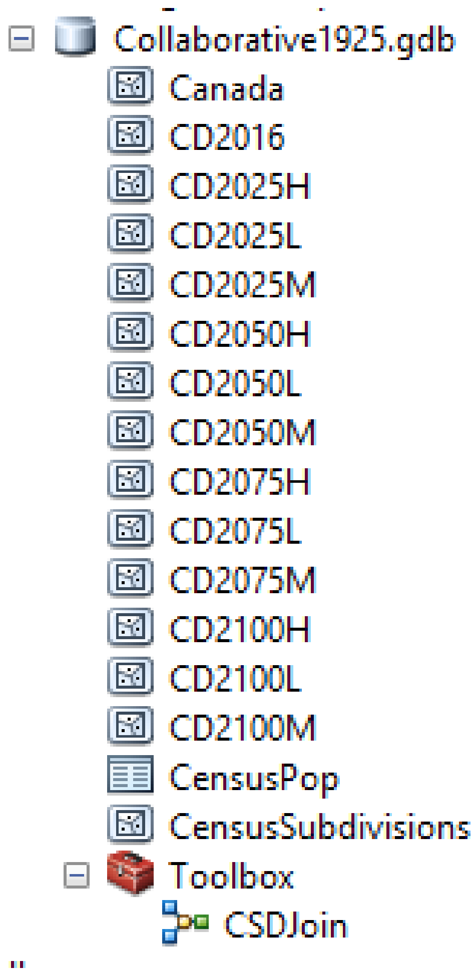


Figure 3: The tables present in the Microsoft Access database that hold all the tabular data acquired and created using Excel.

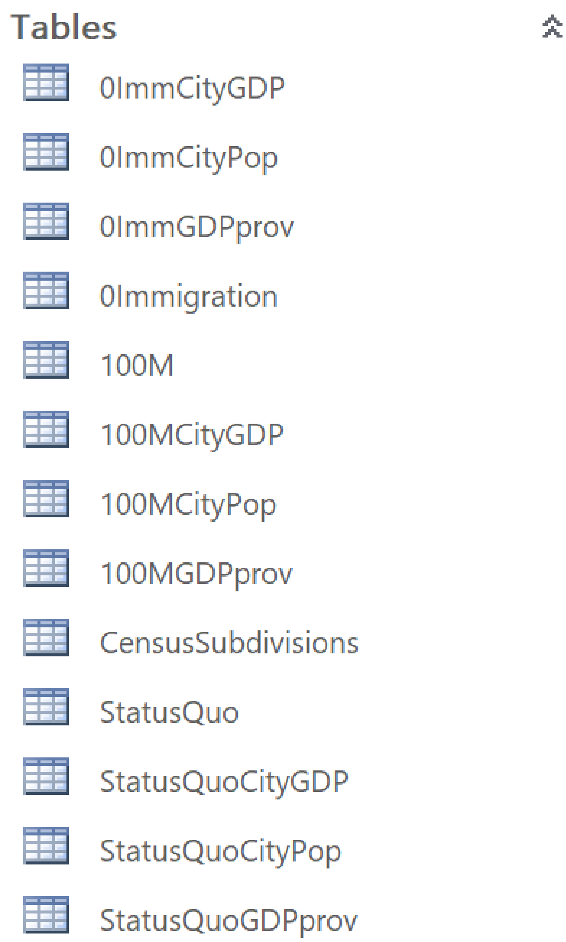


Figure 4: A model generated using ArMap Model Builder to run a join between the Census Subdivision shapefile and the Census Subdivision predictive data, then create feature layers for each desired scenario and time period, and finally export them to new individual shapefiles.

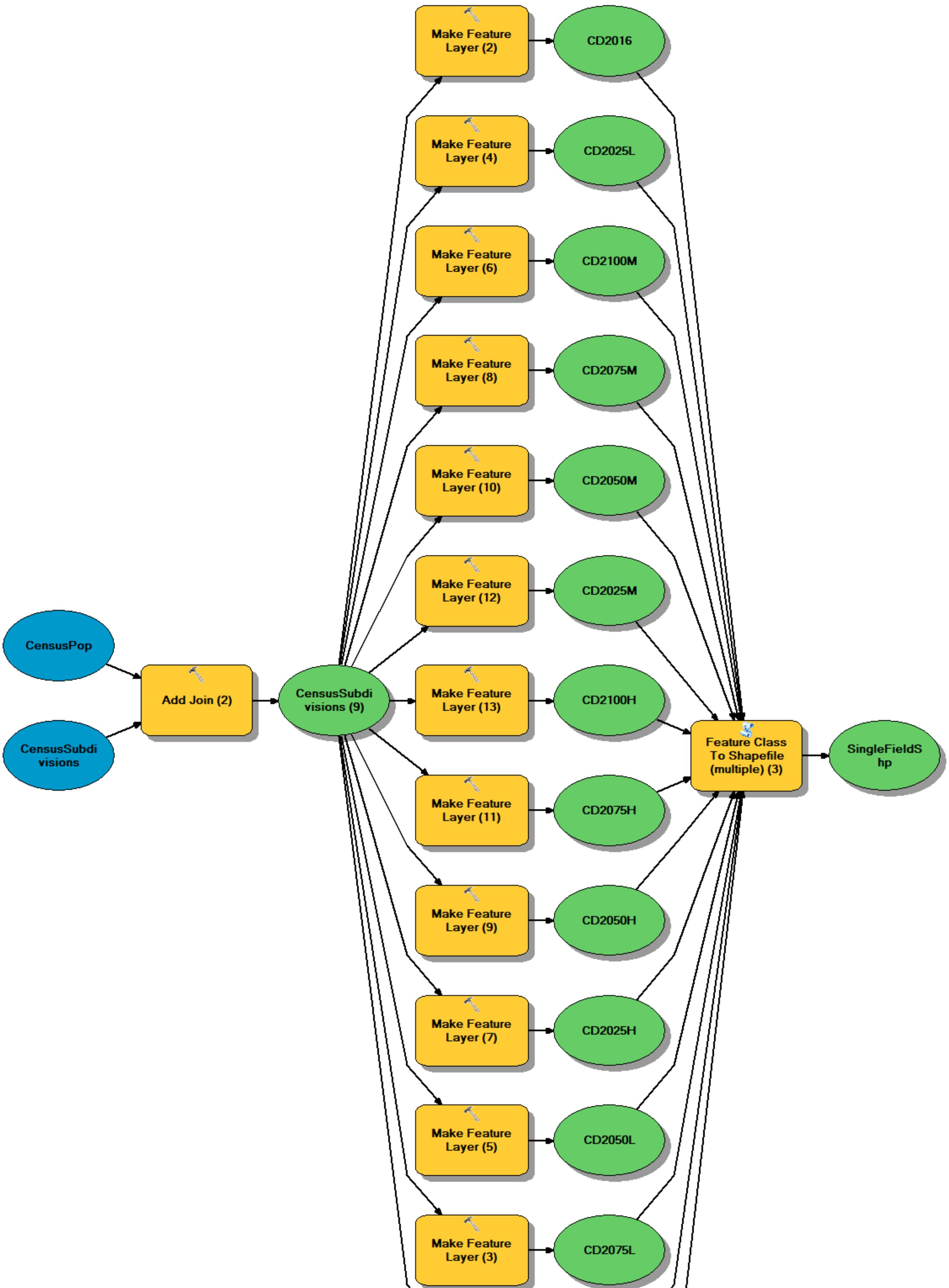

Make Feature Layer (2)
CD2016
Make Feature Layer (4)
CD2025L
Make Feature Layer (6)
CD2100M
Make Feature Layer (8)
CD2075M
Make Feature Layer (10)
CD2050M
Make Feature Layer (12)
CD2025M
CensusPop
Add Join (2)
CensusSubdivisions
CensusSubdivisions (9)
Make Feature Layer (13)
CD2100H
Feature Class To Shapefile (multiple) (3)
SingleFieldShp
Make Feature Layer (11)
CD2075H
Make Feature Layer (9)
CD2050H
Make Feature Layer (7)
CD2025H
Make Feature Layer (5)
CD2050L
Make Feature Layer (3)
CD2075L

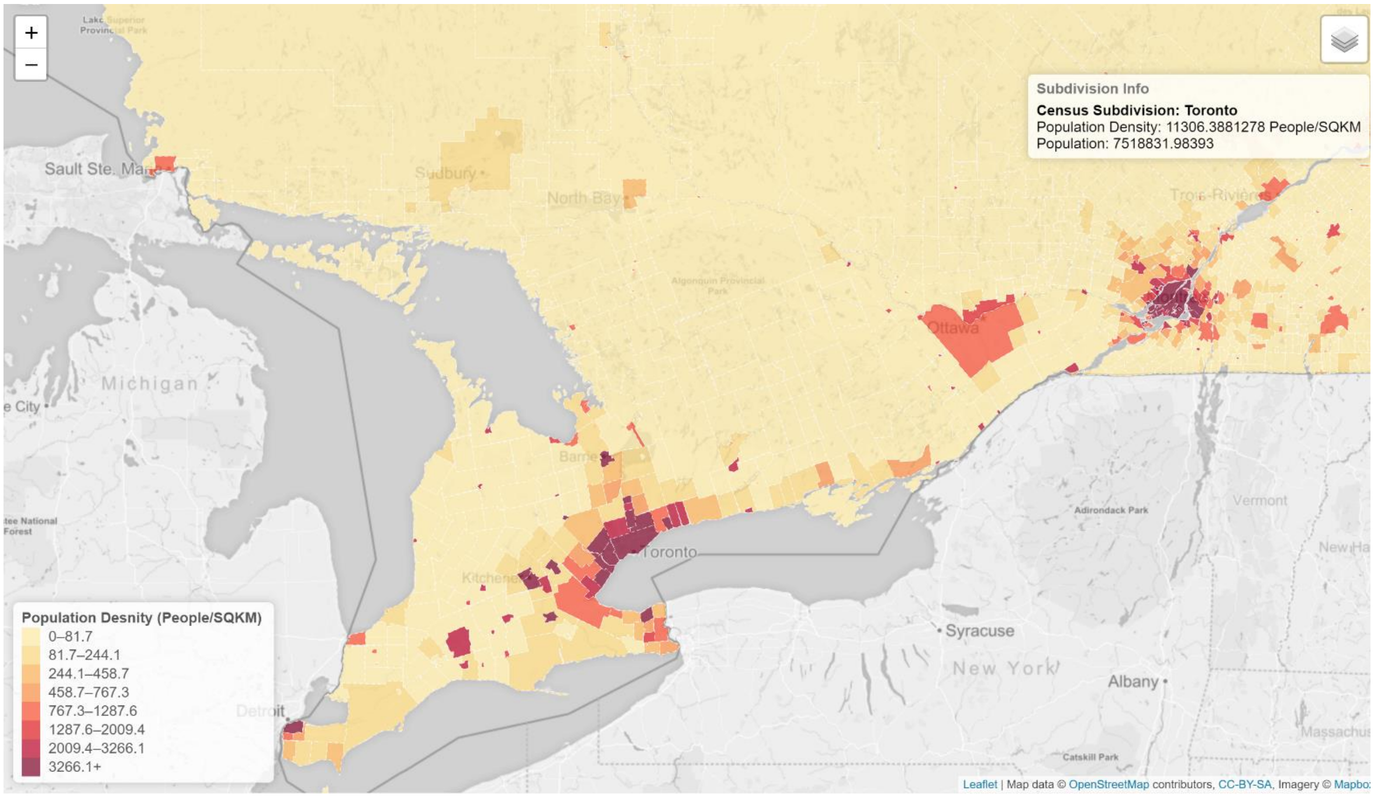
Figure 5: An example of the shapefile exported after our joining model was run.

Contents Preview Description

FID	Shape *	CSDUID	CSDNAME	CensusSub	Shape_Area	CensusPop	Pop	PopDensity	NationalPo	Provincial	Shape_Ar_1
0	Polygon	1001181	Riverhead	57608.20066	108933494.5	1964	185	1.8	3989	285	108933494.7
1	Polygon	1001186	Admirals Beach	25520.40264	26055436.22	1938	135	5.5	4176	311	26055436.21
2	Polygon	1001192	St. Joseph's	27338.32187	33774416.89	1948	115	3.6	4252	324	33774417.02
3	Polygon	1001197	Mount Carmel-Mitchells Brook-St. Catherine's	50675.49547	64424287.74	1935	349	5.7	3388	206	64424288.10
4	Polygon	1001219	Branch	27041.19952	16575775.02	1880	228	14.1	3814	265	16575775.05
5	Polygon	1001225	Point Lance	27720.89949	29805722.16	1951	102	3.5	4305	329	29805722.00
6	Polygon	1001228	St. Bride's	11780.86529	5943641.110	1786	252	43.1	3725	250	5943641.148
7	Polygon	1001234	Division No. 1, Subd. B	237019.9706	505081871.2	1978	360	0.8	3355	205	505081871.6
8	Polygon	1001240	Placentia	102538.1053	60978218.08	1760	3496	60.2	916	20	60978217.74
9	Polygon	1001254	Fox Harbour	30398.74436	21384993.61	1888	252	12.7	3725	250	21384993.57
10	Polygon	1001259	Division No. 1, Subd. A	436488.8139	854508314.6	1975	731	0.9	2486	107	854508314.6
11	Polygon	1001263	Long Harbour-Mount Arlington Heights	42130.33811	19362641.73	1902	185	10.1	3989	285	19362641.68
12	Polygon	1001267	Southern Harbour	15427.62305	5657656.886	1750	369	68.3	3330	203	5657656.905
13	Polygon	1001270	Arnold's Cove	20718.37847	4950064.551	1679	949	198.2	2165	85	4950064.480
14	Polygon	1001101	Division No. 1, Subd. V	238797.7798	964407267.9	2012	36	0	4612	355	964407268.0
15	Polygon	1001105	Portugal Cove South	4598.776948	1194131.345	1702	150	131.5	4114	304	1194131.342
16	Polygon	1001113	Trepassey	62146.94238	58788063.62	1912	481	8.6	3008	166	58788063.59
17	Polygon	1001120	St. Shott's	4353.578438	1152133.087	1762	66	58.4	4475	346	1152133.116
18	Polygon	1001124	Division No. 1, Subd. U	308684.4547	891699679.5	1962	1625	2.2	1551	57	891699679.9
19	Polygon	1001126	Cape Broyle	21849.25441	10906031.83	1776	489	48.6	2997	163	10906031.69
20	Polygon	1001131	Renews-Cappahayden	62084.70659	137261676.2	1959	301	2.4	3565	228	137261675.8
21	Polygon	1001136	Fermeuse	37748.55986	42043730.59	1915	325	8.4	3472	216	42043730.80
22	Polygon	1001140	Port Kirwan	15644.81854	10229638.62	1936	52	5.7	4537	349	10229638.64
23	Polygon	1001144	Aquaforte	15743.77799	7330211.682	1894	80	11.7	4416	340	7330211.688
24	Polygon	1001149	Ferryland	24281.36110	14479222.64	1812	414	30.4	3191	187	14479222.67
25	Polygon	1001155	Division No. 1, Subd. W	340077.4332	964877153.3	1989	435	0.5	3133	179	964877152.5
26	Polygon	1001203	Division No. 1, Subd. X	212735.1283	633541191.0	1976	513	0.9	2938	159	633541190.8
27	Polygon	1001207	Colinet	13467.55064	6328477.427	1887	80	12.8	4416	340	6328477.374
28	Polygon	1001214	Division No. 1, Subd. C	175845.3203	861157695.9	2003	100	0.1	4313	331	861157695.9
29	Polygon	1001169	St. Vincent's-St. Stephen's-Peter's River	64555.06868	91095368.39	1949	313	3.6	3516	223	91095368.42

1 (of 5162)

Figure 6: An example of the Web Application for displaying population and population density for census subdivisions.



APPENDIX B

Table 1: A table displaying the steps taken to complete the project.

ID	Milestone Desc	Tasks	Raise By	Priority	Open Date	Target Date
1	Tabular Data Acquisition	Research and download Stats Can Data for Canadian GDP/Population		High	22/05/2019	22/05/2019
2	Spatial Data Acquisition	Reasearch and download relevant shapefiles for provinces and cities		High	22/05/2019	22/05/2019
3	Data Automation/Manipulation	Generate predicted values for GDP/Population using Excel		High	22/05/2019	22/05/2019
3.b	Data Manipulation (Census Districts)	Generating Future Population for Population		Moderate	22/05/2019	29/05/2019
4	Database Creation	Import GDP/Population data into cohesive Access Database		High	22/05/2019	22/05/2019
5	Web Application Index HTML	Develop barebones webpage to host map application, toggle buttons/drop, html/css		High	22/05/2019	9/6/2019
6	JavaScript Creation	Develop JavaScript for data presentation and application interaction		High	22/05/2019	9/6/2019
7	Final Report	Write Final Report and plan for Final presentation/Oral Defense		High	5/6/2019	12/6/2019
8	Web Application Update	Address issues that arise with the web application and cosmetic issues		Moderate	5/6/2019	16/6/2019
9	Incorpoarate Century Initiative Web Page With Web Application	Merge Web Application with Century's webpage style		Low	22/05/2019	16/6/2019

Table 2: Page 1 of Project 1925B Timeline.

SPRING 2019

COLLAB 1925**B** DELIVERABLES SCHEDULE

JAMES BURTON

TASK	NOTES	DUE DATE	DONE	INITIALS
Tabular Data Acquisition	Compile all the tabular data.	Tuesday, Week 1	X	JB
Spatial Data Acquisition	Compile Spatial/ Natural Earth Data.	Thursday, Week 1	x	JB
Compile Data into cohesive database	Align data into cohesive database.	Sunday, Week 1	X	JB
Data Automation	Create workflow/ SQL query to create new fields and to populate new fields	Sunday, Week 1	X	JB
Understanding Web Presentation	Understanding components required for desired functions. This includes proper attribute and geometry structure, and insuring all information is available for required JavaScript functions.	Thursday, Week 3	X	JB
Web Presentation Part A, Component 1	Re-structure data for appropriate javascript functions	Thursday, Week 3	X	JB
Web Presentation Part B, Component 1a	Create one draft geojson for Canada.	Thursday, Week 3	X	JB
Web Presentation Part B, Component 1a2	Create working geojson for Canada.	Sunday, Week 3	X	JB
Web Presentation Part B, Component 1	Create final geojson for Canada with modified fields	Friday, Week 4		JB

Table 3: Page 2 of Project 1925B Timeline.

TASK	NOTES	DUE DATE	DONE	INITIALS
Web Presentation Part C, component 1a	Apply geojson to filter correctly to Canada file, implement slider and radio buttons.	Thursday, Week 4	X	SUN WEEK 3 JB
Web Presentation Part C, component 1b	Create geojson filter for polygon type to utilize merged tileset	Wednesday, Week 4	X	JB
Web Presentation Part D, Component 1	Apply Geojson to display axillary information on click or hover, apply to static field for demonstration.	Thursday, Week 3	X	JB
Web Presentation Part D, Component 2a	Create functional dynamic text display on click/hover.	Thursday, Week 4	X	FRI WEEK 3 JB
Web Presentation Part D, Component 2b	Create framework for bar chart and text on click	Saturday, Week 3	X	JB
Web Presentation Part D, Component 2c	Apply merged geojoson/Tileset filter to dynamic chart functions	Saturday, Week 4	X	JB
Web Presentation Part E, Component 1	Create functional zoom levels between final Canada file and draft provinces file	Thursday, Week 3	X	JB
Web Presentation Part F, Component 1	Create functional color ramp, dynamically applied to spatial data, use tentative colours for now	Monday, Week 3	X	JB
Web Presentation Part B, Component 2a	Create working draft Province geojson	Monday, Week 4	X	JB
Web Presentation Part B, Component 4a	Merge working geojsons with merge tool	Monday, Week 4	X	JB

Table 4: Page 3 of Project 1925B Timeline.

TASK	NOTES	DUE DATE	DONE	INITIALS
Web Presentation Part B, Component 5a	Export large merge geojson as Mapbox tileset with Tippecanoe	Monday, Week 4	X	JB
Web Presentation Part B, Component 2b	Create final Province geojson	Friday, Week 4	X	JB
Web Presentation Part B, Component 3a	Create draft city geojson, upload to mapbox tileset	Monday, Week 4	X	JB
Web Presentation Part B, Component 3b	Create final city geojson, upload to mapbox tileset	Friday, Week 4	X	JB
Web Presentation Part B, Component 4b	Merge final Canada, Provinces, Cities geojson with geo-merge tool	Friday, Week 4	X	DROPPED TASK
Web Presentation Part B, Component 5b	Create full, final dataset as Mapbox Tileset with Tippecanoe tool	Friday, Week 4	X	JB
Web Presentation Part E Component 2	Create functional zoom level between Canada, Provinces, City	Friday, Week 4	X	Saturday, WEEK 3 JB
Web Presentation Part C, Component 2a	Ensure dynamic adjustment of slider and radio button between zoom levels,	Friday, Week 4	X	SUN Week 3 JB
Web Presentation Part C, Component 2b	incorporate proper classification for each zoom levels	Wednesday, Week 5	X	Monday, Week 6 JB
Web Presentation Part D, Component 3	Apply working dynamic information display for cities, provinces.	Wednesday, Week 5	X	JB
Web Presentation Part F, Component 2	Determine colours and apply colour ramp and classifications to Canada, Provinces and Cities	Thursday, Week 5	X	Tuesday, Week 6 JB

Table 5: Page 4 of Project 1925B Timeline.

TASK	NOTES	DUE DATE	DONE	INITIALS
Web Presentation Part G, Component 1	Application of customized basemap through mapbox studio	Thursday, Week 3	X	JB
Web Presentation Part G, Component 2	Assess functionality and modify if needed basemap colours, labels etc.	Monday, Week 6	X	JB
Web Presentation Part H, Component 1	Implement "frills". Align objects(divs), legends, citation to sources.	Monday, Week 6		
Web Presentation Part H, Component 2	Implement final solution on a copy of the client's existing html page.	Wednesday, Week 6		
Soft Release	Allow family, friends, peers, faculty to view, play with, and hopefully break the final solution	Week 6		
Finished Final Report	Finished final report for 1925B submitted.	Week 6		
Hard Release	Publish link on facebook and bask in glory of an awesome web solution.	Weekend between Week 6/7		
Project Archive	Anticipated date of completion.	Week 6 Sunday		
Oral Defense	Defend solution against faculty.	TBD Week 6		
Open House Presentation		Week 7 Friday, June 21		

APPENDIX C

FIGURE 1: CANADA AND THE PROVINCES/ TERRITORIES USED FOR THE NEW ANALYSIS

Figure 2: A selection of major metropolitan areas, highlighted in green.

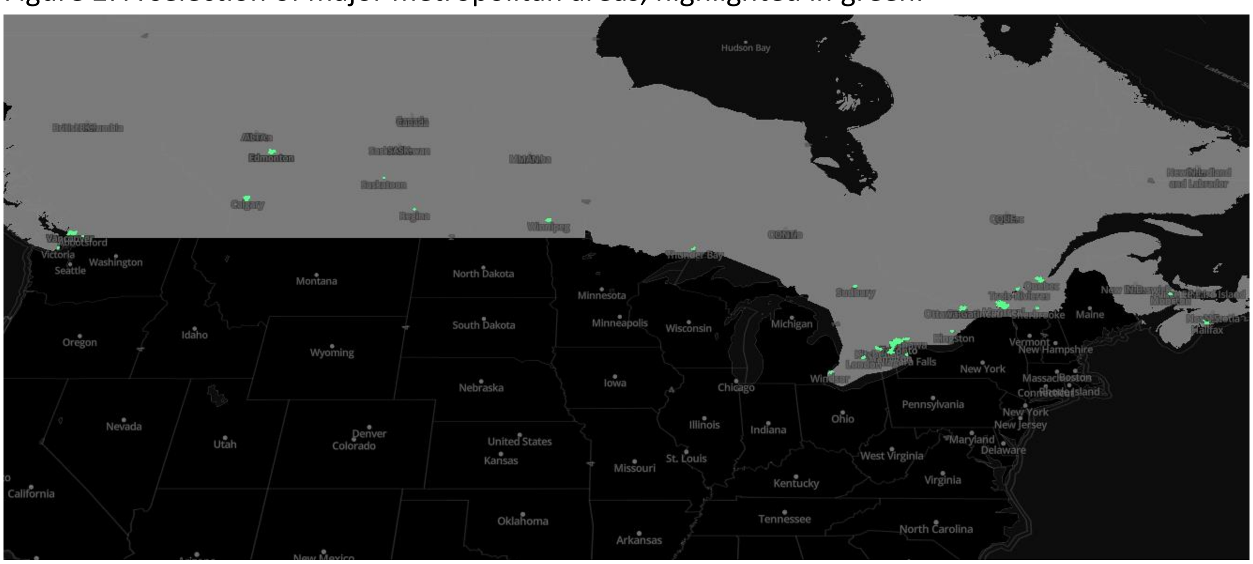
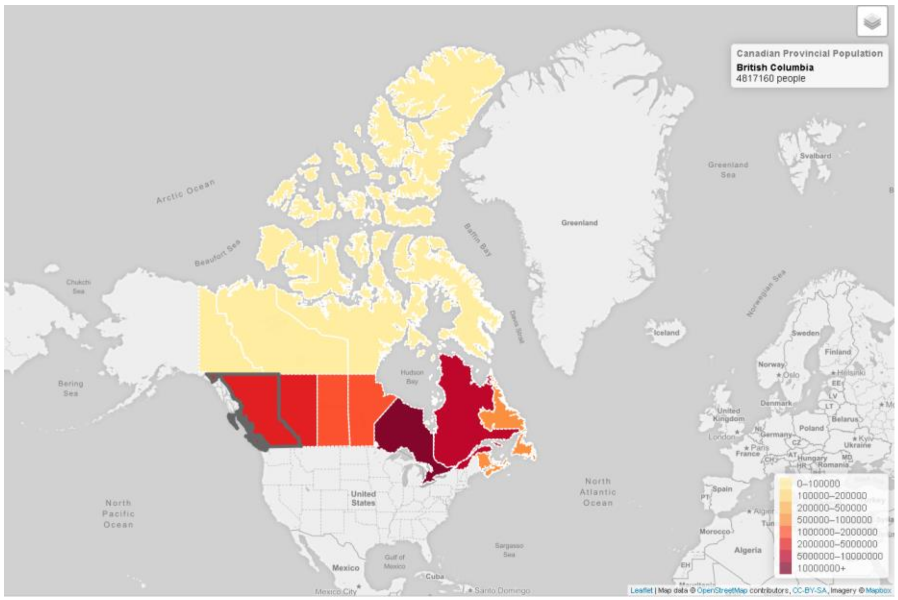


FIGURE 3: EXEMPLAR OF 2D POPULATION DENSITY RENDERING UTILIZING LEAFLET.



APPENDIX D

Table 1: Century Initiative Source Data.

Century Initiative Statistics									
Year	**0 Immigration, Population**	**0 Immigration, gdp growth**	**status quo, population**	**status quo, gpd growth**	**100 million, population**	**100 million, gdp growth**	**0 Immigration, population percent difference with year prior**	**Status Quo, population percent change from year prior**	**100 million, population percent change from year prior**
2016	36300000	1.34%	36300000	1.34%	36300000	1.34%			
2025	36100000	0.99%	39900000	1.69%	40100000	1.82%	-0.55%	9.92%	10.47%
2050	32400000	0.42%	46100000	1.59%	54900000	2.34%	-10.25%	15.54%	36.91%
2075	25600000	0.30%	50200000	1.58%	73200000	2.56%	-20.99%	8.89%	33.33%
2100	19500000	0.21%	53700000	1.55%	100000000	2.57%	-23.83%	6.97%	36.61%

Table 2: Provincial GDP Source Data.

NWT Bureau of Statistics GDP for Provinces		
NAME	**2016**	**2017**
Canada	2,023,824	2,137,528
Northwest Territories	4,603	4,856
Nunavut	2,513	2,846
Yukon	2,715	2,895
British Columbia	263,978	282,204
Alberta	301,711	331,937
Saskatchewan	75,844	79,513
Manitoba	67,391	71,019
Ontario	792,932	825,805
Quebec	397,291	417,173
New Brunswick	34,593	36,088
Nova Scotia	41,492	42,715
Prince Edward Island	6,348	6,652
Newfoundland and Labrador	31,696	33,074

Table 3: City GDP Source Data.

Statistica Data	
City	**2016 GDP in millions**
Toronto	329678
Montreal	169931
Vancouver	129158
Calgary	113151
Edmonton	84382
Ottawa-Gatineau	66435
Regina	37610
Winnipeg	37610
Quebec City	34491
Hamilton	28631
Kitchener-Cambridge-Waterloo	26513
London	21071
Halifax	18358
Saskatoon	17195
Victoria, BC	16920
St. Catherines-Niagara	14609
St. John's	13340
Windsor	13321
Oshawa	12407

Greater Sudbury	8052
Sherbrooke	7524
Kingston	7419
Moncton	6526
Trois-Rivieres	6296
Abbotsford-Mission	6234
Saguenay	5647
Saint John	5282
Thunder Bay	4564

Table 4: Province Population Source Data.

Statistics Canada 2016 Canada & Province Population		
Geographic code	**Geographic name**	**Population, 2016**
1	Canada	35151728
10	Newfoundland and Labrador	519716
11	Prince Edward Island	142907
12	Nova Scotia	923598
13	New Brunswick	747101
24	Quebec	8164361
35	Ontario	13448494
46	Manitoba	1278365
47	Saskatchewan	1098352
48	Alberta	4067175
59	British Columbia	4648055
60	Yukon	35874
61	Northwest Territories	41786
62	Nunavut	35944

Table 5: Metropolitan Population Source Data.

TodoCanada Data Metropolitan Populations	
City	**Population 2016**
Toronto	5928040
Montreal	4098927
Vancouver	2463431
Calgary	1392609
Edmonton	1321426
Ottawa-Gatineau	1323783
Regina	236481
Winnipeg	778489
Quebec City	798162
Hamilton	747545
Kitchener-Cambridge-Waterloo	523894
London	494069
Halifax	403390
Saskatoon	295095
Victoria, BC	367770
St. Catherines-Niagara	406074
St. John's	205655
Windsor	329144
Oshawa	379848
Greater Sudbury	164689
Sherbrooke	212105
Kingston	161175
Moncton	144810
Trois-Rivieres	156042
Abbotsford-Mission	180518
Saguenay	160980
Saint John	126202
Thunder Bay	121621

Table 6: Shapefile Metadata.

Shapefile Metadata			
Source	**Title**	**Type**	**Notes**
Natural Earth, 2019	Admin 0 – Countries	Polygon	Countries around the globe.
Natural Earth, 2019	Admin 1 – States, Provinces	Polygon	Global states and provinces.
Natural Earth, 2019	Urban Areas	Polygon	Just polygons surrounding developed areas
Natural Earth, 2019	Populated Places	Point	Global cities, towns etc.

APPENDIX E

Figure 1: Large Master Database Structure Diagram(Burton, 2019.)

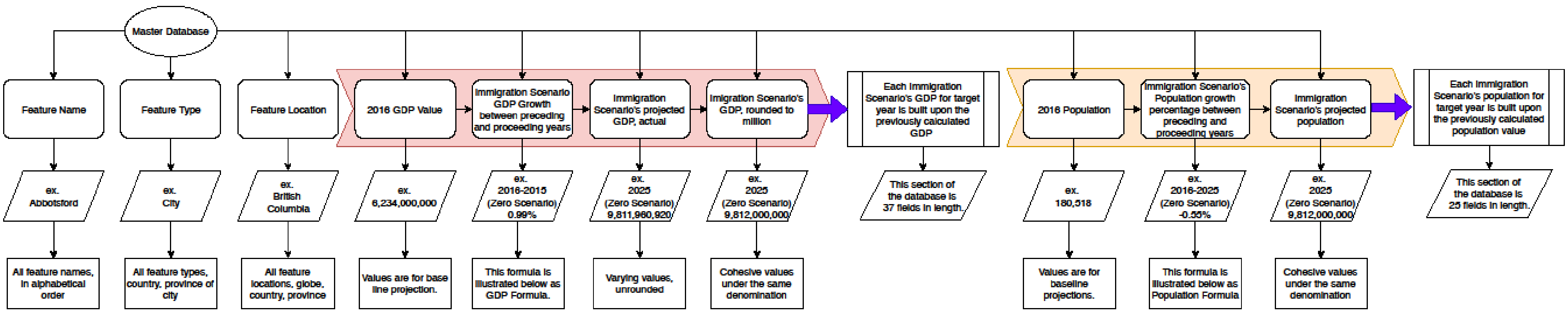


Figure 2: Large Attribute Database Structure Diagram (Burton, 2019).