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VISUALIZATION OF GEOGRAPHIC DATA USING GOOGLE CLOUD PLATFORM

Diploma thesis

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ANOTATION

The aim of the thesis is to analyse, describe and evaluate spatial and geographic aspects of Google Cloud Platform. Focus is on integration with supported tools by Google Cloud Platform (e.g. Google Data Studio), Data Import, Connection and Integration. The main emphasis is on visualisation purposes - both general and cartographical methods, parameters, datasets, implementations. The cartographic outputs and spatial visualization were evaluated by several aspects. Finally, a workflow for spatial data connection and visualisation via Google Cloud Platform was designed. Theoretical knowledge was supported by pilot study. Based on a suitable dataset and defined workflow, case studies demonstrating the benefits and limits for various topics were developed.

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Theses guidelines

The aim of this work is to analyze, describe and evaluate spatial and geographic aspects of Google Cloud Platform. Student will focus on integration with supported tools by the Google Cloud Platform (e.g. Google Data Studio), data import, connection and integration. The main emphasis will be put on visualisation purposes – both general and cartographical methods, parameters, datasets, implementations. Student will analyze the limits and possibilities of Google Cloud Platform for geoinformatic and cartographic use. He will evaluate, quantify and analyze cartographic outputs and spatial visualization by several aspects (cartographical, geoinformatical, user, economic, technical). Finally, he will design a workflow for spatial data connection and visualisation via Google Cloud Platform. Theoretical knowledge will be supported by pilot study. Based on a suitable dataset and defined workflow, case studies demonstrating the benefits and limits for various topics will be developed. The student will attach all the collected datasets and all the animations to the thesis in digital form. The student will create a website about the thesis following the rules available on the department?s website and a poster about the diploma thesis in A2 format. The student will submit entire text (text, attachments, poster, outputs, input and output data) in digital form on a storage medium and the text of the thesis in two bound copies to the secretary of the department.

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Google Cloud Platform [online]. Available at URL: https://cloud.google.com/gcp/
Google Data Studio [online]. Available at URL: https://datastudio.google.com/
Hamlin Ch. (2020). Use Google Maps to get a greater understanding of your Ecommerce geographic data in Google Data Studio.
Kraak M.J., Brown A. (2003). Web Cartography: Developments and Prospects.
Muehlenhaus I. (2013). Web Cartography: Map Design for Interactive and Mobile Devices.
Snipes, G. (2018). Google Data Studio. Journal of Librarianship and Scholarly Communication, 6.

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LIST OF ABBREVIATIONS

Abbreviation	Meaning
AaaS	Application As a Service
CaaS	Container As a Service
CSV	Comma-Separated Values
DaaS	Data As a Service
DNS	Domain Name System
GaaS	GIS As a Service
GCP	Google Cloud Platform
GDS	Google Data Studio
GIS	Geographic Information System
GKE	Google Kubernetes Engine
IaaS	Infrastructure As a Service
PaaS	Platform As a Service
SaaS	Software As a Service
SHP	Shape file
SQL	Structured Query Language

INTRODUCTION

Advances in GIS cloud computing paradigms have opened up possibilities for the visualization and communication of spatial data at scale. Geographic data visualising have undergone profound changes in terms of representation and interactivity (Dodge et al., 2008) whilst encapsulating the real world perception of spatial attributes and processes. The increasing availability of methods and platforms poses a great opportunity for customization of geographic visualization as well as communication across multiple medium. Spatial data visualization involves exploration, analysis, synthesis and communication (Ormeling, 2010). Therefore, reviewing and evaluating the emerging cloud based platforms in the context of the geovisualization process is very critical for the next phase of Geographic data representation where visual communication is gaining traction across multiple organizations.

Google Cloud Platforms (GCP) via its products like Google Data Studio (GDS) and Google Maps have created a unique opportunity for spatial data exploration, analysis, synthesis and presentation which are key to effective geovisualization. Through the interplay of critical product review buttressed by case studies, suitable datasets and workflows, the work explores the spatial dimension of GCP. With emphasis on visualization, general and cartographic methods were explored in the context of potential and limitation for Geoinformatics and Cartographic use.

The study explored the process of data integration, data transformation, visualization and communication using a case study approach. A conceptual framework was developed for spatial data visualization involving Geospatial Data Source, Map Design Considerations, Cartographic Methods Visualization and Evaluation. The work reviewed and adopted a customised workflow based on the design framework and include data connectors, data transformation, data validation and visualization. Various evaluation approaches such as heuristic evaluation, aspect analysis and SWOT analysis were used complementarily to ascertain the extent and overview of spatial dimensions.

1 OBJECTIVES

The aim of the diploma thesis is to analyse, describe and evaluate spatial and geographic aspects of Google Cloud Platform (GCP). The theoretical dimension of the work reviews the general ecosystem of cloud platforms with emphasis on Google Cloud. More specifically, Google Data Studio was selected as the unit of observation. Focus is given to integration with supported tools by the GCP, data import, connection and integration. Also, emphasis is on the visualisation purposes, including both general and cartographical methods, parameters, datasets and implementation approaches.

As a practical approach, cartographic outputs and spatial visualization are evaluated, quantified and analysed by several aspects including the cartographical, geoinformatics, user, technical, and economic. Based on a suitable dataset and defined workflow, case studies demonstrating the benefits and limits for varied topics are developed.

The study is guided by the following objectives:

- To review the spatial and geospatial ecosystem of Google Cloud Platforms
- To investigate the visualization dimensions of Google Cloud Platform with emphasis on general and cartographic methods, parameters, datasets and implementation approaches
- To evaluate, quantify and analyse the cartographic and spatial visualization
- To analyse the limitation and potentials of Google Cloud Platform for geoinformatics and cartographic use
- To develop a workflow for spatial data connection and visualization via Google Cloud Platform

The result of the work will allow for an integrated evaluation framework for Google Data Studio (GDS) as well as detail alternative approach to Geovisualization and Geoanalytics. A library of workflow is also developed to aid a seamless implementation of various geovisualization methods.

2 METHODOLOGY

The chapter gives an overview of the methodologies used to undertake the work, data used as well all the overall procedure followed to achieved the intended outputs.

Used methods

The study adopted a mix methodological approach to address the various objectives. This approach helps optimize results for realism, reliability and validity (Ooms, 2016). The broad methods used includes literature review, case study and heuristic evaluation. To address the first objective which seeks to review the spatial and geospatial ecosystem of GCP, google cloud documentation was reviewed. Relevant literature was also reviewed in relation to Cloud GIS, Geographic data visualization.

The second objective seeks to investigate the visualization dimensions of Google Cloud platform with emphasis on general and cartographic methods, parameters, dataset and implementation approaches. The case study methodology was adopted to realize this. The first case study was on the visualization of Covid-19 data and the second is on Palacký University Olomouc Department of Geoinformatics Web Analytics data whereas the last case study explored the visualization of world population and air pollution death data. The case studies were used to explore and demonstrate the data collection approaches, exploration and visualization in the context of spatial and cartographic dimensions.

Finally, expert evaluation was employed to complement the case studies. This also is to help address the third objective which seeks to evaluate, quantify and analyse the cartographic and spatial visualization and fourth objective to analyse the limitations and potentials of Google Cloud Platform for Geoinformatics and cartographic use. The expert evaluation adopted include SWOT analysis, non-technological aspect (Vondrakova, 2013) and heuristic analysis. All the expert methods were integrated and customised for the research goals.

Used data

Various data were explored using the case studies. The first case study used the Covid-19 data from John Hopkins University GitHub. The latest Covid-19 daily data was downloaded directly in CSV format. For the second case study, the data was streamed directly from the website of the Department of Geoinformatics at the Palacky University of Olomouc. My supervisor created a registration and access to the departments analytics platform for the purpose of the study. The last case study integrated data from two sources. Global population data was extracted from World Bank data catalog for the period of 1960 to 2019. Also, the air pollution data was retrieved from Our World in Data website.

Used software

The main application used is GDS and it is the object of study. Using the connector tool, data was ingested into the platform via direct upload, access from google analytics and google sheets. Microsoft Excel and Notepad Text Editor were employed for preliminary data checks and expert evaluation analysis.

Processing procedure

The project process is defined by the Gantt chart in Figure 1 below dividing the project into manageable task with my supervisor. Following the approval of the thesis proposal was literature review to consolidate related works on the topic. This process included the product review and undertaking basic tutorials on the use of GDS. Weekly meeting was carried out with my supervisor to discuss work progress. There were also periodic meetings with my co-supervisor based at the University of Salzburg.

Case study development were carried out immediately after literature review. Five case studies were initially developed but later streamlined to only three upon discussing with my supervisor. Progress presentation was carried out to ascertain work output and to solicit recommendations. Finally, the work was submitted and defence carried out.
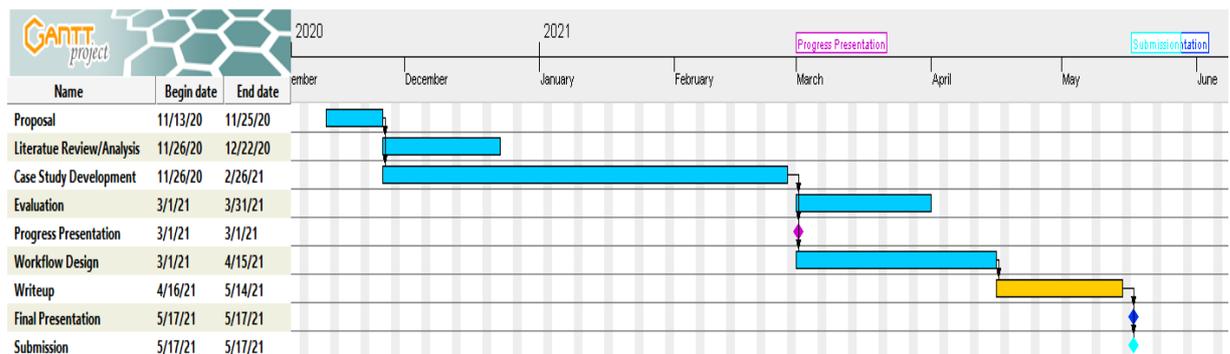

Figure 1 Gantt Chart showing Project Process

3 STATE OF ART

3.1 Cloud Computing and Cloud GIS paradigm

Cloud computing can be expressed to mean harnessing data, computation powers and storage capacities through the internet (Liu, 2013). Whilst the idea of cloud computing in Geographic Information System (GIS) is now gaining momentum, it has been in existence for a while (Yadav et al., 2010). The uniqueness of cloud computing is its distributed resources which everyone can access via the internet. Web GIS has seen a rapid transformation since the last decade due to the increased improvement in internet (Agrawal et al., 2017). This involved client sending a request to server where these request are processed and retrieved. Cloud GIS have seen a transition from Web GIS to Grid GIS then to public Cloud GIS and finally private Cloud GIS (Gao et al., 2012). The authors postulated that Grid system sought to rectify the challenges in Web GIS including rapid computing task. After this was the emergence of the Public cloud and Public cloud GIS. Cloud based GIS solutions are service based, including spatial data and processing taking place over the internet (Park et al., 2010). User accessibility to these services are through web services onto the server (Xu et al., 2009). Also, spatial data and processing by their nature are heavy and intensive especially for simple computer systems (Posey et al., 2019). Therefore, virtualizing allows for extendibility of these storage resources and also for effective processing. Cloud services can be characterised as service based, extendable, elastic, on demand service, measurable, transparent, diversifying access and pay to use (Ma et al., 2012). The approach to dealing with geographic data digitally gained much prominence from the 1980 considerably changing how users perceive and use maps (Ormeling, 2010). Through computer abilities, databases are accessed and maps are able to perform basic operations.

The advances in digital technologies saw the transition into a fully fledged GIS cloud based solutions (Goldberg et al., 2014). Whilst the place of paper maps are not taken away as it is still very crucial for presenting spatial information, the increasing presence of the web wide web and computer provided much capabilities (Kilsedar et al., 2020). Critical is accessibility to map information which was hitherto limited to experts. Aside the increasing capabilities of users to add their data, information sharing was increased and triggered across disciplinary approach to addressing geospatial challenges. Geographic information systems can be applied to various disciplines to explore and answer specific questions and challenges (Alfaqih, 2013). The ability to capture, manipulate and display spatial information make GIS very beneficial. The unique ability for multiple users to access data from different location from a database on a server ensures an effectively and timely decision making. However, performing spatial queries and data process requires robust hardware and software. According to Alfaqih (2013), "data gathering as well as the hardware and software systems are the most expensive in

terms of capital and human cost. With the emergence of big data paradigm, cloud solutions are the best approach to hosting voluminous datasets (McGrath et al., 2017). The shift of web GIS has propelled the use of cloud solutions as it is efficient in analyzing and exploring operations in real-time as well as help to manage work activities and spatial databases (Ramanathan et al., 2011). The broad benefit of GIS cloud in ensuring ease of access, integration huge databases has made it popular. The general service models for cloud computing include Platform As a service (PaaS), Software As a service (SaaS) and Infrastructure As a service (IaaS) (Malawski et al., 2020). However, in GIS, these services can be extended as GIS As a service (GaaS), Application As a service (AaaS), Imagery As a service (IaaS) and Data As a Service (Muenchow et al., 2019; Yang et al., 2011). The use of cloud infrastructure for GIS software services and capabilities on the web can be classified as cloud GIS. There is however a number of approaches and architecture to choose from.

3.2 Geographic Data Visualization

Representation of geographic data have witnessed profound changes in how information can be visualized and interacted with (Dodge et al., 2008). This can be keenly attributed to the growing prominence in digital transformation in GIS, multimedia and web based GIS tools (Gong et al., 2017). Improvements in sensor technologies as well as increasing user generated data offers a unique yet challenging task for the visualization of spatial data (Yang et al., 2010). The open data sharing culture have open up availability of big data which come with it unique characteristics like volume, velocity, variety, veracity and value among others (Tamiminia et al., 2020). Modern geographic data comes in many forms (Kilsedar et al., 2020) including social media (Destiny APUKE, 2018; Konicek et al., 2020) remote sensing (Salcedo-Sanz et al., 2020; Xie & Peng, 2008), mobility (Guerreiro et al., 2018) and transactional data (Wang et al., 2019). New and emerging visualization approaches have emerged to reflect the current trends and taste.

Geographic Visualization as a field is growing rapidly and has a wider reach. It involves the interplay of spatial attributes and processes as perceived in real world by using virtual or graphic representation. Poorthius (2018), categorized visualization of spatial data into visual communication and visual thinking where the former is termed "map to see" and the later "map to read". Geographic Visualization is an interplay of scientific visualization and Cartography, involving human cognition and communication. In DiBiase's work as cited in (Cartwright et al., 2004) he explored the link between visual thinking and visual communication where thinking component was more private and involve the stage of exploration and confirmation. However, the public realm was characterized by synthesis and presentation. A better approach to appreciate the efficacy of visualization is to have a perceptive imagination and work on exploring new spaces (Kraak, 2003). The use of map as geographic form of visualization can be dated back in

time and the mapping of spatial phenomenon is argued to be culturally ubiquitous (Blaut et al., 2003).

The choice of geographic visualization is affected by the users and intended purpose. Also Dodge et al., (2008) classified the approaches to displaying spatial data into 'looking', 'querying' and questioning. Translating complex relations into a more user understandable process is key to geovisualization. As such, it helps to decipher the unseen through the interaction with visual environment. Buckley et al., (2004) argues that the domain application of visualization is very broad and as such invokes a varied perspective. Cartography has now transcended static visualization to include interactions by users as well as leveraging emerging web based platforms for easy communication (Cartwright et al., 2004). There is also a shift from a static to a more interactive approach to geographic data visualization. This change is mainly attributed to the advances in computer capacities making way for understanding more complex spatial data. Key system considerations for visualization must include user interaction, ability to capture spatial change or temporal information as well as a friendly user interface.

3.3 Spatial Data Form

The nature of geographic data makes it unique. The ability to store both spatial and attribute information about a phenomena make it very useful. Spatial information can be categorized into geometrical and non-geometrical (Ormeling, 2010). The data can also be temporal in that it can capture time intervals. More basic, geographic data helps us to answer question of what, where, when, why and how. Spatial data describes the where aspect of geospatial data and this can be relative or absolute. Attribute information are also important and can be a qualitative or quantitative measure. The measurement scale can be nominal, ordinal, interval or ratio scale. GIS data can be vector or raster where their utilization varies based on an intended implementation.

Vector data are characterized as point data, line data and polygon and can be said to require small storage space where visualization is identifiable with its typology maintained (Elwakil et al., 2015). In raster data, contiguous cells with varied colours are used for representation. The data structure is simple but requires a huge storage capacity whereas the visualization is not as great. Data in geographic visualization are often huge and can be one-dimensional, two-dimensional or complex types. There are numerous techniques for visualizing spatial information especially for multi-dimensional data.

3.3.1 Vector data model

Vector data is structured as objects and the representation of spatial features are point based which can be extended to line and polygon (Maraş et al., 2010; Ormeling, 2010). Maraş et al., (2010) categorized vector data into two classes namely, non-topological data structure as well as topological data structure. The former is represented by basic geometry such where point is considered zero dimensional element. Line and polygon shaped features are characterized by one dimensional series and two dimensional closed shape respectively. Topological data structure on the other hand is the geometric link between edges, nodes and faces which can be likened to point, line and polygon (Fang et al., 2014; Maraş et al., 2010). This representation takes into consideration neighborhood relations as well as coincidence, intersection and inclusion. The attributes of vector data are stored in database and linked via some identification means (Fang et al., 2014). Piwowar et al., (1990) explored the conversion between both vector and raster data and argues that algorithms that focus on internal relationships performs better. The representation of vector files on computer screens takes into consideration the resolution, digital scale and ability to separate into various groups (Ormeling, 2010).

Vector formats are stored differently for use in a computer system. There are several formats which describes the basic geometry as well as attribute information. The common vector formats as characterized by Diamond (2019) is shown in Table 1.

Table 1 Vector Data Formats

Format	Description	File extension
Shapefile	Very common and originally designed for ArcGIS	.shp, .shx, .dbf, .prj
KML/KMZ	Keyhole Mark Language"; XML-based storage system	.kmz, .kmz
CSV	"comma-separated values"; can be visualized as a table; can only represent point data; does not support projections; does not store	csv, .tsv (tab-separated values)
GPX	An XML-based format for storing tracked GPS coordinates	
GeoJSON/TopoJSON	A key-value format written in JavaScript Object Notation	.js, .json, .geojson
Geodatabase	An ArcGIS-specific format with several implementation methods	.gdb

PostGIS	A geospatial database extension for PostgreSQL databases	
SpatiaLite	A geospatial database extension for SQLite	.sqlite
Vector tiles	A lightweight storage format for tiled vector data using protocol buffers	.pbf, .mvt
OpenStreetMap	A key-value format written in XML	.osm

3.3.2 Raster data model

In raster data model, regular grids or matrix which represents the geometry of spatial objects (Maraş et al., 2010). The cells of the grid use a binary system to differentiate between observable feature. In raster format, an image is classified by a grid of pixels which are not extending over each other (Piwowar et al., 1990). They function as base units unlike a geospatial object in vector model. As remote sensing imagery became prominent, there are various approaches developed to analyze raster data. The resolution often determines the representativeness of a geographic feature via the size of the cell. The use of raster data model transcends traditional GIS. Raster model is made up of rows and columns representing pixels of equal dimension and serves as the basic component for representing points, lines, areas and surface (Fang et al., 2014). Representation of data in raster are conceptually easy to comprehend and processing time is faster. However, accuracy is often compromised due to pixel resolution and often require large database. Example of raster formats are shown in Table 2.

Table 2 Raster data format

Format	Description
PNG	Portable Network Graphics (PNG) is a raster format which supports lossless compression, compression that does not result in the loss of data
JPG	The JPEG Interchange Format, or JPEG, is the most common format leveraging the Joint Photographic Experts Group's method for storage of photographic images, which is a type of lossy compression, a compression that results in data loss
TIFF	Tagged Image File Format (TIFF) is a widely known generic container format for raster data. TIFF supports multiple band combinations, compression algorithms, and is extensible.

GIF	Graphics Interchange Format (GIF) is a raster image format limited to 8-bits per pixel

3.4 Spatial Visualization Approaches and Methods

Visualization method are industry accepted approaches to applying graphic variables to render spatial data. Maps helps to communicate geographic phenomena and helps to answer questions about its characteristics or nature (Ormeling, 2010). There are various methods of representing spatial data but the most effective and common approach is via a map. A cartographic method representation involves establishing the geospatial relationship between a spatial object and its structure visually. There are various moments that characterized the transformation in spatial data visualization. One of such is the emergence of satellite imagery and the second is the introduction of computers. Taylor (1991) in (Ormeling, 2010) defines cartography as '*the organization, presentation, communication and utilization of geoinformation in graphic, digital or tactile form. It can include all stages from data preparation to end use in the creation of maps and related spatial information products*'. Critical to maps is not only the content but the scale at which information is being represented. Maps can generally be divided into topographic and thematic maps where the later expresses the general nature of earth's surface and the former represents the distribution of a particular phenomenon (Ormeling, 2010). Spatial attributes can also be expressed via general non cartographic methods like chart, tables and infographics. This helps to convey other critical information about a spatial phenomenon.

Spatial visualization seeks to communicate the information process via cartographic or general methods. Inherent in this is the data to be communicated, the purpose or task and the consumers. Understanding data characteristic, correlation, type and distribution is a precursor to deciding an appropriate method. Also, making a choice between the mapping method and graphic variable is important. In choosing a diagram, the complexity and purpose of the visual representation ought to be taken into account. Although there are lots of method and approaches, only a couple selected methods are discussed and also categorized into visualization of common thematic maps and visualization of spatiotemporal information.

3.4.1 Visualization of Common Thematic Maps

Choropleth Maps

Choropleth map is derived from the Greek words choros- area and plethos-value (Ormeling, 2010). This method renders the value of the phenomena in a specified area. The calculated values are relative and the intensity of colour depicts the intensity of the phenomenon. Choropleth maps can be density maps which shows the ratio of the covered area or non-area related ratio map. A choropleth map is a thematic map and applies colour visual variable to represent attribute information (Allison, 2016). Both hue and saturation are employed in a spectral and diverging colour scheme. However, since they are applied to an entire area they can be highly generalised. Figure 3 is a sample Choropleth map showing the population density in Czech Republic.
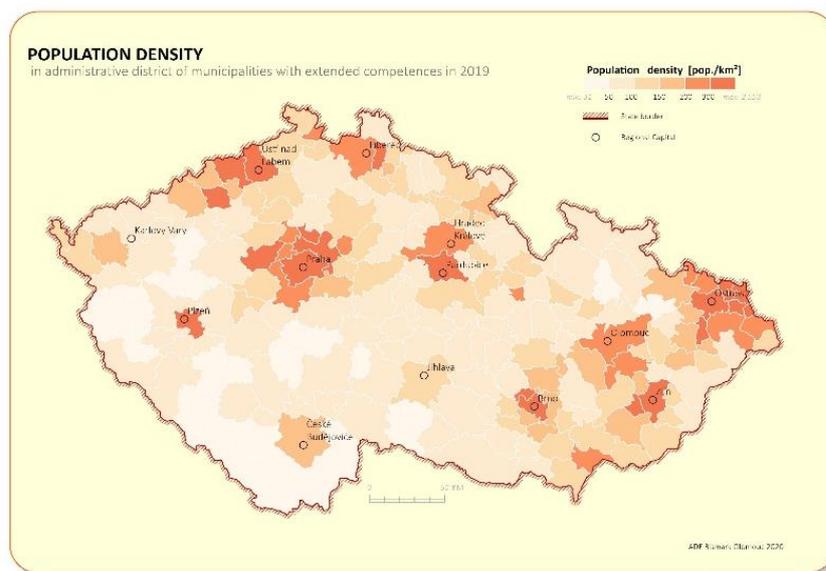

Figure 2 Choropleth Map showing the Population Density in Czechia

Proportional Symbol Maps

Proportional symbols are used when the data type to be rendered is absolute and quantitative. They are used for representing quantitative absolute data by size visual variable. This allows for effective assessment of distribution without being constrained by the area unit. Symbol scaling and overlapping are the main design huddles in using the proportional symbol approach. This can however be addressed using transparency as well as outer layer strokes. Visual complexity can be reducing via classifications such as range grading. Figure 3 is an example of a Proportional symbol map.
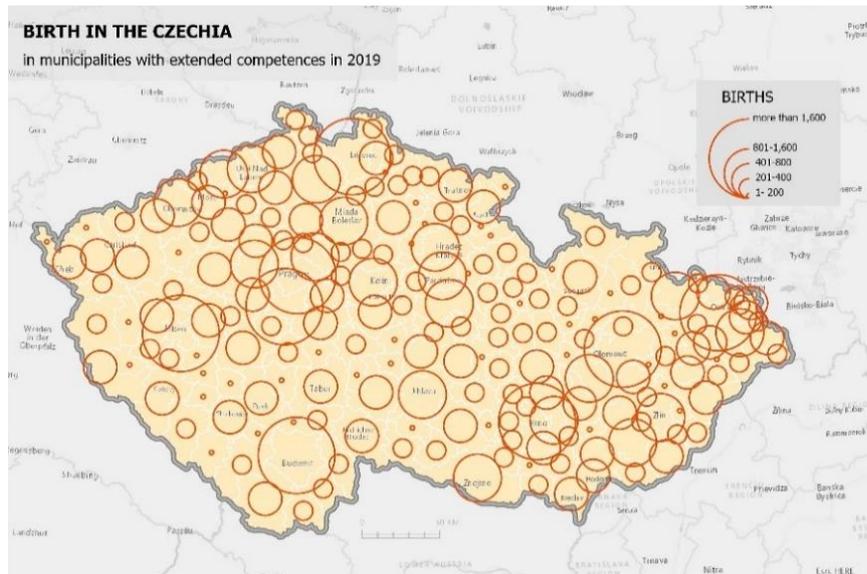
Figure 3 Proportional symbol map showing birth in Czechia

Dasymetric Maps

This method employs other geographic data to better map spatial phenomenon to reflect its distribution. As shown in Figure 4, unlike choropleth map which evokes the perception of distribution across the entire unit or boundary, the dasymetric approach limits the spatial objects to a finer resolution thereby mimicking the true local variability. This can be achieved by incorporating exclusionary or inclusionary data.
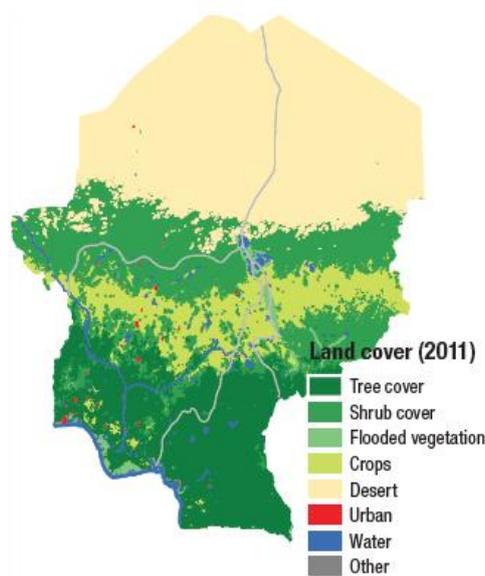

Figure 4 Dasymetric map showing landcover data (Source: Kraak et al, 2020)

Cartograms

Cartograms employs size visual variable to scale area of a phenomena to its attribute value. This results in distortions in the size or shape of the area represented. Different approaches can use to either distort or preserve the phenomenon including the

contiguous and non-contiguous. Generally, cartograms help to correct the perception portrayed by choropleth map to provide a weighted value based on the object of interest Kraak et al, 2020. Figure 5 is an example of different types of cartograms.
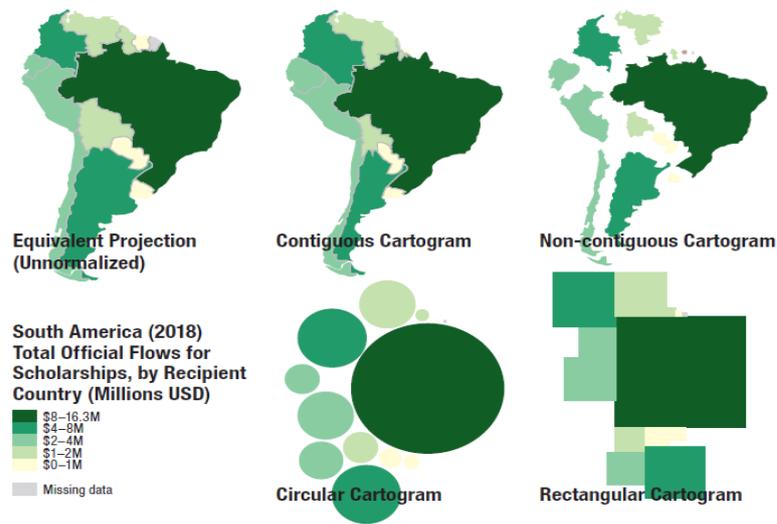

Figure 5 Types of cartograms (Source: Kraak et al, 2020)

Isoline Maps

Isoline map works on the assumption that the represented phenomenon is continuous and therefore point of equal value are connected with line (Ormeling, 2010). As shown in Figure 6, the representation can be areas of equal height, equal amount of precipitation, population density among others.
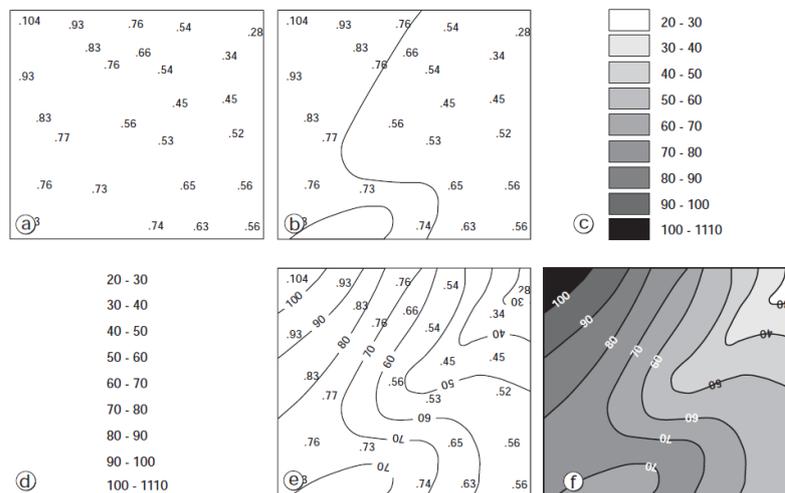

Figure 6 Isoline production (Source: Ormeling, 2010)

Diagrams

Diagrams are very important in representing attribute information about a spatial phenomenon. Unlike maps, diagrams employ visual variables to represent data on a non-geographic. The combination of maps and diagrams on a layout helps to emphasis or tell better story about a geographic object or process. Kraak et al., (2020) categorized diagrams into the following:

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- Univariate Diagrams

- Comparative Diagrams

- Bivariate Diagrams

- Multivariate Diagrams

- Temporal Diagrams

Line charts helps to express trend or phenomena over time whereas bar chart or areas via the subdivision helps to understand other characteristics. Adding diagrams can be either on the map as in the case of diagram maps or adding chart as separately on the map frame to communicate other features. Figure 7 is an example of types of diagrams.
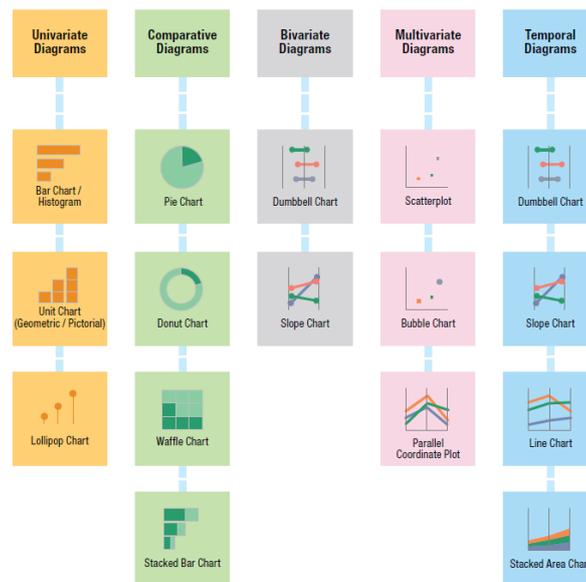

Figure 7 Diagrams (Source: Kraak et al, 2020)

3.4.2 Spatiotemporal Representation

Representation of spatiotemporal data inherits its source from geography of time. Time can be conceptualized according to Berry as space-time matrix, Sinton as including three components namely, time, location and attribute whereas a third conceptualization by Peuquet as TRIAD representing what, where and when (Fish, 2018). Spatiotemporal data can also be classified according to the basis of data characteristics and type of task to be performed (Andrienko et al., 2003). Also, space and time can be represented based on its depiction on a map and as such be classified into Moments, Duration, Structured Time as well as Space as Clock and Time as Distance (Vasiliev, 1997). Although there are various approaches to map spatiotemporal data, the common methods include Single Static Maps, Multiple Static Maps, Single Dynamic Maps and Multiple Dynamic Maps (Fish, 2018) and are shown in Figure 8.

Single Static Map

Multiple Static Map

Single Dynamic Map

Multiple Dynamics Maps
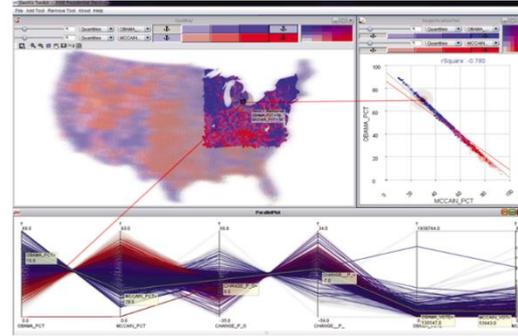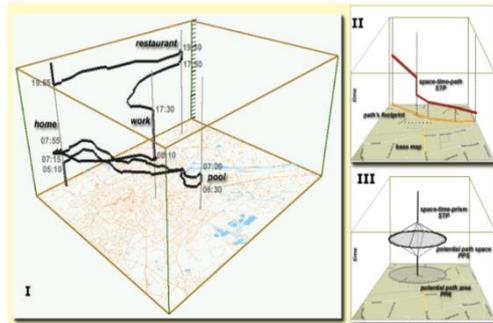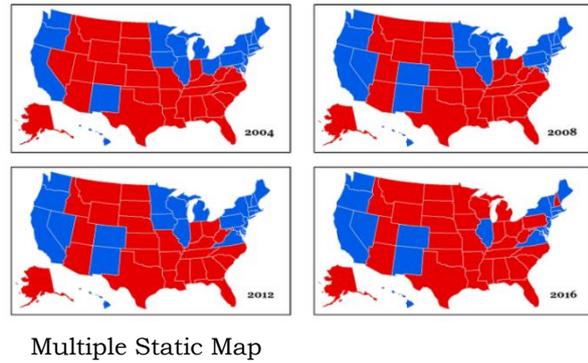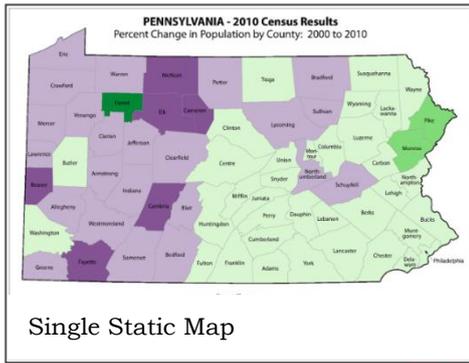
Figure 8 Common Spatiotemporal visualization methods (Source: Fish, 2018)

4 GOOGLE ECOSYSTEM

Google Cloud Platform (GCP) is a set of cloud computing services offered by google company. It offers management tools in a modular way and service include data storage, analytics and machine learning. The platform provides services such as infrastructure as a service, also another service provided is platform and serverless computing. The first cloud computing service was App Engine, developed in 2008 for hosting as well as deploying web applications via a dedicated data centers. The platform is an integrated part of the entire Google Ecosystem.

Google cloud is made up of made up of both physical and virtual systems and are distributed across regions in Asia, North and South America, Australia and Europe called zones.

4.1 Google cloud platform framework

4.1.1 Projects

Projects is the base entity containing the resources for executing a set of functions. The project contains the required settings and enables interaction with resources internally. The project is made up a tuple and must contain the following:

- Project name
- Project ID
- Project number

The project name is a text field which provides a description of the intended work. The project ID is a unique string generated randomly but can only be used ones whereas the project number is assigned during the creation of the project. Figure 9 shows the project setting.
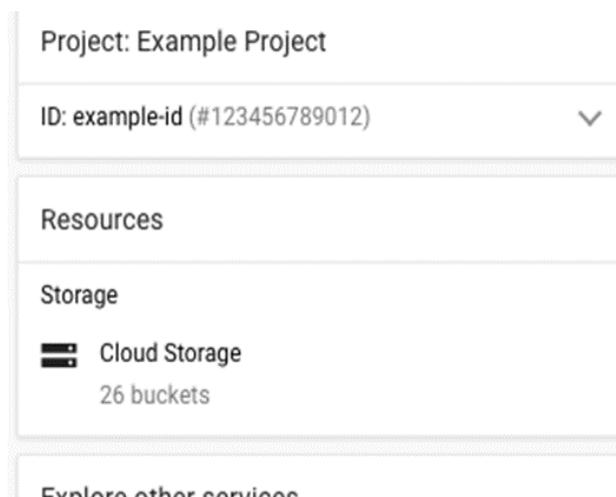

Figure 9 Google Project Setting

One can interact with google cloud via three approaches. They include the Google Cloud Console (Figure 10), command line interface (Figure 11) and client library.
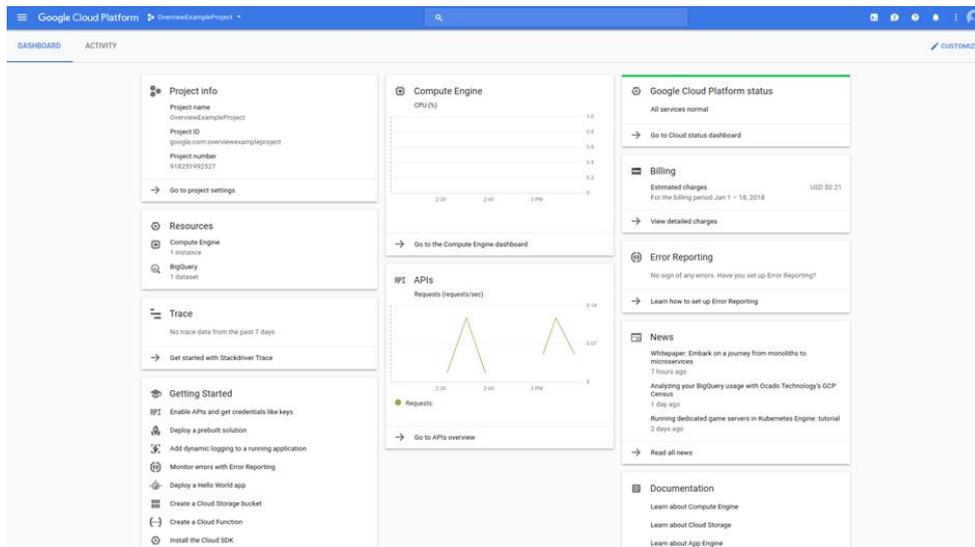
Figure 10 Google cloud console

Figure 11 Command line interface

The Google Cloud Console is a Graphical user interface with which projects and associated resources can be managed. For the command line tool, a task can be completed by running the gcloud command. Also the client libraries provide Application Progamming Interface (APIs) to help manage and create resources.

4.1.2 Global, Regional and Zones

The resources of cloud platforms are distributed across various zones and regions globally. Zones are located in regions and also nested in global scope. Resources accessibility is dependent on their availability at a zone. Figure 12 shows the relations between the global, regional and zonal levels.

Figure 12 Scope of Operation

4.1.3 Cloud platform products

Google Cloud services can be grouped into the following:

- Compute and hosting
- Storage
- Databases
- Networking
- Big data
- Machine learning

The compute and hosting service provides an option for the management of application platform as well as working via a serverless environment. It integrates container approach and helps to build customized infrastructure with greater flexibility. The main services provided under the compute include serverless computing, application platform, containers and virtual machines. The serverless computing is made up of cloud functions as a service (FaaS) which allows for a serverless platform to build cloud service. The Application platform functions as Platform AS a Service (PaaS) where computing resources are scaled to the need of your project. Via the Google Kubernetes Engine (GKE), Google provides the Container As a Service (CaaS). Users can create and deploy several compute engines called clusters. Also the clouds compute engine functions as an infrastructure as a service IaaS). This can be deployed using Virtual Machines (VMs) and there are various instances according to needs. Users can also decide the zones in which they deploy their resources and can as well choose their preferred technologies like the operating system as well as frameworks. The services are such that you can use multiple features as may be useful to the project purpose. Table 3 gives an overview of common services by Google.

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Table 3 Summary of Google Cloud Services

Google Cloud Services	Computing and hosting	Serverless Computing	Cloud Functions (FaaS)
		Application platform	
		Containers	Google kubernetes (GKE)
		Virtual Machines	
	Storage	Cloud Storage	
		Compute Engine	
		Filestore	
	Database Service	Cloud SQL	
		Cloud Spanner	
		NoSQL	Firestore
			Clould Bigtable
	Networking	Networks,Firewalls&Route	Virtual Private cloud (VPC) Firewall route
		Load balancing	Network load balancing HTTP(S) load balancing
		Cloud DNS	
		Advanced Connectivity	Cloud interconnect Cloud VPN Direct peering Carrier peering
	Big Data Services	Data Analysis	BigQuery
		Batch and streaming data processing	Dataflow
		Asynchronous messaging	pub/Sub
	machine Learning	Machine Learning APIs	Video Intelligence API
			Speech-Text
			Cloud Vision
			Cloud Natural language API
			Cloud Translation
			Dialogflow
		AI Platform	

Google Cloud Storage Services allows for a scalable and large volume cloud storage. The options include the zonal persistent disk which is a durable network storage with data distributed across various disk. They are often shared separately on the virtual

machine instance. This service also allows for the creation of file store instance on the compute engine.

The Database services can be categorized under SQL and NoSQL. Via cloud SQL, database services for MySQL and PostgreSQL are provided. Relational database services are provided via cloud spanner whereas Firestore and cloud Bigtable are used for NoSQL data where the former is suitable for document like data and later for tabular data.

The Network services include a virtual private clouds and are governed by firewall rules. Using routes, one can perform further functions. With the compute engine, workloads of the application can be distributed using the server-side load balancing feature. This can be achieved by using the network load balancing where the former distributes your traffic base on regional cluster via the feedback from your protocol. With the cloud Domain Name System (DNS), you can manage features either by the consul, command line or Rest API.

The Big data services include data analysis, batch and streaming data processing as well as asynchronous messaging. With BigQuery, various analytical task can be performed to explore and manage ones' data. The service allows for the creation of customized schemas and querying of data. Dataflow allows for batch and streaming data processing for high volume task. Using the Pub/Sub asynchronous messaging service, a message can be sent using the JSON format.

The machine learning service of the Google cloud include machine APIs and AI platforms. The Machine learning APIs such as video intelligence API, Speech to test, cloud vision, cloud natural language API, cloud translation and dialogflow allow for a customized training and running of models. Through cloud integration with tensorflow, AI platforms helps to mage computing resources needed for training and running ones' organizational models.

4.2 Google Data Studio

The process of extracting value from data is critical to solving societal challenges. This process involves data gathering, data transformation into information, analysis of information for actionable insights, communicating the insights to needed and relevant impacts.

Data visualization allows for the effective communication of information derived from data and the means for conveying the message include graphical representation such as maps or charts. This helps to present the known and explore the unknown patterns in a data. Even more critical is communication of results in a clear and coherent manner. GDS is part of google marketing platform and used for visualization and reporting of data to support decision making and insights. It allows for the creation of useful reports which are customizable and easy to comprehend. Although GDS is relatively new, it is agile and

introduces new features often. The initial release was in June 2016 as a public beta (Hurst, 2020). Fundamentally, the goal of GDS is to tell your story in data. GDS allows for the visualization of data via customizable charts and tables. It also helps connect easily with variety of data options and sources where the insights from data can be shared internally or publicly. The collaborative capabilities allow to build organization focused reports faster for quick insights.

GDS creates a pipeline to integrate various data to achieves work objective. The connectors allow for the ingestion of data from sources including, BigQuery, Analytics MySQL and CSV formats among others. The raw ingested data can be transformed into metrics, dimensions and explored either with default feature or customized queries and codes. Most importantly, a compelling visualization can be created to communicate insights with charts, graphs and maps. Reports can be created in dashboards to internal or public consumption as well as collaboration.

4.2.1 Data Connectors

Unique to GDS is the underlying ability to build a pipeline of data sources for report via its connectors. Connectors serves as the bridge between your data source to data studio. There are prebuilt connectors by google and also by partners.

Google Connectors

The google connector facilitates the interaction with existing google products. As at the time of this report, connection to the following google product was possible:

- Campaign Manager 360
- Google Ad manager 360
- Display & Video 360
- Google Ads
- Firebase (vis BigQuery)
- Google Analytics
- Google Cloud Storage
- Google sheets
- Google surveys
- Search Ads 360
- Search Console
- YouTube Analytics

Campaign Manager 360 allows for the performance review of digital marketing campaigns. This allows the accessibility of data to measure metrics like clicks, impression, ad spend and also to report on advertisers, campaigns and creatives for relevant stakeholders. The Display & Video 360 Connectors helps to visualize compelling reports and generate insights on audience data, as well as planning campaign. Another

google product connector is firebase, a mobile map analytics platform which allows access to a sharable information of users and data. Google Ad Manager 360 helps to manage and deliver your ads to various platforms whereas google ads ensures easy reach the potential users of your product. With Google Analytics, inferences about the traffic and characteristic of user behavior of your site can be tracked and measured. GCP via the cloud storage connector allows for storing and exhibiting data and google sheet connectors allows for the integration of data from spreadsheet. Other direct google product connectors are search Ad 360, search console and YouTube analytics. Examples of common Google connectors are shown in Figure 13.
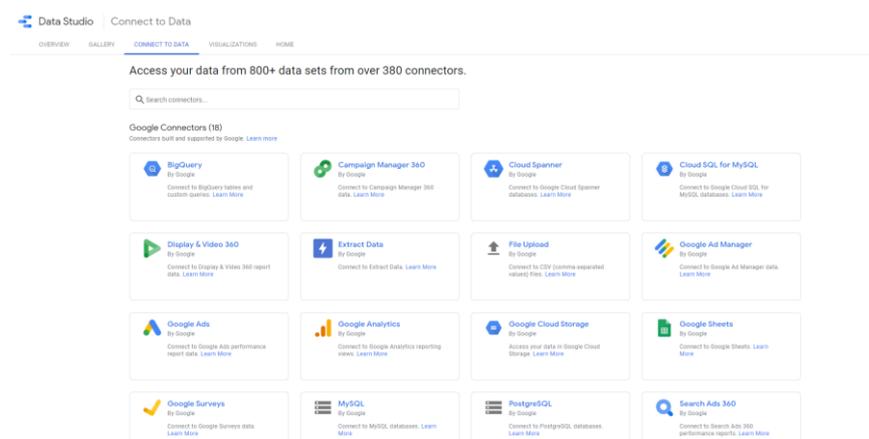

Figure 13 Example of Google connectors

GCP connectors allows for integration to Google BigQuery, Google Cloud Spanner, Cloud SQL for MySQL, MySQL and PostgreSQL. User can also integrate their data into GDS by direct upload of Comma-separated values (CSV) files. However, when uploading data, it's important to ensure the appropriate format is adhered to. Usually UTF-8 encoding is the appropriate standard to use. To improve the performance of your report, it is appropriate to extract subset of the data.

Community Connectors

The novelty of GDS is its flexibility for users to integrate their own data sources. The community connectors are an open source to ensure an open and flexible user involvement. Because they are not developed by google, it sometimes might require authorization to work. The authentication method used is the OAuth 2.0 which is and standard protocol recognized by industry. Figure 14 illustrates some partner connectors.
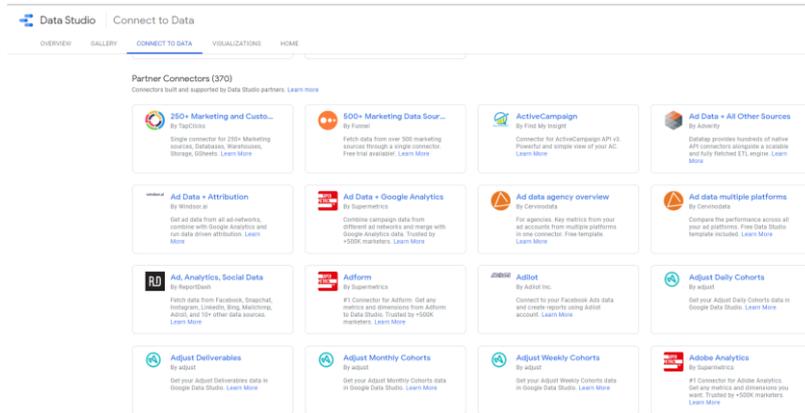
Figure 14 Example of Partner Connectors

Using Google Apps Script, it is possible to build a connector, use and test the connector, deploy and distribute the connector. GDC provides huge incentive for building a customize community connector by way that one can monetize them or make it open to the public.

4.2.2 Data Transformation

A critical part of understanding data in GDS is data transformation. This allows for discovering patterns in the data and important to deriving useful features to focus on. GDS uses the explorer, calculated metrics and function tools to translate the data dimensions and metrics into building compelling visualizations.

As shown in Figure 15, with the explorer, prompt inferences can be drawn easily from data. Users can examine the data and switch between same visualization in a report. Despite the similarity between the report and explorer, the latter is temporal and often private. They are optimized for filters allowing you to make modifications by using the dimensions and metrics panel. Explorers are however not sharable but can be exported into a new report.
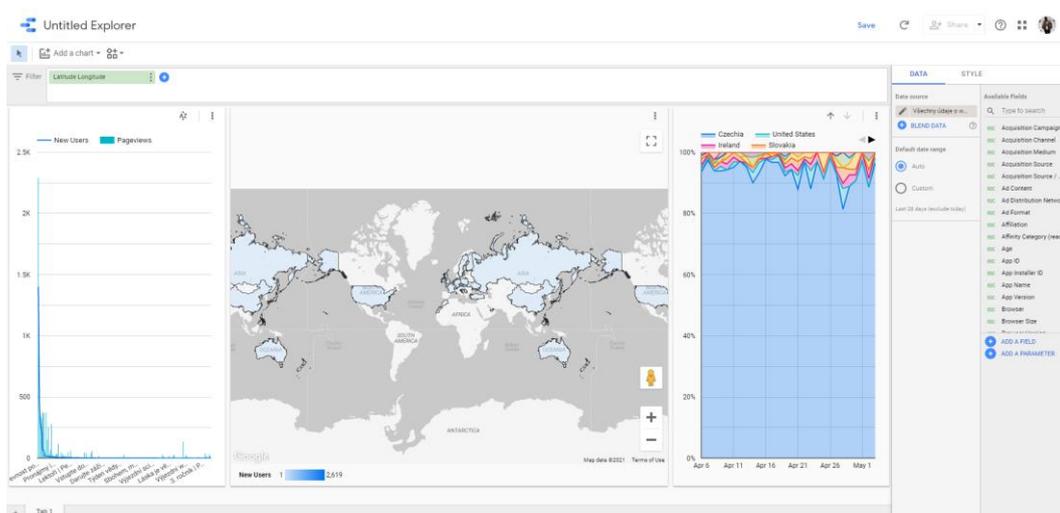

Figure 15 Explorer example

Data modelling

Reports are created either by introducing new or existing dataset, therefore having a consistent metrics and dimensions are import reusability. The source of data contains the schema of the data and the place where you configure the fields necessary to support the visualization needed. A data source can have the following fields;

- Dimensions
- Metrics
- Calculated field
- Parameters

Dimension basically describes your data whereas metrics measure the dimension. In effect dimension is about categorizing your data and any type of data can be used. The application of aggregation function to a data or a set of values results in metrics. Also calculated field are achieved when functions or a particular logical operation is applied to a dataset. Parameters are used to store a specific or customized data by the user.

In GDC data source can be embedded or reusable (Figure 16). Embedded data sources allow for the transferability inherent properties.

Figure 16 Embedded and Reusable data

Calculated field allows for the users to derive new dimensions or metrics by extending the information in the data source. It is a formula and can perform arithmetic or math operation. It can also be used to manipulate data with functions and as well be used as branching logic via CASE statement.

Figure 17 Functions

33

Function in calculated field helps create a powerful tool beyond simple arithmetic. There are more than 50 functions in GDS and they can be categorized under aggregation, arithmetic, date, geo and text. Figure 17 gives an overview of the function field.

4.2.3 Data Visualization

GDS uses report to tell stories in a data regarding a business decision, actionable insight or present a preposition. Key advantages of report in story telling is the ability to dive into the data with mouse interactions over the visuals. Also GDS allows for the maintenance of data freshness using the data studio cache which temporary stores data to ensure a faster query execution during data fetching.
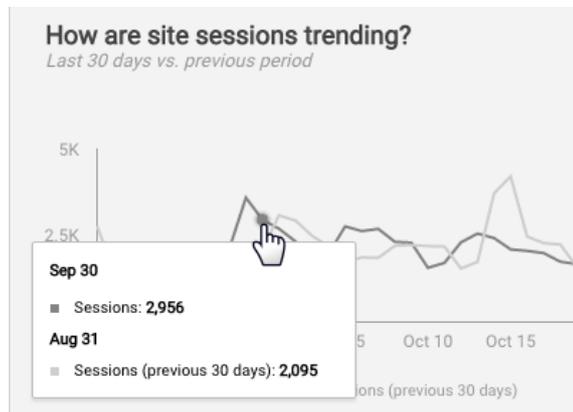

Figure 18 Interactive visualization

Area Chart

Area chat in GDS allows for the visualization of a single dimension and single metrics over time. It is another form of a time series chart and uses shaded areas to depict volume. The organization of data is dependent on data properties in the panel.
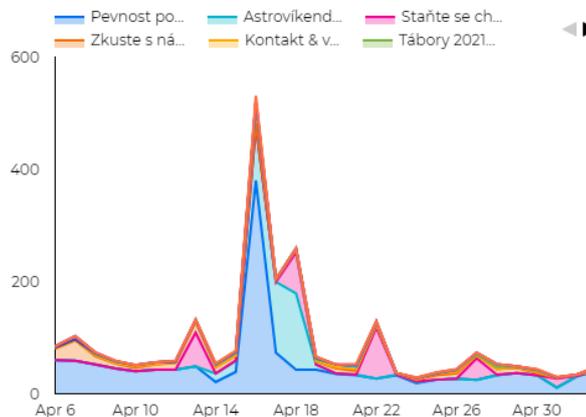
Figure 19 Area Chart

Bar Chart

They utilize vertical or horizontal bars to depict the form or compare categories. Base on the number of dimension, they can compare or determine relationship between values. Bar charts type influences its overall appearance. They can be column or stacked bar.
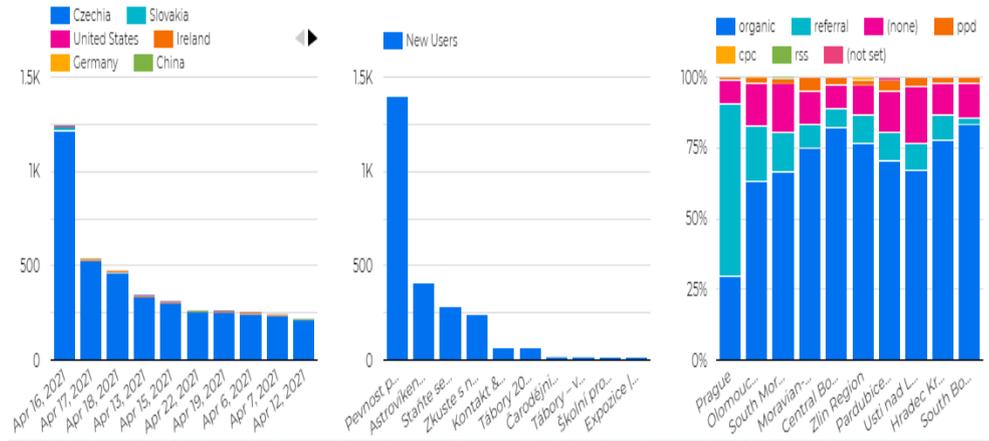
Figure 20 Bar Chart

Bullet Chart

The bullet chat helps to compare an indicator or metric with a standard. They have three components which are a center bars depicting the target metrics, a vertical line showing the value and a colored band showing the ranges which can be poor, average or good.
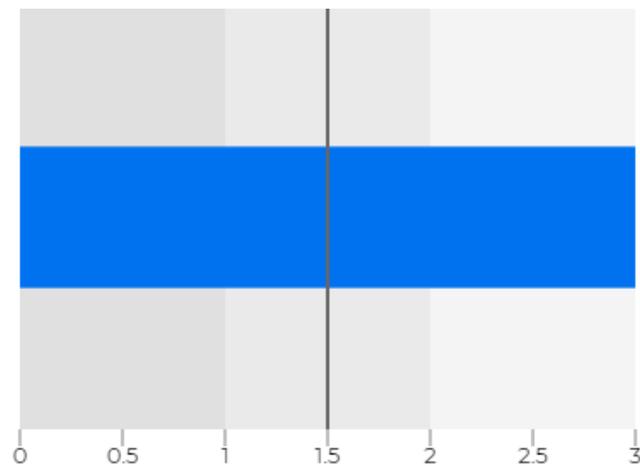
Figure 21 Bullet Chart

Maps

GDS represents maps in with the a tool called "Geo chart" and "google map" which is used for visualization based on the geographic area. In GDS, this is represented by the geographic dimension (County, City, Region), a metric and a map zoom area. However, they utilize the mecartor projection and distort land areas. As such it is not recommended for the comparism of geographical countries.

Figure 22 Map Representation

Line Chart and Pie Chart

Line chart is helpful in analyzing the trends and they can be represented by line, bars or a combination of the two. Pie chart also helps visualization of data series in proportions. In GDS, the number of division in a chart is based on the metrics.
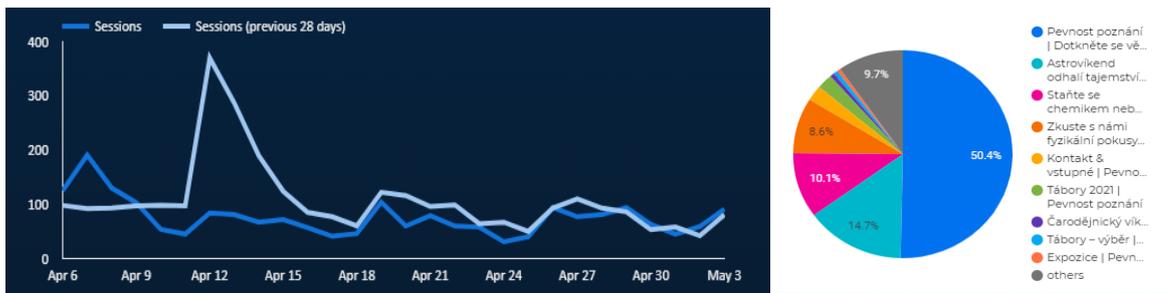
Figure 23 Line and Pie Chart

5 VISUALIZATION DIMENSIONS-CASE STUDIES

This chapter employs case study approach to investigate the visualization dimensions of google cloud platforms. As reviewed in early sections, google cloud platform offers comprehensive, scalable and easy to use service. The work however focused on google data studio and to investigate its visualization dimensions. Emphasis is placed on the cartographic and general methods whilst exploring various datasets, parameters and implementation approaches.

Case study approach is suitable to have a deeper exploration of a subject and helps develop robust strategies and procedures (Tellis, 1997). Unlike experimental approach which conceals critical details in the exploration and analysis phase, case studies expound the details in critical to the observed or studied phenomena. The goal of a case is either describe, explain or explore a topic and this can be intrinsic, instrumental or collective.

To critically investigate the visualization dimensions, four case studies we conducted to better explore the subject. The studies included the Covid-19 visualization dashboard, Palacký University Olomouc department of Geoinformatics web analytics and world population and share of air pollution death. The study explored different themes as a quest to construct both validity and reliability using multiple data sources. The process followed include the definition of thematic areas, preparation of data, analysis and development of conclusion and recommendations.

5.1 Case Study 1: Covid 19 Visualization Dashboard

The Global pandemic Covid-19 also known as coronavirus brought the world to a standstill after it was first discover in December 2019. The Coronavirus disease is a very contagious disease caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). The unique characteristic of Covid-19 disease in terms of its geographic, environmental and social demographic patterns have made it a critical point for geospatial analysis. Visualizing the spatial and temporal trends is critical for evidence based and timely decision to avert greater catastrophe.

An interactive dashboard was created to monitor the number of cases and geographic spread of the pandemic. Various general and cartographic methods and principles were employed to investigate and ascertain the tools (Google Data Studio) potential and drawbacks for spatial data visualization.

5.1.1 Data source

The data for the case study was retrieved from the COVID-19 Data Repository by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University on

GitHub. The repository contains aggregated data sources from the World Health Organization (WHO), European Centre for Disease Prevention and Control (ECDC), DXY.cn. Pneumonia. 2020, US CDC, BNO News, WorldMeters, 1Point3Arces, COVID Tracking Project, Los Angeles Times and the Mercury News.
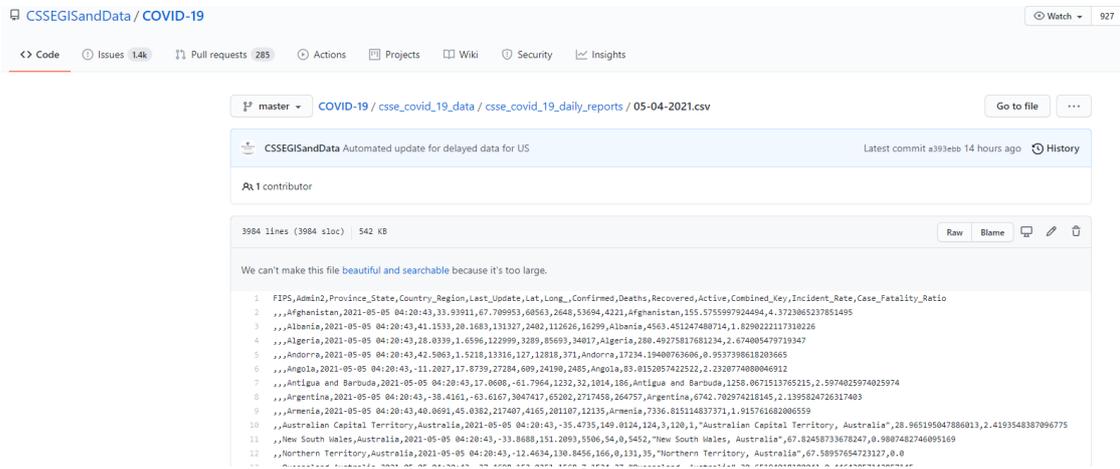
Figure 24 Covid 19 Data (Source: https://github.com/CSSEGISandData/COVID-19/blob/master/csse_covid_19_data/csse_covid_19_daily_reports/05-04-2021.csv)

The updated data as at writing this report was on 5 May, 2021. The most important data fields include County_name, Last Update, Lat and Long_, Confirmed, Deaths, Recovered, Active among others. Data was downloaded in a CSV format (Figure 24) and incorporated into google data studio.

5.1.2 Spatial Data connection

The downloaded CSV data was added to google data studio via connectors. Once registered for google data studio, you are able to create reports, add data source or explore your data as shown in Figure 25. Report allows you to tell a story about your data in an integrated way and allows for sharing of insights. A report can be created from exiting templates or build one.
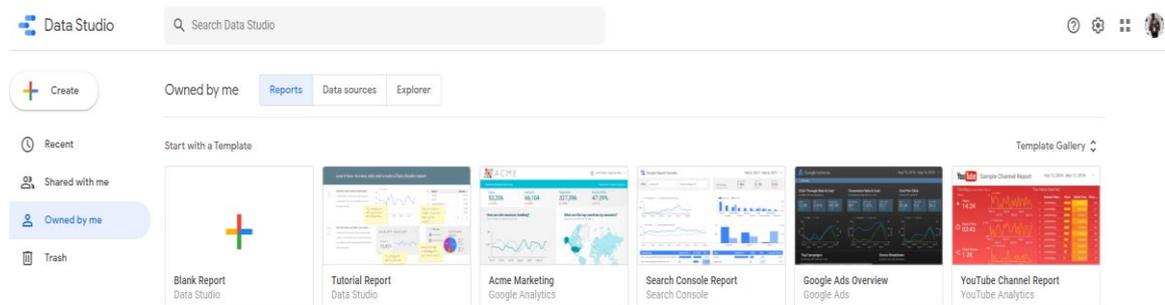
Figure 25 Google data studio interface

To add a dataset in GDS, connectors are used. The covid data is in CSV format hence was uploaded directly.
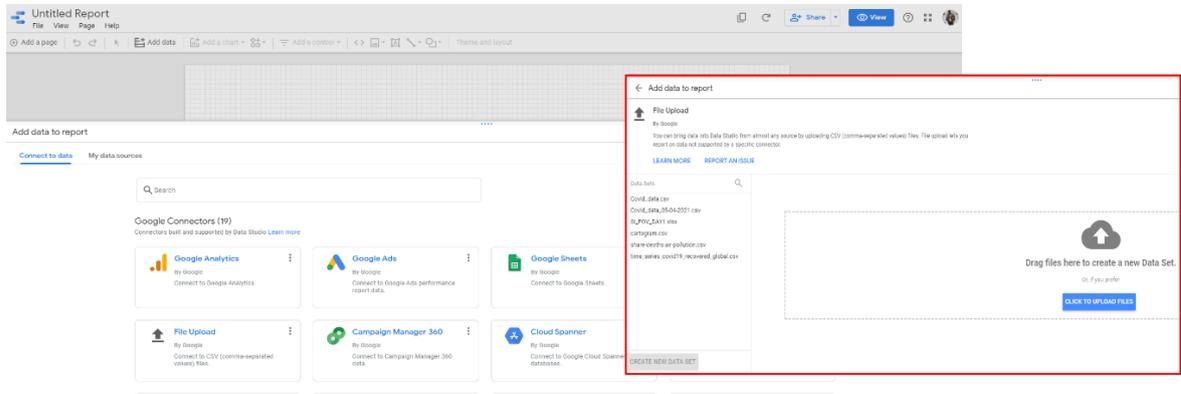
Figure 26 Adding Covid-19 Dataset

5.1.3 Data Transformation

Data exploration is helpful in comprehending the various features and parameters in a data set. First of all, the data dimensions were checked to ensure its conformity to its intended use. As shown in the Figure 27 below, to ensure spatial visualization, it is critical to select the appropriate geographic field type. The geo dimension types in GDS are address, city, city code, continent, continent ID, country, county code, latitude and longitude, metro code, metro, postal code, region, sub-continent and sub-continent code. Any of these field initiate the spatial visualization but can be used under certain conditions only. For instance, the address can only be used in google maps chart type whereas city is available in Google map and Geo Charts.
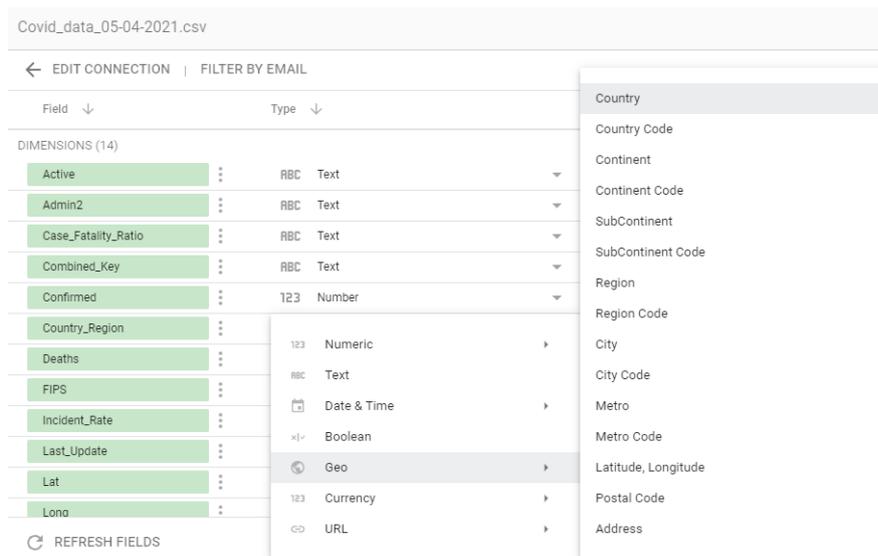
Figure 27 Changing Data types

The goal is to explore the spatio-temporal spread of the covid-19 at both the country, sub-continental and global level. This can be modified by changing the field type for each dimension to represent. To assess the various tools in the context of Covid-19 data, an exploratory analysis was carried out. As indicated in Figure 28, both chart and map options were used to understand the data. First, bubbles (proportional circles) were overlaid on google map chart type to visualize the quantitative scale of confirmed cases. Tree map was also used to understand the dimensional hierarchy of covid death using size and color visual variables. Other tools tested were the bullet charts, tables and line charts and scatter plots.
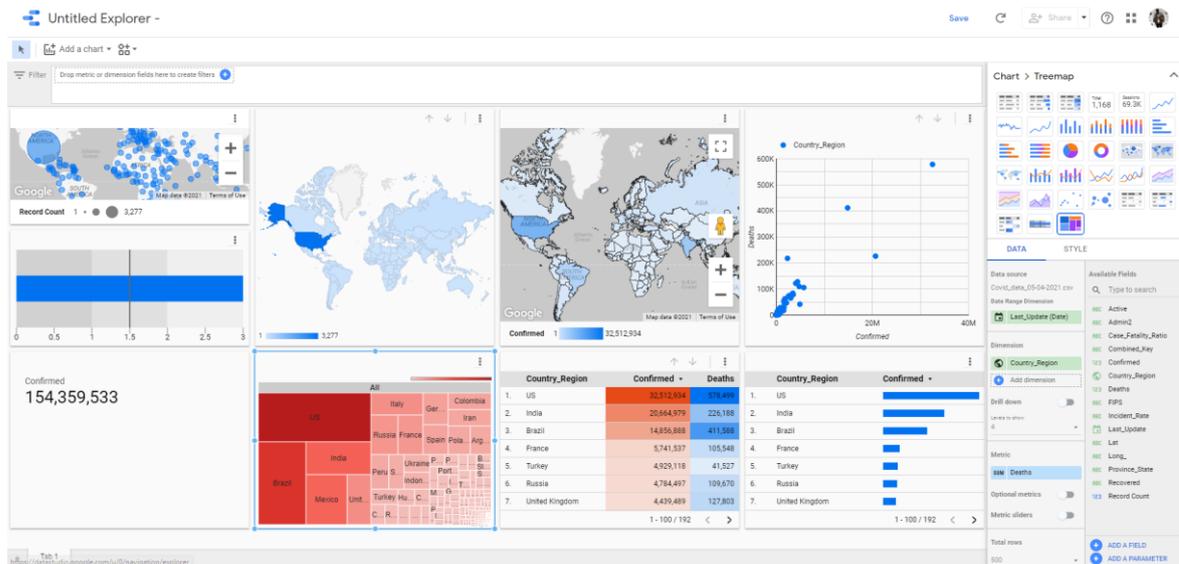
Figure 28 Exploratory Data Analysis

5.1.4 Data Visualization and Report Design

For effective visualization there must be a synergy in selecting appropriate methods and the application of key cartographic principles. In designing the dashboard, key focus was on the design principles, visual variables, typology as well as general and cartographic methods. Several principles of design were employed such as balance which is reflected in the equal distribution of visual weights. Other principle like Proximity, Graphic Alignment, Repetition, Contrast and White Space were incorportated in the Design.

For visual variables, attention is on the usability and effectiveness of geometry, internal and external variables. Sizes were used to distinguish quantitative methods whereas colors adopted to compare and contrast different phenomena. Choropleth map was used to visualize the global recovered cases and also confirmed cases at the Europe level. Using line chart, comparism between confirmed cases and death was establish. The proportional circle with size and color visual variable was used to establish or visualize

the relationship between confirmed cases and deaths. The final interactive dashboard can be seen in Figure 29 below.
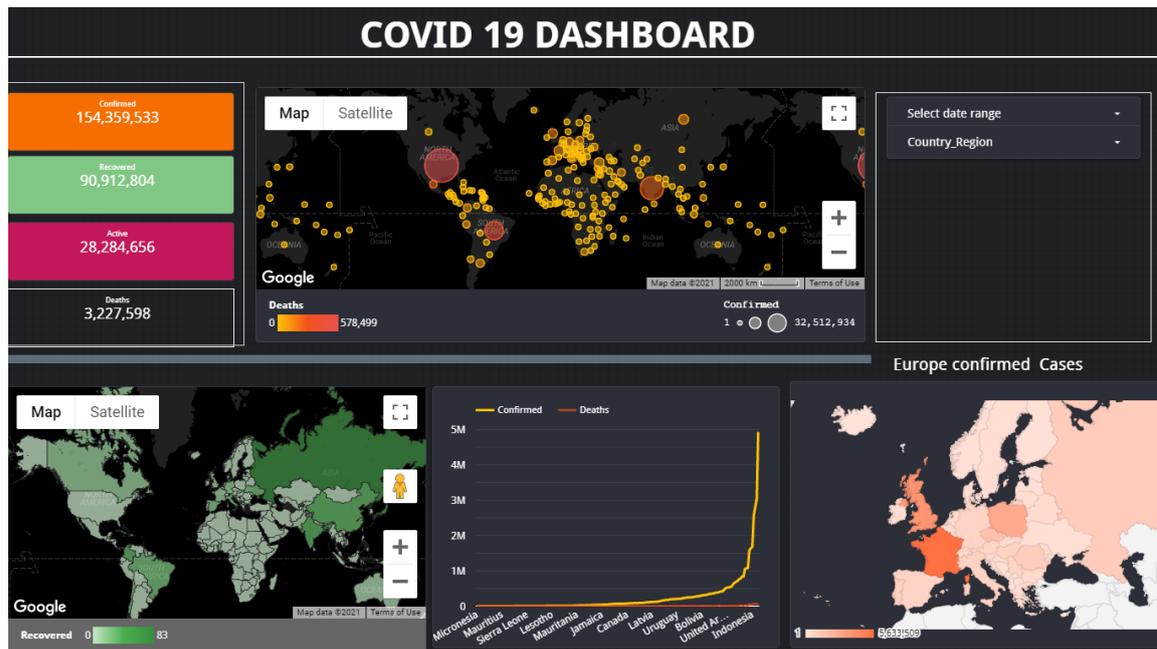
Figure 29 Interactive Covid-19 Dashboard (Access URL:
https://datastudio.google.com/u/0/reporting/e898d7b5-9862-4f6a-92c0-21da3417c62e/page/vIypB)

5.2 Case Study-2: UPOL Department of Geoinformatics Web Analytics

This case study seeks to explore the use of Google Data Studio in visualizing analytics data of Palacký University Olomouc Department of Geoinformatics website. The novel of Google Analytics is the ability to track traffic on website. Activities to track include session duration, the number of sessions per page, bounce rate of site users. However, the focus is on how various general and cartographic methods can be visualized within the remit of Data Studio.

5.2.1 Data source

The Google Analytics data from the Department of Geoinformatics at the Palacký University Olomouc was used for the case study demonstration as shown in Figure 30. This require having access to the analytics platform via web authorization. The data from Analytics can be used to monitor and report real-time user activities on the site including the number of people on the page, their geographic location, the pages viewed and conversions. With the continuous updates of page views, a real time statistics of users, can be derived. Also, characteristics of the audience can be gathered and analyzed to

under their demographics, the operating systems they are using. This can be categorized under acquisition, behavior and conversions. Figure 30 show the analytics interface from where data were streamed into data studio.
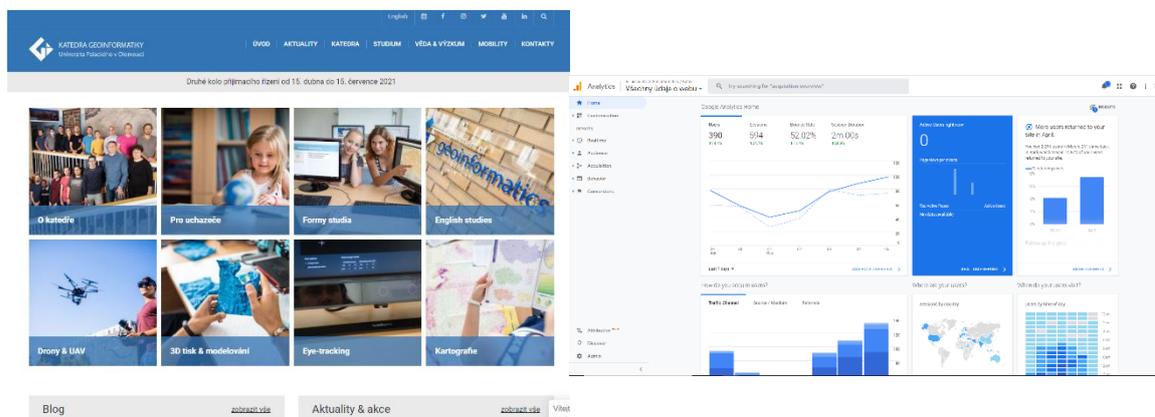
Figure 30 Department of Geoinformatics Website and Analytics Interface

5.2.2 Spatial Data Connection

The Analytics data from the website were streamed directly using the google analytics connector as shown in Figure 31. Dimension and metrics data are accessed using the universal analytics web connection, a google analytics reporting API.
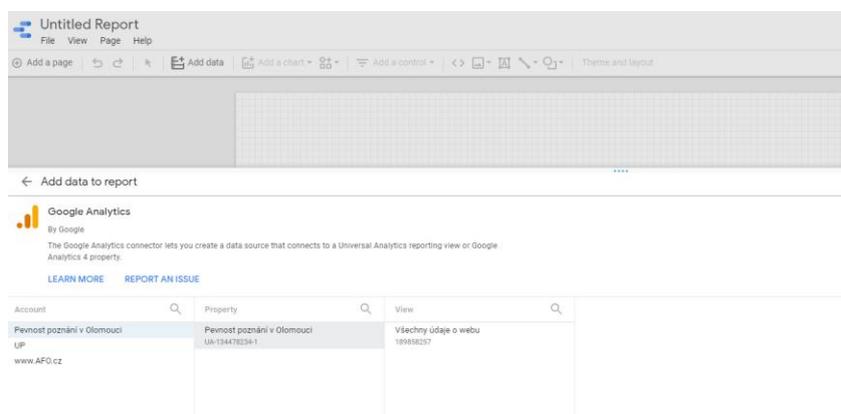
Figure 31 Google Analytics Connector

5.2.3 Data Transformation

As shown in Figure 32, various cartographic and general visualization tools and methods we tested to understand the data. This exercise is to explore some patterns in the data and to have a better overview of their representation. The general visualization approaches tested include the donut chart so exploring new user by page views. Also using the stacked column chart and tree map, we can visually see the number of page view by their geographic dimension. This allows for a visual representation at various

geographic scale like continental, regional and country level. The geo-charts and google maps were explored to see the spatial aggregation of sessions or users on the page.
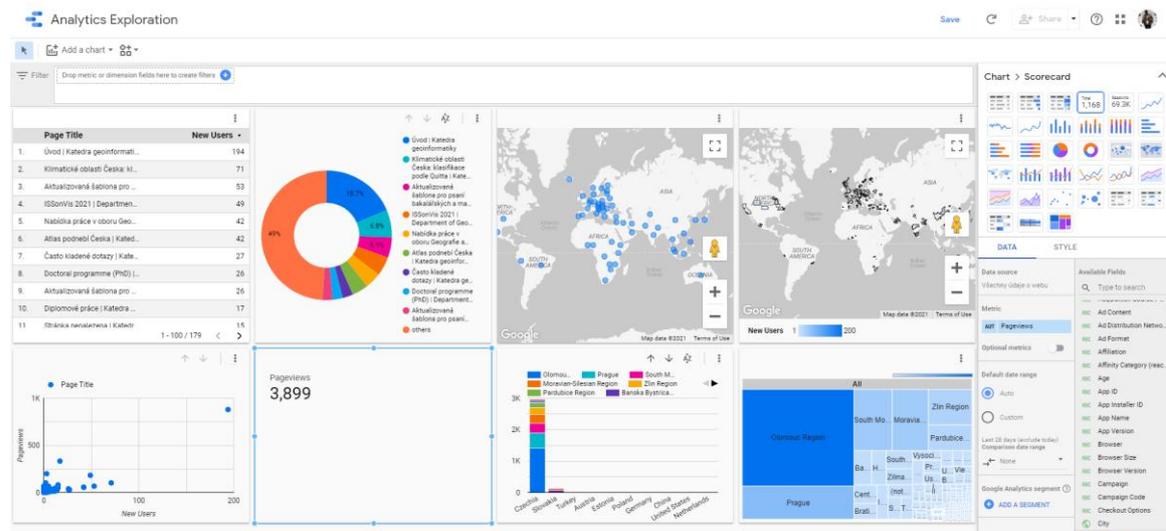
Figure 32 Google Analytics data exploration

5.2.4 Data visualization and Report Design

Based on the exploratory data analysis, the choropleth method was adopted for the cartographic representation. Tree map, table and line Chart was used for the general visualization. The choropleth map was used to interactively visualize sessions, users and page views at the country level as shown in Figure 33 below. The observed phenomena (sessions, users and page views) of interest are represented by a sequential (unipolar) color scale where the more intense the phenomena, the more intense the color.

Figure 33 Interactive Choropleth Map

For the general method visualizations, data studio was used treemap and line chart. The tree map can be used to interactively explore the sessions, pageview and user counts

into a dimension hierarchy. Also, the line chart was used to comparatively depict the various phenomena over 28 days' period as shown in Figure 34.

Figure 34 Line chart and Treemap

Another general visualization method demonstrated is table. In Figure 35, table was used to effectively capture session change, page view and average time of events on the website and have options to modify to suit reporting needs.

Figure 35 Table

The final report as shown in Figure 36 below employed basic design principles, cartographic and general visualization guidelines for information representation. The dashboard aims at achieving a simple yet compelling interface.

Figure 36 Google Analytics Report (Access URl:
https://datastudio.google.com/u/0/reporting/3edb294f-25a7-4322-82f7-
894d31b18f40/page/c2P1)

5.3 Case Study-3: World Population and Share of Air Pollution death

The case study explores the use of Data Studio to visualize world population data and share of air pollution death. The focus is on the integration of multiple data sources for an effective visualization. Population and pollution are highly correlated and that most urbanized areas contributed a higher share to green high gas emission. Also air pollution contributes about 9 percent to global death.

5.3.1 Data source

The data for the global population is from world bank data catalog. The data feature includes county information and population from 1960 to 2019. Data was extracted in excel in store as google sheet to integration into data studio after cleaning. The air pollution data was retrieved from Our World in Data in a CSV format.

Figure 37 Population data

45

5.3.2 Spatial Data Connection

The data world population data was integrated into data studio using google sheet connector which is part of the Google Studio Connectors. However, the connection for the air pollution was done using CSV format and uploaded directly. Figure 38 shows data connection from google sheets.
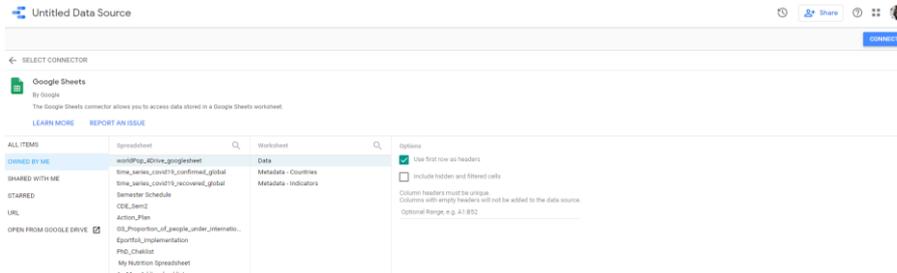
Figure 38 Data connection

5.3.3 Data Transformation

To facilitate effective data integration and visualization, an exploration analysis of data was conducted. Google map and Geochart was use to explore the cartographic representativeness of the data. Other options analyzed include tables, charts, treemap, donut charts among others as shown in Figure 39.
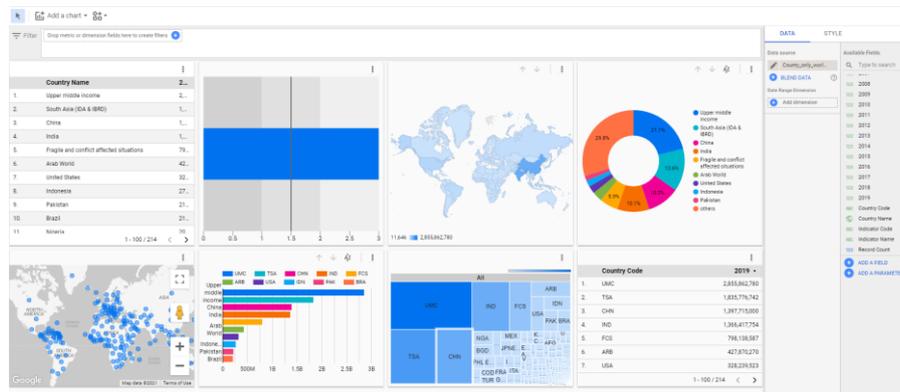
Figure 39 Data Exploration

5.3.4 Data visualization and Report Design

The world population was represent using google map geochart. A choropleth map with unipolar color scale was adopted for the population visualization. Also using the combination of tables with bar charts, city hierarchy was created based on population. In terms of design, infographics were integrated to enhance the visual communication of the map.

Figure 40 Visualization of Population data

In the case of the share of death by air pollution, infographics, charts and maps was used for visual communication as shown in figure 45. Figure 47 shows the final dashboard.
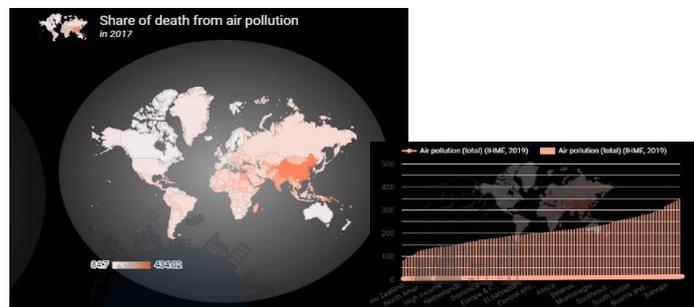
Figure 41 Share of death from air pollution
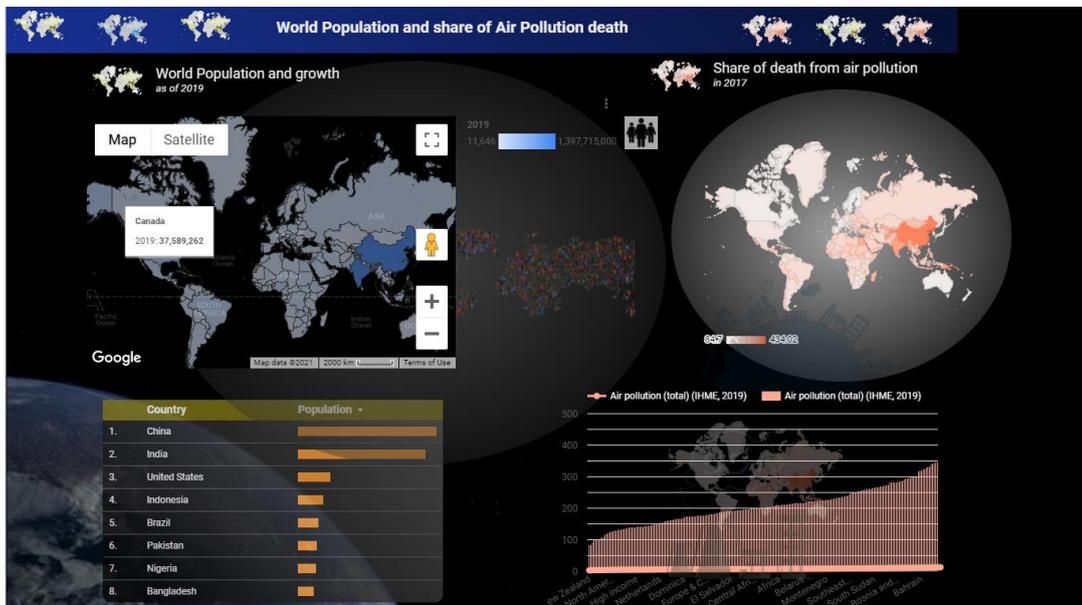
Figure 42 Final Dashboard (Access url:
https://datastudio.google.com/u/0/reporting/e2198ca6-27e0-4c7c-ad07-
4bb193cacac3/page/MM)

6 DESIGN FRAMEWORK, WORKFLOW AND EVALUATION

6.1 Design Framework

A design framework was developed to detail the basic considerations when building a visualization product from google cloud platform. This is to serve as a guide and involves four broad stages. The approach was adapted to steer the case studies in the in addressing the relevant objectives. As indicated in Table 4, the categories include Geospatial data source, Map design considerations, Cartographic Method visualization and Evaluation or simple put GMCE- framework. Key to starting a project is the identification of data source and integration approach. After which the various map design considerations needs to be evaluated. These include scale, generalization, symbolization, color, typology, layout and visual hierarchy. Pursuant to the purpose of the project is the integration of key cartographic visualization methods such as choropleth maps, proportional symbol maps, dasymetric maps, cartograms and diagrams. As at this writing, it is not possible to construct cartograms. Critical after the visualization is evaluation of work in terms of user, geoinformatical, economics, methodological and visualization.

Table 4 Design Framework

Geospatial Data Source					
Web Analytics		Covid-19 Data		SDG Indicators (EO Datasets)	

Map Design Considerations					
Cartographic Scale	Generalization	Symbolization and visual variables	Colour	Typography	Layout and Visual Hierarchy

Cartographic Method Visualization				
Choropleth Map	Proportional Symbol map	Dasymetric Map	Cartograms	Diagrams

Evaluation				
User	Geoinformatical	Economic	Methodological	Visualization

6.2 Workflow

The general workflow is show in Figure 48 below and includes data connection via google or community connector. Sample connector include BigQuery, Analytics, CSV, PostgreSQL, google sheets and community connectors. After connection stage is the data transformation stage which involves using the explorer to test various visualization methods as well as using in-built functions and to create customized metrics and dimensions. After the exploration is Data visualization which can be map visualization ion the case of cartographic visualization or charts for general method visualization. Also, various shapes can be integrated, customizations made for dynamic control. The final part of the workflow is the evaluation, by taking into consideration the user, cartographical, geoinformatical and economic aspects.
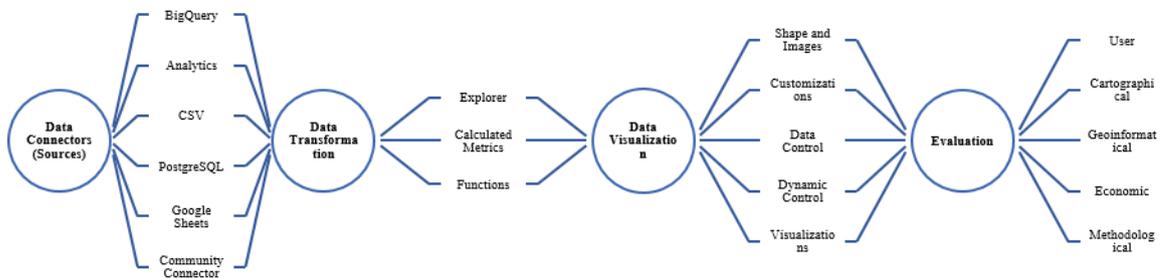
Figure 43 Workflow

6.3 SWOT Analysis

The SWOT is an analytical approach used to ascertain the key strengths, weaknesses, opportunities and threats. The general strength of google cloud is its scalable and robust nature. Cloud service are distributed across various zone with services customizes to regions in that zone. Also, with cloud platforms, via services like PaaS, IaaS, GaaS users pay per use. Google studio is however free and to with the only requirement being registration. The ability to integrate one's data and multi-partner working at the same time makes it very efficient. Also, users are able to develop their own connector to introduce any data using the app scrip. However, the major weakness of the platform is that user are limited to the tools and functionalities provided. Also, performing very complicated analysis is not possible. The cartographic aspect of the platform is not very well developed and cannot be juxtaposed to a traditional GIS software. Also, this is because google studio fall into the category for telling story with data. A key opportunity is that it is cloud based and offers viable solution at the time GIS is transitioning into cloud base. A potential treat is the constant change in feature and the likelihood of having to make google studio a paid product or deprecate it.
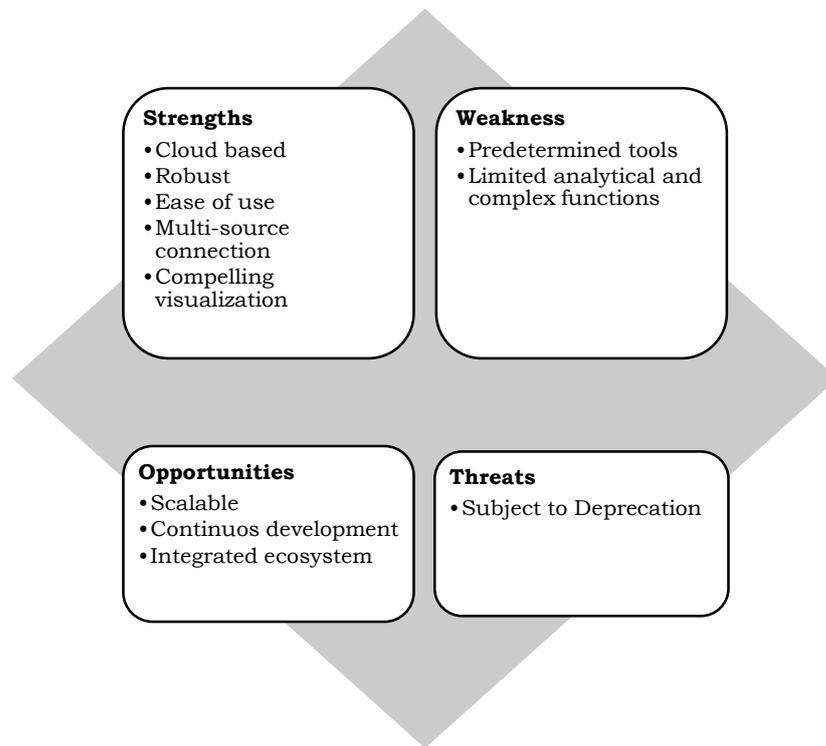
Figure 44 SWOT Analysis for Google Data Studio

6.4 Aspect Evaluation

Various aspects were evaluated to ascertain the spatial and visualization of google cloud platform. As a proxy, the three case studies were evaluated internally according to user aspect, Geoinformatics aspects, economic aspect, methodological aspect and cartographic aspects.

Cartographic Aspect

The case studies have demonsted various visualization approaches using google data studio. For the covid-19 case studies, a mix of cartographic methods like choropleth map, proportional symbol maps were employed Also, charts like line graph, table, pie chart among others are used for visualization purposes. It is possible to apply symbolization and various visual variable as evident by using size and color hues to represent the covid phenomenon as well as air pollution in the case studies. Map legend are customizable and visual hierarchy can be achieved.

Geoinformatics Aspect

In terms of Geoinformatics aspects, basic GIS operations like zoom and click can be used to interact with the maps and charts in the dashboards. As indicated in the case studies, it is possible to add a scale, zoom to a particular geographic region. Also the projection

used is the Mercator projection and is based on the World Geodetic System (WGS) 1984. Also, as evident in the case studies, multiple vector data sources and formats can be integrated in the platform. In addition, both temporal and attribute information can be implemented to support the spatial data representation. In terms of analysis and modelling, although there is a possibility for an exploratory data analysis and the creation of new features, complex GIS analysis cannot be performed.

Economic Aspect

The economic aspect in this case was observation in the time taken to complete a full geovisualization product which in is the case study in this case. Although this is dependent on the type of visualization methods as well as availability of data, the main times spent is much lower. Also, google data studio is a free product.

Methodological Aspect

The platform allows for a seamless integration of various dataset and analytical approaches. As demonstrated by the case studies, different options were used to integrate the data. Also data exploration can be performed and feature modified to meet one's need. Also, filters and formulas can be created to visualize a set of features or generate new insights. Also, various visual various can be modified including color, geometry and shape.

User Aspect

The three case studies are used to represent different user requirements and needs. In the covid-19 dashboard, different analytical tools were used to ensure a visual communication. A well composed layout, charts and maps are helps user understand the information. For instance, the proportional circles together with the line chart helps to know which countries have the most covid-19 cases and also record the most death. At a glance, users are able to clearly understand the trends and dynamics of the global pandemic. They are also able to interact with the map and chart information. As shown in the second case study, users can choose which options to display, be it sessions or views.

6.5 Heuristic Evaluation

Heuristic analysis was adopted to complement the aspect evaluation which focused on user, geoinformatics, economic, methodological and visualization. Heuristic evaluation is an expert evaluation over a system or application (Gómez et al., 2014) and evaluators pass judgment based on some usability criteria (Skarlatidou et al., 2010). The study

adopted the evaulation questions base on six main aspects which are general, GIS, Cartography, User experience (UI), content and graphics using a set of 51 questions. Because existing heuristics are generic, there is the need for a customized domain specific option (Kuparinen et al., 2013).

The case studies evaluated were based on the six aspects with each question evaluted on a scale of -1, 0 and 1 representing does not satisfy, partially satisfy and satisfies repectively. The score are accumulated and summaried according to the aspected as shown in figure 50. It was realised that GIS aspect scored the lowest with 60 percent. This is because of the fact that there is restricting regarding GIS analysis on google cloud platform. The results also correlates with the weakness of the platform as being restricted to more basic functionalities.

Aspects	Points	Questions	Answers	Answered	Score
General	6	10	8	80%	88%
GIS	2	10	10	100%	60%
Carto	7	11	11	100%	82%
UX	3	6	4	67%	88%
Content	7	9	9	100%	89%
Graphics	5	5	5	100%	100%
Total	30	51	47	92%	82%

Figure 45 Heuristic Evaluation

With the platform scoring relatively great in the cartographic, User experince and content and graphics attest to the ability to support effivtive visualization as well as communication. Key cartographic features like scale, legend and sybology can be manipulated to meet the basic standard. Users can design the layout to meet the required design principles and logos as well as other infographics can be attached to further communicate attibute informations. Over all, the possibility to create a positive artistic impression is very high and evident with the 100 percent score in graphics.

7 DISCUSSION

The chapter gives a summary of all the results of the work in addressing the research objectives. It begins by expounding on the spatial and geospatial ecosystem of google cloud platform and then further explored the visualization dimensions leveraging on the google data studio tool. Expert evaluation of key functionalities of google cloud platform was discussed and also bringing to light potential strength and limitations of the platform. Finally, a design workflow for spatial data visualization was explored. There are varied tools and services offered by google to support geospatial data visualization but the study settled on google data studio. This choice is informed by its free and ease of use making it a choice for more people. Another reason for this choice is the transitions of geospatial visualization and analysis to user centric approach where significant technical requirement will not stonewall data usage and integration into business decision. When it comes to making profound decision making, both speed and accuracy are critical components. This also falls in line with the GeoAI moonshot of have making on intelligent decision based on data. Another deal breaker was the easy reporting component of data studio using dashboards. Dashboards are very pivotal for generating insights and presenting them on a single platform. The ability to interplay maps, diagrams and other attribute information allows for a strategic, analytical and operational use.

Spatial and Geospatial Ecosystem of Google Cloud Platforms

The first objective of the work is to review the spatial and geospatial ecosystem of google cloud platform. An exploratory review was conducted involving google product and documentation review. General literacy review on cloud computing paradigm in the context of cloud GIS was also explored. This analysis was supplemented with case studies. Broadly, google cloud services can be categorized under computing and hosting, storage, database service, networking, big data service and machine learning. The study realized that google data ecosystem supports spatial data integration and processing. They operate on a distributed physical and virtual system across the globe called zones. The considerations for the review include, data connection and integration, data analysis or exploration and data visualization and generation of insights. Since the focus on the general ecosystem, a handful products and associated service was used for this review and the choice of google data studio is discussed earlier. Overall, the entire ecosystems support interconnected data integration, scalability and ease of use, thereby reducing the technical barriers to entry as with other geospatial products.

Visualization Dimension of Google Cloud, methods, parameters and implementation approaches

There are numerous ways to integrate data into google cloud's data studio platform. The platform allows for data integration through specially developed connectors and also

via customized connectors. This allows for a seamless data ingestion based on users preferred choice. Spatial data can be integrated via BigQuery and accessed directly on the cloud storage. Also, users can add the data directly from their computer or create their own connectors. The first case study explored covid 19 visualization using google data studio. Spatial data for the study was download from the Johns Hopkins University github in CSV data format. The data was then integrated into google data studio using the file upload option. However, the second case study- Palacký University Olomouc Department of Geoinformatics Web analytics, integrated data directly via google analytics connectors. For the case study 3, population data was integrated directly from google sheets whereas global air pollution data was added as a CSV. More importantly, the data were integrated for visualization.

As the another goal of the research is to ascertain the spatial visualization of google cloud platforms, various general and cartographic methods were tested. The study found through the various case studies the application of various visualization strategies to generate insight from data. In the first case study on Covid- 19 Dashboard, an exploratory data analysis was conducted on the data. This involved feature selections and testing out various visualization methods. The study ascertained that both charts and maps can be harmonized to provide more insight. The first case study adopted the proportional symbol map visualized the death and confirmed cases in of global Covid-19 using color and size visual variables. Also, being able to employ various cartographic methods like the choropleth maps and proportional symbol maps as well as charts, Google data studio allows for a synergistic understanding of observed phenomena. The case study also demonstrated the ability to use basic map design features like cartographic scale, color, typography layout and visual hierarchy. The case study 2 adopted a choropleth map in visualizing the sessions and page views of the Department of Geoinformatics website. Using line chats, a session trend analysis was determined for the last 28 days. Also, Tree maps, were used to augment the countries with more interaction with the platform. It was realized that, users can customize map interfaces according to critical design principles like proximity, alignments, balance, contrast, repetition and white space among others. The case study 3 explored the visualization of world population and share of pollution death data. The extra goal of this case is to test out the design capabilities of google data studio. A 3D impression was created to visualize the share of global air pollution. Infographics were tested to create a visually appealing representation of the phenomena. In all, google data studio allows for the visualization of key cartographic and basic visualization methods and allows for integration of key deign principles in visualization.

Evaluation of Cartographic and spatial Visualization

Whilst the case studies offer a comprehensive overview of the spatial visualization potentials of Google Data Studio and Google Cloud Platforms in general, other evaluation approaches were tested to complement the case studies. For an effective evaluation, a design framework was developed. The framework has four components including Geospatial data source, Map design considerations, Cartographic method visualization and Evaluations. The study revealed that Google Data Studio integrates numerous data types and formats. As demonstrated by the case studies, both raw data from a computer or data in a cloud can be integrated for visualization. For the map design considerations, it is possible to work with scale, visual variables and symbolizations including color, size among others. It also offers the opportunity to incorporate typography, customized layout and visual hierarchy. For cartographic and general method visualization, only simple methods like choropleth maps, proportional symbol maps and diagrams can be applied. As the time of this report, it is not possible to implement more advanced visualizations methods like cartograms.

Limitations and Potentials of Google Cloud Platform

The limitation of Google Cloud Platform just like most GIS cloud is the limitation of the methods and approaches that can be used. As evident by the various case studies, only basic cartographic and general methods like choropleth maps, proportional symbol maps. It is also not possible as at the of this report not able to perform complex analytical geospatial operation. However, a key potential is the ability to tell stories with data through generating insights. Also, it is possible to worked in a collaborative manner among teams and allows for control of user functionalities.

Workflow for spatial data connection and visualization

Working with Google Data Studio requires registration and creating an account. The major stages include data connectors, data transformation, data visualization and evaluation. Data integration can be done either via google or community connectors after which exploratory data analysis process then performing actual visualization. Here, controls and interactions can be integrated. The final stage is evaluation in terms of user, cartographical, methodological and general visualization.

8 CONCLUSION

The overall goal of the thesis is to analyze, describe and evaluate the spatial and geographic aspects of Google Cloud Platforms. To achieve this broad goal, several objectives were developed. The first objective is the review the spatial and geospatial ecosystem of Google Cloud Platforms. Extensive review of the entire ecosystem was performed but case studies developed in Google Data Studio because it is free and offers great tools for visualization. The theoretical part was supplement with case three case studies to demonstrate the spatial and visualization dimensions of google platforms. The study found out that the ecosystem of google cloud supports scalable and robust spatial data via its various cloud based services.

Case study approach was adopted for the study due to limited scope of academic literature on the topic. Also the second objective which seeks to investigate the visualization dimension of Google Cloud Platform with emphasis on the general and cartographic methods, parameters, datasets and implementation approach requires a case study approach. Using three case studies, namely, covid-19 data visualization, Palacky University Olomouc department of Geoinformatics web Analytics, and World population and share of Air pollution death visualization various cartographic and general visualization methods were studied. It was realized that, Google' data studio platform support multi spatial data integration via in-build or community connectors. Also basic map design considerations like scale, symbolization and visual variable are possible. The study found out that the interactive nature coupled with ability to customize layouts and support for visual hierarchy make is a great tool for cartographic visualization. SWOT analysis and heuristic evaluation was conducted for indebt expert opinion on the visualization, user, methodological and geoinformatical aspects. The study realized that data studio is better with visualization, user need and more economical. There are however, some limitation with methodological and geoinformatical aspects.

The study also seeks to analyze the general limitation and potential of google cloud platform and as well develop a workflow flow. The major potential identified is the scalability and ease of use whereas the uncertainty due to frequent product update was a limiting factor. A four process design framework was developed to for spatial data visualization in google studio. This include geospatial data source, map design considerations, cartographic method visualization and Evaluation.

A major contribution of the study is exploring an alternative visual communication approach. A recommendation for further study is on comparing the spatial data visualization dimensions across multiple cloud GIS platforms.

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ATTACHMENTS

LIST OF ATTACHMENTS

Bound attachments:

Attachment 1   Case Study 1

Attachment 1   Case Study 2

Attachment 1   Case Study 3

Free attachments

Attachment 4   Heuristic Evaluation (Excel Sheet)

Attachment 5   Poster

Attachment 6   USB Pen Drive

Structure of USB Pen Drive

Folders:

    Heuristic Analysis

    Data

    Case-study links

    Poster

    Text

    Website

APPENDIX 1

Case Study 1: Covid 19 Visualization Dashboard

Link https://datastudio.google.com/u/0/reporting/e898d7b5-9862-4f6a-92c0-21da3417c62e/page/vIypB
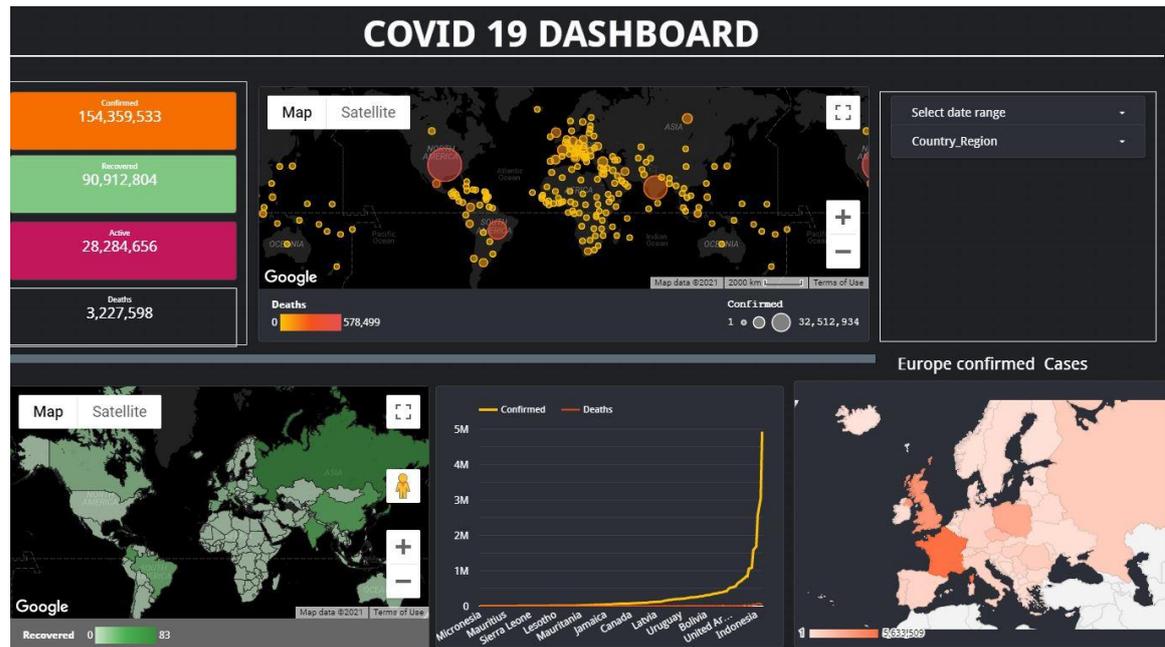
APPENDIX 2

Case Study-2: UPOL Department of Geoinformatics Web Analytics

https://datastudio.google.com/u/0/reporting/3edb294f-25a7-4322-82f7-894d31b18f40/page/c2P1
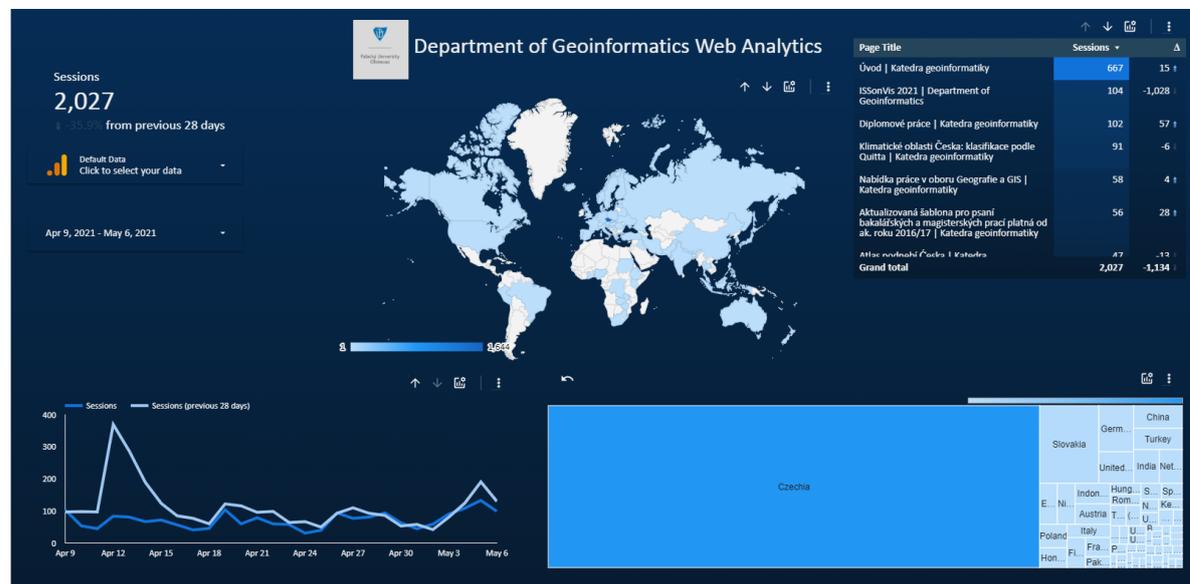
APPENDIX 3

Case Study-3: World Population and Share of Air Pollution death

https://datastudio.google.com/u/0/reporting/e2198ca6-27e0-4c7c-ad07-4bb193cacac3/page/MM