BIG DATA AS CLIMATE CHANGE INTERVENTION: A POLICY DELPHI STUDY ON DATA ANALYTICS MATURITY WITHIN THE CLIMATE ACTION ECOSYSTEM

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May 2021

UNIVERSITY OF THE PHILIPPINES
OPEN UNIVERSITY

DOCTOR OF COMMUNICATION PROGRAM

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Big Data as Climate Change Intervention: A Policy Delphi Study on Data Analytics Maturity Within the Climate Action Ecosystem

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Date of Submission
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Acceptance Page

This dissertation titled **Big Data as Climate Change Intervention: A Policy Delphi Study on Data Analytics Maturity Within the Climate Action Ecosystem** is hereby accepted by the Faculty of Information and Communication Studies, U.P. Open University, in partial fulfillment of the requirements for the degree Doctor of Communication (DCOMM).

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ACKNOWLEDGEMENTS

This dissertation, while an individual work, benefited from the insights and direction of several people who have contributed to the fulfilment of this project.

DR. ALEXANDER G. FLOR, dissertation adviser for his unwavering support and invaluable guidance at every stage of the dissertation process; DR. RIA MAE H. BORROMEO, panel member, and DR. DAVIDE DALL' AGATA, panel member for their valuable insights, suggestions and recommendations on the improvement of this paper;

DR. FELIX LIBRERO for the inspiration and learnings that prompted the researcher to use Systems Theory as study framework;

DR. ELENA E. PERNIA and VINCENT M. SERVELLO for the support and encouragement to pursue her graduate studies;

TO FAMILY, FRIENDS and COLLEAGUES for providing constant support and inspiration;

TO THE POLICY DELPHI PANEL OF EXPERTS for their active participation and the generosity they extended as research participants;

And to all those who have contributed in making this study possible, most especially to God who provided the knowledge, perseverance, and strength to fulfill this dream.

DEDICATION

To Ed and Alex, for always believing in me.

To my mother Linda and my siblings, Allan and Starr.

To my late father Jimmy and Amma Choleng.

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ABSTRACT

The effects of climate change are being felt now and continues to be one of the most urgent issues facing the world particularly for developing nations such as the Philippines. Despite the significant measures being taken to reduce greenhouse gas (GHG) emissions, some degree of climate change will remain and cause considerable economic, social, and environmental impacts. Individuals, communities, and organizations need to take action to prepare for and adjust to the current effects of climate change as well as the predicted impacts in the future. Climate change adaptation is an emerging area of study. Adaptation is essential to alleviate the inevitable damages brought about by climate change. Data analytics can provide organizations the ability to anticipate a range of potential climate conditions, enabling them to take action before the worst impacts happen.

This research aimed to contribute to the development of an analytics maturity framework relevant to development programs and institutions focused on climate change. This demands an understanding of the epistemological challenges presented by big data and the existing knowledge in the area of data and analytics. A Policy Delphi was organized involving experts from the academe, data analytics and climate sectors comprising three Delphi rounds. The Delphi method was used to construct consensus views and forecasts from the panel of experts in an iterative manner which enabled the identification of important dimensions of a data-driven climate action ecosystem. This research adopted the cybernetics stance that conceptualizes big data as a complex system where the interacting elements, whether living or nonliving, macro or micro, influence one another and are able to function, and why they often malfunction. The analytics maturity framework discussed in this dissertation could potentially help uncover important variables, patterns, challenges, and opportunities

in the data and analytics processes of climate communities which could create and promote an ecosystem that enables insight and action.

Chapter 1

INTRODUCTION

Background of the Study

> *"The world is reaching the tipping point beyond which climate change may become irreversible. If this happens, we risk denying present and future generations the right to a healthy and sustainable planet – the whole of humanity stands to lose."*
> *- Kofi Annan, Former Secretary-General of UN*

Changes in the Earth's climate can be attributed to natural variations that have been occurring for millions of years, and increasingly, from human activities that release excessive amounts of greenhouse gases (GHG) into the atmosphere that lead to anthropogenic global warming. These GHGs comprise of carbon dioxide mostly from fossil fuel combustion and forest burning, and other heat-trapping gases such as methane from irrigated agriculture, animal husbandry and oil extraction, nitrous oxide and various human-made halocarbons (WHO, 2003).

The Intergovernmental Panel on Climate Change (IPCC) reports indicate that the average global temperature increased by 0.74°C from 1906-2005 and predict an increase of 0.2°C to 0.4°C in the next two decades. By 2015, the global average surface temperature reached 1°C above pre-industrial times. At current or higher levels of greenhouse gas emissions, further warming can be expected that will initiate many changes in the global climate system in the 21st century. Large amounts of new and more comprehensive data, more sophisticated data analysis, and improved climate models in the latter half of the 20th century have convinced most climate scientists that the rise in anthropogenic greenhouse gas concentrations are directly responsible for most of the observed increase in global average temperatures. The effect and impact of climate change are already being felt worldwide and will likely continue to intensify over time.

The United Nations declared 17 sustainable development goals in 2015, of which SDG13 is "Take urgent action to combat climate and its impacts by regulating emissions and promoting developments in renewable energy" (UN, 2016). In the same year, the Paris Agreement, a legally binding international treaty on climate change, has been signed and adopted by 197 nations. It aims to limit global average temperature rises well below 2°C above preindustrial levels, while pursuing the means to limit the increase to 1.5°C recognizing that this can significantly reduce climate risks and impacts (Rogelj et al., 2016).

In recent years, accelerated development and adoption of new technologies coupled with rapid progress in social media, digital communication and the internet of things have propelled the accessibility, availability and growing magnitude of data and information. The amount of data that is being created and stored on a global level is almost unimaginable. In 2018, Social Media Today reported that over 2.5 quintillion bytes of data are created each day and 90 percent of the world's data was generated in the last two years. The World Economic Forum reports that by 2025, the amount of data generated each day is expected to reach 463 exabytes globally. Enhanced connectivity, technological advancements and practical applications have significantly reduced the cost of data collection, storage and processing making it possible to generate and analyze huge datasets. This continues to provide people and organizations greater ability to derive key insights from available information that can bring about unforeseen benefits to society.

The research and development community still rely largely on traditional tools and methods to understand and measure the effectiveness and impact of programs or policies. However, traditional methods such as household surveys and census data can be ineffective in delivering timely action to protect vulnerable populations in a fastchanging world. Both historical and real-time information derived from big data offer various trends and patterns that better predict the future and arrive at more viable solutions for dealing with imminent problems. The emerging ability to use big data for development promises many useful applications for socioeconomic and environmental sustainability. Big Data is being increasingly explored for development purposes and as an approach to sift through the massive amount of information.

Rationale and Knowledge Gap

Big data has attracted a lot of attention from both academia and various industries. It can help organizations address real-world problems and create solutions by optimizing existing processes and utilizing data analysis to yield meaningful information. Such analytics offer valuable insights that deepens understanding, fosters innovation, improves decision making, and enhances the performance of predicting outcomes. While there is clear benefit in data analytics, many still struggle in defining the scope of their data analytics programs, understanding what is critical and distilling a roadmap that will enhance value derived from various datasets. Empirical evidence points to the lack of research or knowledge in this area that would have provided new directions to evaluate and enhance ongoing development programs.

Climate change has a direct and immediate impact on development. It continues to disrupt economies and remain as a top global risk affecting many countries. This requires urgent attention as delaying action will be more difficult and costly in the future. The United Nations states that "there is alarming evidence that important tipping points, leading to irreversible changes in major ecosystems and the planetary climate system, may already have been reached or passed." The World Bank reports that the Philippines is among the most vulnerable countries to climate-related weather events. Its greenhouse gas emissions rank in the top 25 percent among low- and middle-income countries. The transport sector is expected to double its emissions and the energy sector is projected to quadruple by 2030. The 2017 Climate Change Risk in the Philippines: Country Fact Sheet states that the Philippines is highly endangered to the impacts of climate change, including rise in sea level, increased frequency of extreme weather events, rising temperatures and extreme rainfall due to high exposure to natural hazards (cyclones, landslides, floods, droughts). These weather patterns frequently jeopardize the welfare of communities in high-risk areas and require responses to curtail climate forcing and adapt to impending changes. Near and medium-term effects of climate change are unavoidable. Thus, adaptation responses and strategies that will make societies more resilient to these impending changes are essential to sustainability.

Juan Murillo, the Head of Analytic Outreach in BBVA's Data Strategy and Data Science Innovation department, during his presentation at Big data to Action 2019, held in Madrid stated that the role of big data in the non-profit areas "is the same as in a corporate environment: using data helps to chart a course, supported with knowledge and a vision of the route, and of the obstacles that we might find in the path." However, there are still challenges and barriers to data collaboration that need to be overcome such as discounting the vulnerable groups who are least likely to leave a digital fingerprint. This implies limitations on the implementation of data initiatives for the common good.

Research Question and Objectives

The present study intends to answer the research question, *"Is Big Data Analytics applicable in solving development problems such as Climate Change?"* It aims to explore the applicability and potential of using Big Data Analytics in addressing development issues related to climate change. Organizations must be able to quickly respond to rapid changes in the environment by discovering evolving patterns of climate change and predicting climate change impacts. Data and analytics programs improve outcomes that enable organizations to manage and utilize the available resources effectively. A key determinant to the success of an analytics program is the organization's level of data and analytics maturity. As a program matures, the optimal architecture will evolve along with the processes and skills needed to support it including tools, people, processes, data and technologies. The specific objectives are described below:

1. To understand the current state of data and analytics in the climate community along the analytics maturity continuum;
2. To identify dimensions from existing analytics maturity frameworks that can be applied in the context of climate change programs generated through secondary exploratory and anticipatory research;
3. To determine current and anticipated challenges and obstacles in existing and future data and analytics processes that hamper progression along the maturity continuum; and
4. To build a conceptual framework relevant to development institutions to elevate the level of data and analytics.

Research Significance and Contribution

The effects of climate change are being felt now and will intensify in the coming decades. This makes climate change one of the most urgent issues facing the world today, particularly for developing nations. In the Global Climate Risk Index report by Germanwatch, the Philippines ranked second globally among countries most affected by climate-related disasters in 2018. Recognizing the challenges posed by climate change, a methodical application of big data could potentially revolutionize our capability to manage the risks of climate change.

The conceptual framework on Big Data analytics discussed in this dissertation could potentially help uncover important variables, patterns, challenges, and improvement opportunities in the data and analytics processes of climate change programs which could create and promote an ecosystem that enables insight and action. This research will contribute to the existing body of knowledge by identifying and addressing the knowledge gap between the application of big data solutions on climate change, thereby elevating methods to manage, process and analyze data in terms of volume, variety, velocity, veracity and value for sustained value delivery, insight generation and impactful initiatives.

Chapter 2

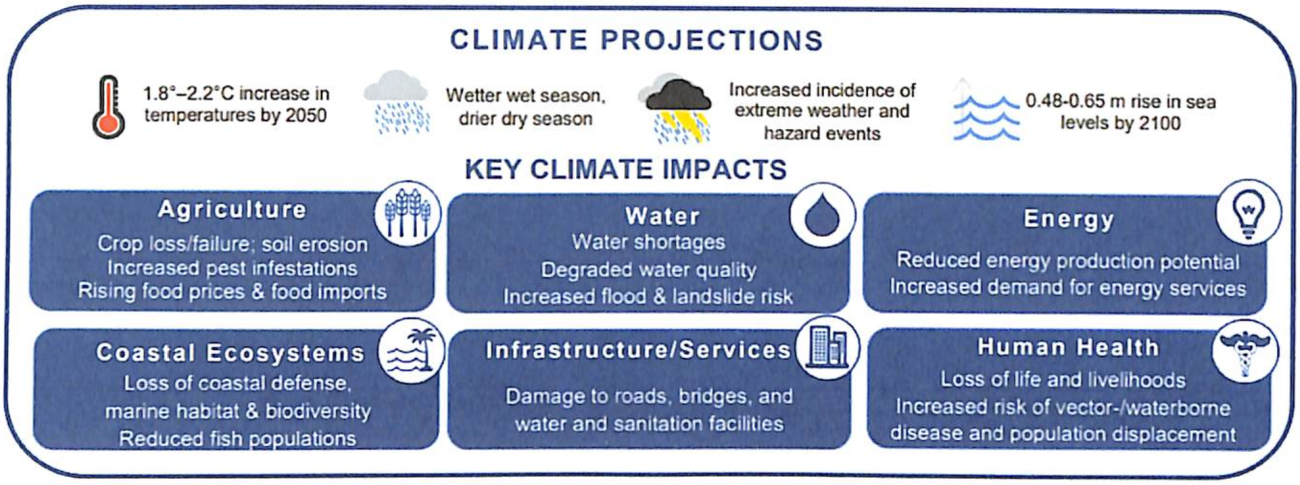
REVIEW OF RELATED LITERATURE

This research and its framework stem from various views on Big Data as an epistemological inquiry that arises from the rapidly growing volume of digital data. Kitchin (2014) argues that "there is an urgent need for wider critical reflection within the academy on the epistemological implications of the unfolding data revolution." The proliferation in the volume and types of data available presents tremendous potential in informing and transforming society and protecting the environment.

Climate Change in the Philippines

The Philippines lies in the world's most cyclone-prone region. It averages 19–20 cyclones each year, of which 7–9 make landfall. Historic climate trends show an increase in average temperature of 0.65°C from 1951–2010 resulting to increased number of "hot" days and decreased number of "cold nights"; increased number of cyclones during El Niño years; increased sea surface temperatures of 0.6°– 1°C since 1910, with most significant warming occurring after the 1970s; and rise in sea level of 0.15 meters since 1940. Projected changes in climate by 2050 include increased temperatures, reduced rainfall making the dry season drier, increased heavy and extreme rainfall in some areas making the wet season wetter, increased frequency of extreme weather events, and further rise in sea levels by 2100 (see Figure 1). The potential impacts of climate change continue to threaten the health and living conditions of large numbers of people from direct effects such as heat stress and flooding, to indirect influences such as disease transmission and malnutrition. Most at risk are the urban poor living in temporary shelters and lacking the resources to prevent or mitigate the threat of coastal inundation and storm surge.

Figure 1. Climate Projections and Key Climate Impacts



The Climate Change Commission and Adaptation Initiatives

In response to the urgency for action on climate change, the Philippines passed the Climate Change Act of 2009. This is anchored on the constitutional provision which states that "it is the policy of the State to afford full protection and the advancement of the right of the people to a balanced and healthful ecology…to fulfill human needs while maintaining the quality of the natural environment for current and future generations." Being the lead policy-making body on climate change concerns, it requires local government units (LGUs) to draft local climate change action plans (LCCAPs). As of July 2016, only 160 of the total 1,700 LGUs had LCCAPs in place.

The Climate Change Commission (CCC) is the lead policy-making body of the government tasked to develop policies and coordinate programs on climate change. It ensures the integration of climate change initiatives in national, local, and sectoral development plans towards a climate-resilient and climate-smart Philippines. The CCC participates in the global effort to confront the challenges caused by climate change. The Commission developed the National Climate Change Action Plan that serves as a road map for all climate change programs in the Philippines. These programs include the CCC's flagship capacity building program, the Communities for Resilience (CORE), the National Integrated Climate Change Database and Information Exchange System (NICCDIES), the People's Survival Fund (PSF), and the Comprehensive Integrated Climate Change Adaptation and Resilience Program for the Indigenous Peoples, among others.

The National Integrated Climate Change Database and Information Exchange System (NICCDIES) serves as the integrated climate information portal of the Climate Change Commission to track climate actions. NICCDIES is used to consolidate and monitor data and information on climate change and climate action from different sources to allow decision-makers to access, distribute, and exchange these data and use them in policymaking, development planning, and investment decision-making. The primary components of the NICCDIES include database and information systems for the following: Greenhouse Gas (GHG) Inventory; Climate Change Mitigation: Measurement, Reporting, and Verification (MRV) System; Climate Change Action Plans: NCCAP and LCCAP; Climate Finance; and Climate Reports.

The Philippine Development Plan 2017-2022, under the Duterte Administration, recognizes the widespread impacts of climate change and the need for a nationwide climate and disaster vulnerability and risk assessment to deal with the impacts of natural hazards.

Individuals, governments, organizations, and communities around the world are already taking steps to adapt to climate change. Adaptation refers to adjustments in ecological, social, or economic systems in response to actual or expected effects or impacts of climate change. Anticipatory adaptation or planning for climate change before impacts have occurred can be a way to substantially reduce vulnerability and realize opportunities based on observed changes in climate and adjusting policies and actions accordingly. Adaptation measures and programs including new technologies and policies are already in place in many areas and are continuously being expanded or modified.

Big Data and Climate Studies

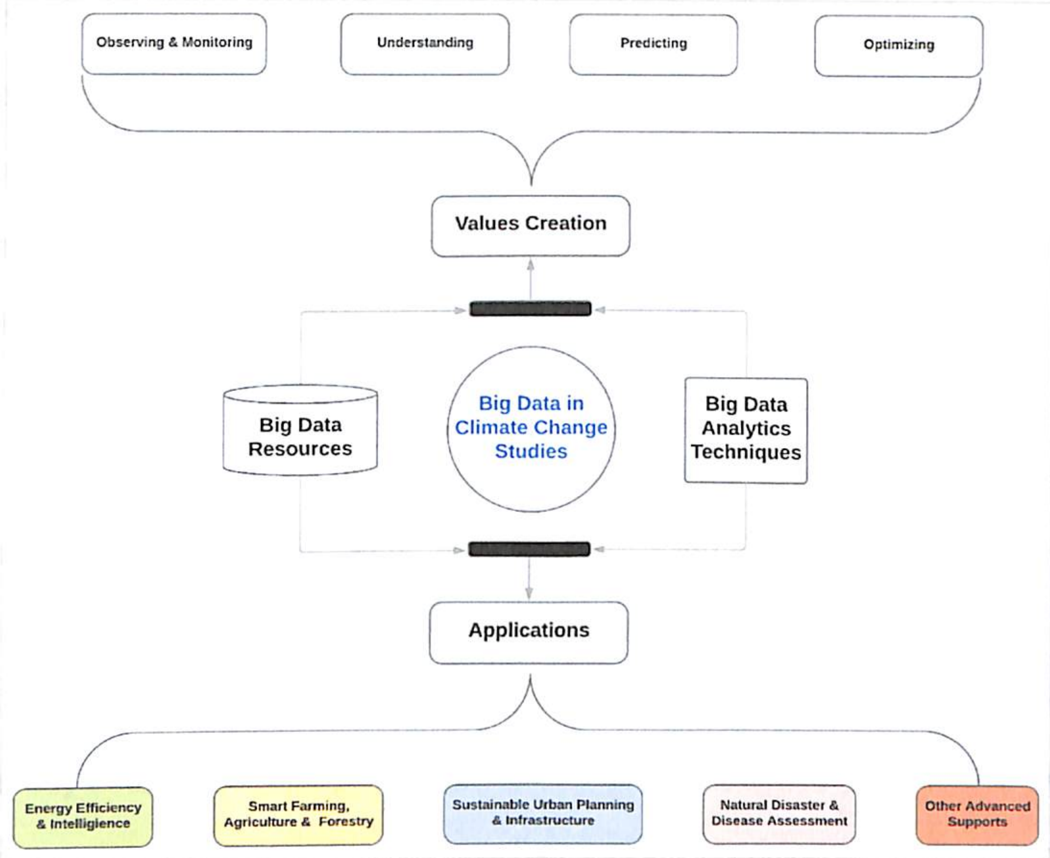
Big Data applies to the large volume of structured and unstructured data that are so large or complex that it cannot be processed or analyzed using traditional tools or methods. Boyd and Crawford (2012) defines big data as "a cultural, technological, and scholarly phenomenon that rests on the interplay of technology, analysis, and mythology." It is a holistic approach to manage, process and analyze volume, variety, velocity, veracity and value in order to create actionable insights for sustained value delivery, measuring performance and establishing competitive advantages (Fosso Wamba et al., 2015).

Large datasets have been used in climate science to understand how climate systems function, but the field has been slow to use the passively generated information from digital devices and big data solutions. According to Ford, et. al. (2016), "the capacity to collect and analyze massive amounts of data is transforming research in the natural and social sciences. And yet, the climate change adaptation community has largely overlooked these developments."

Research that investigates the topic of big data in climate change are relatively recent. Sebestyén, et. al. (2021) provides a higher-level overview of the interconnectedness of disciplines, systems, data, and tools related to climate change. This research highlights the potential in the System of Systems (SoS) theorem. It explores the synergies between diverse disciplines and research ideas and shows how data and models can be bridged to understand the complex problems of climate change. Data and systems science enable a large amount of heterogeneous data to be integrated and simulation models developed, while taking into consideration socio-environmental interrelations. Climate-related Big Data articles that were analyzed and categorized revealed the increasing number of applications of data-driven solutions in specific areas with less focus on broad integrative analyses.

Hassani, et. al. (2019) presented an overview of the current status of big data analytics applications in climate change covering over 100 research papers. Their research indicates that over 80% of the listed applications were after 2016, making their review the most comprehensive and recent review of this topic. The authors identified big climate data resources and big data analytics techniques as the fundamental elements in the applications of big data in climate change. They classified the studies into four aspects of value creation: observing and monitoring, understanding, predicting and optimizing; as well as their specific application grouped into five topics: energy efficiency and intelligence, smart farming and agriculture and forestry, sustainable urban planning and infrastructure, natural disaster and disease assessment, and other advanced supports (see Figure 2).

Figure 2. Framework of big data in climate change studies (Hassani, et al, 2019)



The study revealed that much of the existing research apply big data analytics in the area of energy efficiency, intelligent agriculture, smart urban planning, weather forecast, natural disaster management, etc. Energy efficiency remains the most popular topic followed by smart farming/agriculture and natural disaster assessment. Numerous literatures can be found on big data and smart cities, but the sustainable aspect that links to climate change remains in the early stage of its development. There is no recent review that particularly investigates the topic of Big Data in climate changes. Thus, it becomes critical to find measures and solutions to control the global increase in temperature. Big Data can produce practical insights that can aid in promoting and strengthening environment sustainability.

Big Data is advancing in the area of sustainability with research aimed at improving social and environmental sustainability in supply chains (Dubey et al., 2019), augmenting the informational landscape of smart sustainable cities with big data applications (Bibri, 2018), improving natural resource allocations and utilization (Song et al., 2017), and developing a knowledge management-based approach to sustainability assessment (Konys, 2018). The Big Data for Development Network (BD4D) initiative emphasizes the importance of big data in implementing the 2030 Agenda in the global south by highlighting its current uses and applications for sustainable development. It aims to develop research on BD4D and generate capacities among researchers enabling countries to overcome information gaps, expand official statistical operations and generate evidence-based policies. Big data provides key information that policymakers can use to structure policies that address socio economic development challenges that include reducing the risk of economic losses by predicting optimum climatic conditions.

Public-private sector collaboration using data sources for external initiatives can produce significant benefits. "The SDGs are nothing more than KPIs for social development, and all KPIs have to be measured, their performance tracked over time, because that is how they will indicate if we are on the right path or not." explains Juan Murillo. Different groups such as the United Nations, governments, and not-for-profit organizations are using big data to work towards achieving the SDGs. A survey conducted by the task team indicates that data are commonly sourced from mobile phones and big data projects are mostly focused on the no poverty goal.

Pulse Lab Jakarta, a joint effort between the United Nations (Global Pulse) and the Government of Indonesia (Ministry of National Development Planning, Bappenas), is working on various projects to close information gaps and accelerate the adoption of Big Data for sustainable development and humanitarian action. One of their projects is the Vulnerability Analysis Monitoring Platform for Impact of Regional Events (VAMPIRE) platform which analyzes satellite imagery and creates maps that incorporate anomalies related to climate and rainfall to help track slow-onset climate changes.

The International Institute for Sustainable Development (IISD) partnered with the Global Environment Facility (GEF), the MAVA Foundation, and the United Nations Industrial Development Organization (UNIDO) to work on systemic approaches and simulations for nature-based infrastructure (NBI) promoting the use of systems thinking, system dynamics simulation, and project finance modelling. The predictability and certainty of NBI performance increases by employing systems thinking and simulations that look at climate change risks as well as environmental, social, and economic benefits, costs, and externalities. There are many other potential uses for Big Data related to the SDGs.

Big Data Challenges and Opportunities

There are numerous challenges, risks and costs in collecting, storing and analyzing large amounts of data that can have implications on technological and infrastructure requirements. A study by Faghmous and Kumar (2014) discusses some of the major Big Data challenges researchers encounter when handling climate data. The climate science community faces issues on data availability or having short observational records, and continuously changing instruments and algorithms used to monitor and process observational data, especially for satellites and other remote sensing tools. This raises questions on the applicability of such data to study long-term climate conditions. The use of multiple technologies to monitor key variables causes heterogeneity in climate data. This requires effective methods of merging data from various sources that are complimentary yet possibly redundant.

There is also the risk of growing inequality and bias. Sampling bias occurs when data analysis is based on a biased or nonrandom dataset. Some types of Big Data may not fully represent the underlying population of interest due to language, poverty, lack of education, lack of technology infrastructure, remoteness or prejudice and discrimination, making it difficult to establish how representative the data is. Less developed countries have limited access to technology resulting to higher survey response rates from high-income countries than lower-income ones. The proper processing and handling of personal data observes privacy, ethics and respect for data sovereignty. In most cases, removal of sensitive or explicit personal information from datasets may not fully protect privacy.

Another major challenge involves technological infrastructure since many data-mining tools may not be suitable for large datasets. Big Data needs better bandwidth infrastructure to download, catalogue, organize and process it in a timely manner as big data can result in massive data points. Organizations report many challenges with many of their data and analytics initiatives. This research aims to evaluate data analytics maturity frameworks useful in assessing and measuring an organization's data and analytics processes and capabilities. This will allow organizations to increase program value by improving the maturity of its data analytics capability.

Existing research has applied Big Data analytics in mainly the aspects of energy efficiency, intelligent agriculture, smart urban planning, weather forecast, natural disaster management, etc. (Hassani, et. al. ,2019). For instance, in Jakarta, Twitter conversations have provided an innovative way to monitor actual prices of rice. In the Philippines, the World Bank teamed up with Grab to launch the Open Traffic Initiative using driver data to collect near real-time traffic data and statistics, including speed, flow, and delays at intersections to study critical areas in traffic management. Other examples include call detail records with information on mobile customer behavior being used to proxy the poverty status of mobile users. Digital traces of mobile phone use can help track population movements and examine people's behavior during disaster events (Martinez and Albert, 2018).

Other studies have used Big Data-based tools to build complex analyses and models in climate science, for example, develop scalable data processing framework and efficient change detection algorithms to monitor seasonal changes in climate change (Manogaran et al., 2018), understand climate change as a theory-guided data science paradigm (Faghmous et al., 2014), manage the risks of climate change (Ford et al., 2016). Expanding big data techniques to climate studies could offer real-time insights into people's wellbeing and target interventions to vulnerable groups. The analysis of big data combines traditional methods of statistical analysis with computational approaches. Data analysis can be a simple data query or a combination of sophisticated techniques depending on the complexity between the variables and the type of results required (Al-Shiakhli, 2019).

Analytics Maturity Models

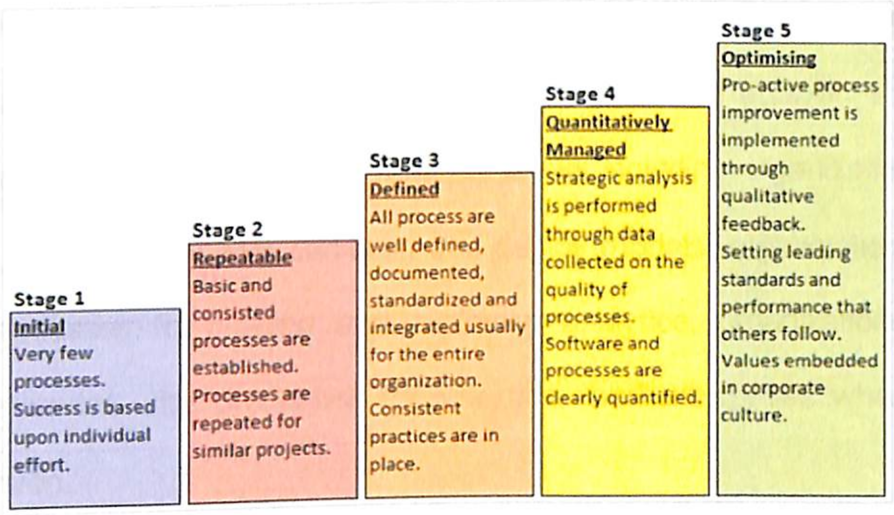
A maturity model is an approach that uses a set of structured levels to help describe and measure how well the behaviors, practices and processes of an organization can reliably and sustainably produce desired outcomes. Data and analytics programs aim to improve outcomes and enable organizations to respond in a dynamic way to the constantly changing environment. A key determinant to the success of an analytics program is the organization's level of data and analytics maturity. As a program matures, the optimal architecture will evolve along with the processes and skills needed to support it including tools, people, processes, data and technologies.

Maturity models have been proposed as early as the 1970's and to date, over a hundred maturity models have been published in the field of information systems (Król and Zdonek, 2020). There are several frameworks that measure the data and analytics maturity of organizations. These models mainly aim to create an ecosystem to integrate and manage all relevant data sources into insight and action.

The Software Engineering Institute (SEI) at Carnegie Mellon University first developed the Capability Maturity Model (CMM) in 1986. This model was originally intended to quantify the level of an organization's business processes to complete a software project and formed the basis for measuring the maturity of processes for developing software. The model involves five aspects including maturity levels or a 5-level process maturity continuum, key process areas that identify a cluster of related activities performed simultaneously to achieve a set of goals, goals that summarize the states that must exist for that key process area to have been implemented in an effective and lasting way, common features or practices that implement and institutionalize a key process area, and key practices that describe the elements of infrastructure and practice that contribute most effectively to the implementation and institutionalization of the area.

The model provides five levels defined along a theoretical continuum (see Figure 3). As the organization moves up these five levels consecutively, the predictability, effectiveness, and control of an organization's software processes are believed to improve.

Figure 3. Capability Maturity Model (CMM) - The data-group.com.au

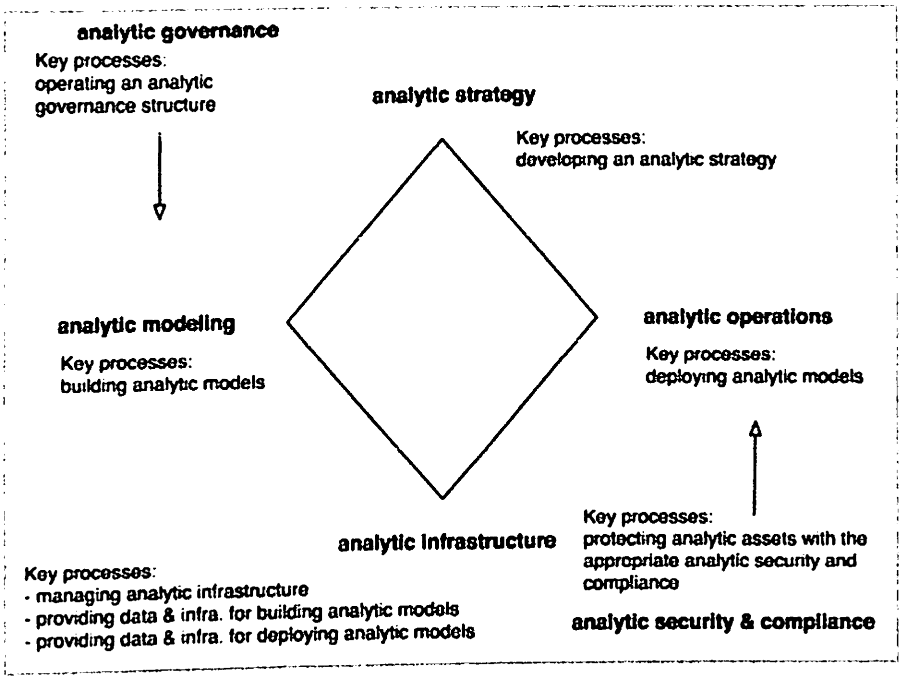


The Initial Stage is the starting point for use of a new or undocumented repeat process and is in a state of dynamic change, tending to be driven in an ad hoc, uncontrolled and reactive manner by users or events. The Repeatable Stage is at least documented sufficiently such that repeating the same steps may be attempted, possibly with consistent results. The Defined Stage has sets of defined and documented standard processes established and subject to some degree of improvement or validation in a range of situations. The Managed Stage uses process metrics to effectively achieve objectives, demonstrate competence and establish process capability across a range of conditions or multiple environments. The Optimizing Stage focuses on continually improving process performance through both incremental and innovative technological changes. The factors in this model are not necessarily unique to CMM and represent the stages that organizations must go through on the way to becoming mature.

Broadly based upon the CMM is the Analytic Processes Maturity Model (APMM). The model identifies analytic-related processes in six key process areas: building analytic models, deploying analytic models, managing and operating analytic infrastructure, protecting analytic assets through appropriate policies and procedures, operating an analytic governance structure, and identifying analytic opportunities, making decisions, and allocating resources based upon an analytic strategy. The APMM divides organizations into five maturity levels including organizations that can build reports, organizations that can build and deploy models, organizations that have repeatable processes for building and deploying analytics, organizations that have consistent enterprise wide processes for analytics, and enterprises whose analytics is strategy driven.

The data mining process model or Knowledge Discovery in Databases (KDD) exhibits some similarity with the APMM (Fayyad, Piatetsky-Shapiro, & Smyth, 1996). The KDD process consists of selecting target data from the available data, pre-processing the target data, transforming the preprocessed data, using data mining on the transformed data to produce patterns, and interpreting and evaluating the patterns to produce knowledge. The most important difference between the APMM and the KDD process model is that the latter focuses on activities within the modeling or data mining group, while the former identifies activities related to IT, modeling, operations and strategy that span the organization.

Figure 4. Key processes for analytics



The Data Analytics Maturity Model for Associations (DAMM) was developed by Association Analytics (A2) in response to the analytics needs of various associations and non-profit organizations at industry meetings (Association Analytics Network meeting). This model assesses the four key elements of data analytics: organization and culture, architecture/technology, data governance, and strategic alignment. Associations that are at the Learning Stage lack knowledge, tools, and processes which prevents them from taking immediate actions. This is commonly observed in departments that operate independently where data are not integrated and where decision-making is based on experience, the adopted policy, and tradition. The Planning Stage have employees that are willing to work with data and are aware of the benefits of data analytics. At the Building Stage, strategies and implementation plans are in place including the central data repository and tools for data analysis and visualization. At the Applying Stage, associations employ interactive visualizations and dashboards to obtain and deliver key information and use data analysis to solve business problems. At the Leading Stage, associations make data-based decisions which affects the effectiveness of actions taken. The DAMM model supports democratization of data or making data accessible to everyone, instilling an analytics-guided culture by employing leaders who are data analytics champions, developing clearly defined Key Performance Indicators, creating a central repository of all key data sources, and implementing a data governance program.

Figure 5. Data Analytics Maturity Model (Association Analytics)

The International Institute for Analytics (IIA) developed the Analytics Maturity Assessment (AMA) that is designed to assess an organization's capacity to apply corporate analytics. This assessment is carried out based on the DELTA Plus model and five analytics maturity stages: Data, Enterprise, Leadership, Targets, and Analysts. Data should be organized, integrated, available, and of a high quality in order to obtain valuable and reliable analysis results. An analytical ecosystem or analytics culture should be present in the organization for the design and implementation of an analytics strategy and the adoption of analytics goals. Their leaders make full use of analytics and steer the organization's development to achieve data analytics potential and streamline the implementation of analytics initiatives. These analytics initiatives should correspond to specific and strategic targets in line with corporate objectives that are executed by analytical professionals. This model later extended to include Technology and Analytics Techniques.

Parallel to AMA and DELTA Plus model is the Analytics Maturity Quotient that is based on an assessment of data quality, data-driven leadership, people with analytics skills, data-driven decision-making process, and agile infrastructure. This model holds that data quality is the core of analytics and that bad data quality can severely impair customer and product understanding. It is crucial to have data-driven leaders who trust data to prove or disprove their own beliefs and continue to be open to learn from new information. In order to effectively analyze data and draw insights, people with the right analytics and technical skills have to be in place.

The SAS Analytics Maturity Scorecard is based on an analysis carried out in four dimensions: Culture, Internal Process Readiness, Analytical Capabilities, and Data Environment: Infrastructure and Software. An organization can be placed on one of the five analytics maturity stages. The Analytically Unaware Stage relies on perceptions, historical decisions, and non-validated beliefs with no defined data management or analytic processes. The Analytically Aware Stage recognizes benefits of analytics to support decision-making but do not leverage analytics consistently. The Analytically Astute Stage adopts analytics for all decisions with an established set of common data management processes and use of data and analytics. The Empowered Stage has widely deployed data processes and leverages analytics across the organization to support business decisions. The Explorative Stage discovers innovative ways to use advanced analytics and new techniques to support business decisions.

The Web Analytics Maturity Model (WAMM) or Online Analytics Maturity Model (OAMM) provides an unbiased and easy-to-understand representation of an organization's expectations of, and commitment to, analytics infrastructure and initiatives by using a benchmark to identify where the organization sits compared to others in the industry. The WAMM evaluates organizations along six dimensions: management, governance, and adoption; objectives definition; scoping; the analytics team and expertise; continuous improvement process and analysis methodology; and tools, technology and data integration. According to the WAMM model, an organization that is not analytically mature has no clear objectives or measures of their fulfillment and data analysis is limited to browsing through reports that usually concern basic metrics. Everyone in the organization has access to data but with only basic knowledge of analytics tools which often leads to incorrect configuration and wrong conclusions.

The Blast Analytics Maturity Assessment Framework, based on the Online Analytics Maturity Model developed by S. Hamel, lists six key process areas and success factor dimensions: strategy, governance, data management, insights, evolution, and resources. Blast's Analytics Maturity Assessment aims to address the gap between perception and reality by assessing the factual circumstances and progress in the implementation of analytics opportunities. This enables organizations to prioritize their analytics efforts, increase structure and governance, and ensure better outcomes.

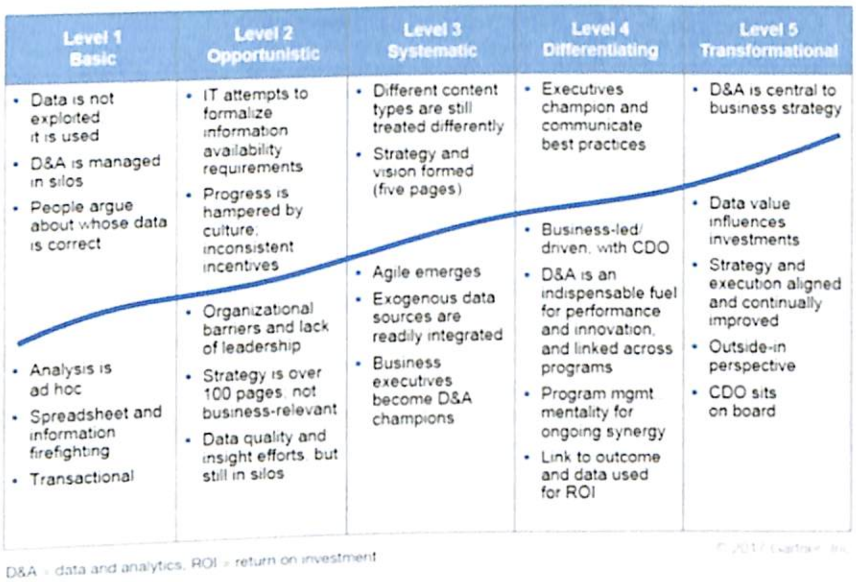
The LogiAnalytics Maturity Model (LAMM) assumes that integrating and implementing analytics in the structure of business applications will increase the extent to which analytics is used in everyday work. The LAMM has five stages of analytics maturity. The Standalone Analytics level employs standalone solution to analyze data.

The Bolt-On Analytics level provides security integration such as single sign-on but users still have to switch from one application to another. The Inline Analytics level provides user interface integration allowing business intelligence in context of an existing application but with some limitations. The Infused Analytics level provides workflow integration allowing functional interactions between analytics and the primary application. The Genius Analytics level provides embedded self-service analytics that support unanticipated use cases within a managed, seamless environment where users can spontaneously ask new questions of the data.

Transforming Data With Intelligence (TDWI) Analytics Maturity Model provides the methodology for measuring and monitoring the status of analytics implementation in the organization by indicating the actions that should be taken to develop the organization's analytics culture. This model carries out its assessment based on 35 questions asked in five areas of analytics maturity. The organizational area focuses on the extent to which the organizational strategy, culture, leadership, skills, and financing support the analytics program. The infrastructural area focuses on the issues related to the advancement and accessibility of infrastructure for analytics applications. The data management area tackles data quality, accessibility, processing, and the company's data management method. The analytics area looks at the assessment of analytics culture and the extent to which analytics tools are used. The TDWI Analytics Maturity Model consists of five stages: nascent, pre-adoption, early adoption, corporate adoption, and mature/visionary.

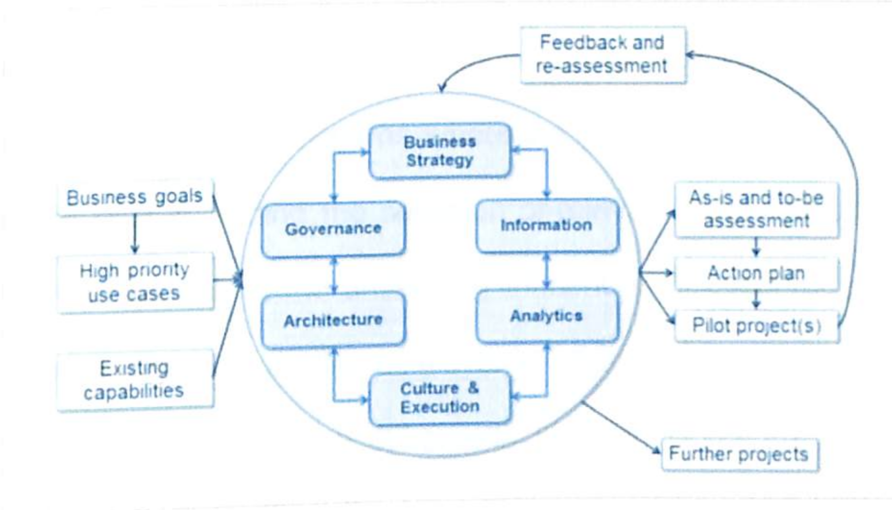
The Gartner's Maturity Model for Data and Analytics sets an organization in one of the five analytics maturity stages. At the Basic level, data and analytics are managed in silos and people argue about whose data are correct. The Opportunistic level attempts to formalize information availability requirements but progress is hampered by culture or inconsistent incentives. At the Systematic level, different content types are still treated differently but agile emerges with the formation of strategy and vision. At the Differentiating level, executives champion and communicate best practices. Data analytics are linked across programs and outcomes.

Figure 6. Gartner's Maturity Model for Data and Analytics



IBM's big data model is designed to assess the desired target state, finding gaps, and providing feedback on the measures required to achieve the desired goal status. It aims to define the appropriate phases and technologies leading an organization towards the maturity of big data. The model is based on four maturity levels: ad-hoc, foundational, competitive, differentiating, and break away (Halper & Stodder, 2014).

Figure 7. Big Data and Analytics Maturity Model (Nott, 2015b)



Most of the aforementioned analytics maturity models have five analytics maturity levels starting from organizations having basic to no data and analytics and advancing to become mature analytics organizations. According to Fern Halper (2020), "Analytics maturity [is] the evolution of an organization to integrate, manage, and leverage all relevant internal and external data sources into key decision points… creating an ecosystem that enables insight and action." A model is a simplified representation of a more complex system or reality. All reviewed models share some similarities in their attempt to define a "framework and objective criteria to determine the sophistication of an organization's measurement and analysis skills" (Webtrends 2009). Maturity models are used to guide organizations as they use tools, people, processes, and strategy to make business decisions. Thoughtful application of data analytics could transform the approach and ways to manage the risks of climate change by optimizing and leveraging on available information.

Cybernetics Tradition of Communication Research: A Systems Perspective on Climate Change

This research was guided by the Cybernetics Tradition of Communication Research that looks at complex systems where the interacting elements influence one another. Theories help in guiding the selection of relevant data, interpreting the data, and proposing explanations of the underlying influences of observed phenomena. In this tradition, we view communication as a system of processing information, feedback and control. Communication in the cybernetic tradition is theorized as information processing and explains how all kinds of complex systems, whether living or nonliving, macro or micro, are able to function, and why they often malfunction. This cybernetic tradition extends to current theories in areas as diverse as systems and information science, cognitive science and artificial intelligence, functionalist social theory, network analysis, and the Batesonian school of interpersonal communication (e.g., Watzlawick, Beavin, & Jackson, 1967).

A great practical lesson of cybernetics is that the whole is greater than the sum of the parts, making it imperative to look at the communication process from a broader, systemic viewpoint, and not to hold individuals responsible for systemic outcomes that no individual can control. The concept of "system" is the core of the cybernetic tradition. It maintains that systems are structures that one can study and see how the parts of the system interact. The main assumption of systems theory is that a complex system is made up of multiple smaller systems, and it is the interactions between these smaller systems that create a complex system. Systems theory can be used to holistically examine how smaller systems come together to affect the greater complex system. It is also possible to improve the system by manipulating its inputs. Systems will continually monitor, self-regulate and control their outputs to remain efficient. In a dynamic environment, it is essential that they are adaptable. Evaluating various factors as it relates to other factors within the system can be a complicated process. Certain characteristics of the complex system (whole) cannot be easily explained when looking singularly at any one of its systems (its parts).Theorists of this tradition are interested in showing how the system works, identifying variables that would change it, and processes that can improve it. Concepts based on systems theory (von Bertalanffy 1950) are needed to reduce the risk of unintended consequences from potential responses to climate change.

Some of the concepts of systems theory as they apply to climate change:

System: An entity that's made up of interrelated/interdependent parts.

Complex system: The greater, whole system made up of individual, smaller systems.

Ecological systems: The various systems in an organization that influence outcomes.

Homeostasis: The state of steady conditions within a system. A system is always moving toward homeostasis.

Adaptation: A system's tendency to make changes that will protect itself when presented with new environmental factors.

Feedback loop: When the outputs of a system ultimately affect its inputs, causing the system to feed back into itself circularly.

Conceptual Framework

A conceptual model aims to illustrate what can be expected from the research, defines the relevant study variables and maps out their interrelationships. This section tackles the identification and selection of key dimensions from existing maturity models reviewed previously that will later be used to better understand the current state analysis. By integrating cognitive systems analysis into the analytics maturity framework, relevant elements of control and communication theories (Cybernetics) and human factors, a conceptual framework is developed.

Based on existing models, there are five dimensions deemed relevant to the assessment of the analytics maturity for development programs and institutions: data, people and culture, technology, analytics process, and strategy and vision. The complexity of analytics maturity framework will further be explored to understand the potential of future dynamic interaction among variables at different maturity levels. The cybernetics approach used to develop the framework will be the basis for future new ideas to advance data maturity useful for development institutions and programs geared towards climate change.

This framework illustrates the concept of a system and its assumption that multiple smaller systems make up a complex system, and it is the interactions between these smaller systems that create a complex system. A system is defined as a group of interacting, interdependent elements that form a complex whole, showing the dynamic interplay among the key dimensions in the maturity model (see Figure 9). General system theory was generally interpreted to be focused on equilibrium. The ideal balanced state is where all the dimensions measure equally. Unequal proportions would indicate deficits in certain areas that would indicate potential impediment in obtaining an ideal ecosystem.

Figure 8. Big Data and Analytics Maturity Model (own elaboration)

Chapter 3

METHODOLOGY

This chapter provides a description of the research method and procedure that was used to investigate the research problem. According to Mahrt and Scharkow (2013), "researchers need to consider whether the analysis of huge quantities of data is theoretically justified... small-scale analyses of communication content or user behavior can provide equally meaningful inferences when using proper sampling, measurement, and analytical procedures".

Research Approach

For the purpose of this research, qualitative research that seeks to find patterns of human communication in a more practical and concise manner was followed. This approach is useful in developing a concept and provides a more holistic understanding of the research problem. An analysis of the review of literature was conducted to identify various dimensions of existing analytics maturity frameworks that are relevant to development programs and institutions.

Futures Research and The Delphi Method

Futures Research is the systematic study of possible future events and circumstances and distills the infinite information that shapes the world and how those forces might change to create new opportunities, threats and uncertainties. The purpose of futures methodology is to systematically explore and create desirable future visions that can help generate long-term plans, strategies and programs (Glenn, 1994). The increasing complexity and acceleration of change increases the value of early warning by enabling the creation of more intelligent and relevant decisions

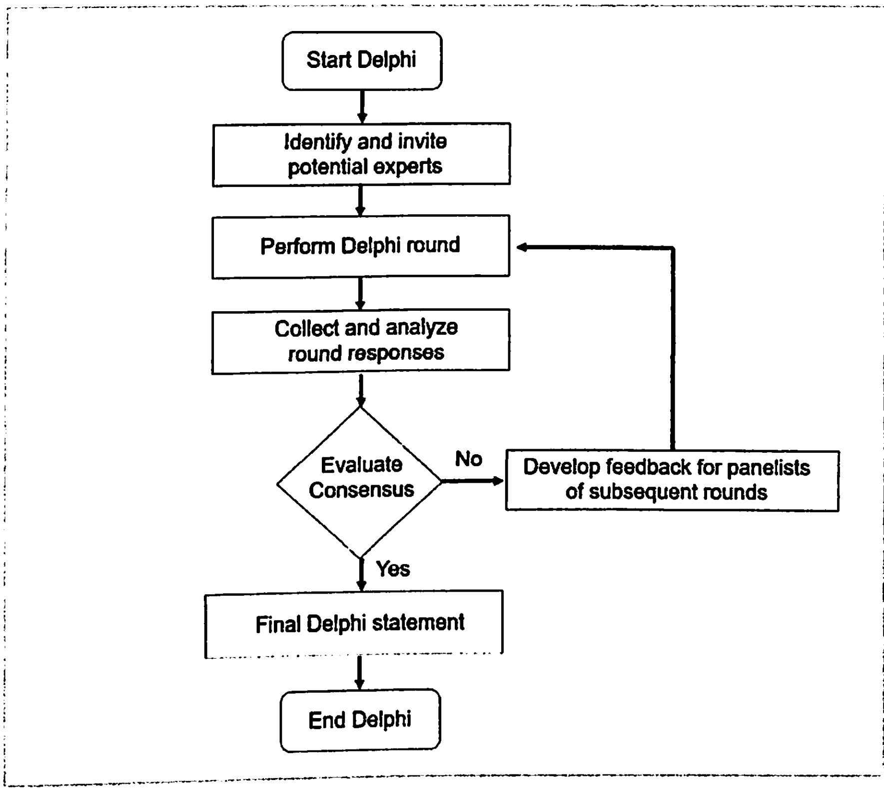
(Glenn, 2003). Despite the limitation of not being able to produce totally accurate and complete information about the future, having some researched information can still provide value when engaging in decision making for long-term perspective.

The Delphi Method is a widely used technique in conducting futures studies. Kristen Dufresne (2017) noted that since the development of the Delphi technique in the 1950's by the RAND Corporation, several refinements and modifications had been made for specific strategies in different fields including business, government, and healthcare. However, there remains to be no universally agreed upon working definition. She lists three characteristic features of the Delphi technique relevant to this research: *anonymity, iteration with controlled feedback,* and *expert input.*

The Delphi technique is a group knowledge acquisition method or process framework based on the results of multiple rounds of iterations among a panel of experts. It is a suitable approach to explore future thinking in an area where there is no true or knowable answer, such as decision-making, policy, or long-range forecasting. It is an organized method for aggregating opinions from a diverse set of experts that allow them to react to and assess differing viewpoints. A wide range of opinions on the topic can be determined, which can be useful in cases where relying on a single expert would lead to bias. It can be conveniently and effectively implemented without having to bring everyone together for a physical meeting.

The steps are illustrated and summarized in Figure 9.

Figure 9. Steps of Policy Delphi



Panel Selection and Procedure

Study participants were subject matter experts who had an interest in the outcome of the study to limit attrition and encourage thoughtful responses to the research questions. The Delphi panel was composed of eleven (11) representative members from the academe, data analytics and climate science sectors (see Table 1).

The Delphi procedure involved asking the panel questions on three separate occasions. These questions were sent to the group of experts through email.

First Round (March 15 to March 29, 2021): Each expert was asked to independently answer general open-ended questions to explore and get a broad range of opinions related to the research problem and objectives, which were aggregated and shared in future rounds. Ideally, in a classic Delphi, no items should be added or removed, and the wording used by participants should be kept for round two. However, this was not feasible in this case due to the types of responses received. For instance, some experts from the academe shared their extensive knowledge and experiences in climate change outside the scope of the research problem. These items were excluded from the second round Delphi summary.

Table 1. List of Delphi panel of experts by sector, name and affiliation

The Academe	
Dr. Felino Lansigan	*Professor of Environmental Statistics at the UPLB; Affiliate Professor of Land and Water Resources at the UPLB College of Engineering and Agro-industrial Technology; Affiliate Professor of Environmental Science at the UPLB School of Environmental Science and Management*
Dr. Ricardo Bagarinao	*Dean of the UPOU Faculty of Education; Climate change and GIS expert*
Dr. Nestor Baguinon	*Member of the International Panel for Biodiversity; UP Scientist; Authored books on biodiversity published by DENR; International experience as climate change consultant*
Data Analytics / Data Science	
Helena Sternkopf	*Master of Science (M.Sc.) Business Intelligence and Process Management in Berlin; Published work include Doing Good with Data - Development of a Maturity Model for Data Literacy in Non-Governmental Organizations*
JC Albert Peralta	*Climate Scientist and Data Scientist at AC Energy*
Climate Science / Climate Change Commission	
Sheryl Gutierrez, EnP, EMDRCM	*Environmental Sustainability and Resilience Professional*
Joe Mari Francisco Francisco III Dacumos Richard Palma Joshua Carrasco Alith Jean Leyba	*CCC Implementation Oversight Division (IOD) provides monitoring, evaluation, and reporting support to the Climate Change Commission on national, subnational, and sectoral climate action.*

Second Round (April 5 to April 19, 2021): The anonymous responses from the first round were analysed to identify convergence and differences in participant responses, summarised, and communicated back to the participants for the second round, a process called controlled feedback. The experts were allowed to adjust their answers in subsequent rounds depending on how they interpreted the group response.

Third Round (April 26 to May 10, 2021): Comments or inputs from the second round fed into the final round. The process generated themes and dimensions relevant to a data-driven climate action ecosystem and resulted in a set of forecasts relevant to policy recommendations. A consolidated Delphi statement was shared to the participants and the group was asked to make necessary adjustments in the final round.

The three round Delphi with three-week intervals between rounds was sufficient in fully answering the research problem and objectives, reaching group consensus and preventing high attrition or participant burnout.

In summary, the Delphi technique presented the following advantages to this study:

- Given that all participants are experts in their respective fields, anonymity reduced the impact of dominant individuals and opinions were considered in a non-adversarial manner. Anonymity also helped reduce peer pressure to conform given that close to half of the participants belong in the same organization.
- Providing controlled feedback on the group opinion enabled the researcher to exclude responses outside the research problem and allowed participants to reconsider their outlook based on other experts' views.

- Recruitment proved to be challenging given people's busy schedules and their inability to commit to the three Delphi rounds. The technique's flexibility in using email to carry out the rounds was welcomed by the panel of experts.

On the other hand, there were several challenges encountered in using this technique:

- Continued commitment was required from participants who were being asked to comment on the same question over several rounds.
- It did not allow participants to elaborate on their views through group discussion and could be frustrating for some.
- It did not provide the researcher the opportunity to probe or immediately clarify on unclear or incomplete responses.
- Arriving at a consensus merely helped to identify areas that were considered important among the selected panel of experts, but it does not necessarily mean it is the correct answer.

Method of Analysis

The Delphi process focused on the qualitative elements of the method following an inductive approach to the data analysis process. The intent of using Delphi was to offer participants the opportunity to comment on group differences from the first round. The first round consisted of open-ended, general questions which allowed experts to share their views without the constraints imposed by highly structured questions. Responses from the experts were coded separately to identify key areas of correspondence and difference among the groups. The coding strategy drew on inductive approach by identifying repeating ideas in the data. Several important themes and group differences emerged during the open coding process. These first-level codes were analyzed and further narrowed into several explanatory codes that identify an emergent theme using the details of the text. Drawing together the first-level codes, several themes were identified as important dimensions of data maturity framework. The following chapters will discuss these dimensions including challenges and how the Delphi process was used to suggest practical solutions to each.

Chapter 4

RESULTS AND DISCUSSION

This chapter presents the Delphi Study findings based on the responses provided by the panel members. The panel members were requested to answer the following research questions: As a professional in the area of climate change and/or big data analytics, how would you describe the current state or level of big data analytics in relation to climate change? (i.e., Is big data sufficient in form and substance? Are big data analytics mature enough to give us a sense of this sufficiency?) What policy directions or interventions should be pursued by climate change organizations with regard to data, technology, analytics, people skills and leadership support, vision/strategy, other relevant factors? The current state of data analytics in climate change and corresponding policy interventions will be discussed in the perspective of systems theory as the challenges and opportunities influencing climate ecosystem cannot be fully examined without the exploration of the synergies among its dimensions. This integrated thinking lays the groundwork for developing effective policies and programs that drive insight and action.

Main themes and sub-themes were generated from the responses and are presented in detail by their area of expertise.

Delphi First Round Q1: As a professional in the area of climate change and/or big data analytics, how would you describe the current state or level of big data analytics in relation to climate change? (i.e., Is big data sufficient in form and substance? Are big data analytics mature enough to give us a sense of this sufficiency?)

Delphi First Round Q2: What policy directions or interventions should be pursued by climate change organizations with regard to data, technology, analytics, people skills and leadership support, vision/strategy, other relevant factors?

The Academe: *End-to-end view with emphasis in adopting sound methods to ensure data quality and integrating climate awareness and responsibility across the value chain.*

The experts from the academe demonstrate their intellectual curiosity and extensive knowledge of the origins, drivers, dynamics and the range of conditions affecting climate change. They support their opinions and arguments with evidence, events, stories and experiences.

> *It has been difficult to clearly establish what fraction of the temperature increase is caused by greenhouse warming and what fraction is caused by natural climate variability.*
>
> *Based on what I perceived as personal atmospheric data from my birthplace (province of Cagayan) to my UPLB life in years 1972 to retirement time, I cannot feel there is such thing as anthropogenic climate change. However, because personal data banking is not limited to personal perception...Through contextualization, the anthropogenic climate change as a continuation of natural climate change is the truth.*
>
> *Anthropogenic Climate Change is truth not just perception. It is based in science.*

There is group consensus that the current level of big data on climate change is perceived as sufficient enough to arrive at some projections of the climate useful in making decisions to manage the impacts of climate change. Technological advances have enabled scientists to collect many different types of information about the climate on a global scale. This is supported by some studies showing that Big Data-based tools are widely being used to build complex analyses and models in climate science (Manogaran et al., 2018, Faghmous et al., 2014, Ford et al., 2016).

> *The many available information on climate projections in the internet published by various agencies here and abroad are clear manifestations of such sufficiency. There are also a number of studies being conducted globally regarding the changing climatic conditions and their impacts on the various ecological as well as socio-cultural systems in the globe.*
>
> *Big data sensors are now being operated internationally as per IPCC recommendation to track down the status of Anthropogenic Climate Change.*
>
> *Advances in modeling activities made possible by the availability of satellite global data sets.*
>
> *This pool of climate data at various spatial and temporal scales will help scientists predict where climate extremes will strike and how government (national to local) will react and timely warn possible victims how to resiliently behave.*

However, the issue extends beyond the quantitative aspect of the big data but on its quality and validity. Variability in data from past events as well as statistical extrapolation characterize a high degree of uncertainty. Thus, it is crucial to ensure that the data being used can be completely trusted to be accurate, clean and useful.

> *Although these data are coming from carefully planned and executed scientific studies, they are but results of modeling and/or projections, which may not be appropriate for long term projections such as that of the changing climate. The issue may not be on the sufficiency of big data per se, but on the sufficiency of big data that can be trusted for decision-making.*
>
> *There are lots of data collected and also generated on climate change based on simulation studies at different levels (global, regional, sub-regional, national or even provincial). These datasets should be consolidated and analyzed to be useful for decision-making at appropriate levels.*
>
> *The accessibility of these data can somehow allow transparency on various matters about climate change such as how projections were done, what are the assumptions being used, the time element of the data used in the projections.*

There is agreement that the government plays a key role in establishing policies on data sharing as well as programs and initiatives aimed at informing and educating people on the conditions and impacts brought about by climate change and the significance of shifting towards green living.

> *A policy on big data sharing can also be formulated. The accessibility of these data can somehow allow transparency on various matters about climate change such as how projections were done, what are the assumptions being used, the time element of the data used in the projections.*
>
> *Need to create a policy that enhances the integration of climate change concepts in education – whether formal or non-formal. At present, there is no technology that provides a laymanized presentation of data on climate change.*
>
> *Government continues its programs in shifting to renewable energy, i.e. geothermal power plants, hydroelectric power plants, solar panels as power generation, more wind farm installations, etc. Collaboration of all government line agencies in educating citizens so they change lifestyles in favor of green living (as opposed to consumerism). PAGASA-DOST leads in monitoring climate and weather parameters at local scales and their compilation to national scales.*

Technology, training and capacity building equally plays an important role in climate change.

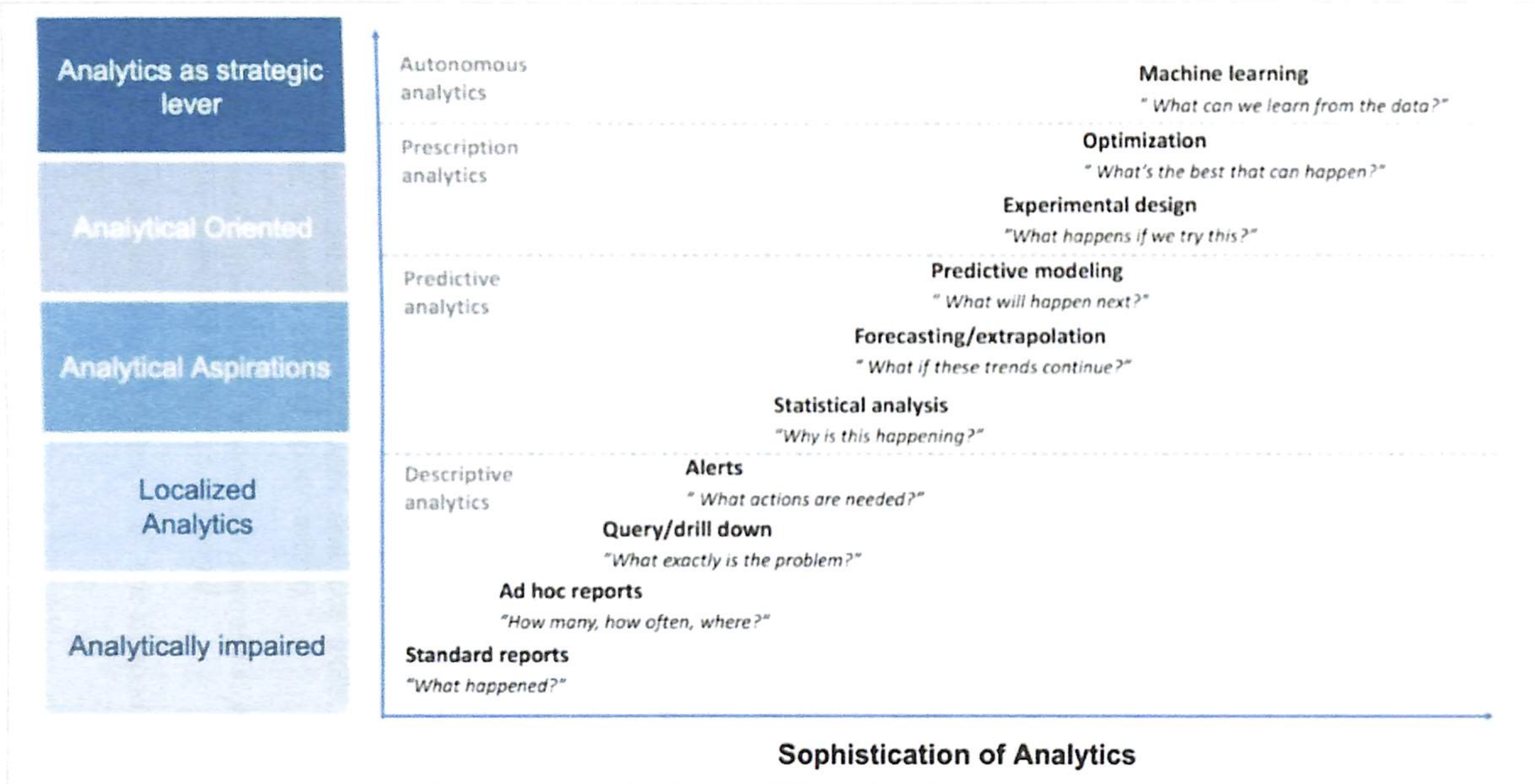
> *Training and capacity building on the data acquisition, consolidation and integration and analysis should be conducted for different stakeholders or users of these datasets.*
>
> *Datasets consolidation and integration can be facilitated by using the advances in technology. Applications of these technologies should be maximized so that use of the data can be optimized to decision-making and management at different levels.*

Data Analytics Specialists: *Recognizes climate science as a data intensive domain with potential for optimization; views data and analytics as strategic and operational levers.*

The data analytics experts recognize that climate science is a data intensive domain. There is much potential and value to be derived from higher levels of analytics by anticipating what, when and, why something might happen. The Big Data and Analytics Maturity Model (Tom Davenport, 2018) was shared to illustrate the various levels of data analytics and the corresponding value they offer (see Figure 10).

> *Local climate institutions do not create climate models. They only use global coverage model output from leading institutions in developed countries and localize the data by modelling it further to increase resolution in a process called downscaling.*
>
> *The base for advanced analytics, being rich data sources, is there and will only get richer in the future. Much of analytical insights are still in the descriptive and predictive part. Studies suggest that climate change analytics create value in these aspects: observing and monitoring, understanding, and predicting and optimizing. I see a possible trend to move upwards to more analytical oriented data as strategic/operational levers in the future.*
>
> *Volume, variety, veracity and velocity are sufficient and advanced in the area of climate change. However, the value part of big data could be lagging behind due to insufficient analytical methods and understanding of which questions to ask or problems to solve.*

Figure 10. Big Data and Analytics Maturity Model (Tom Davenport, 2018)



Policy directions or interventions were discussed in terms of the growing size of data and related requirements, optimization derived from advances in technology, analytics and analytical expertise, and the components of data-driven culture. All these elements, taken together, produce the greatest value.

> *More data transparency is needed...policies that help investors and consumers to make better choices when it comes to investing in and purchasing goods. A big keyword here is open data.*
>
> *Data is expected to increase in size in the coming years. Sooner or later, academic training would not be able to keep up. Industry grade big data infrastructure and analytics training are needed.*
>
> *To get most value out of big data analytics explore trends like cloud computing, machine learning, IoT to profit from reduced costs, optimized processes and data abundance.*
>
> *Organizations need domain experts, strategic thinkers, impacted people ("users" or "beneficiaries") and data experts to realize successful analytics projects for climate change.*
>
> *There is a huge gap in the technical capabilities of climate researchers who generate climate data and those who use climate data.*
>
> *Data culture is a key driver for analytics success, even more than technology. Key pillars of a culture that enhances data-driven activities are:*
>
> - *Trust (responsible use of data, people trust insights/support from data)*
> - *Commitment (data as a strategic asset, leadership models data-driven work, org. structure reflects value of data)*
> - *Talent (job descriptions highlight analytics skills, data use is rewarded, analytics training opportunities)*
> - *Transparency (employees share data success stories to inspire each other, data shared across functions)*
> - *Growth Mindset (experimentation is encouraged, learn from mistakes).*

Climate Scientists and Professionals: *Imperative to address challenges around data infrastructure and access as well as to have the necessary governance and information systems.*

There is agreement from the responses received from the climate science sector that several challenges must be addressed to create the right data infrastructure to make data and analytics sufficient, publicly available, accessible and consolidated. One of the common issues raised was the availability of and access to open data sources and localized data. Individual pieces of data must be presented in standard formats to enable sharing within and across sectors.

> *Most of the available data globally are available in a macro-scale level. We need more of disaggregated data to derive value and define the impacts of climate change to different sectors of society and environmental assemblage.*
>
> *There are two challenges in making sense of the available big data for a climate change study – (1) the accessibility of data and (2) the availability of localized data.*
>
> *Big data analytics in climate change are multi-faceted and scattered.*
> *Various government agencies report climate change data for the use of its sector, not institutionally consolidated into one interconnected data ecosystem.*
>
> *While it is good to have platforms ready for Big Data Analytics on Climate Change, but before we can rely on these analytics, the information and data on Climate Change Initiatives must be really good in quality.*
>
> *Though there are already significant amount of data that are produced already, it's hard to look for reliable data. There's no single repository/source of climate change data.*
>
> *Most organizations rely on past historical data such as the climatological extremes and characteristics of the past strongest typhoon for climate projections. Data analytics must offer opportunities for probabilistic assessments to prepare communities for any unforeseen disasters related to climate change.*

Policy directions or interventions centered around having an open data platform, technology and capacity-building programs with corresponding governance and information systems.

> *Organizations should push for a common repository of disaggregated data across geographies. Open access to these timely and reliable data, manifesting statistics not only on a global scale, but down to the city or even barangay level, may support the required climate interventions and solutions. What gets measured, gets managed and done. Only when we collect and analyze data on a local or community-based level would we be able to utilize big data for a much bigger purpose and translate the significance of the phrase, "data can save lives".*
>
> *Acquire technologies that can help in climate change mitigation and adaptation along with the provision of best practices, methodologies, and capacity-building capabilities which can address the need to further increase level of people skills and leadership support*
>
> *There should be a strong implementation of the mandated tasks of the climate change organizations. This includes investment on technology, capacity building of the organization and the people, and effective dissemination/communication of data to the public.*
>
> *The prerequisite to effective adaptation is putting first the necessary governance and information systems in place and provide adequate focus and support for these systems to reach maturity and stability.*
> *The issuance of further policies on climate action should not only be enforcing but also compelling enough for participants to appreciate their value (e.g. incentives, access to means).*

The following table presents an overall view or summary of the current state of data analytics in climate change as perceived by the Delphi experts. While their discussion on these topics were heavily influenced by their background and specializations, it was clear that the challenges and obstacles around the various dimensions of data and analytics processes in climate change are consistent across sectors.

Table 2. Assessment of the Dimensions and Sub-dimensions of Analytics Maturity Framework

Main Dimension	Sub-dimensions	Definition	Current State / Gap / Opportunity
Data	Volume	The size of the data sets that need to be analyzed and processed	• There is a rich mine of data and information on climate • Most of the available data globally are available in macro-scale
	Velocity	The speed with which data are being generated	• There is large volume of data generated from different sources daily
	Variety	Diversity of data in a data collection	• Various government agencies report climate data for the use of its sector thus are multi-faceted and scattered • Organizations should push for a common repository of disaggregated data across geographies
	Veracity	The biases, noise and abnormality in data source, type, and processing	• The issue may not be on the sufficiency of big data per se, but on the sufficiency of big data that can be trusted for decision-making • It is salient to look into how projections were done, what are the assumptions being used, the time element of the data used in the projections
Tools and Technology	Optimization	Can be used alongside their current tools or that can augment their existing processes and analytics	• Technology trends like cloud computing, machine learning, IoT can drive value out of big data analytics • Technologies that can help in climate change mitigation and adaptation along with the provision of best practices, methodologies and capacity-building should be acquired
	Performance	Real-time analytics and insights	• Technologies that can translate climate data into easy-to-understand information useful for stakeholders to make actionable decisions should be acquired

Current Level Low Moderate High

Table 2. Assessment of the Dimensions and Sub-dimensions of Analytics Maturity Framework (cont'd)

Main Dimension		Sub-dimensions	Definition	Current State / Gap / Opportunity
Analytics	●	Sophistication	Breadth and accuracy of analytics used to inform decisions	• Much of the analytical insights are still in the descriptive and predictive stage
	●	Relevance	Derived insights meet the objective or desired outcome	• Possible trend to more analytical oriented data as strategic/operational levers in the future
People & Culture	●	Leadership	Government, climate institution leaders	• Effective national climate change policies, legislations, and institutions are required
	●	Skills and Experience	Data and climate analysts, scientists, and professionals	• Equip and future proof climate researchers by investing in trainings on current data science trends and advanced analytics methods and techniques
Strategy & Vision	●	Value	Potential social or economic value that the data might create	• The value part of big data could be lagging behind due to insufficient analytical methods and understanding of which questions to ask or problems to solve

Current Level ● Low ● Moderate ● High

It is essential to discuss these findings in the context of an integrated systems approach as this offers an understanding of the interplay among the different dimensions of a climate system. Effective policies and programs can stem from a broad systems perspective that consider existing as well as subsequent issues/opportunities that may arise from other components in the system.

Global and macro level data appear abundant in different forms and structures. However, access to quality and reliable data remain a concern. Climate data are essential in climate research including analyses of climate variability, trends, and modeling. Data quality issues may occur at various stages of the data generation process. Undetected data quality issues negatively impact the results of important and frequently used observational datasets that feed into a number of climatological studies. Based on the review of some of the research that has been done on this topic, there are common, consistent challenges being faced by the climate science community on data availability or having short observational records that raise questions on the applicability of such data to study long-term climate conditions. There is also the risk of growing inequality and bias in the sample.

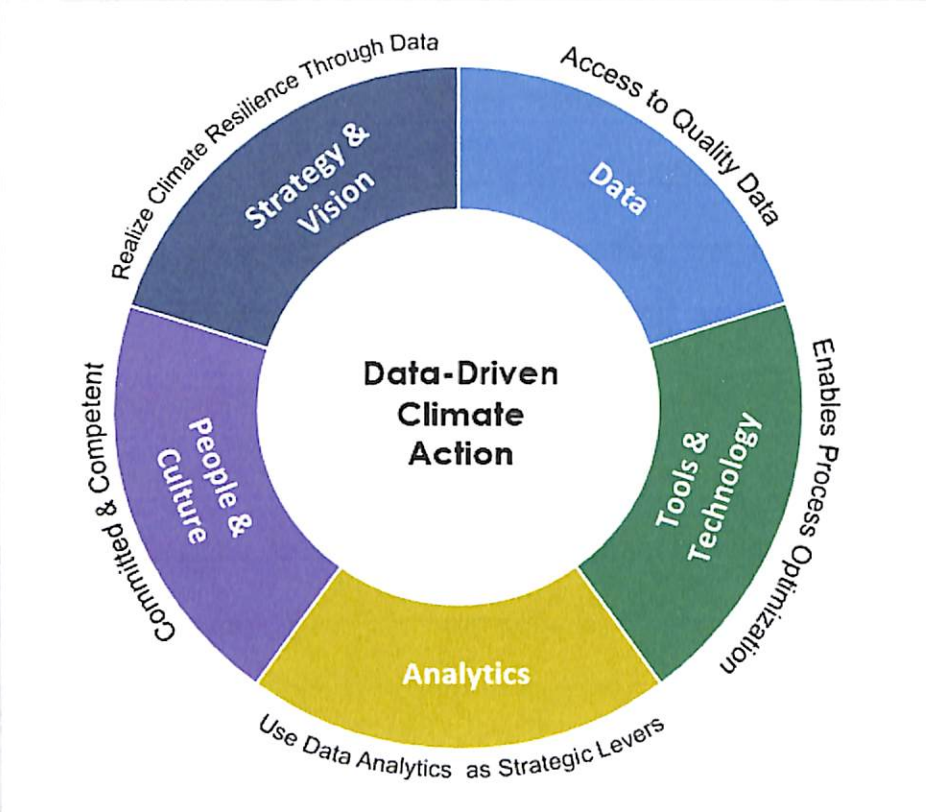
There is clearly a gap between data that is currently available and what is needed, i.e., climate data that cover local areas in formats that are useful and can easily be incorporated into existing decision-making frameworks. There is opportunity to institutionally consolidate disaggregated data into one interconnected data ecosystem. How does this relate to tools and technology? Once various information sources have been linked, this open linked data can feed into sophisticated tools and technology that enable and facilitate the use of advanced analytics. Technology trends such as cloud computing, machine learning, internet of things can drive greater value in big data analytics. The climate community will continue to be increasingly driven by data. This will require tools and technology that serve as mechanisms to scale up and optimize data analytics for faster insights generation and decision making. Tools and technology are enablers. For example, there are new set of analytics tools designed specifically to analyze large amounts of structured and unstructured data. Data warehousing technology help in enabling analytics by centralizing and consolidating large amounts of data from multiple sources. Big data analysis tools enable the development of new Machine Learning algorithms.

How does having sufficient and useful data, in conjunction with the right tools and technology relate to analytics? A huge part of analytics involves the capability to run advanced analytics. It is critical to develop expertise in choosing the best model and have the adequate knowledge of science to apply them. Results need to be translated into lay terminology and presented in a simple yet meaningful way that users can understand and apply.

This is where analytics connect to people and culture. To be effective in generating insights and recommendations, analysts should not only be technically or analytically competent but they should have the necessary communication skills and strategic mind to understand the data and translate it in a way that users can understand and apply. Leaders have to recognize the need to train and develop people in both technical and non-technical aspects of data analytics among climate researchers who generate climate data and those who use climate data.

This is where it all comes together. Skilled data analysts with the right technology and infrastructure working towards a clear vision will provide an enormous opportunity to diversify and deepen understanding of adaptation and inform decision-making. Figure 11 illustrates a conceptual framework conducive to an ecosystem that promotes the use of data and analytics for insight and action.

Figure 11. Conceptual Framework Towards an Optimized Analytics Ecosystem



This framework was developed using the consolidated learnings from the Delphi panel, secondary exploratory research and guided by the Cybernetic Tradition that theorizes communication as information processing with the assumption that an organization is a system comprised of many interdependent parts. Having climate data that are diverse, integrated, and good quality could fill considerable gaps in existing knowledge and initiatives. However, this is just one important component of the climate ecosystem. Adaptive decision-making and real-time, actionable intelligence require a balance on data, processes, and people. Being able to examine the interconnection among the key dimensions of a data-driven climate action offer the ability to manage and utilize data and analytics in more strategic ways.

Chapter 6

CONCLUSION

This research presented a conceptual framework for a data-driven ecosystem geared towards climate action using the Policy Delphi method. Realizing a data-driven climate action is complex as it involves understanding the interconnection among several independent dimensions that either enhance or hamper the data analytics maturity of an organization. Using a framework built on systems thinking, a deeper understanding of the interactions occurring among the living (people, culture and vision) and nonliving (data, technology and techniques) components of a climate ecosystem can be achieved.

Notable Findings

Findings of the study expounded on the significance of Big Data in helping solve development problems such as climate change. Having a mature data analytics platform is essential in becoming an organization that drives the use of data for insight and action. It enables optimization of models and structures that provide deeper understanding and prediction of observations and changes to support adaptive decision-making. Results show that maturity is relatively low in most dimensions of the climate ecosystem.

1. All sectors agree that big data is sufficient in terms of volume, variety and velocity. However, a fundamental issue exists around data veracity or quality, accessibility, and availability.
    a. There is a vast amount of data and information on climate. But these models are developed for specific purposes and are frequently not consistent due to the different assumptions used in developing the model.

b. Data transparency and open data platforms are needed. Downscaled climate data and information based on scenario models and forecasts are useful for local government planning and operations.

c. Consolidating data from disparate sources into a single dataset provides users with consistent, timely and reliable access to and use of data.

d. Data quality is the core of analytics. Poor data quality negatively impacts accuracy and credibility and can lead to wrong decisions and missed opportunities. It is salient to first look at how the different datasets were generated, what procedures were used, and what assumptions were made before consolidating them.

e. Addressing this issue will require restructuring of data platforms and implementing policies from the national and local government.

2. The Delphi panel of experts see tools and technology as essential and serve as mechanisms that can enhance and optimize analytics.

   a. Computer-based statistical data processing system will help manage the large volume of data generated from different sources daily.

   b. Technology that can deliver a simple but insightful presentation of data on climate change.

3. People and culture are key drivers for analytics success.

   a. Having the right analytics skills makes it possible to generate hindsight, insight and foresight for better planning and action.

   b. The analytics skills of people who are not analytics experts should be developed and the analytics capability should not be limited to selected data experts only.

c. To become a truly data-driven organization, leaders need to make full use of analytics and steer the organization towards integrating analytics into day-to-day activities.

4. Building a data and analytics strategy begins with vision consistent to the organization's purpose and specific needs.
5. The Delphi method resulted in a set of forecasts relevant to the policy recommendations below.

Forecast 1: The Delphi panel anticipates that data will only get richer as the volume of climate data available globally is expanding rapidly. This will continue to create challenges for physical archiving and sharing, availability and ease of access to localized and disaggregated climate data. In the context of a system, this enables us to be more aware of the interplay or interrelationships among the various dimensions, "cause and effect" if you will, to help better plan and execute actions. As data become available and accessible, what tools, technology and analytical infrastructure and support are needed?

Forecast 2: The Delphi panel views technology as an enabler to climate action. Digital or communication technologies can improve the access to and use of knowledge. Technological innovation can lead to social awareness and new climate change solutions. How can we best leverage on technology and analytics?

Forecast 3: The Delphi panel recognizes that there is a huge gap in the technical capabilities of climate researchers who generate climate data and those who use climate data. Training in analytics communication and strategic thinking will develop the ability to demystify the data and deliver an easy-to-understand and actionable narrative for stakeholders.

Contributions and Recommendations

This research contributed to the existing body of knowledge on the following levels:

Theoretical. Investigating the research problem and objectives in the context of Cybernetic Tradition offered a better understanding of the interrelationships or dynamics of big data analytics within a climate organization. Concepts based on systems theory particularly ecological system, homeostasis, and feedback loop are crucial in identifying important dimensions, challenges and opportunities that enhance or hamper progression towards a data-driven climate action organization. There are fundamental aspects of the climate data and analytics system dynamics that are deficient and may invariably lead to increased uncertainty in the ability to accurately understand and predict outcomes. As humans interact with and rely more on technology, climate and data scientists need a deeper understanding of gaps and opportunities in these processes, may it be human or machine. A systems theory perspective helps to evaluate a broad range of climate action prerequisites and strategies to effectively respond to climate change.

Methodological. The Policy Delphi was used to identify the current state, gaps, challenges and potential interventions in the application of big data solutions to climate change initiatives. The three Delphi forecasts are relevant and useful in global and local planning in anticipation of big data trends and how it can be leveraged for future strategic decision and action. An optimized maturity framework was developed relevant to climate institutions highlighting possible methods to manage, process and analyze data in terms of 5 Vs for sustained value delivery, insight generation and impactful initiatives. In consideration of the nature of the research problem, research timing and timeline, and resources available, the Policy Delphi was deemed the ideal method to use. The challenges encountered during data collection can serve as basis for future methodological refinements in related studies.

Practical. The following recommendations were drawn from the findings of the Policy Delphi study:

1. Government and other climate institutions need to develop and implement policies and support in the following:

   Data

   a. Prioritize creating open data platforms particularly in government institutions such as PAGASA, NDRRMC, and other climate research institutions. This can be achieved by formulating a policy on big data sharing.

   b. Implement policy instruments (Executive Order, or Resolutions) or institutional arrangements with relevant stakeholders in relation to data mining, consolidation, validation, and analysis of climate data for decision-making at appropriate levels (e.g. agriculture, transportation safety, shelter stability, health, care for natural resources, etc.)

   c. Create a common repository of disaggregated climate data and information across geographies based on sound statistical procedures. Ensure good quality data by having acceptable number of replicates taken from related places sharing homogenous environmental settings (e.g. same elevation, similar historical climate experiences, etc.). Reliable models arise from data taken from sufficient replicates.

   Tools and Technology

   a. Tools and technology should be maximized so that use of the data can be optimized for decision-making and management at different levels. Explore trends in cloud computing, machine learning, IoT, Explainable AI (XAI) to profit from reduced costs, optimized processes and data abundance.

b. Support the development of technologies that can translate climate data into easy to understand information (even to non-scientific individuals) and can be used in decision-making for climate change-contributing actions including scenario analysis in graphical or map form.

c. Acquire analytics technologies that provide best practices, methodologies, and capacity-building capabilities.

d. Utilize technology or techniques that encourage the general public to contribute and become more involved in climate change initiatives. Crowdsensing or mobile crowdsensing is a technique where a large group of individuals having mobile devices capable of sensing and computing can collectively and voluntarily share data and extract information related to climate (temperature in a given location, current weather condition, etc.). This can enrich the ability to perform data mining tasks including data fusion, analysis, and information dissemination.

Analytics

a. Support the development and integration of the analytics processes in the production chains. Such technologies can be integrated into household appliances, gadgets, vehicles, etc. This will allow individuals to stay informed and be responsible in their consumption at the household level that can potentially contribute to the production of GHGs.

b. Conduct training and capacity building on data acquisition, consolidation, integration and analysis across different stakeholders or users, e.g., LGU personnel involved in planning (LCCAP, CDP, DRRMP, etc.).
c. Invest in trainings on current data science trends especially cloud computing to equip and future proof climate researchers.

<u>People and Culture</u>

a. Encourage the practice of being "data critical", i.e., conscientious of datasets to be used by first evaluating how datasets were generated, assumptions, etc.
b. Build a culture that enhances data-driven activities with the key pillars of trust, commitment, talent, transparency, and growth mindset.

<u>Strategy and Vision</u>

a. Have a clear strategy and vision as this directs which problems to solve and which analytical or algorithmic methods to use. Not every organization needs to answer the most complex questions, make predictions or automate analytics.
b. Have a strong implementation of the mandated tasks of the climate change organizations such as investment in technology, capacity building of the organization and the people, and effective dissemination of data to the public.
c. Increased capabilities in strategic planning and transitioning plans to operational planning and development.

2. Funding bodies play a central role in promoting the use of big data for adaptation and other necessary interventions. The panel of experts cited the following gaps and opportunities in policy directions and initiatives:

a. Acquisition and maintenance of data infrastructure in climate research institutions such as a centralized computing facility that institutions could share.
b. Open access of data on a local or community-based level down to the city or even barangay level to support the required climate interventions and solutions.
c. Technology installed in institutions and establishments such as universities, schools, supermarkets, department stores, etc. can enrich the collection of data on climate change/GHGs production. This information will provide firms with the information on producing GHG beyond the allowable limits in the specific locations where they operate.
d. The issuance of policies on climate action should not only be enforcing but also compelling enough for participants to appreciate their value (e.g. incentives, access to means).
e. Enhance the integration of the science of climate change in education, whether formal or non-formal, to increase the level of awareness of people as to its manifestations and consequences.
f. Establishing policies to address climate change implies the need for global agreements, as well as a strong commitment by local governments. This, evidently, continues to be a major challenge.
g. Current knowledge of adaptation and adaptive capacity is insufficient for reliable prediction of adaptations and rigorous evaluation of planned adaptation options, measures, and policies of governments.

Final Remarks

Over the past decade, various organizations have aspired to become data-driven, recognizing data as an important asset that drive analytical decisions and actions. However, progress has been gradual as they encounter many challenges with their data and analytics initiatives. Large datasets have been used in climate science to understand how climate systems function, but the field has been slow to use the passively generated information from digital devices and big data solutions. According to Ford and others, "the capacity to collect and analyze massive amounts of data is transforming research in the natural and social sciences. And yet, the climate change adaptation community has largely overlooked these developments." This research presented a systematic approach to investigate why some data and analytics initiatives are futile and ineffective taking into consideration both technological and human/cultural barriers in achieving a data-driven ecosystem. Understanding the dimensions and dynamics of a mature data analytics platform can help optimize processes and create better solutions that support adaptive decision-making. Careful application of big data could revolutionize our understanding of how to manage the risks of climate change.

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Appendix A

POLICY DELPHI STUDY

Letter of Invitation

Dear *NAME*,

I hope you are safe and well.

I am writing to invite you to participate in a Delphi Study to understand the role that a data analytics and maturity framework has in climate change adaptation programs. As an established expert in the field of/advocate of data analytics/climate change, I am eager to obtain your views on this topic.

Organizations must be able to quickly respond to rapid changes in the environment by discovering evolving patterns and predicting impacts of climate change. Data and analytics programs can enable organizations to manage and use the available resources effectively. A key determinant to the success of an analytics program is the organization's level of data and analytics maturity. As a program matures, the optimal architecture will include processes and skills needed to support it.

The aim of this research is to develop a framework to assess and improve organizational capabilities in data analytics applicable to the climate change adaptation community in order to promote an ecosystem that enables insight and action.

Your expertise would be extremely beneficial in developing a credible data analytics maturity framework and I would be very grateful if you would consider participating in this Delphi Study. This is purely voluntary. All responses will be treated with utmost confidentiality and anonymity.

If you would like to participate, please confirm by email and I will forward the instructions for the first Delphi round. Further details are provided in the attached study information sheet.

Please feel free to contact me should you require further information. Thank you and I look forward to a favorable response from you.

Respectfully yours,

Anna Liza Po
Doctor in Communication Student
University of the Philippines Open University
acpo@up.edu.ph

Appendix B

POLICY DELPHI STUDY

<u>First Round</u>

DELPHI QUESTION: *As a professional in the area of climate change and/or big data analytics, how would you describe the current state or level of big data analytics in relation to climate change? (i.e., Is big data sufficient in form and substance? Are big data analytics mature enough to give us a sense of this sufficiency?) What policy directions or interventions should be pursued by climate change organizations with regard to data, technology, analytics, people skills and leadership support, vision/strategy, other relevant factors?*

YOUR ANSWER:

Appendix C

POLICY DELPHI STUDY

Policy Statement for the Third Round

As per the Intergovernmental Panel on Climate Change Fifth Assessment Report (IPCC AR5, 2007), it is unequivocal that the ongoing anthropogenic increase in atmospheric greenhouse gases is behind the observed global warming which reflects the melting of ice in polar regions and subsequent increase in sea level. Out of the observed warming, it is difficult to quantify what fraction is due to anthropogenic greenhouse gas increase and what fraction is natural. The only feasible way to resolve this problem is through the use of numerical models that simulate the Earth's climate system enabling one to compare its scenario under natural situation as against its scenario under anthropogenic greenhouse situation. Such models were previously not considered very reliable because of the complexity of the climate system and the lack of adequate global data used as input to these models. However, advances in modeling activities made possible by the availability of satellite global datasets and the advent of powerful computers have enabled scientists to state in the IPCC 2007 report, with 90 percent confidence, that the observed warming is caused primarily by greenhouse effects. Big data sensors are now being operated internationally as per IPCC recommendation to track down the status of anthropogenic climate change.

Climate science is generally known to be a data-intense domain. Input datasets used to run and verify climate models take up to 2-5TB and are expected to increase in the coming years as the number and variety of data sources increase as well. The base for advanced analytics, being rich data sources, exists and is expected to get richer. There is an upward trend towards using data and analytics as strategic or operational levers in the future. This pool of climate data at various spatial and temporal scales will help scientists predict where climate extremes will strike. This can guide organizations and institutions on what actions to take and adequately warn possible victims on how to resiliently behave.

There is a significant amount of data that are being collected and generated on climate change based on simulation studies at different levels (global, regional, sub-regional, national or even provincial). Big data analytics on climate change, if sufficient, can deliver some climate projections, which in turn can help drive some decisions in relation to managing the impacts of the changing climate. The many available information on climate projections on the internet published by various agencies are clear manifestations of such sufficiency. There are also a number of studies being conducted globally regarding the changing climatic conditions and their impacts on the various ecological as well as socio-cultural systems on the globe. Many governments worldwide have accessed these big data in formulating policies that could guide their responses to climate change. Many international organizations and inter-governmental associations have used such big data in developing interventions that could either reduce or help improve the adaptive capacity of communities to the impacts of the changing climate. Thus, volume, variety, and velocity are deemed sufficient and advanced in the area of climate change. However, the veracity and value aspects of big data could be lagging behind due to insufficient data consolidation and analytical methods, including uncertainties on what relevant questions to ask or what problems to solve. Data were generated from different models for specific purposes and with different sets of assumptions. Thus, consolidation of these datasets should consider the reconciliation of these assumptions to squeeze out information from big datasets.

Studies suggest that climate change analytics create value on these aspects: observing and monitoring, understanding and contextualizing, and predicting and optimizing. Currently, majority of analytical efforts and insights are still on the level of descriptive and predictive analytics and not so much on optimizing and automating. Most organizations rely on historical data such as the climatological extremes and characteristics of the past strongest typhoon for climate projections. However, changing weather patterns and climatological scenarios may reveal the possibility of stronger typhoons, higher temperature increase, more prolonged drought and others. Although the assumption that ongoing climate change generates stronger typhoons surpassing historical trend is the norm, there are places that this expectation has not yet been experienced. Historical data and information may not be sufficient for planning when there are changing precipitation patterns and a rising temperature. Climatic extremes should be treated as stochastic processes where there are underlying probability distributions that define their occurrences. The probability of exceedance, or the return period of extreme should be the basis for decision-making.

There is a big need for organizations and individuals to have an awareness of which problem to solve and which analytical or algorithmic method to use (e.g., observing / understanding / monitoring / predicting / optimizing / prescribing / personalizing / automating). It is also important to evaluate which analytical maturity you actually need to have in order to answer your questions. Not every organization needs to answer the most complex questions, make predictions or automate analytics. While it is good to have platforms ready for big data analytics on climate change, before we can rely on these analytics, the information and data on climate change initiatives must be of good quality. In addition, good quality data taken from one place should have acceptable number of replicates taken from related places sharing homogenous environmental settings (e.g. same elevation, similar historical climate experiences, etc.). Reliable models arise from data taken from sufficient replicates.

Big data in relation to climate change in the Philippines is multi-faceted, fragmented, and scattered. Available climate data can be sourced from multiple sectors given its dynamic nature. Outside the Philippine Atmospheric, Geophysical, and Astronomical Services Administration, Department of Science and Technology (PAGASA-DOST), there is no single repository or source of climate change data. A big keyword here is open data. Only a few governments offer open data sources. More data transparency is needed. Downscaled climate data and information based on scenario models and forecasts are useful for local government planning and operations. However, access to climate data and information by local communities, local government units (LGUs) and researchers are still very limited. Most of the available data globally is available at a macro-scale level. Its indicators for data mining cut across the natural and social sectors. We need more disaggregated data that are based on sound statistical procedures to derive value and define the impacts of climate change on different sectors of society and environmental assemblage.

Organizations should push for a common repository of disaggregated climate data and information across geographies as well as related studies on climate change. Government institutions (PAGASA, NDRRMC, etc.) should prioritize creating open data platforms for their data. Other climate research institutions must share their data on open data platforms. A policy on big data sharing can also be formulated. The accessibility of these data can somehow allow transparency on various matters about climate change such as what are the assumptions being used, the time element of the data used in the projections, and the like. Funding is scarce for acquiring and maintenance of data infrastructure in climate research institutions—more funding from the government and private sector could address this. Government funds should be allocated for a centralized computing facility that institutions could share. Open access to these timely and reliable data, manifesting statistics not only on a global scale, but down to the city or even barangay level, may support the required climate interventions and solutions. Only when we collect and analyze data on a local or community-based level would we be able to utilize big data for a much bigger purpose and translate the significance of the phrase, "data can save lives". Localized and disaggregated data decreases inequality as they provide more detailed information to get everyone counted in the process, leaving no one behind. Localized or downscaled big data analytics lead to more targeted solutions, adaptation and mitigation measures to climate change impacts, thus elevating the effectiveness of evidence-based assessment. For example, data and information on climate hazards for specific LGUs should be made available for the LCCAP and DRRMP planning activities.

Various government agencies report climate change data for use of its respective sector or sectors. To institutionally consolidate them into one interconnected data ecosystem may open new challenges in climate related governance at national and local levels. On the national scale, the data ecosystem is not yet harmonized. These datasets should be consolidated and analyzed to be useful for decision-making at appropriate levels (e.g. agriculture, transportation safety, shelter stability, health, care for natural resources, etc.). Modern statistics offer one method to classify big data taken from an array of different geographic locations into related clusters and this method is called "ordination analysis". With the large volume of data generated from different sources daily, this situation is difficult if without computer-based statistical data processing system. Said large data surfaces its value depending on the requirements of the organization on climate change initiatives. Each has a different purpose and use of data and information. The scientific challenge is how to develop an integrating framework to link these datasets so that information may be extracted from them. The issue may not be on the sufficiency of big data per se, but in terms of how flexible rigid structures of governance adapt to anticipated and sudden changes and how much of the data can be trusted for decision-making or its validity (i.e., data undergo science-based statistical analysis). Although these data are coming from carefully planned and executed scientific studies, they are but results of modeling and/or projections.

Possibilities within statistical frame are expected but for long-term projections under current changing climate, unpredictable climate extreme events can unfold.

There is a need to harmonize the data on climate change. Issues raised by the antagonists should be addressed by the proponents of the phenomenon. Otherwise, the users of these data would be placed in limbo and confusion as to which data they should use in making decisions. Models on which the datasets are generated based on the use of certain models vary through time. The reliability of models also improves over time as new knowledge and information are incorporated into the model. Consolidation and analysis of these datasets should enable updating of previous data and information to better improve decision-making particularly in climate and disaster management financing and insurance. Data and information on GHG emissions, NDCs, tradeoffs, etc. based on science should be made available to policy makers. This will contribute to a significant reduction in losses and damages due to these calamities. While climate models that are developed for specific purposes provide a vast amount of data and information on climate, they are often not consistent due to the different assumptions used in the model development. These datasets need to be consolidated and synthesized to be useful in the analysis of changing climate including trends, extreme events, thresholds, etc. It is salient to first look at how the different datasets were generated, what procedures were used, and what assumptions were made before consolidating them.

Dataset consolidation and integration can be facilitated by using the advances in technology. Applications of these technologies should be maximized so that use of the data can be optimized for decision-making and management at different levels. To get the most value out of big data analytics, data practitioners are recommended to explore trends like cloud computing, machine learning, IoT to profit from reduced costs, optimized processes and data abundance. Data science organizations mostly use cloud-based computing technologies. A shift to cloud computing will greatly improve cost-effectiveness but would incur training costs and time. With analytical methods getting more complex and non-transparent even for data experts (e.g. neural networks, deep learning) efforts towards Explainable AI (XAI) should be undertaken.

A policy requiring the development and integration of the analytics process in the production chains should be formulated and implemented, i.e., how such technologies can be integrated into household appliances, gadgets, vehicles, etc. This will guide people in using these tools. A technology that could measure the amount of GHGs at the household level can be developed. A policy that could support the free installation of this technology can be formulated. This way, the household will be well-informed about their contribution to climate change while at the same time data on the contribution of a household to climate change can be established. These data can be analyzed so that the status in relation to GHGs and/or climate change contribution of a barangay or a municipality can be measured and analyzed. The same technology can likewise be installed in other establishments such as universities, schools, supermarkets, department stores, etc. This would enrich the data on climate change/GHGs production. The analytics should provide all firms with the information that they are already producing beyond the allowable limits of greenhouse gases in the place where they are located. It should also provide them with information as to which process had contributed much of their produced GHGs, and options that they can take.

At present, there is no technology that provides a laymanized presentation of data on climate change. Graphs or maps provide a simple method of presenting data on climate change. It would be more useful and beneficial if technologies will be developed that can translate climate data into information that are easy to understand by non-scientific individuals. Visuals are better. We should also acquire analytics technologies that can help in climate change mitigation and adaptation along with the provision of best practices, methodologies, and capacity-building capabilities. Technologies that can help decision-making in relation to climate change-contributing actions are equally important. These technologies and methodologies should include scenario analysis in graphical or map form.

Skills on data analytics especially in relation to climate change may be required to be developed aside from those that are needed for academic programs. Each institution, industry, business firm, school, university, etc. should likewise be required to have someone or a team who are trained in data analytics. These people will be in-charge in monitoring and analyzing big data on climate change available for their institutions and provide guidance on their operation especially those that can potentially contribute to the production of GHGs. This would entail support from the leadership or administration of these institutions.

Training and capacity building on the data acquisition, consolidation, integration and analysis should be conducted for different stakeholders or users of these datasets, e.g., LGU personnel involved in planning (LCCAP, CDP, DRRMP, etc.). Basic data skills required for a climate researcher include (1) spreadsheet and high-level programming skills, (2) mapping software, and (3) knowledge of geospatial analytics and statistics. Developed countries regularly provide trainings. Each institution trains its own researchers via classes in universities or informal senior-junior instruction. But data is expected to increase in size in the coming years. Sooner or later, academic training will not be able to keep up. Industry grade big data infrastructure and analytics training is needed. To future proof our climate researchers, investment for trainings in current data science trends especially cloud computing would be helpful. Basic data literacy training including data visualization, and data interpretation must also be done for end-users (e.g., LGU, DRRM). Tools and techniques for data analytics are still wanting. Development of sound methods or techniques is a must.

Developing a science communicator pool and science communication as a field is crucial. Researchers must be trained in science communication to better present their results. There is a huge gap in the technical capabilities of climate researchers who generate climate data and those who use climate data, e.g. LGU DRR officers, agricultural sector representatives. These people are usually numbers averse and would be easily intimidated by simple graphs and number tables. They prefer that climate insights are spelled out in words instead of graphs and have to translate the simplest of tables and graphs into sentences. It's usually the researchers/scientists who are tasked to explain climate reports, but these people are not necessarily communication experts. There is a growing field of science communication in the country that could bridge the gap between data producers and data users but their numbers are not yet enough for our nationwide needs.

Data culture is a key driver for analytics success, even more than technology. Key pillars of a culture that enhances data-driven activities are (1) trust (responsible use of data, people trust insights/support from data), (2) commitment (data as a strategic asset, leadership models data-driven work, org. structure reflects value of data), (3) talent (job descriptions highlight analytics skills, data use is rewarded, analytics training opportunities), (4) transparency (employees share data success stories to inspire each other, data shared across functions), and (5) growth mindset (experimentation is encouraged, learn from mistakes). One must also be taught to be "data critical", i.e. conscientious of datasets to be used by first evaluating how datasets were generated, assumptions, etc. An interdisciplinary approach is essential. Organizations need domain experts, strategic thinkers, impacted people ("users" or "beneficiaries") and data experts to realize successful analytics projects for climate change.

Climate change organizations abroad are already making strides in terms of influence (especially in Europe) but in the Philippines, we see the lack of importance given to the issue. This stems from the fact that our policies and laws in the Philippines relevant to climate change are yet to be aggressively implemented and the priorities of the current administration are elsewhere. We have yet to truly commit and see the value of sustainability. What is needed in the Philippines is to have the election and sensitization of legislators that can escalate the argument further. There is a need for an institutional arrangement with the involved stakeholders in the state and non-state actors when it comes to climate change data mining, consolidation, validation, and analytics. This could be done through policy instruments (Executive Order, or Resolutions) led by the Climate Change Commission as the lead policy and coordinating body on climate change matters as provided under the Climate Change Act, as amended. This way, funding and other necessary interventions can be created and implemented.

The prerequisite to effective adaptation is putting first the necessary governance and information systems in place and provide adequate focus and support for these systems to reach maturity and stability. Climate risk is determined by the combination of measures of hazard, exposure, and vulnerability. Adaptation actions range from those that solely confront climate hazards, to those that address risk, and to those that address vulnerabilities (thereby decreasing overall risk score). There is need to assess what Climate Change Adaptation options are available, their effectiveness as well as evaluation of their location-specificity. There are traditional approaches e.g., crop improvement, adjusting management practices, insurance, etc. There are also innovative approaches e.g., WIBI agri-insurance products, calamity fund, etc. While domestic policies and frameworks that govern climate action were already institutionalized, further support is needed in the areas of convergence planning and budgeting, legitimizing uptake of LGUs of the national development agenda, and access to means of implementation. Additionally, the issuance of further policies on climate action should not only be enforcing but also compelling enough for participants to appreciate their value (e.g. incentives, access to means). There should be a strong implementation of the mandated tasks of the climate change organizations. This includes investment in technology, capacity building of the organization and the people, and effective dissemination/communication of data to the public. A policy that enhances the integration of the science of climate change in education, whether formal or non-formal, to increase the level of awareness of people as to its manifestations and consequences. Currently, this aspect is just being done by some altruistic individuals and organizations with very limited scope or reach.

There should be increased capabilities in strategic planning and transitioning the plans to operational planning and development. The IPCC regularly conducts assessments of climate change, and issues official IPCC Assessment Reports to guide governments and agencies to address the adverse effects and impacts of climate change. This assessment process is usually done every 6 years. The IPCC is now preparing its 6th Assessment Report to be out in late 2021 or early 2022. Incidentally, the group of Filipino scientists working on climate change had initiated similar assessments of changing Philippine climate to come up with 3 reports in 2017, 2018, and 2019 on different aspects of climate change (i.e. physical basis of changing climate; effects, impacts and adaptations; and greenhouse gas emissions). The Philippine Climate Change Assessment (PhilCCA) Reports are published by CCC and the OML Center. Discussions and preparations for the next round of assessment studies are underway.