Geospatial Analytics for Healthy and Resilient Urban Systems

Participating disciplines/academic units/departments

Center for Applied Geographic Information Science

School of Data Science

Urban Institute

Institute for Social Capital

Ribarsky Center for Visual Analytics

Charlotte Action Research Project (CHARP)

Geography and Earth Sciences

Civil and Environmental Engineering

Computer Science

Mathematics and Statistics

Sociology

Africana Studies

Public Health Sciences

Business Information Systems and Operations Management

Arts + Architecture

Infrastructure and Environmental Systems (INES)

USDOT CAMMSE University Transportation Center

IDEAS Center

Leadership Team
1) **Eric Delmelle**, Ph.D. Associate Professor, Geography and Earth Sciences
2) **Wenwu Tang**, Ph.D. Associate Professor, Geography and Earth Sciences; Executive Director, Center for Applied Geographic Information Science.
3) **Lori Thomas**, Ph.D., Associate Professor of Social Work; Director, Institute for Social Capital; Director of Research and Faculty Engagement, Office of Urban Research and Community Engagement.

Target Category: Existing and Emerging Excellence

Keywords: geospatial analytics and innovation, urban systems, environment health and wellbeing, smart cities, cyberinfrastructure

Executive Summary

How can we harness the vast amounts of existing and emerging geospatial (geographic) big data (GBD) to inform and guide sustainable urbanization that ensures healthy and resilient urban regions for all urban dwellers, also recognizing the importance of urban-rural connections? Teams of researchers at UNC Charlotte are poised to tackle this challenge through the creation of a research enterprise built on three pillars of existing campus assets: 1) Urban Institute's extensive experience in urban data curation, 2) CAGIS' (Center for Applied Geographic Information Science) expertise and research in geoanalytics (geographic analysis), and 3) established application nodes that incorporate geospatial techniques into research knowledge domains. CHARP (Charlotte Action Research Project) offers a more critical perspective to ensure these efforts pursue questions relevant to communities and do not overlook disenfranchised segments of the population. Translational efforts will include visualization for communication (VizCenter) and best practices in dashboards (CAGIS).

As of 2018, an estimated 55% of the world's population lived in urban areas, a percentage projected to increase to 68% by 2050 (UN). In the U.S., the proportion is already over 80% with migration and growth patterns varying by region. Within this context, Mecklenburg County is one of the fastest growing urban areas in the U.S., increasing in population from 700,802 in 2000 to 1,143,570 in 2020. While urban centers provide immense residential, employment infrastructure and leisure opportunities, they also exhibit intense social and economic inequities and extensive environmental impacts that undeniably influence people's longevity, livelihood and well-being.

Simultaneously in recent years, the amount and availability of immense amounts of geographic data provide extraordinary opportunities for place-based, evidence-driven decision making that captures the complexity of urban systems. As an illustration of the rapidity of vast data generation, 90% of all data in existence was generated in the two years prior to 2018. An estimated 80% of these data are geographic/location-enabled. Transforming geospatial big data into information poses immense challenges, particularly with regard to efficient data management, information extraction, spatial data mining and analytics, and visualization. Capturing patterns of physical, social, and built environment urban systems requires integrated datasets, domain knowledge, and novel data mining technologies. Researchers need appropriate and secure access to multi-scalar (coarse to fine) geoanalytics capabilities to inform crucial time-sensitive adaptations necessary for healthy, resilient and equitable urban areas.

The Geospatial Analytics for Healthy and Resilient Urban Systems is a research enterprise leveraging an opportunity for the expansion and transformation of endeavors in data curation (Urban Institute), geoanalytics (CAGIS), and big data (Data Science). The structure enables groups of researchers in knowledge domains/nodes to undertake collaborative research and to seek competitive funding. The partnership between the Urban Institute and the School of Data Science provides faculty and student researchers the opportunity to access approved deidentified datasets from ISC and other data sources stored in SOPHI repository for analysis, as well as store new deidentified datasets for public access and review, as now frequently required by funders and academic journals. CAGIS and researchers in various knowledge domains expand the use of sensitive data, in a secure and confidential manner, to form and analyze new classes of grounded social data: de-identified, synthetic populations, and distributed computing. Insights gained from advanced geospatial analytics can be incorporated as new variables into visualization applications, moving local data access beyond current sources to also include variables that reflect the knowledge gained from a more sophisticated use of local and regional information.

Evidence of Strength & Excellence

The Geospatial Analytics for Healthy and Resilient Urban System Area of Excellence is uniquely positioned to address societal, healthy, and environmental challenges facing complex urban systems through synergizing interdisciplinary expertise. Specifically, it consists of: 1) a leadership team, 2) advisory board, and 3) 50 participating faculty and researchers. Over the past five years, these faculty produced 785 publications, received 195 grants ($55,616,551 totaled by faculty, not grant), and supervised 158 PhD students/348 Master students. Building on this strong research foundation, the Urban Institute, School of Data Science, Center for Applied Geographic Information Science, CHARP, and Ribarsky Center for Visual Analytics will come together in an exciting way as a hub for synergetic integration of expertise and resources.

Urban Institute/School of Data Science. Data Access and Repository. The UNC Charlotte Urban Institute is a nationally recognized curator of Charlotte-Mecklenburg data through two data systems, the Quality of Life (QOL) Explorer and the Institute for Social Capital. The QOL Explorer, a partnership with the City of Charlotte, Mecklenburg County, and surrounding towns, tracks over 80 variables providing detailed information about neighborhood housing stock, household income, jobs, health, education, tree canopy coverage, crime rates, community engagement, energy consumption, and many other indicators. The data are available for 462 neighborhood profile areas. The Institute for Social Capital is an integrated data system that links identifiable data on individuals across organizations and health and human service sectors. ISC is a nonprofit organization guided by organizational and community stakeholders and staffed by the Urban Institute. It has current data sharing agreements with over 40 organizations including Charlotte-Mecklenburg Schools, the Homeless Management Information System, Mecklenburg County Sheriff's Office, Cardinal Innovations, and Atrium Health. In 2018, the Urban Institute received a grant from the Foundation For the Carolinas and the Gambrell Foundation to engage a data infrastructure consultant to guide the improvement and scaling of its capacity to facilitate impactful research, particularly to address complex challenges like economic mobility. Data infrastructure improvements are currently underway to 1) move ISC to cloud technology, 2) enhance ISC's unstructured data lake using a data vault methodology, and 3) build a web-based interface (in collaboration with the School of Data Science) for data users and depositors. Ongoing ISC processes and relationships with community stakeholders through the ISC Board, Data and Research Oversight Committee, and Citizens Advisory Committee, as well as CHARP, ensure that data are used ethically and are meaningfully translated to actionable information.

CAGIS. Geoanalytics, Tools, and Models. CAGIS is an interdisciplinary research center that has expertise using advanced space-time theories, geospatial analytics methods, and cyberinfrastructure-driven computing technologies to address pressing multi-scale resource and sustainability issues. CAGIS is increasingly active in urban research-related activities and is evolving to become a hub of geospatial activity across campus that facilitates geospatial applications across a variety of knowledge domains. For the period 2016-2020, CAGIS has worked with over 90 on-campus faculty and staff researchers across 29 campus departments/institutes and 66 external collaborators from 36 institutions globally on proposals (74 submitted for about $47m since 2016), funded projects (24 funded with $4.6m since 2016), and publications (88 since 2016).

CHARP. The Charlotte Action Research Project (CHARP) is a community-engaged research initiative that integrates teaching, research, and action to enable neighborhoods to advocate for themselves, create sustainable neighborhood coalitions to implement structural change, and work toward a larger agenda of social justice. Through long-standing partnerships with marginalized communities in Charlotte and an asset-based approach to participatory action research, CHARP

contributes expertise from residents and local leaders to scientific applications and ensures the relevance of research to local decision-making. **Ribarsky Center for Visual Analytics.** The Center is a highly interdisciplinary center that applies interactive visualization and visual analytics to a variety of large scale and complex problems in science, engineering, medicine, business, design, and the arts.

Knowledge Node Collaborative Clusters (Dark Bubbles in Figure 1 on Page 7)

1. Urban Change. The growth and change of cities is influenced by multiscale drivers including shifting location preferences of firms and households, economic development policies, and the spatial distribution of public and private investment. However, the prosperity brought by economic and population growth is spatially unequal, resulting in the increasing separation of populations by race and income, contributing to rising levels of economic inequality. Researchers use novel data sets and methods that contribute fundamental knowledge on urban growth and change at the individual, neighborhood, city, and regional scales. The interdependencies between urban and rural changes are also examined. Our team members have received funding from NSF, US Fish and Wildlife, various foundations, and state/local governments to explore these issues.

2. Environmental Quality and Monitoring. The health of our communities is affected by a myriad of factors including air quality, land use, soil, and water quality. Our teams members are successfully developing place-based solutions to improve the quality of the environment we live, such as increasing access to water, creating new mapping techniques to detect and ultimately reduce water contamination, protecting biodiversity and the accurate monitoring of air pollution (funded research: NIH, CDC, NC WRRI, NC DOQ, NCDOT, NSF, USDA Forest Services). Leveraging the computational infrastructure of CAGIS and strong community connections (CHARP), enables adding important lines of inquiry about environmental (in)justice.

3. Health and Wellbeing. Through geospatial analytics and community-engaged research, our team has made significant advances to reveal disparities in access to vital resources (food, health services), uneven distribution of amenities known to improve mental health (parks, greenways), and how these inequalities can be different for various segments of the population (elderly, immigrants…). One of our objectives is to use big data to characterize social and environmental determinants of health disparities by building a detailed geospatial database of individual, residential, and neighborhood characteristics (including sociodemographic, built environment, social stressor characteristics, and environmental exposures) for the Charlotte area.

4. Climate Change and Disasters. Climate change is one of the greatest challenges facing humanity and is already altering physical environments and social systems. Every year disasters (both climate-related and non-climate) impact millions of people worldwide, resulting in thousands of deaths and billions of dollars of damage, though with uneven and inequitable effects. This team will use integrated geospatial approaches to capture place-based vulnerability in human-environment-built systems to guide increasing resilience in the Charlotte Region as a test bed for other urban areas.

5. Smart and Connected Infrastructure. Smart cities can be connected, resilient, innovative and safe, along with an environment that is healthier, more convenient, more affordable and enhances the quality of life for all its residents. Rapid urbanization presents new needs and challenges and cities must be prepared to accommodate them. Our team is well poised to leverage on new technologies and innovative ideas to build urban environments for the future, including Intelligent Transportation and Green Living.

Alignment with Regional and National Priorities

Building on an already strong foundation of research and bringing together existing entities at UNC Charlotte in an innovative way provides the infrastructure and organizational structure to bring nimble teams of researchers together to seek external regional and national funding and tackle the most pressing urban challenges facing society today. This exceptional configuration with extraordinarily rich regional datasets and geoanalytical power would be a national leader, particularly with the explicit connection to community voices through the Urban Institute's advisory group and to the deep community action research of CHARP. The work focusing on the Charlotte Region can translate to other locations through comparative studies and simultaneously leverage the generated knowledge as a guide for other urban regions.

The ongoing pandemic illustrates the importance of maintaining healthy and resilient urban systems and also exemplifies how researchers can come together rapidly to address an unfolding societal challenge (at least ten, and likely many more, UNC Charlotte researchers conduct research directly on the COVID-19 pandemic, several of whom are on this proposal). The geospatial analytics cluster that we propose will play a pivotal role in providing informed and actionable decision support to achieve this goal. As climate change, COVID-19, racial equity, economy, and health care become immediate priorities of Biden's administration, it is urgent and timely to leverage geospatial analytics and innovation for tackling challenges facing these prioritized areas often associated with diverse and massive spatiotemporal data. Through convergence science that spans and transcends disciplines, geospatial technologies and computing infrastructure provide an ideal platform to understand the complexities of urban communities. This geospatial analytics cluster is well positioned to serve this role via the synergistic partnership among Center for Applied Geographic Information Science, Urban Institute, and School of Data Science. Building on the existing research and scholarship, faculty and researchers in this cluster will actively work together to pursue funding opportunities emerging from these priority areas.

This Geospatial Analytics Area of Excellence is inline with our University's mission to best serve the environmental, healthy, and social needs of the Greater Charlotte Metropolitan region by expanding and fostering competitive research and educational programs. It will become a unique and powerful catalyst for local and regional stakeholders (government and private sectors) in need of geospatial analytics support particularly with respect to the five application domain themes identified in this proposal. This supports a healthy and resilient urban system for the Greater Charlotte Metropolitan region, and supports several of Charlotte/Mecklenburg's stated strategic priorities in connected communities, economic opportunities, and healthy communities.

Data-driven interdisciplinary discovery and innovation are prioritized nationally by NSF (Big Ideas), USGS, USDA, USDOT, CDC, and FEMA, and regionally by, for example, NCDEQ and NCDOT (See Support Document for reference). The proposed cluster will serve as a centralized hub to provide unique and innovative geospatial data analytics solutions to resolve societal and environmental challenges facing complex urban systems while attracting increasing funding, talented scholars and students. Besides federal and state-level funding agencies, the proposed cluster holds great potential in seeking external funding internationally (e.g., from USAID, UN for geospatial applications in Africa, Europe, or Asia) based on successful collaboration already built (e.g., in Nigeria, Ghana, and Tanzania). This will substantially increase the visibility and reputation of UNC Charlotte and greatly help secure R1 status in the foreseeable future.

Supporting Documents

Supporting Document 1: Team organization
Supporting Document 2: References for regional and national priorities
Supporting Document 3: CVs of participants

Supporting Document 1: Team organization

The Geospatial Analytics for Healthy and Resilient Urban System Cluster (see Figure 1) is uniquely positioned to address societal, healthy, and environmental challenges facing complex urban systems by synergizing interdisciplinary expertise. Specifically, the team consists of 1) leadership team, 2) advisory board, and 3) participating faculty and researchers.
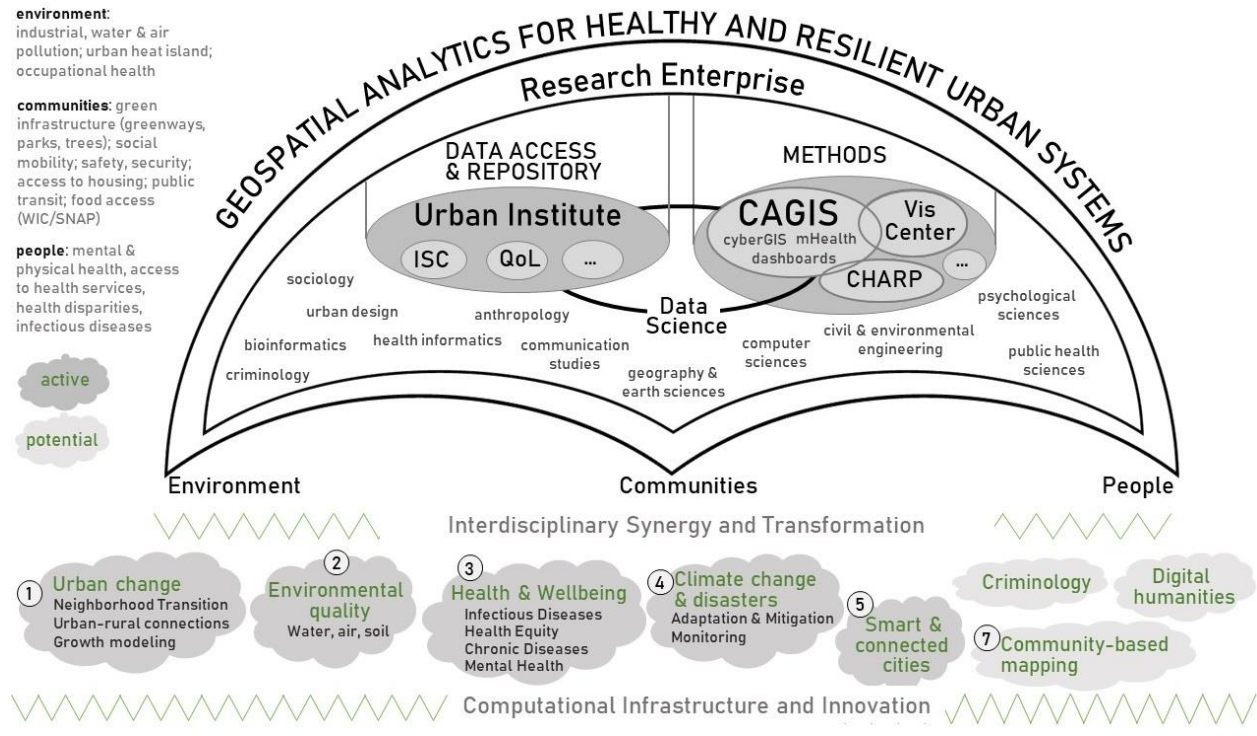

Figure 1. Overarching framework of the proposed Cluster.

1. Leadership Team:

Eric Delmelle has recently received funding from the CDC and NC WRRI in the area of environmental health (water contamination) and infectious diseases. Over the last five years, he has published 40 papers and graduated 6 Ph.D. students.

Wenwu Tang serves the Executive Director of CAGIS. Tang has over 90 peer-reviewed publications and two edited books. Wenwu's research has been supported by federal and state funding agencies (about $3.5 million in total), including USDA Forest Services, US CDC, US Fish and Wildlife, NCDOT, NC Forest Service, and Electric Power Research Institute. Wenwu is currently supervising 2 PhD students, and 1 Master student, with 6 graduate students completed (3 Ph.D., and 3 Master).

Lori Thomas is the Director of the Institute for Social Capital. She is a macro social work scholar who focuses programmatic and systemic responses to homelessness and housing instability across the life course. Her research has been supported by nearly $1 million in primarily local government funding, emphasizing my professional commitment to make actionable scholarly contributions to my local community as well as broader social science. She currently has funding from Mecklenburg County and the United Way.

2. Advisory Board

Name	Title	Academic Unit
Jeff Michael	Director	Urban Institute
Doug Hague	Director	School of Data Science
Zachary Wartel	Co-Director	Ribarsky Center for Visual Analytics
Colleen Hammelman	Director	Charlotte Research Action Project
Jy Wu	Director	INES (Infrastructure and Environmental Systems) Program
Deb Thomas	Department Chair	Department of Geography and Earth Sciences

3. List of Participants

Name	Title	Relevant Expertise	College/Unit	Node
Eric Delmelle	Associate Professor	GIScience, Health Geography, Environmental Health, Visualization, Infectious Diseases	CLAS	2,3,5
Wenwu Tang	Associate Professor	Spatial Analysis and Modeling, Spatial Cyberinfrastructure, Land Use and Land Cover Change, Agent-based Modeling	CLAS	1,2,3,4, 5,
Lori Thomas	Associate Professor, Director	Social Work (macro), Director of Research and Faculty Engagement, UNC Charlotte Urban Institute	AA/OURCE	1,3,5, 6
Srinivas Akella	Professor	Robotics, UAV based inspection, optimization algorithms	CCI	1,2,3,4,5

Craig Allan	Professor	Hydrology	CLAS	2,4
Ahmed Arif	Professor	Epidemiology	CHHS	3
Chen Chen	Assistant Professor	Computer vision, machine learning	COE	1,2,3,4,5
Don Chen	Professor	Pavement Management System, Building Information Modeling	COE	1,2,4,5
Gang Chen	Associate Professor	Remote Sensing, landscape change, forest disturbances	CLAS	1,4
Shenen Chen	Professor	Remote sensing for bridge monitoring; power transmission structures; forensic investigation	COE	1,2,4
Sandra Clinton	Research Assistant Professor	Ecosystem ecology, urban water, restoration	CLAS	1,2,4,5
Casey Davenport	Assistant Professor	Severe thunderstorms, numerical modeling	CLAS	4
Elizabeth Delmelle	Associate Professor	Neighborhood Change, GIScience, transportation, spatial analysis and modeling	CLAS	1,5
Wenwen Dou	Assistant Professor	Visual Analytics, Human Centered AI, Social Media data analysis, Cognitive Biases	CCI	1,2,3,4,5

Michael Dulin	Professor	Public Health, Health Informatics, Implementation Science, CBPR	CHHS	3
Missy Eppes	Professor	soils, weathering, impacts of climate on erosion and weathering	CLAS	2,4
Michael Ewers	Assistant Professor	Migration, labor markets, economic impacts	CLAS	1
Wei Fan	Professor	Connected and autonomous vehicles; Shared mobility; Multimodal transportation system planning; Traffic operations and control	COE	1,5
Sara Gagne	Associate Professor	Landscape Ecology; Urban Ecology	CLAS	1,2,4
Cynthia Gibas	Professor	Bioinformatics, Environmental Monitoring	CCI	2,5
Justin Grandinetti	Assistant Professor	Mobile media, streaming media, big data, AI, spatial materialism, Global South	CLAS	5
Doug Hague	Professor of Practice	Data Science, financial services, data infrastructure, data governance	CCI	1,5

Colleen Hammelman	Assistant Professor	Migration, social inequality, urban food systems, community-engaged research	SDS	1,3
Jiancheng Jiang	Professor	Statistical modeling	CLAS	1,2,3,4,5
Joseph Kangmennaang	Assistant Professor	Health and wellbeing, health inequities, Healthy communities, Immigrant Health, Mixed methods	CLAS	2,3
Taufiquar Khan	Professor	Parameter Estimation, Mathematical Modeling and Simulation, Machine Learning	CLAS	1,2,3,4,5
Ming-Chun Lee	Associate Professor	Urban Design, Civic Engagement, Geodesign, Immersive Technologies	COAA	1,5
Brian Magi	Associate Professor	Air quality, climate change	CLAS	2,4
Jeff Michael	Director	Urban studies	Urban Institute	1,4
Stephanie Moller	Professor	Income Inequality across Counties, US States, and Countries	CLAS	1.3
Isabelle Nilsson	Assistant Professor	Residential mobility, transportation, economic development, spatial analysis and statistical modeling	CLAS	1,5
Akin Ogundiran	Professor	Archaeology & Social Ecology	CLAS	1,2,3,4

Dimitris Papanikolaou	Assistant Professor	Urban Computing, System Dynamics, Agent Based Systems, Shared Mobility (Planning/Operations), Internet of Things, Information Visualization, HCI	COAA/CCI	5
Stephanie Pilkington	Assistant Professor	Natural hazards, community resilience, hazard impact and recovery modeling, data gathering and analytics	COE	3,4,5
Stephanie Potochnick	Assistant Professor	Social Demography, Immigrant Education and Health, Population and Migration Policy, Health and Education Policy	CLAS	3
Srinivas Pulugurtha	Professor	Transportation planning, Traffic operations & safety, Connected and automated vehicles, Data analytics & visualization, Operational, economic and societal impacts	COE	1,5
Elizabeth Racine	Professor	Public health; food security	CHHS	3
Rebekah Rogers	Assistant Professor	Population Genomics	CCI	3
Erik Saule	Associate Professor	High performance computing and applications	COAA	1,2,3,4,5
Jack Scheff	Assistant Professor	Climate Change, Climate Change Impacts	CLAS	4

Douglas A. Shoemaker	Director, Research and Outreach	Urban Growth, Ecosystem Services	CLAS	1,5
Hamed Tabkhi	Assistant Professor	Smart Cities, Video Analytics, AI	COE	4
Deb Thomas	Professor	Disaster, Environmental Health, Human-Environment Interaction	CLAS	1,2,3,4
David Vinson	Assistant Professor	Natural contaminants of public health concern, urban waters, water quality	CLAS	1,2
Zachary Wartell	Associate Professor, Director	Visualization, Big Data Analytics	CCI	1,2,3,5
Jy Wu	Professor	Energy and Environmental Systems, Water Resources,	COE	1,2
Yonghong Yan	Associate Professor	High Performance Computing and Scientific Simulation	CCI	1,2,3,4,5
Jing Yang	Professor	Visual analytics of urban traffic data, time-oriented data, multidimensional data, and text document collections	CCI	1,2,5
Dongsong Zhang	Professor	Business Analytics	BCB	2,3,4,5
Lei Zhu	Assistant Professor	Spatial sensing and smart mobility, GIS in transportation, GPS/GIS	COE	5

4. Summary of existing research and scholarship in area of excellence

# Collaborators	50
#Publication over the past 5 years	785
Total number of publication	2001
#Grants received over the past 5 years	195
Total Funding over the past 5 years	$55,616,551*
Funding total	$102,038,772*
#Phd students supervised	158
#Master students supervised	348
Representative funding agencies of funded grants	NSF, NIH, CDC, USDOT, USDA Forest Service, US Fish and Wildlife, NEH, National Geographic, American Philosophical Society, NCDOT, NC Forest Service, Electric Power Research Institute

*This represents the total amount of the grants for each PI/co-PI and is not broken down by contribution. Thus, the total amounts represent a higher dollar amount than summing by grant rather than PI.

Supporting Document 2: References for regional and national priorities

1. CDC Strategic Framework and Priorities, https://www.cdc.gov/about/organization/strategic-framework/index.html
2. FEMA (Federal Emergency Management Agency), 2018-2022 Strategic Plan: Helping People Together. https://www.fema.gov/sites/default/files/2020-03/fema-strategic-plan_2018-2022.pdf
3. NC Department of Environmental Quality Strategic Plan: 2019-2021, https://files.nc.gov/ncosbm/documents/files/FY2019-21_StrategicPlan_DEQ.pdf
4. NC Department of Transportation Agency & IT Strategic Plan: 2019-2021, https://files.nc.gov/ncosbm/documents/files/FY2019-21_StrategicPlan_DOT.pdf
5. NSF Ten Big Ideas, https://www.nsf.gov/news/special_reports/big_ideas/
   6. USGS 2020-2030 Strategic Plan, https://pubs.er.usgs.gov/publication/cir1476
7. USDA Strategic Plan 2018-2022, https://www.usda.gov/sites/default/files/documents/usda-strategic-plan-2018-2022.pdf
8. US DOT Strategic Plan for FY 2018-2022, https://www.usda.gov/sites/default/files/documents/usda-strategic-plan-2018-2022.pdf
9. UN Global Sustainable Development Report, 2019, The Future is now: Science for achieving sustainable development, https://sustainabledevelopment.un.org/content/documents/24797GSDR_report_2019.pdf

Supporting Document 3: CVs of Participants