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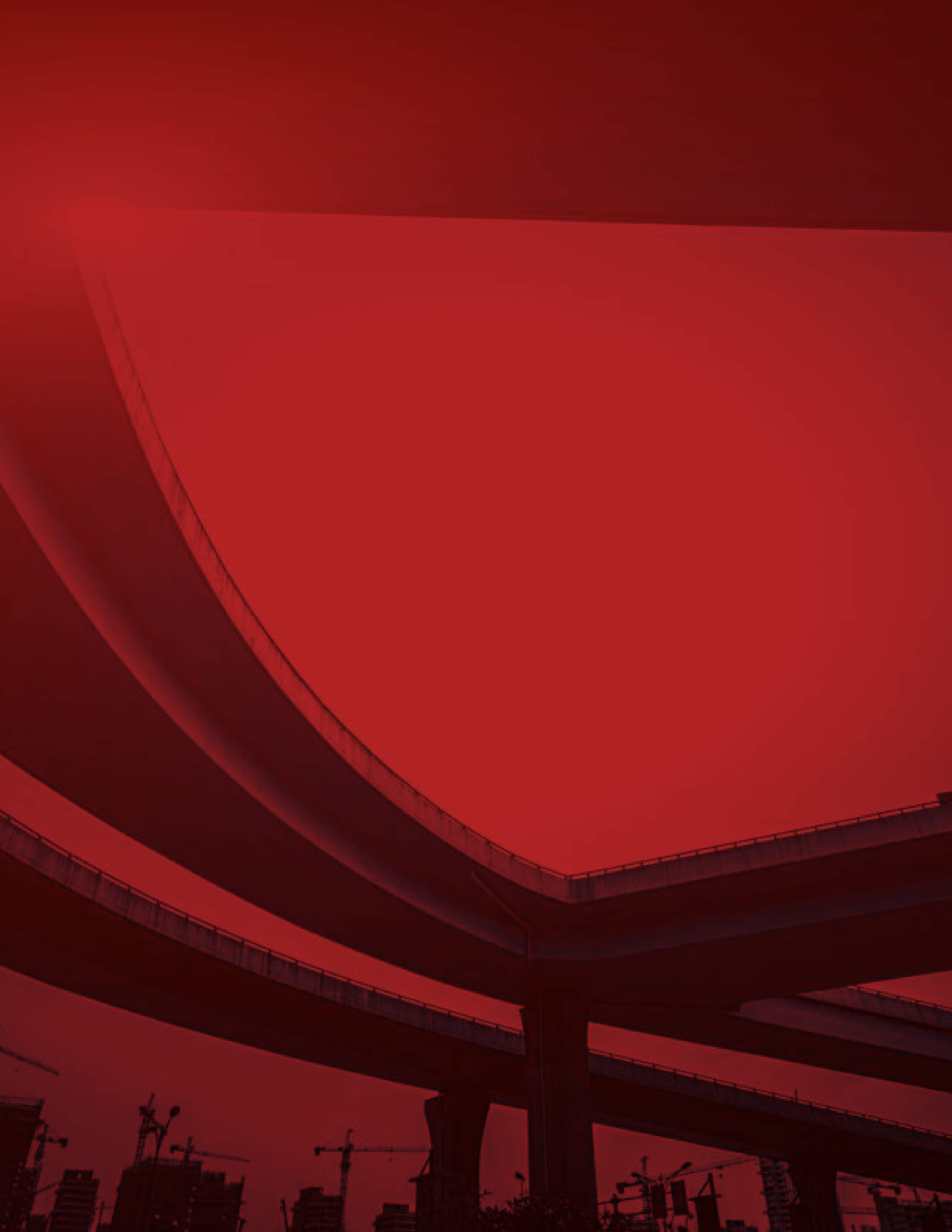
White Paper

The value of Integrated Geospatial and Building Information Modelling (BIM) solutions to advance the United Nations Sustainable Development Goals (Agenda 2030) with specific focus on resilient infrastructure



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Objective

In 2015, Member States of the United Nations adopted the 2030 Agenda for Sustainable Development, inclusive of its 17 Sustainable Development Goals (SDGs), as a call to action to end poverty, protect the planet and ensure that all people enjoy peace and prosperity by 2030. The 17 SDGs are integrated in a manner to balance social, economic and environmental sustainability.

To achieve the 17 goals and to leave no one behind, integrated geospatial technology and building information modelling (BIM) are found to be critical. Geospatial and BIM solutions, enabled by the fourth industrial revolution (4IR) technologies such as Artificial Intelligence (AI), Internet of Things (IoT), Big Data, etc., provide better access to accurate, high-resolution data, techniques and tools to provide a balanced assessment and solution for the SDGs. For this purpose, this white paper, 'The value of integrated geospatial and BIM solutions to advance the United Nations Sustainable Development Goals (SDGs)' is developed with the goal to:

1. Demonstrate the use of integrated geospatial and BIM solutions to advance the SDGs with a special focus on resilient infrastructure.
2. Present relevant case studies to show how the value of integrated geospatial and building information modelling solutions addresses developmental challenges especially with regards to resilient infrastructure.
3. Identify critical challenges that act as a barrier in adoption of geospatial and BIM solutions for building resilient infrastructure as defined by the SDGs.
4. Define recommendations to streamline effective use of integrated geospatial information and BIM solutions.

The white paper stresses on the use of geospatial and engineering technologies (supported by relevant case studies) for building resilient and sustainable communities across three SDG goals – Goal 9: Industry, Innovation and Infrastructure; and Goal 11: Sustainable Cities and Communities and Goal 13: Climate Action.

Preamble and Rationale

Geospatial and engineering technologies have an enabling and coherent capability to achieve the 2030 Agenda for Sustainable Development by rendering tools and mechanisms for the creation of practical applications across all sectors. In 2019, the United Nations released the Global Sustainable Development Report (GSDR), written to formulate strategic actions to achieve the 2030 Agenda for Sustainable Development. The report titled, **"The Future is now: Science for achieving the SDGs",** emphasizes the role of science and technology as one of four levers to achieve the transformation needed to achieve the SDGs across the globe. However, while documentation on the use of science and technology exists, the lack of technology awareness and understanding to advance SDGs acts as a barrier in the adoption of technology.

Over the past few years, there is a persistent digital divide that continues to exist between the developed and the developing countries. Developed countries are found to be rich in geospatial data and information, technology and innovation; whereas vulnerable communities suffer from the lack of it. The difference that exists between the two worlds with regards to geospatial data and information results in a vast 'geospatial divide'. The geospatial divide brings forth strikingly complex dimensions to the geospatial knowledge infrastructure of the different countries. This emphasizes the need to build a robust national information system and associated geospatial frameworks. For countries to achieve the goal of the 2030 Agenda by utilizing geospatial technologies – it is imperative for them to bridge the geospatial knowledge gap. Simultaneously, they should enable the development of a national geospatial data ecosystem. Integrated geospatial and BIM solutions, advanced by 4IR technologies in particular, are thus crucial for achieving the selective goals of the SDGs.

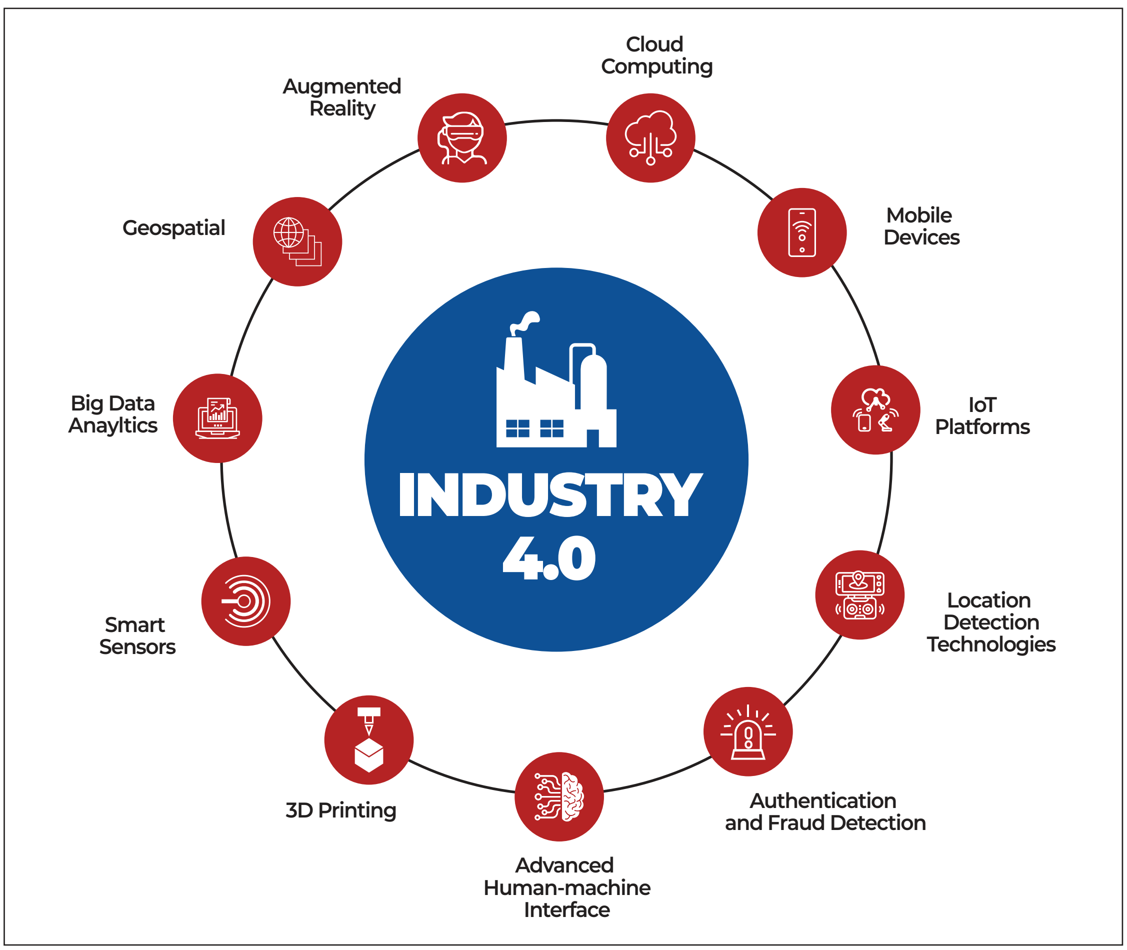
To achieve the 2030 Agenda, and bridge the geospatial divide, countries need to enable the development of a national geospatial data ecosystem, robust national information system and associated geospatial frameworks.

Fourth Industrial Revolution (4IR) Technologies to Advance the SDGs

Resilient infrastructure, climate change and sustainable communities are a predominant urban challenge which often faces difficulties in prioritization of infrastructure up-gradation, determination of optimal location for greenfield projects, climate-change mitigation, and development of sustainable infrastructure. For resilient infrastructure in particular, the previous decade has witnessed a considerable surge in the urban data revolution, to shape infrastructural interventions through evidence-based decision making to prioritize investments and sustainable growth. 4IR technologies (including geospatial and BIM as part of this white paper) are crucial players to steer resilient development, and mitigate climate change by enabling local authorities to integrate their data for spatially informed planning and infrastructure prioritization. Thus, for resilient and sustainable infrastructure, the opportunities are ripe to stimulate and invest in 4IR technologies.

Over the last decade, many advanced and innovative solutions came up. Collectively, they play a critical role in understanding the

Figure 1: What are the fourth industrial revolution (4IR) technologies?



vulnerabilities associated with disasters and prepare accordingly. As the global infrastructure community galvanizes towards resiliency, there is an opportunity for them to embrace technology that enables data collection and assessment to evaluate risk frequency and severity to strengthen the resilience of today's and tomorrow's cities. From smartphones to satellite sensors, from ground-penetrating radar (GPR) to LiDAR to Building Information Modelling (BIM), from drones to AI to IoT and other immersive technologies – the level of ubiquity with which technology incorporation is happening across the construction lifecycle of infrastructure projects, indicates the growing value and utility of 4IR technologies in building better, smarter, resilient and more sustainable infrastructure to meet the selective goals of the SDGs (Figure 1).

Also, to make buildings more resilient to climate change risks, to facilitate economic activity and to avoid future GDP loss, there is an opportunity for governments to organize themselves to innovate and experiment with the available tools and technologies. In this context, geospatial and BIM solutions are available in silos. If integrated, they can enhance broader resilience of infrastructure in countries and lead to an elastic incremental growth. The economic value unlocked by the use of 4IR technologies addresses the most pressing challenges of disaster risks and rightfully assesses the target areas highly exposed to disasters. 4IR technologies – developed on the backbone of IoT and Artificial Intelligence (AI) present an excellent promise for countries to actively move to a sustainable future. In hindsight, it is up to project owners of infrastructure projects, old and new, to take initiatives to harness pioneering technologies and enhance resilience and urban economic productivity.

For a concerted move to reach the goal of resiliency and sustainability, the development sector stakeholders must work in close coordination with technology solution providers to successfully adapt holistic, industry-wide solutions to identify and manage risks. With the use of 4IR technologies, to achieve resiliency to move beyond one-dimensional issues; but also, to successfully find and exploit their vulnerabilities. Thus, digital technologies are the bedrock of the hyper-connected epoch of Industry 4.0. It's an essential thread of technology confluence in the broader context of SDGs for establishing a path-breaking force to ensure sustainable development and effective planning.

The Role of Geospatial Technology in Achieving The SDGs

Geospatial technology facilitation is a major pillar for the implementation of the 2030 Agenda. To eradicate poverty, meet the challenges of urban planning, to develop resilient and sustainable cities, and to reorient the current unsustainable development trajectories - technology solutions have to be developed and disseminated widely over the next ten years. It is imperative that both public and private sectors collaborate to move cities towards achieving the 2030 Agenda using science, technology and engineering as a lever of transformation for urban planning and land use, high-quality infrastructure and public services, transport systems, and digital connectivity. To advance the SDGs – there is a pressing need to utilize analytical capabilities of AI, virtual reality, BIM, machine learning technologies, geospatial and other technologies.

The confluence of geospatial and engineering tools helps to gather and integrate data from varied sources and offer cutting-edge analysis to garner actionable insights by better visualization of a variety of challenges. Moreover, 3D maps and data modelling systems help to discern adaptive patterns for real-case scenarios imperative for the development of resilient and sustainable cities. Above all this, using a wealth of geospatial information and geospatial technologies – city planners and policy makers can increase nature-based solutions to adapt for climate change, address pollution, reduce CO2 emissions, taking into account the needs for a circular economy and resilient and sustainable cities.

Resilient Infrastructure

Infrastructure, in its truest sense, encompasses the built infrastructure (transport, industrial and building) and the integrated built and natural systems which provide for the essential needs of society.

In the context of infrastructure systems, resilience is defined as the ability of an infrastructure asset to absorb the disturbances caused by disaster and climate risks (Arup, 2014) and retain its functionality and structural capacity. The widely accepted UN definition for resilience is, 'the ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including the preservation and restoration of its essential basic structures and functions," (UNISDR, 2009). The high occurrences of disasters, associated climate change risks, and the exposure of urban cities to disasters has necessitated governments and communities all over the world to emphasize on resilient and sustainable infrastructure. A case in point is, in July 2015, as a result of Hurricane Sandy, the U.S. Government Accountability Office (GAO) issued a report which articulated the meaning of resilience. It encouraged the government authorities at the level of federal department – state, territorial, tribal and local government, and private and non-profit sector entities to work towards national resilience for future disasters. Additionally, the SDGs emphasizes infrastructure development to be essential to achieve SDG Goal 9 – 'building resilient infrastructure to provide sustainable industrialization and foster innovation'.

Box 1: Resilient Infrastructure as part of Goal 9 as defined under the SDGs.

United Nations established the targets for resilient infrastructure as part of Goal 9 –

- Develop quality, reliable, sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all.
- By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities.
- Facilitate sustainable and resilient infrastructure development in developing countries through enhanced financial, technological and technical support to African countries, least developed countries, landlocked developing countries and small islands developing states.

Need For Resilient Infrastructure

POPULATION EXPLOSION

The codependency of economic growth, resiliency and population growth is often ignored. The United Nations observes two intertwined reasons for urbanization – increase in population and an upward trend in people moving to cities in search of better opportunities, more efficient infrastructure and services. As the global population significantly rises, and new urban clusters are formed, society's vulnerability to disasters and climate-change forces will also continue to grow. The United Nations, Department of Economics and Social Affairs, Population Division, in its recent report, **World Population Prospects 2019: Highlights,** emphasizes that the world population reached 7.7 billion in mid-2019, having added one billion people since 2007. Also, according to the UN report, the global population is estimated to reach 8.5 billion in 2050, and 10.9 billion in 2100 respectively (Table 1).

Table 1: Population of the world, SDG regions and selected groups of countries, 2019, 2030, 2050, and 2100 – according to the medium variant projections.

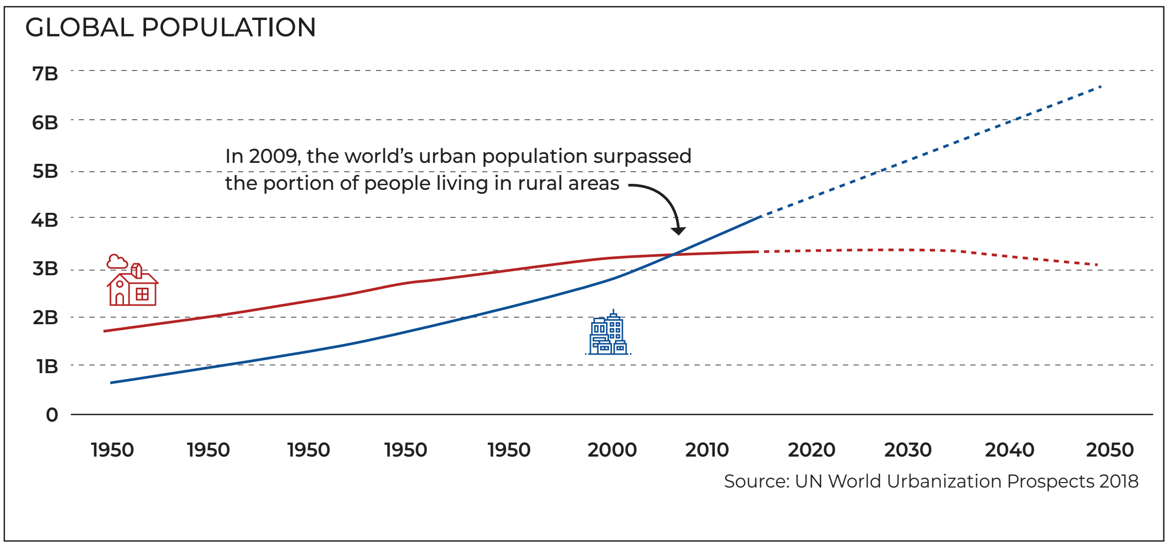
Region	Population (millions)			
	2019	2030	2050	2100
World	**7713**	**8548**	**9735**	**10875**
Sub-Saharan Africa	1066	1400	2118	3775
Northern Africa and Western Asia	517	609	754	924
Central and Southern Asia	1991	2227	2496	2334
Eastern and South-Eastern Asia	2335	2427	2411	1967
Latin America and the Caribbean	648	706	762	680
Australia/New Zeland	30	33	38	49
Oceania*	12	15	19	26
Europe and Northern America	1114	1132	1136	1120
Least developed countries	1033	1314	1877	3047
Land-locked Developing Countries	521	659	926	1406
Small Island Developing States	71	78	87	88

It was in 2009, the world's urban population surpassed the portion of people living in rural areas and by 2050, and moving towards 2100, the rural population will eventually decline while the urban sector will shoot up to six billion people or more (Figure 2). There is going to be a rapid rise in population in megacities and the number of regional to mid-sized cities (500k to 5 million) will rise drastically by 2030. In such a situation, the existing physical infrastructure worldwide is and will continue being under stress – hampering economic progress and putting communities to significant risk.

CLIMATE-CHANGE RISKS AND ADAPTATION

Alongside rising population and increasing vulnerability to economic stability; climate-related forces such as rising sea levels, droughts, earthquakes, volcanoes and violent storms have a far-reaching negative impact on the humanitarian, economical and infrastructure assets of communities. The UN Environment Global Status Report 2017 presents a holistic picture of the carbon emissions in the world from the construction sector during the entire construction lifecycle.

Figure 2: Urban and Rural Population Trends



Rapid urbanization and increasing exposure to hazards threaten to drive the risk of stresses and shocks to dangerous and unpredictable levels with systemic global impacts. With the majority of the urban areas still to be designed and built, it is critical to respond to the call of putting in place resilient and sustainable practices and avoid committing insurmountable resources in retrofitting and reinforcements. Resilient and sustainable infrastructure is the need of the hour. To not only meet the requirements of the future generation, but also to re-build the ageing infrastructure exposed to global risks and natural catastrophes.

The challenge of building climate resilient infrastructure is set within a wider challenge of securing sufficient investment to build a low-carbon society.

Today, the building and construction sector accounts for 39% of all carbon emissions in the world, wherein 11% is associated upfront with building materials during the entire lifecycle of a project. A further 28% is caused by operational emissions. The building industry never set targets for energy efficiency or carbon reductions. Therefore, the industry will have to focus on construction of low carbon-built environment going forward.

The World Bank integrates climate resilience into/and with urban planning and infrastructure development. With approximately 68% of the global population expected to live in cities by 2050- the global infrastructure is going to face numerous elusive challenges. This includes informal settlements and the need to withstand the effects of climate change which shall increase the impact intensity and frequency of natural and human-made hazards.

According to an estimate by the Economic Intelligence Unit (EIU), climate change could directly cost the world economy nearly US$ 7.9 trillion by 2050 as increased drought, flooding and crop failures hamper growth and threaten infrastructure. A case in point is that of the USA, wherein in the last 20 years, i.e., between 2000 and 2019, there has been a total of 178 disasters, with a total damage cost worth US$ 1,312.3 billion, CPI-adjusted (Table 2). The 178 disasters resulted in total deaths of 8,268 people spread as 1 death from Freezing; 117 deaths spread across 6 Winter Storms; 259 deaths spread across 21 Floods, 318 deaths spread across 14 Wildfires; 400+ deaths due to 16 Droughts and a total of 7000+ deaths spread across 92 Severe Storms, and 26 Tropical Cyclones.

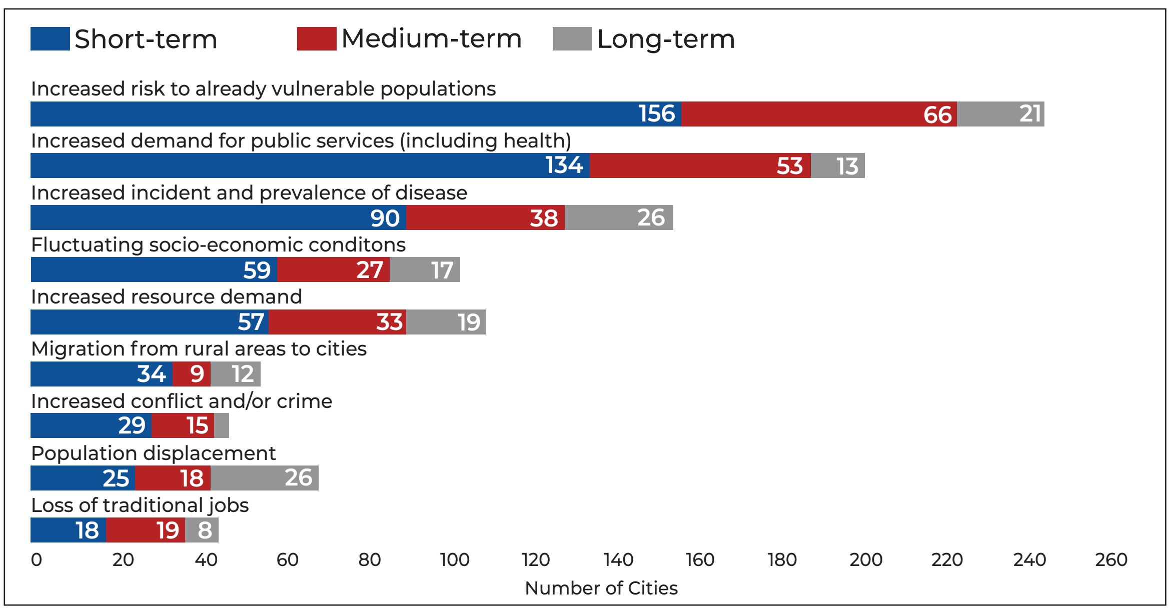
Table 2: Billion-dollar events to affect the United States of America from 2000 to 2019 (CPI-Adjusted)

Disaster Type	Events	Events/ Year	Percent Frequency	Total Costs	Percent of Total Costs	Cost/ Event	Cost/ Year	Deaths †	Deaths/ Year
Drought	16	0.8	9.0%	$133.2B	10.2%	$8.3B	$6.7B	461	23
Flooding	21	1.1	11.8%	$76.0B	5.8%	$3.6B	$3.8B	259	13
Freeze	3	0.2	1.7%	$5.5B	0.4%	$1.8B	$0.3B	1	0
Severe Storm	92	4.6	51.7%	$207.2B	15.8%	$2.3B	$10.4B	1,107	55
Tropical Cyclone	26	1.3	14.6%	$803.3B	61.2%	$30.9B	$40.2B	6,005	300
Wildfire	14	0.7	7.9%	$74.8B	5.7%	$5.3B	$5.7B	318	16
Winter Storm	6	0.3	3.4%	$12.3B	0.9%	$2.1B	$0.6B	117	6
All Disasters	178	8.9	100.0	$1312.3B	100.0%	$7.4B	$65.6B	8268	413

Resilient and sustainable infrastructure is the need of the hour to meet the requirements of the future generation, and to re-build the ageing infrastructure exposed to global risks and natural catastrophes.

The rapid and unprecedented growth in population and increasing impact of climate change – will hit the poorest of society the most. In the coming decade, climate change is going to bring forth a high number of social risks spread across long and short time-periods. A recent report by CDP highlights that in a short-term period, increasing risk to already vulnerable populations is one of a significant risk whereas, in the long-term, increased incidence and prevalence of the disease, and population displacement is the top-social risks of climate change. The knowledge of the type of risk associated with climate change, alongside the period in which these risks manifest, is imperative for communities to understand and act (Figure 3).

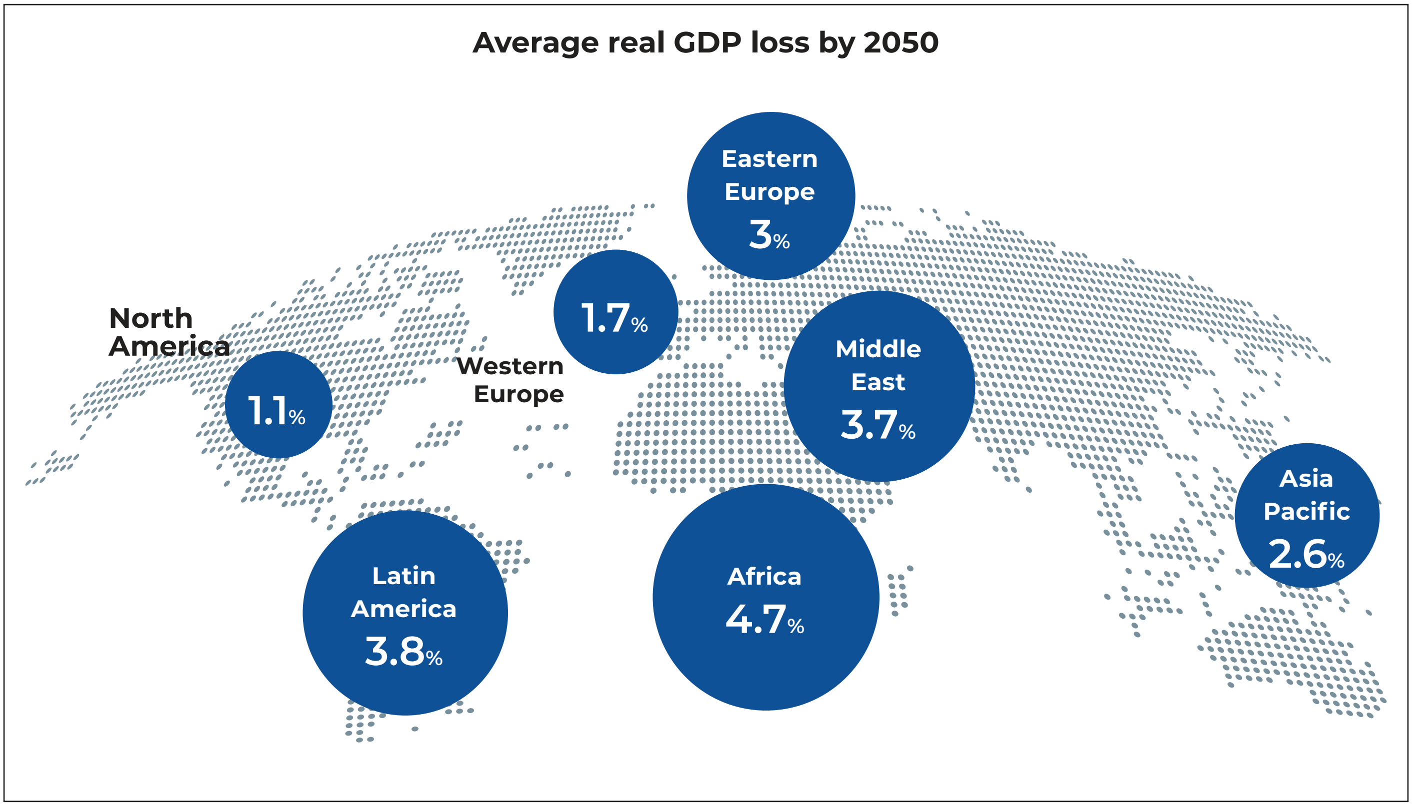
Figure 3: Climate Change and Social Risks



CLIMATE-CHANGE RESILIENCE INDEX

The Economist Intelligence Unit's (The EIU) Climate Change Resilience Index (CCRI) is based on eight indicators; namely, the loss of land/physical capital due to extreme weather conditions, impact on public services, impact on agriculture sector, loss of labour productivity, tourism loss, trade loss, and adaptation costs and mitigation costs. The index highlights the average GDP loss – by region (in real terms) by 2050 with the global economy to be 3% (i.e. loss in GDP of 3%). It brings forth that the emerging countries, with high average temperatures and increasing carbon emissions, will be the most affected. Key findings from the report in terms of resilience shows North America (1.1% smaller i.e. the North American region will suffer a 1.1% of GDP loss) and Western Europe (1.7% smaller i.e. a 1.7% of GDP loss) to display high resilience, whereas Africa (4.7% smaller i.e. 4.7% of GDP loss) be the least resilient region followed by Latin America, Middle East, Eastern Europe and the Asia Pacific (Figure 4). The index explicitly reveals the vulnerabilities that exist in the developing countries and presents an overview of their capacity to withstand the impacts of higher temperatures and in turn, its economic impact. The average GDP loss predicted for countries for 2050, for both developed and developing countries, highlight that countries will have to put in much greater effort to build in resiliency in order to reduce the predicted economic impacts.

Figure 4: Economic Impacts of Climate Change



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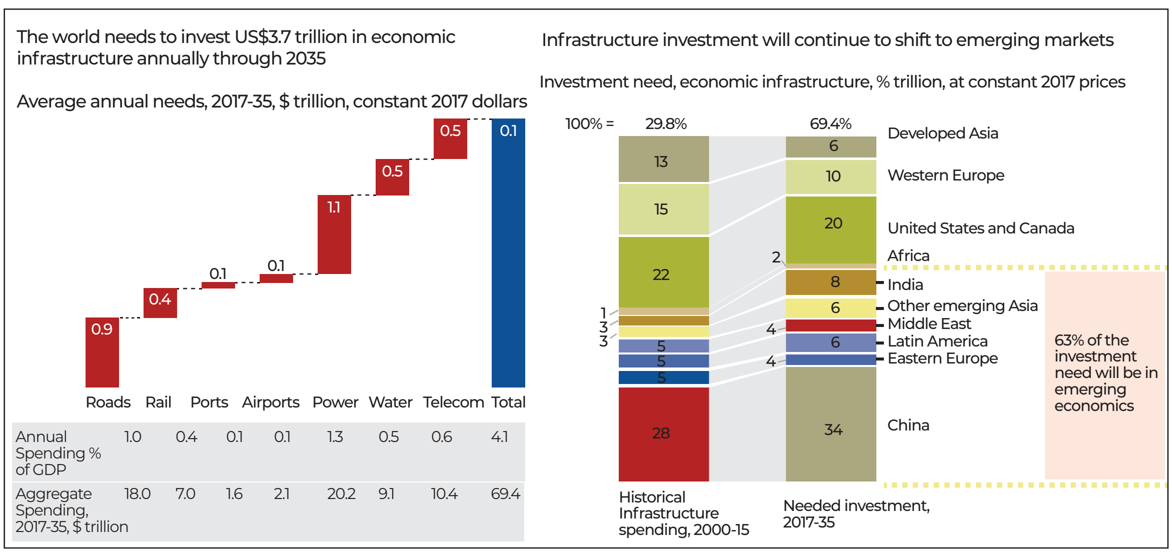
Global Infrastructure Investment

Population explosion and climate-change-related risks along with other hazards present a compelling case for resiliency in infrastructure as these are high-value and interconnected assets with long-operational lifetimes. Since the existing infrastructure assets, i.e. roads and highways, bridges, power stations and buildings are already vulnerable to the present extreme climate conditions – the vulnerabilities will only extend in future. For economies to transition to low carbon society i.e., a green economy, substantial investments are required in concentrated sectors to increase infrastructure's resilience and help protect the potential economic opportunities and future growth.

vested in low-and middle-income countries. An analysis by McKinsey Global Institute brings forth that globally, to build resilient infrastructure and to support economies – roads, railways, ports, airports, buildings and campuses, the world needs to invest at least US$ 3.7 trillion in infrastructure every year from now until 2035. This number is expected to rise by US$ 1 trillion to 'future-proof' the communities in the next decades in order to counteract natural disasters, population growth and ageing population.

In the future, emerging economies like Asia-Pacific, Middle East, Africa, Latin America and Eastern Europe are going to

Figure 5: Global Infrastructure Investment: Trends and Directions (Sourced from McKinsey Report)



Today, integrating resilience into global infrastructure development investments is imperative. According to a report from the World Bank and the Global Facility for Disaster Reduction and Recovery (GFDRR), **Lifelines: The Resilient Infrastructure Opportunity,** the net benefit on average investment in resilient infrastructure can be US$ 4.2 trillion – with US$ 4 in benefit for each US$ 1 in-

attract 63 per cent of the infrastructure investment need. From Asia-Pacific, China will account for 34 per cent of the global need and India will account for 8 per cent. This is keeping in mind the population growth and increasing urbanization in these countries. Additionally, as per the Global Infrastructure Outlook, a report developed by the Global Infrastructure Hub and Oxford

Economics, worldwide investment in infrastructure is expected to be US$ 79 trillion by 2040, while the global investment need is expected to be US$ 97 trillion. Further, to close this US$ 18 trillion gap (the difference between actual and expected expenditures), the average annual global infrastructure investment would need to increase by approximately 23 per cent per year. Organizations need to start understanding the vulnerabilities of infrastructure to disaster and natural catastrophes. Eventually, they should link infrastructure investments to the fourth industrial revolution to build a resilient and sustainable infrastructure of tomorrow (Figure 5).

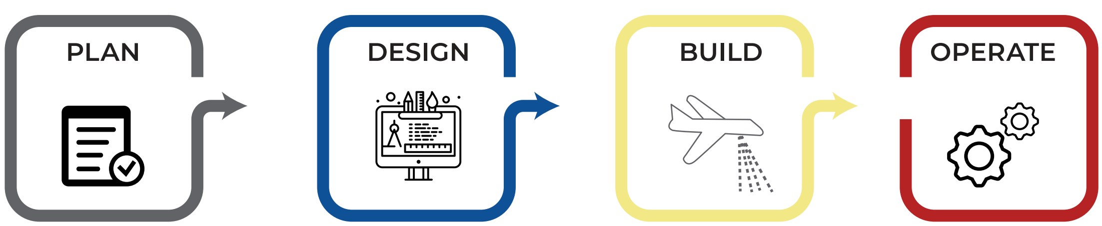
Credit: NASA

Geospatial and BIM Solutions for Resilient Infrastructure

Technology is central to manage the complex interactions within building resilient infrastructures in sustainable cities. To achieve the goal of resilience, many of the low-and middle-income countries need to improve their construction processes by way of the use of integrated geospatial and engineering solutions across the construction lifecycle. BIM, as it is defined, refers to a "combination or a set of technologies and organizational solutions to increase inter-organizational and disciplinary collaboration in the construction industry and to improve the productivity and quality of the design, construction and maintenance of buildings" (Miettinen and Paavola, 2014).

On the other hand, geospatial technology is defined as "any technology that enables the creation, management, analysis and visualization of geospatial data". Geospatial technologies – GNSS and Positioning, Geographic Information Systems (GIS) and Spatial Analytics, Earth Observation (EO) and Scanning – act as a common denominator for identifying vulnerable areas and conduct risk assessments to monitor and model critical assets and construct resilient infrastructure. Geospatial technologies collect accurate geo-referenced data which assists countries in developing resilient infrastructure approaches. Geospatial technologies for resilient infrastructure include the exploitation of geospatial data – from satellite/aerial imagery and visually depict physical features on the earth for land use planning to disaster management and emergency management. Geospatial dimensions are, thus, essential for developing resiliency strategies for the built environment. Consequently, geospatial hardware, software, and data (content) are necessary for smart planning and the construction of roads, bridges, airports, railways and metros, buildings and campuses, and other essential infrastructure for resilient surroundings.

Figure 6: Geospatial and BIM solutions across the construction lifecycle



PLAN
- Satelite Remote Sensing
- Total Station
- GIS
- LiDAR
- Photogrammetry
- BIM/CAD
- Drones/UAVs
- GNSS

DESIGN
- BIM/CAD
- GIS
- Point Clouds

BUILD
- LiDAR
- Total Station
- Ground Penetrating Radar
- Machine Control
- 3D Printing
- Drones/UAVs

OPERATE
- Enterprise GIS
- BIM
- GNSS
- Total Stations
- LiDAR

Source: Geospatial Media Analysis

The blend of a GIS layer with the BIM model provides designers with accurate information to design and construct resilient infrastructure, orientation and even construction materials.

When it comes to the utility of geospatial in resilient infrastructure – scanning, remote sensing, total stations, drones/UAVs, photogrammetry, and GIS are critical for building durable, resilient and sustainable infrastructure. Year after year, organizations and countries have been investing a substantial sum in repair and renovation of the crumbling infrastructure with modern construction. The confluence of geospatial, BIM, IoT and Big Data emerges as one of the core technologies shaping the future trends in resilient infrastructure by adding value to infrastructure project execution and also a geographic dimension for the built environment. Geospatial technologies, and BIM in particular are integral to Industry 4.0 frameworks that mandate digitization of the sector for operational efficiency such as cost-effectiveness, and to address data redundancy across the entire continuum of the plan, design, build and operate lifecycle of infrastructure projects. Digital engineering models emphasize delivering an integrated set of digital technologies, geometric models, data to craft design models in a digitized environment and overlays on 2D maps.

On the other hand, for engineering organizations, resilient infrastructure is related to the concept of the structural integrity of the physical infrastructure in extreme situations and conditions for which the use of BIM is imperative. From the engineering concept of resilience, resilient and sustainable infrastructure is based on the four 'R' principles (Bruneau et al., 2003) – namely,

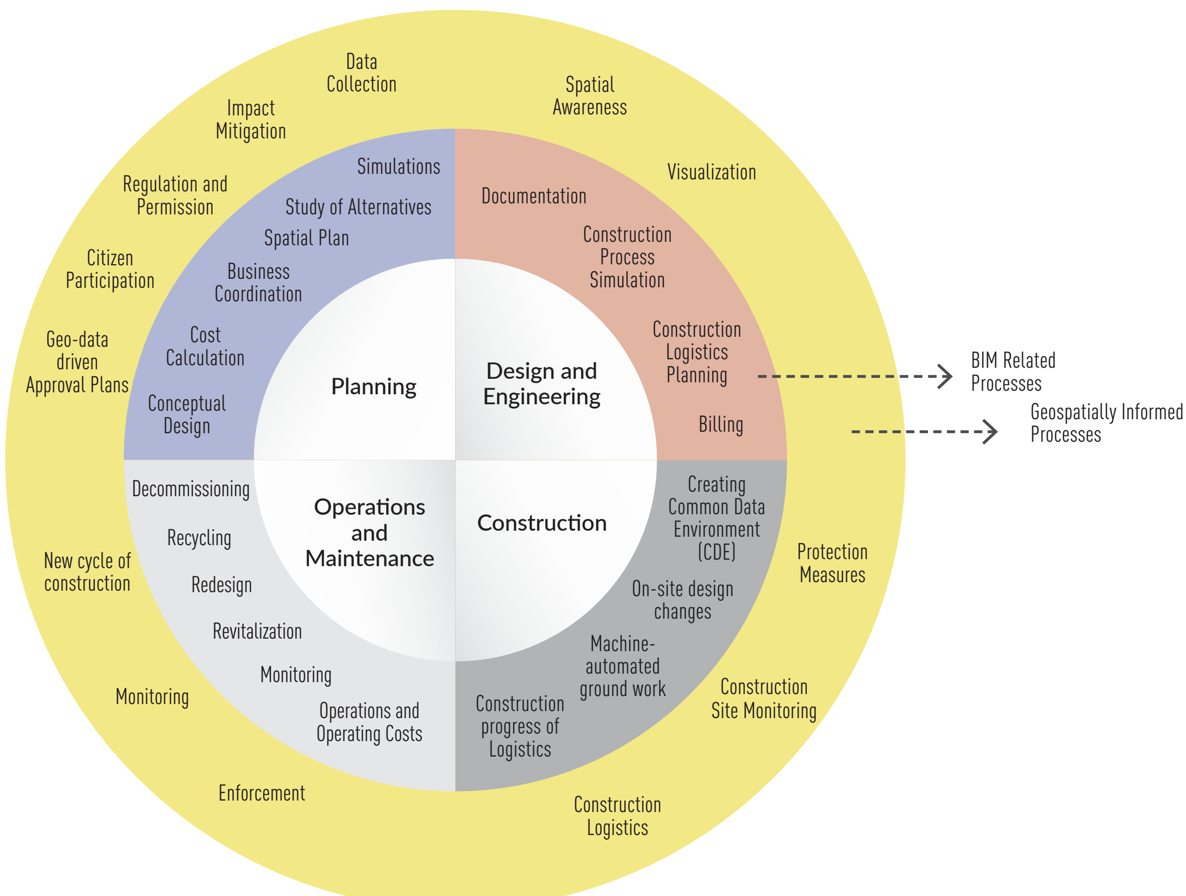
- Robustness: the inherent strength or resistance of an infrastructure asset to withstand extreme conditions and degradation
- Redundancy: infrastructure system properties that allow for alternative options, choices, and substitutions under stress
- Resourcefulness: the capacity to mobilize needed resources and services in emergencies
- Rapidity: the speed with which disruption can be overcome

The rapid growth in construction projects all over the world will come with sublime consequences. For countries to build resilient infrastructure – backed by the four 'R' principles, they will have to embrace geospatial and BIM solutions and accelerate international collaboration to address the impact on major socio-economic and environmental concerns. Identification of hazard and risk assessment using GIS yield effective models for crisis reaction; a GIS-based infrastructure resiliency model accounts for an event-driven solution based on what-if scenario visualizations. Spatial data are an important factor in such model while their availability, accessibility and interoperability remain decisive in the accuracy of the model. The challenge of data collection, processing and sharing is overcome by contemporary technologies like mobile mapping and remote sensing. The integration of a GIS-based model with other modelling techniques, including BIM, will strengthen infrastructure resiliency assessment.

Integrated Geospatial and BIM Solutions for Resilient Infrastructure

The integration of geospatial solutions with, notably, CAD and/or BIM, creates a binding synergy between spatial, technical and commercial data attributes – providing a much-required seamlessness among different spatial and non-spatial datasets. This has proven to be a prerequisite for a complex, connected, resilient and sustainable infrastructure. The concept of resilient infrastructure is, thus achieved, by the visible integration of massive data collection tools and technologies for the detection of vulnerable areas (LiDAR, 3D Scanning, etc.), BIM digitalization solutions for infrastructure, and protocols of actions and strategies for smart planning and smart construction.

Theoretically, digital engineering has been part of the AEC industry for quite some time now; there is still a scope for adopting digital engineering solutions for resiliency. 3D models can be used to collaborate and design the existing transport, building and industrial infrastructure, while simultaneously adding pioneering design and engineering dimensions to construct new infrastructure. Innovative digital engineering solutions have led to the creation of 3D design models and BIM for project management, drones and cloud computing for mapping, and surveillance of construction projects and virtual reality to provide a 360-degree and immersive view for monitoring construction projects. The im-



Source: Geospatial Media Analysis

plementation of digital engineering solutions improves product development at a high velocity. Furthermore, it creates a heightened product ownership experience, and lastly, it creates alternative revenue streams leading to efficient processes and quality control.

The usage of these integrated solutions across the construction lifecycle enhances resilience of the construction industry in both pre-and post-disaster phases across the supply chain, construction processes and operations and maintenance processes. The blend of a GIS layer with the BIM model provides designers with accurate information to design and construct resilient infrastructure, orientation and even construction materials. The confluence of the two relative scales of the GIS and BIM models provides for a better geospatial context and a 3D context to the project owner. Consequently, it leads AEC firms involved in resilient construction to better design and maximizing long-term value to solve those sustainability and resiliency issues facing infrastructure today. Also, engineers and planners can use geospatial data to accurately assess the resiliency of the large infrastructure projects from the planning to permitting phases. Thus, by the adoption of integrated geospatial and BIM technologies, the building and construction industry shall set forth the developing nations to a growth trajectory, paving the way for public-private partnership investments in building robust and resilient infrastructure to address major socio-economic and environmental concerns.

Key components of resilient infrastructure also include:

Geospatial Technologies for Urban Planning and Construction of Medical and Health Facilities: Geospatial technologies play a critical role in urban planning, for they possess the ability to better understand the needs for a city. Also, they enable the use of spatial information to design and fulfill those needs. Urban planners can use geospatial data sourced from satellites, aerial photography, scanners, remote sensors; process them utilizing GIS and gain a comprehensive perspective on land use and infrastructure. In today's time, the COVID-19 pandemic, wherein the world is demanding a descriptive, predictive and prescriptive analysis of infrastructure esp., geospatial technologies play a crucial role in progress monitoring of the swift construction of temporary hospitals and medical health facilities. Using geospatial technologies, urban planners can perform land use analysis, and guide new construction projects in being less prone to damage from natural disasters areas. Using GIS, project owners can synthesize information from diverse set of sources, model and predict the outcomes of multiple courses of action and share data with policy makers and urban planners to design and construct heath care facilities in cities. Geospatial technologies thus enable construction companies and health care organizations to create actionable plans for strategically planning the cities and meet the health infrastructure needs of a country.

Geospatial Technology to Protect Cultural Heritage: The use of remote sensing, 3D scanning and GIS tools for archeological applications is not new. Advanced remote sensing technologies allow archaeologists and the relevant organizations working in protection and restoration of cultural heritage to detect subtle landscape features by sensing 'light' that is invisible to humans (infrared, microwave etc.). Remote sensing data, together with spatial maps and CAD drawings (if available) pertaining to archeological sites can be processed via GIS and be better understood using 3D visualization. Today, more and more central and local authorities who are responsible for cultural heritage have embarked on creating complex and integrated information systems which include GIS. In times of disaster, and in conflict zones (during war time), geospatial technologies (especially remote sensing) play a critical role in providing accessible and precise resources to map the changes to the landscape. Also, they are immediately of help to appraise and detect the damage to cultural heritage sites located near these zones.

Geospatial and BIM Technology Ecosystem For Resilient Infrastructure

Geospatial Technology	Application/Benefit
Geographic Information System (GIS)	• Provides monitoring and visualization of critical infrastructure to provide answers to how to protect life and property in extreme situations. • Real-time update and collaboration with the project team, government stakeholders and non-profit organizations on the condition of an affected asset and its surrounding environment. • Captures location, discovers patterns and generate hypothesis of the affected utilities to simplify future construction and relocation activities.
Satellite Remote Sensing	• Helps in feasibility studies, designing & developing, monitoring strategy and policy making, and calculating benefits of disaster management systems. • Provides high-resolution and frequent data to map disasters and monitor forest deforestation and disturbances. • Offers the most effective way of monitoring activities which might not always be possible from the ground. Remote sensing data/earth observation data from different satellites provide periodic data for infrastructure asset monitoring, land use and land change. • Improves mapping of risks and priority areas, particularly ways in which local organizations and district or state-level forest authorities can provide input and interact with stakeholders.
LiDAR/Scanning tools	• Provide efficient and accurate mapping of storms' flood inundation, modeling storm surge, evaluating topographic changes, among others. Current elevation data comes in handy for infrastructure repair and redevelopment plans after a disaster. • Generate detailed 3D maps of topography and retrieve digital elevation data generated from point clouds. This allows for emergency responders to easily identify areas most affected by calamities.
BIM/CAD tools	• Are a cost-effective solution for infrastructure project development and delivery, as they include the ability to investigate multiple scenarios, data-driven – reducing errors and increase cost predictability and resilience. • Accurately locate the project design, also presenting the conditions of the climate, location and surrounding areas. The models can be reoriented and edited to optimize the required resources. • Can be used with energy analysis software to map and reduce the carbon footprint by optimizing resources.
Drone/UAVs	• Enable key identification of the local infrastructure and ecosystems. • Provide risk assessment, thus helping areas better prepare for disasters. • Generate maps more cost-effectively than traditional methods for emergency personnel coordinate response efforts, identify disaster prone areas and flag critical infrastructure.
Machine Control with GNSS and Positioning	• Provides for a three-dimensional position, velocity and time solution that enables the understand the reality of the ground in real time. • Results in minimization of environmental footprint, fuel consumption, thus lowering carbon emissions

Insights Through Case Studies

Leading geospatial and engineering solution providers play an instrumental role in providing geospatial and BIM solutions to address the critical infrastructure challenges of climate-change-related risks, energy risks (wasted fuel and carbon emissions), etc. Integrated geospatial and BIM solutions backed by 4IR technologies ensure the confluence of two different layers (GIS and BIM) for better design in 3D context. These result in the construction of a resilient infrastructure. The case studies have been segregated for the three SDGs in focus:

CASE STUDY I: Gorkha, Nepal Earthquake – 5th May 2015[1]

SDG GOALS: Goal 9: Industry, Innovation and Infrastructure; and Goal 11: Sustainable Cities and Communities

Mission Statement: The Gorkha earthquake in and around Kathmandu, Nepal, resulted in a structural loss – 8,700 people killed, complete and partial destruction of 7,69,000 houses and rubble of fallen public schools and government buildings.

Impact Objective: Radically transform how governments and homeowners build disaster resilient housing using technology and to reduce deaths, injuries, and economic losses caused by housing and school collapses due to earthquakes and typhoons in developing countries such as India, Nepal, etc.

Technology Use: The implementing organization Build Change used geospatial and BIM solutions to effectively conduct structural assessments, build 3D models, digital models, etc., to deliver its mission of building resilient infrastructure at a large scale in Nepal. Build Change used drone flights to conduct surveys by experimenting with camera settings to pursue 3D modelling of the disaster-hit villages. Build Change also used BIM solutions - alongside 4IR technologies to construct (and reconstruct) structurally resilient homes and schools. In this context, Build Change continues to work with the Government of Nepal to develop and test pre-engineered retrofit type design – to retrofit rather than rebuild resilient infrastructure.

Benefits: Improved structural workflows, refined construction models, obtained insights into how buildings will perform (resilience), developed better quality designs and improved project quality/delivery to make projects more resilient and profitable.

CASE STUDY II: Lisbon, Portugal Operational Resilient Digital Twin Model[2]

SDG GOALS: Goal 9: Industry, Innovation and Infrastructure; and Goal 11: Sustainable Cities and Communities

Mission Statement: To manage and maintain Lisbon City Government's drain infrastructure against climate change conditions and develop a drainage masterplan to mitigate the risks from rising sea levels and fre-

1 Autodesk Foundation, Team4Tech, and Build Change: https://buildchange.org/3-organizations-8-volunteers-and-500000-damaged-houses-how-autodesk-foundation-team4tech-and-build-change-are-collaborating-on-efficient-earthquake-recovery-in-nepal/

2 City-scale Digital Twins for Flood Resilience: https://www.gim-international.com/content/article/city-scale-digital-twins-for-flood-resilience

quent extreme rainfall events which results in increased flood risks leading to soil imperviousness and more flooding in the region. Goal is to reduce the registered inundations.

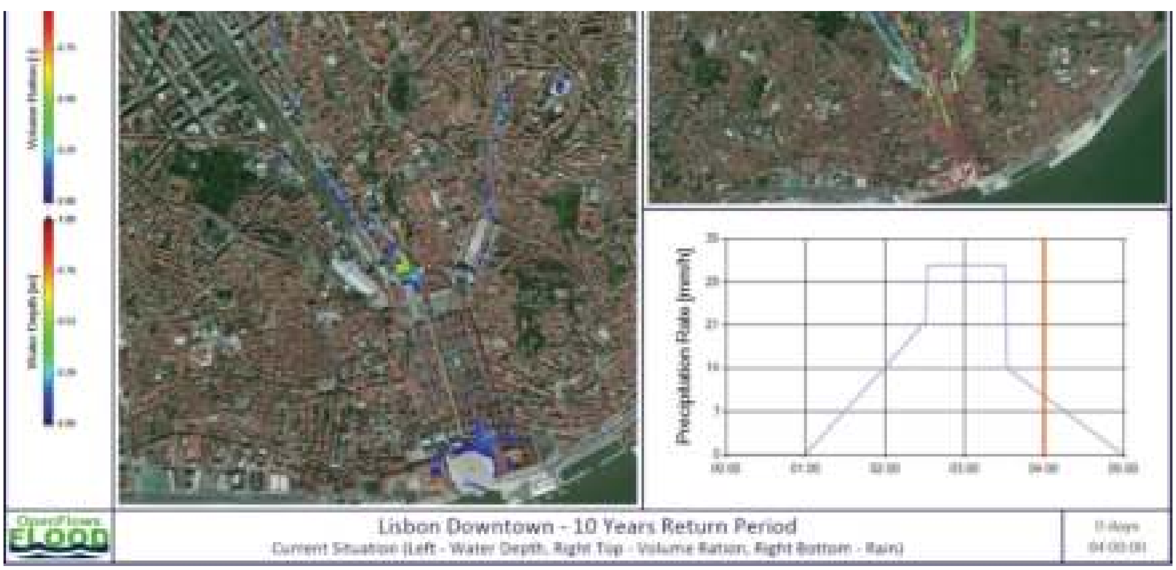
Impact Objective: To achieve Urban Flood Simulation that enables Lisbon to comprehensively model alternative scenarios and help the city avoid a predicted amount of 20 floods over the next century.

Technology Use: In 2008-2014, Lisbon City Government created a digital twin for urban flood simulations in order to model alternative scenarios. Using a connected data environment, Águas do Porto, EM created a digital twin consisting of terrain information, real-time sensors, video surveillance of infrastructure, numerical modeling, remote data acquisition, and public reporting. The organization wanted to use a digital twin to model and perform predictive analysis of the city's water supply, wastewater, stormwater, and bathing water systems to forecast flooding and water quality issues. The end goal was to improve the city's response and resilience. It developed a comprehensive drainage plan that guards the city against the changing climate risks—using the digital twin models, thus transitioning from a reactive to a proactive mindset to mitigate flood risk through developing models by intervening with existing infrastructure. Flood modeling scenarios include many different data types such as hydrometeorological data, GIS, BIM, and more. The flood models can help calculate where the water is going, how deep and at what velocity. The model helped to predict behavior based on changes made in the modeling scenarios, so that risk mitigation planning can occur.

Benefit: The result of the digital twin is that between 2008-2014, only 15 inundations events occurred. The use of digital twins enhanced the drainage capacity of existing stormwater systems - resulting in the creation of a new mitigation strategy - leading Lisbon to avoid 20 floods over 100 years and save 100 million of Euros.

CASE STUDY III: 100 Resilient Cities – pioneered by the Rockefeller Foundation (Concluded in August 2019)[3]

SDG GOALS: Goal 9: Industry, Innovation and Infrastructure; and Goal 11: Sustainable Cities and Communities



3 100 Resilient Cities – Pioneered by the Rockefeller Foundation – Teams with Trimble for Innovative Global Urban Resilience Initiative: https://www.wateronline.com/doc/resilient-cities-trimble-for-innovative-global-urban-resilience-initiative-0001

Mission Statement: Develop a robust resilience strategy for 100 Resilient Cities, to helping cities become resilient to shocks and catastrophic events like hurricanes, fires, earthquakes, and floods. It's a $ 8 million commitment to continue supporting the work of Chief Resilience Officers of 100 member cities within the Resilient Cities Network.

Impact Objective: To support the implementation of resilience initiatives across the country.

Technology Use: Rockefeller Foundation collaborated with one of the leading geospatial technology providers to provide a vital resilient building tool to the selected 100 cities to enable more informed decision by putting big data to work. Using Trimble's eCognition Essentials Software, cities are able to leverage satellite and aerial imagery from Unmanned Aerial Vehicles (UAVs) to collect highly accurate geodata and use it with GIS. Using the eCognition Essentials Software, cities build infrastructure transforming images into quantifiable, actionable insights. Also, using the software cities could focus on reducing their carbon footprint by increasing their urban forest. To track success, the software allows cities to establish a baseline to measure their future progress. Besides, the software helps to classify high number of ground covers, from permeable and impermeable surfaces to grassland, as well as areas with flooding or fire damage. The software is used in collaboration with Digital Globe (2015) – provider of high-resolution satellite imagery; and Esri's repository of GIS data.

Benefit: Data collected from satellite and UAV's is accelerated and automated via the eCognition Essential Software for easy change detection transforming geodata into intelligence for building resilient infrastructure.

CASE STUDY IV: Alto Ceira Project[4]

SDG GOALS: Goal 9: Industry, Innovation and Infrastructure

Mission Statement: To monitor the leading causes of dam deterioration and the effects of the serviceability and safety of the dam – and define strategies to build a more resilient and sustainable dam.

Impact Objective: Dam Monitoring using combined terrestrial imaging systems.

Technology Use: The Alto Ciera project is a concrete arch dam located in Coimbra, Portugal. Over the years the dam has shown an anomalous behavior highlighting the deterioration of the dam inclusive of cracking such that experts found it difficult to conduct surveying and mapping of and on the dam. For visual inspection of the dam, terrestrial laser scanning technology and the digital image registration is used to acquire a digital surface model. Also, with CAE software and relevant geospatial technology, 3D data models built on spatial information are collected, which approach reality as closely as possible - like contours, longitudinal and transversal cross-sections. The visualization of 3D texturized models in virtual reality environments where analysis and decisions are made, sparing additional fieldwork. The 3D models so developed lead to the production of engineering documents to evaluate the state of the dam. The gathered information is accurate from a positional point of view and less subjective from a semantic point of view.

Benefits: The use of scanning technology is suitable, as it allows complete coverage of the dam structure, as well as of the near slopes in a fast, accurate and economical way. The data so collected is integrated with

4 Assisted visual inspection of dams as a tool for structural safety control: A case study https://www.researchgate.net/publication/281295783_Assisted_visual_inspection_of_dams_as_a_tool_for_structural_safety_control_A_case_study

conventional CAD software and classified into a database management system which helps in building resilient infrastructure.

CASE STUDY V: City Resilience from natural disasters with GIS

SDG GOALS: Goal 9: Industry, Innovation and Infrastructure; and Goal 11: Sustainable Cities and Communities

Mission Statement: Building enabling infrastructure by embracing GIS to make cities more resilient.

Impact Objective: To implement enterprise-wide GIS while putting a strong focus on standards and centralization to ensure no silos of information exists.

Technology Use: To map the 1800+ trees which fell in June 2013 in a storm in the USA, city professionals used an ArcGIS based app called MapIt on mobile devices to develop an inventory of the fallen trees. This app enables the removal of the tree debris, removal of the stumps, and strategize and plan reimbursements and replantation of trees. Deploying MapIt, operation data, or location data in this case, is immediately integrated with layers using ArcGIS on mobile devices. The use of GIS helped the city remove hazardous fallen trees, repair infrastructure damage (near fallen trees), and recover funds. The purpose of the application is to enhance the city's resiliency and save the city's money.

Benefits: The long-term benefit of using GIS is that it streamlines data collection processes and enable collaboration, communication and analysis on the basis of the needs and requirements of the users.

CASE STUDY VI: The hole that saved a city

SDG GOALS: Goal 9: Industry, Innovation and Infrastructure; and Goal 11: Sustainable Cities and Communities

Mission Statement: To use total robotic stations to collect and monitor dataset control points for registering 3D laser scanner point cloud data.

Impact Objective: To reduce the destruction caused by intense weather systems.

Technology Use: The Metropolitan Water Reclamation Project (MWRD), Chicago, undertook an expansion project at the wastewater treatment facility to improve stormwater management at the facility. It also includes the construction of a diversion structure for high-level emergency overflow. The project consists of a new weather reservoir which includes a well in large in-ground structure of 215X165X30-feet deep, reliable, leak-proof and capable of handling overflow from the most significant storms. To collect data for monitoring operations, a laser scanner was used owing to its portability, and one-person operation, to create point clouds of the excavated sheer walls to monitor any movement. The significant benefit of using the ScanMaster for the built-in CAD functions allowed the construction/operations and maintenance company to collaborate with stakeholders in the and provide accurate data in real-time. Using the scanner, the contractor is now able to conduct weekly scans of the rock walls and provide highly accurate data for repurpose use. By the use of laser scanning technologies – the MWRP has restored confidence that the city will be resilient from unstable weather situations in the region, i.e. flooding, etc.

Benefits: The use of scanning technology provides a high degree of accurate data for monitoring and operations and maintenance of projects.

Case Study VII: (Re)Building heritage sites by resilience standards[5]

SDG GOALS: Goal 9: Industry, Innovation and Infrastructure

Mission Statement: To use technology to help analyze and return the heritage sites lost due to destruction due to astounding rate with mounting pressures from climate change, urban development, natural disasters and armed conflict.

Impact Objective: To (re)build heritage sites across three principal areas – conservation, recovery and discovery.

Technology Use: The organization involved recognizes the importance of landscape and heritage recording and documentation with optical remote sensing sensors, digital 3D documentation, new sensors, data capture methodologies, and multi-resolution 3D representations. The organization, thus, uses artificial reality capture technology to create a holistic and accurate 3D surface model of the sites. To collect spatial data, the company uses, LiDAR or laser scanning tools which provide with high-resolution imagery from the ground in combination with high resolution aerial imagery captured from drones – to combine it into a 3D model. Further, an immersive and virtual reality environment is created for heritage sites wherein reconstruction is not possible. The organization involved has been able to complete 200 projects across 7 continents by using LiDAR and photogrammetry tools to maintain the heritage sites, and discover materials that were unknown before, thus, in long-term benefitting the country's environment, economy and GDP.

Benefits: The use of technology has helped the organization to meet 8 targets of the 9th Sustainable Development Goal, while at the same time ensuring cultural sustainability and resilience of existing infrastructure.

CASE STUDY VIII: Mapping Landslide-Prone Areas along Continental Divide

SDG GOALS: Goal 9: Industry, Innovation and Infrastructure; and Goal 13: Climate Action

Mission Statement: Using high-resolution LiDAR data and aerial imagery to assess three landslide-prone areas to evaluate, prioritize and mitigate possible landslide events.

Impact Objective: To analyze and monitor habitually unstable areas and further mitigate the impact of these natural landslides.

Technology Use: In Wyoming, the region near the Shoshone National Forest boundary, east of Togwotee Pass and west of Dubois – closer to Yellowstone National Park

5 LiDAR key tool for preserving cultural heritage: https://www.directionsmag.com/article/6807

and along the Continental Divide – various geological conditions have caused multiple landslides over the past decade. Wyoming Department of Transportation (WYDOT) contracted Woolpert to utilize the organizations' Terrain Mapper LiDAR sensor to deliver classified LiDAR data and aerial imagery to enable WYDOT's photogrammetry and survey section to create well-defined digital terrain models (DTMs), and triangulation irregular network (TIN) models specific to the needs of the department. Advanced mapping data collected was used essentially for disaster resilience applications at multiple local, state and federal level.

Benefits: Clearly defined, highly accurate and custom digital terrain models to mitigate landslide areas.

Case Study IX: Spatial Digital Twin to help Shape the Cities of Tomorrow[6]

SDG GOALS: Goal 9: Industry, Innovation and Infrastructure; and Goal 11: Sustainable Cities and Communities

Mission Statement: To develop a Spatial Digital Twin by way of 3D and 4D digital spatial data and a model of the built environment in New South Wales.

Impact Objective: To use digital twin models to transform urban planning and infrastructure across Western Sydney.

Technology Use: The project entails use of powerful data visualization, simulation and collaboration tools to create a digital twin model of the small and large-scale physical objects, buildings, cities, regions and systems in New South Wales. The NSW Spatial Digital Twin – digital real-world model of NSW - leverages web-mapping and visualizing data in 3D+time to build a real-world digital twin prototype of Western Sydney (in collaboration with the NSW Department of Customer Services' Spatial Services). The Spatial Digital Twin integrates data sets from across the NSW government such as live transport data, above and sub-surface infrastructure (above and below ground), building information models, property models, health infrastructure, etc., to help enable integrated city planning. The interactive tool includes 22 million trees with height and canopy attributes, almost 20,000km of 3D roads, and 7,000 3D strata plans and 546,206 buildings.

Benefits: Access to better data for developing better solutions to help improve the modeling, improve the accuracy of cities and integrate city planning to transform urban planning and infrastructure. Using the spatial data from the Spatial Digital Twin model, the national, state and local governments can also improve their disaster management strategies.

CASE STUDY X: Lowering Climate Change Risks with Machine Control in Faroe Islands

SDG GOALS: Goal 13: Climate Action

Mission Statement: Plan Sp/f's, a 40-year-old construction company aims to work in a green and efficient way by way of reducing fuel consumption and consequently, lower CO2 emissions. in order to lower climate change risks.

Impact Objective: To minimize carbon footprint by saving time and rework.

Technology Use: The Faroese Islands poses serious climatic challenges due to unpredictable and everchanging climatic behavior. Due to extreme water conditions, construction companies/project owners need to stra-

6 New South Wales government launches Digital Twins: https://www.smartcitiesworld.net/news/news/new-south-wales-government-launches-digital-twin-5060

tegically prepare construction sites to be dry instead of muddy. To meet the ambition of Plan Sp/f of minimizing the environmental footprint – the construction company employed GNSS based positioning systems on machine control equipment's to save costs, time and fuel. Combined with real-time machine positioning solutions, GNSS based machine control systems – contains a data controller which creates the 3D model or digital terrain model which enables location sharing, and spatial information of the construction site for contractors to work in a more precise and faster fashion. By using a real-time monitoring tool on the excavator, the field workers are directly able to see the construction site on their machine control systems – to work on only what is necessary, and save time, fuel and costs.

Benefits: The use of GNSS embedded excavators results in minimization of environmental footprint, fuel consumption, and consequently lowers carbon emissions, leading to a step towards building resilient infrastructure.

Case Study XI: Smart maps guide Covid-19 investigations and actions and monitor effectiveness

SDG GOALS: Goal 3: Good Health and Well-Being; and Goal 11: Sustainable Cities and Communities

Mission Statement: To determine who an infected person has come in contact with; monitor the spread of virus through time and space to implement control, preventive and surveillance measures using location intelligence

Impact Objective: To help policymakers and heath care professionals to use GIS to evaluate available facilities and increase healthcare capacity.

Technology Use: Health Analysts use GIS to track the Covid-19 situation. GIS and spatial datasets to link the interactions of infected people by mapping credit card transactions and mobile phone location traces to see where an infected person has been and who

Johannes Hellisdal of Plan Sp/f in his new hybrid excavator equipped with iXE3 solution.

they may have come in contract with. Investigators using the GIS app, used it to map boundaries around areas of known infection to trace who may have been exposed to infection, and how spatial information and location tools can compound the spread. The tool also helps the authorities to trace and get in touch with people who may have entered the infected person's orbit to quarantine themselves.

The spatial information of the surrounding area also enables the policy makers to implement travel bans, cancel group events, and implement all effective tactics to flatten the curve – and slowdown the spread. GIS tools are also helping the people to map the shortage of hospitals and monitor diminishing capacity and compare it against the increasing infection rates allowing real-time shuffling of resources to boost capacity where COVID-19 response is needed most.

Benefits: The use of GIS enables the health professionals to forecast and visualize the changing rates of diseases to guide decisions, and implement control, preventative and surveillance measures. The science and evidence-based underpinnings of GIS maps also serve to suppress misinformation.

Identification of hazard and risk assessment using GIS yield effective models for crisis reaction; a GIS-based infrastructure resiliency model accounts for an event driven solution based on what-if scenario visualizations.

Challenges in the Adoption of Integrated Geospatial and BIM Solutions for Building A Resilient Infrastructure as Per SDGs

Resilient infrastructure is required to absorb shocks and have economies self-organize themselves during periods of disaster and crisis. Integrated geospatial and BIM technologies backed by 4IR technologies have a critical role to play in decoupling the economic development from environmental degradation as defined under the UNSDGs. However, countries/organizations often find it difficult to adapt new technologies as part of their workflows to reduce vulnerabilities and build capacities to assess, monitor and manage risks and create a resilient built environment. Some of the challenges in geospatial and BIM technology adoption are as follows:

1. Lack of Technology Awareness

The use of technology to meet the SDGs is still improper, and in a very nascent stage. Particularly, infrastructure, construction, and urban planning, which are critical for most of the goals as defined under SDGs, have conventionally been lagging in technology adoption throughout the world. Most of it can be attributed to the low awareness of the benefits of technology adoption. Addressing this challenge will require multi-pronged initiatives that would among other things, include:

- awareness campaigns (spreading knowledge about the availability of technology solutions, address their viability, training programs to enable ease of usage)
- policy-level interventions (mandating the use of suitable technologies, reducing the waste produced during construction, incentivizing best practices),
- re-skilling drives (joint programs to re/up-skill the workforce)
- social stimulation (educating the end-users to demand greener and cleaner infrastructure)

2. Cost of Technology and Disruptive Implementation

Developing countries often find the cost of technology and its implementation to be high. They believe this can cause a potential dent to their investments with no clear sign of benefits. The construction and infrastructure sector, in particular, is a highly cost-intensive and competitive industry, wherein most EPC companies and contractors operate on slim margins. Due to poor financial outlook and profitability, many of the organizations responsible for building resilient infrastructure, especially in developing countries, do not find it beneficial to invest in new technologies. Additionally, integrated geospatial and BIM solutions are seen to be a disruptive implementation, especially with regards to its adoption across the construction lifecycle. While the developed countries are known to be using a confluence of technologies to build the infrastructure of tomorrow, drones, BIM, GIS, etc.; the cost of technology coupled with lack of awareness is a significant challenge in developing countries. Because technology resilience is costly, it is a frequent target for infrastructure budget cuts. However, with growing numbers of pilot projects where new and disruptive technologies prove their merits, it will become easier for businesses to adopt these new-age technologies and step forward with a technology-driven resilience strategy.

3. Data Availability and Accuracy

Data availability and accuracy continue to be a predominant challenge for developing countries to meet the UNSDGs and in return build resilient infrastructure. The geospatial divide which exists between the developed and developing countries is of paramount importance. Spatial data, which is core to the decision-making process to identify the vulnerable areas, needs to be updated in real-time to target areas of high exposure to disasters. More often than not, the spatial data available with urban planning bodies, construction companies, national data agencies, etc., is not accurate or of high-resolution. Consequently, the data proves to be worthless for decisions related to infrastructure planning. Using cutting-edge geospatial technologies such as scanning tools (LiDAR), earth observation, GNSS and Positioning, organizations can collect highly accurate and real-time spatial data which has the potential to change the entire paradigm of building resilient infrastructure. It is only when the stakeholders understand the benefits of embedding smart technology, the likelihood of the highest impact on extreme weather events and natural disasters. Thus, by extension, resilient infrastructure is very much data-dependent and by extension of it on the technology embedded during the process.

4. Lack of Skilled Manpower

The construction industry is the least digitalized amongst all sectors. Furthermore, the sector suffers because of the lack of a skilled workforce. Adoption of new technology calls for skilled and educated professionals which is majorly deficient in the construction industry – and thus, impedes the construction of resilient infrastructure. Because both geospatial and BIM are niche technologies, and resilient infrastructure is a new paradigm, the construction industry is in need of human resources with a competitive geospatial skill set to ensure the adaptation of technology to build the requisite infrastructure productively and efficiently. It also requires a strong collaboration within the geospatial industry, AEC firms, research and academia to develop the necessary skillset and develop a geospatial and BIM resilience program to hone the skills of the upcoming graduates and future employees. This may require a mandate from the policy-decision makers to mandate the use of technology, especially in the developing world across all infrastructure projects.

5. Lack of Policy Mandate

A lack of policy mandate is a significant impediment in the construction of resilient infrastructure. While many countries such as France, UK, Spain, Denmark, etc., have mandated BIM (mostly inclusive of geospatial) across infrastructure projects, developing countries are still at a nascent stage of adoption. Governments must mandate the use of integrated geospatial and BIM technologies for they lead to resilient infrastructure design and documentation, information management, and asset management. Integrating resilience, BIM, geospatial and green building entails a keen focus of the contractor/developer on design for durability over time. It further entails resiliency design, which is planning the design of the project by thinking carefully about the typical use scenarios of the building, and its likely response to the challenges in the environment. A mandatory geospatial and BIM system will, ensure high standards of construction are met to address the UNSDGs.

6. Lack of Available Value-Based/Return-On-Investment Case Studies

A major roadblock in the adoption of integrated geospatial and BIM technologies, as also mentioned above, is the lack of awareness of the technology. However, this lack of awareness arises due to the dearth of case studies which emphasize the value proposition, the return on investment and the need for using integrated geospatial and BIM solutions in infrastructure projects. While the AEC industry for the longest time has found it challenging to measure the return on investment on technology in infrastructure projects – however, there are still many ways in which the ROIs communicated to the broader ecosystem. For instance, an increase in productivity in terms of time and cost savings is a critical factor for assessing the benefit of an assisted tool/technology. Thus, the geospatial and BIM industry along with the AEC firms can play a strategic role in imparting the required knowledge via case studies and news articles to the government and policymakers on the benefits of accelerating technology use across the construction lifecycle to further the goal of resilience.

7. No Clear-Cut Data Sharing Guidelines/ Lack of Single Interactive Platform

For any infrastructure project to successfully take off, base map data – made available via National Mapping Agencies and/ or the Geological Survey is critical. In many of the developing countries, most of the geospatial data created, lies in silos because there is no single interactive platform which collates all value-added data from the different departments of the ecosystem. The lack of up-to-date, contextual data-sharing guidelines leads to multiple departments controlling permission – thus, leading to a slow decision-making process. It is imperative for the developing countries to formulate their data-sharing guidelines and simultaneously develop a mutli-source interactive data platform to aid the infrastructure ecosystem.

Integrated geospatial and BIM solutions are seen to be a disruptive implementation, especially with regards to its adoption across the construction lifecycle.

Way Forward

The value proposition of integrated geospatial and BIM solutions to advance the UN SDGs with specific focus on resilient infrastructure and the challenges faced by stakeholders in adoption of geospatial technologies has been well established in the previous sections of this white paper. To bridge the geospatial digital divide, the United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM) and the World Bank have developed a strategic framework, called the **Integrated Geospatial Information Framework (IGIF)** which provides a basis and guide for lower to middle-income countries to encapsulate new and innovative approaches to develop national geospatial information management, and implement integrated evidence-based decision-making solutions[1].

The IGIF, provides for societal, economic and environmental benefits to bridge the digital divide in developing countries. The framework is implemented such that it helps to create awareness, improve services to citizens, build capacity for using geospatial technology, enhance government decision making processes, and undertake practices to achieve a digital transformation.

The IGIF establishes nine strategic pathways in three main areas of influence: governance, technology and people. The nine strategic pathways – Governance and Institutions, Legal and Policy, Financial, Data, Innovation, Standards, Partnerships, Capacity and Education, and Communication and Engagement – defined by the IGIF framework is used to draft the following recommendations for implementing integrated geospatial and BIM technologies to advance SDGs from the perspective of resilient infrastructure:

Governance and Institutions, Legal and Policy

- Integrated geospatial and BIM technology solutions should be incorporated as a policy/guideline for all infrastructure projects in policy; industrial strategies and procurement guidelines at a national level.
- Project owners should be encouraged to mandate the use of integrated geospatial and BIM technologies in their Detailed Project Reports (DPRs) – a detailed and elaborate plan which encompasses the different roles and responsibilities, activities, and resources – financial and technology required during a construction project lifecycle. Policy mandates aimed at integrating technology in key features of infrastructure projects shall enhance the uptake of geospatial and BIM solutions across the lifecycle.
- Technology and data help cities absorb climate-change shocks and population growth coming their way. Government authorities should work towards mandating smart technologies and open data sharing (real-time information) to optimize existing systems and reduce strain on the available and limited resources. Cities can use technology to manage their every-day stress and prepare for worst-case scenarios to improve operational capabilities and future-proof infrastructure.

Data, Innovation, and Standards

- Resilience should be made part of asset

1 Integrated Geospatial Information Framework: https://ggim.un.org/meetings/GGIM-committee/8th-Session/documents/Part%201-IGIF-Overarching-Strategic-Framework-24July2018.pdf

development and the design phase of buildings and infrastructure using new-age construction technologies such as CAD, BIM, Digital Twins enabled by the 4IR technologies such as AI, IoT, etc. Using 3D models, energy modules and high-precision data collection technology, stakeholders involved in a resilient infrastructure project should consider consulting with technology experts and strategists to implement a successful resilience strategy.
- Since technology is advancing at a fast pace and becomes more accessible, advanced analytics on data collected from sensors can help infrastructure owners to decide whether to maintain or replace an asset.
- Infrastructure owners need to formulate layered plans and use a range of adaptation strategies to mitigate climate-related asset risks. Owners should extensively look at adopting integrated geospatial and BIM solutions to: Firstly, build robust designs in the planning and designing phase of the construction lifecycle; and secondly, to focus on asset-level infrastructure assessments.

Partnerships, Capacity and Education, and Communication and Engagement

- To build resilient and sustainable infrastructure, the necessary stakeholders – infrastructure owners, contractors and operators must build forward-looking leadership teams, technology enthusiasts, and investors to support new solutions, reshape capital markets and take a long-term approach to infrastructure asset development. Associations like the World Federation of Engineering Organizations, and the World Geospatial Industry Council can play a pivotal role in enabling collaboration amongst the technology providers and the research and academia organizations to stimulate discussions on skills gaps. If the two ecosystems collaborate, they can jointly develop integrated geospatial and BIM technology solutions as part of elective/main courses in the curriculums of engineering schools leading to technology sensitization at an early stage in students (future employees).
- Professional and industry associations can provide short term orientation courses for infrastructure professionals to enhance the adoption of geospatial and BIM solutions across infrastructure projects.
- Technology providers should collaborate to develop and present successful case studies on the value-proposition and return on investment in geospatial and BIM technology and share it with the larger ecosystem. When the key stakeholders (project owners/government, architecture, engineering and construction firms) become aware of the implementing guidelines of technology, benefits and the return on investments they are motivated to adopt geospatial and BIM technology in the project lifecycles.

Financials, Partnerships

- Incorporate low-carbon development strategies by rethinking infrastructure investments to mitigate climate change and adapt to its risks, planned investments must be steered towards lower-carbon, climate-resilient options. Currently, very few administrations around the world look at emissions during construction and operations as a cost. A transition to low-carbon, climate-resilient cities requires better and more intelligent urban infrastructure investments and a shift in the way existing financing streams are allocated.
- Communities may want to start looking at building a forward-looking investment model and accelerate investment in infrastructure to carry out proactive repairs of their ageing and inefficient assets. This also includes investment in new technologies and green infrastructure to build robust and flexible infrastructure systems.

Glossary

1. **Building Information Modeling (BIM):** Refers to a combination or a set of technologies and organizational solutions to increase inter-organizational and disciplinary collaboration in the construction industry and to improve the productivity and quality of the design, construction and maintenance of buildings
2. **Geospatial technology:** Any technology that enables the creation, management, analysis and visualization of geospatial data. Types of geospatial technologies are – GNSS and Positioning, GIS and Spatial Analytics, Earth Observation, and Scanning
3. **Resilient Infrastructure:** As the ability of an infrastructure asset to absorb the disturbances caused by disaster and climate risks (Arup, 2014) and retain its functionality and structural capacity.
4. **Terrestrial laser scanners:** Contact-free measuring devices which can collect dense point-clouds of objects – in 3D. The emitted beams are highly directional, contain a lot of energy, bridge hundreds of meters and are reflected from the surfaces of objects.
5. **LiDAR:** LIDAR, which stands for Light Detection and Ranging, is a remote sensing method that uses light in the form of a pulsed laser to measure ranges (variable distances) to the Earth. These light pulses—combined with other data recorded by the airborne system— generate precise, three-dimensional information about the shape of the Earth and its surface characteristics. A LIDAR instrument principally consists of a laser, a scanner, and a specialized GPS receiver (NOAA).
6. **CAD:** CAD (computer-aided design) software is used by architects, engineers, drafters, artists, and others to create precision drawings or technical illustrations. CAD software can be used to create two-dimensional (2-D) drawings or three-dimensional (3-D) models.
7. **Bathymetric Survey:** Bathymetric surveys allow us to measure the depth of a water body as well as map the underwater features of a water body. Multiple methods can be used for bathymetric surveys: Multi-beam surveying: A multi-beam echo sounder attached to a boat sends out a wide array of beams across a "swath" of the waterbody floor (USGS).
8. **3D-Modelling:** 3D modeling is the use of software to create a virtual three-dimensional model of some physical object.
9. **Photogrammetry:** Photogrammetry is the science of making measurements from (aerial) photographs. The input to photogrammetry is a photograph, often referred to as a 'raster image'. The output is typically a map, a drawing, a measurement, or a 3D model of some real-world object or scene.
10. **Remote Sensing:** Remote sensing is the science of obtaining information about objects or areas from a distance, typically from aircraft or satellites.
11. **Total Robotic Stations:** Robotic Total Station (RTS) is a Total Station that allows remote operation by one land surveyor. This means you only need one operator and can perform far more calculations and inspections in less time than with a traditional Total Station.
12. **Digital Twin:** A digital twin is a virtual model of a process, product or service. This pairing of the virtual and physical worlds allows analysis of data and monitoring of systems to head off problems before they even occur, prevent downtime, develop new opportunities and even plan for the future by using simulations (Forbes).
13. **Fourth Industrial Revolution:** The Fourth Industrial Revolution is a way of describing the blurring of boundaries between the physical, digital, and biological worlds. It's a fusion of advances in artificial intelligence (AI), robotics, the Internet of Things (IoT), 3D printing, genetic engineering, quantum computing, and other technologies.

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