DEMARCATING THE DEADLIEST ROADS AND ACHIEVING AIoT AMELIORATION

- Uncovering the Perils of the Nilgiris

An All- Encompassing Case Study

Overview

The district of Nilgiris, located in the southern Indian state of Tamil Nadu, is a picturesque area dotted with tea plantations and home to the **hill station of Ooty**, known as the **"Queen of the Mountains."** However, the district presents a unique set of challenges for emergency responders, healthcare providers, and policymakers, including **road accidents and landslides**, In order to address these challenges and improve the safety and well-being of residents and visitors, our team of researchers and GIS experts has developed a set of four maps that **leverage cutting-edge technologies such as QGIS, AIoT and HNT** to provide critical insights into the district's infrastructure, healthcare facilities, and hazardous zones.

Project Goals and Objectives

- The objective of this project is to develop a **comprehensive safety and healthcare network for the Nilgiris** district using advanced technologies like **AIoT (Artificial Intelligence of Things) enabled networks**.
- This project aims to achieve the following:
- ***Identify landslide hazard zones and dangerous roads*** in the district.
- ***Develop hospital catchment areas*** according to district health facility, community health facility, and primary medical facility.
- Create a ***hierarchical network topology using SpaceNet and AeroNet*** to scale the network to a national level.
- Facilitate the ***timely delivery of information to nearby hospitals and police stations*** to save lives in case of accidents.

Geospatial Data Collection

- **Healthcare Catchment Area and police station Map**: The geospatial data was collected using **satellite imagery, digital mapping and aerial surveys**. The data was processed and analyzed using Geographic Information Systems (GIS) software to identify the areas that are most in need of healthcare facilities and collected information on all the police station's location, infrastructure, and services provided in the particular district. This information was then **digitized and integrated** into a geospatial database using specialized mapping software.

- **Landslide Vulnerable Hazard Zones and Deadliest Roads Map**: The geospatial data was collected through **field surveys, satellite imagery, and remote sensing techniques**. The data was then processed and analyzed using GIS software to identify the areas that are most at risk of landslides and identify the roads that require attention.

Workflow Tools

https://www.figma.com/

https://download.qgis.org/

QGIS

Sources of Map Data

https://ndma.gov.in/

https://data.gov.in/

https://nilgiris.nic.in

https://www.nrsc.gov.in/

https://www.isro.gov.in/

https://bhuvan.nrsc.gov.in/

https://www.ncess.gov.in/

Exploring the Study Area

These Study Area maps displays the geographical region of the Nilgiris district, encompassing a total area of approximately **2,565 square kilometers** covering various villages, towns, and cities in the district, including **Ooty, Coonoor, Kotagiri, Gudalur, Pandalur and Kundah**. To gather comprehensive data on the district, geospatial data was collected and analyzed for four key maps. ***The first map*** highlights the different ***healthcare catchment areas and police station distributions***, providing vital information for emergency responders and healthcare providers. ***The second map*** identifies ***landslide vulnerable hazard zones and dangerous roads***, providing critical information to emergency responders and residents. ***The third and fourth maps*** utilize HNT models to scale the project to a national level, utilizing ***AeroNet and SpaceNet technologies*** to create a network of interconnected units and layers for efficient data transmission and analysis.

Map 1: AIOT- Driven Safety and Healthcare Network of the Nilgiris

Imagine a map that is not just a collection of lines and dots, but ***a lifeline that shows the way to safety and well-being***. This map highlights the distribution of healthcare facilities in the district, including ***Primary Health Centers, Community Health Centers, and District Hospitals***, with buffer zones of ***5 km, 15 km, and 30 km*** indicating their respective ***catchment areas***. Additionally, the map displays the ***locations of police precincts*** in the Nilgiris district. The inclusion of ***ambulance services*** and their accessibility in the catchment areas of healthcare facilities and police precincts can aid in ***emergency response management***. This comprehensive representation of healthcare and safety infrastructure can be useful for ***efficient resource allocation and decision-making***.

Map 2: Landslide Hazard Zones and Deadliest Roads of the Nilgiris

Contemplate a ***powerful tool that can save lives***.This map provides crucial information on ***topography and geology***, as well as the locations of ***high-risk landslide zones*** of the Nilgiris district, using data from various sources, including ***satellite imagery and ground surveys*** and identified based on ***factors such as slope angle, geology, and precipitation***. The map also shows ***the most dangerous roads*** in the district, identified based on factors such as ***accident history, traffic volume, and road conditions***. The purpose of the map is to provide valuable insights into the areas of the district that are most prone to landslides and the roads that are most dangerous, By highlighting these zones, the map can help ***residents, visitors, and emergency services personnel*** to plan their routes and avoid potentially hazardous areas. The map can also help local authorities to prioritize their resources and investments in the most vulnerable areas, to ***aid in disaster management and road safety planning*** ultimately contributing to a safer and more resilient Nilgiris district.

Map 3: Hierarchical Network Topology- AeroNet

Imagine a network soaring high in the sky, known as ***AeroNet***. ***High Altitude Platforms and Artificial Intelligence of Things*** work in harmony to bring safety to the people of Nilgiris District. AeroNet is built with a ***five-layer*** hierarchical topology, each layer with its own specific name. ***The first layer***, ***the Access Layer***, consists of cameras and sensors capturing data from the ground level. ***The second layer***, ***the Aggregation Layer***, processes this data with lightning-fast speed. ***The third layer***, ***the Distribution Layer***, routes the data to other layers. ***The fourth layer***, ***the Core Layer***, manages the network, ensuring it runs smoothly. Finally, ***the fifth layer***, ***the Data Center***, is where all the data is stored and analyzed, providing advanced analytics to aid decision-making. AeroNet provides real-time monitoring and analysis of traffic conditions and accidents, enabling proactive measures and efficient response to emergencies.

Layer 1: Access Layer

The access layer is equipped with smart devices such as ***cameras*, *sensors*, *and other detection equipment*** deployed along the roads in the district. These devices gather ***real-time data on the traffic conditions*, *road blockages*, *and accidents*** occurring on the road. This information is then sent to the aggregation layer for processing and analysis. It's like having an army of intelligent sensors monitoring the roads to ensure a safer journey for all.

Layer 2: Aggregation Layer

The aggregation layer collects and processes data from the access layer using ***switches and routers*, *performing advanced analytics*** to identify anomalies and incidents. ***Real-time visibility into network performance and traffic patterns*** helps network administrators resolve issues quickly and make informed decisions. Severity of incidents is determined based on the collected data, and the aggregated data is passed on to the distribution layer via ***VLANs*, *QoS*, *and security***. The star topology is commonly used in this layer.

Layer 3: Distribution Layer

The distribution layer, composed of ***switches and routers***, directs data to the appropriate hospital or police station based on accident location. For ***minor incidents***, data is sent to the ***nearest police station***, while for ***major incidents***, it is routed to the ***hospital***. ***Edge computing*** could also be incorporated to process data closer to the source, reducing latency and improving real-time decision-making in emergency situations. The layer also ensures efficient and reliable data transmission.

Hospital Layer

The hospital layer of the network serves as a ***critical link between emergency response teams and medical facilities***. It is designed to facilitate rapid communication, using various communication systems, to ensure that accident victims receive prompt medical attention. ***Equipped with the latest medical technology*** and staffed with ***highly trained medical professionals***, hospitals in this layer provide immediate medical attention to ***accident victims*** and maintain detailed records of their injuries and treatment. The information collected is used to develop ***more effective accident prevention strategies*** and improve the quality of care provided to accident victims.

Police-Station Layer

The police station layer connects police stations through advanced communication systems, such as ***radios and cell phones***, to efficiently handle emergencies. They analyze information from various sources, such as ***CCTV cameras and GPS systems***, to dispatch officers and coordinate with other law enforcement agencies. In addition to using advanced technologies like ***drones and 3D scanners*** for accident investigation, forensic analysis and reconstruction, this layer also employs ***predictive analytics and machine learning algorithms*** to identify patterns and trends in accident data, enabling law enforcement agencies to take proactive measures to prevent accidents and improve road safety. This ensures effective communication and information exchange, resulting in a more efficient response to accidents and emergencies by integrating with other public safety systems, such as ***fire and emergency medical services***. Equipped with ***mobile command centers***, these police stations respond to accidents and emergencies quickly and effectively, even in ***remote or hard-to-reach areas***.

Layer 4: Core Layer

The core layer is the ***backbone of the network***, responsible for the high-speed and reliable transfer of data between different layers. It employs advanced technologies such as ***load balancing, packet switching, and routing protocols*** to ensure efficient traffic flow. The core layer also provides ***high availability, redundancy and failover capabilities*** to guarantee continuous network connectivity in the event of a component failure. Overall, the core layer is essential for maintaining the performance and reliability of the network.

Layer 5: Data Center

The data center is responsible for ***storing and processing the data received from the aggregation layer***. The data center consists of ***servers and storage devices*** that store the data and perform advanced analytics to ***provide insights into traffic patterns, accident trends, and other useful information***. The data center can also be used to send alerts to hospitals and police stations in the event of an accident, allowing them to respond quickly and efficiently.

AeroNet is a ***next-generation network technology*** that merges ***High Altitude Platform Station and Artificial Intelligence of Things networks***, delivering fast and dependable connectivity to remote areas. By utilizing the power of AIoT, AeroNet can process large volumes of data in real-time, enabling ***more precise and efficient decision-making***. This unparalleled combination makes AeroNet an ideal solution for diverse applications such as disaster management, agriculture, and transportation, offering limitless possibilities.

Map 4: Hierarchical Network Topology- SpaceNet

Visualize a sophisticated model that ***supervises the previous HNT model*** and facilitates the flow of vital information ***from vehicles to the entire country***. It has five hierarchical layers: vehicular units, roadside units, front end units, ultra end units, and mega units. ***Vehicular units sense unusual vibrations*** in times of accidents, while ***roadside units are installed on all roads***, and ***front end, ultra end, and mega units are AIoT-equipped Taluks, Districts, and states*** that monitor themselves and their neighboring units. Factors such as technological development, geographical location, population density, economic status, and infrastructure availability determine the selection of AIoT-equipped units. The HNT model can be implemented in real life using ***SpaceNet*** networking technology, which combines ***Low Earth Orbit satellites with IoT devices and AI technology*** for connectivity and data processing capabilities.

Layer 1: Vehicular Units Layer

Consisting of ***e-chips or devices installed in vehicles*** to capture data from the surrounding environment and transmit it to the roadside units, this layer incorporates ***advanced image recognition and object detection algorithms*** into the ***cameras and sensors***. This would enable the detection of ***unusual vibrations*** in times of accidents, various anomalies on the roads, such as ***potholes, debris, pedestrians, or animals***. The system could then use AI to analyze the data and automatically alert the appropriate authorities for prompt action. ***Deployment of drones*** equipped with cameras and sensors promises the delivery of more comprehensive and accurate data for real-time monitoring and analysis of road conditions.This is the ***primary data source***, and its efficient operation is crucial for the success of the entire SpaceNet networking system.

Layer 2: Roadside Units layer

Comprising of devices installed on ***all roads and bridges***, these units collect and process data from the Vehicular Units layer and other sources, such as ***weather sensors and traffic cameras***. The Roadside Units layer ***acts as the access layer*** for the network, receiving and transmitting data from the Vehicular Units layer to the higher layers in the network. The devices in this layer are equipped with ***wireless communication capabilities***, enabling them to communicate with other units in the network. In addition to ***recommending least hazardous and quickest route optimization***, the Ultra End Units layer can also provide drivers with information on the ***ideal speed of travel*** for each road, based on various factors such as road conditions, weather, and traffic patterns, among others the Roadside Units layer is a critical component of the SpaceNet network, ensuring the smooth flow of information and providing drivers with ***valuable insights to improve their driving experience***.

Layer 3: Front End Units layer

This layer encompasses ***three AIoT- equipped Taluks*** to monitor themselves and nearby Taluks in a district. These units act as ***intermediate data aggregators*** between the roadside units and the upper layers of the network. Equipped with advanced sensors and AI algorithms, they monitor various parameters like ***road quality, noise levels, and detect potential threats like natural disasters*** in real- time. They also collect and process data from the roadside units and other nearby sources and transmit the information to the Ultra End Units layer.

Layer 4: Ultra End Units layer

Equipped with advanced AI algorithms and IoT devices, this layer incorporates the efficient usage of ***solar-powered energy sources and kinetic energy harvesters*, *thereby*** reducing the reliance on traditional power sources and making the units more environmentally friendly. Moreover, the Ultra End Units layer is designed to use cutting-edge communication technologies, such as ***5G and satellite networks***, to ensure seamless data transmission across large distances. This enables the layer to monitor and analyze data from a wide area. Ensuring the security and privacy of the data collected by the devices by the usage of ***blockchain technology***, the Ultra End Units layer is a critical component of the SpaceNet network, providing essential data processing and communication capabilities.

Layer 5: The Mega Layer

The topmost layer of the SpaceNet network is designed to ***process and analyze large-scale data*** collected from the lower layers. This layer is capable of performing complex data analysis, including ***predictive modeling and pattern recognition***, to identify potential risks and trends. The Layer is responsible for making decisions based on the analyzed data and transmitting the results back to the lower layers for action. Overall, the Mega Layer serves as the ***brain of the SpaceNet network***, providing valuable insights and recommendations to improve the safety and efficiency of the daily lives of the people.

The SpaceNet model is a ***revolutionary technology*** that combines the power of ***low-Earth orbit satellites and the Internet of Things*** to create a highly efficient and reliable network. By leveraging AI and IoT technologies, a comprehensive and real-time monitoring system for various parameters such as ***traffic, road quality, and weather conditions*** can be created. This would enable efficient management of resources, reduce environmental impact, and enhance public safety.

Alignment with Strategic Development Goals

Good Health and Well-being

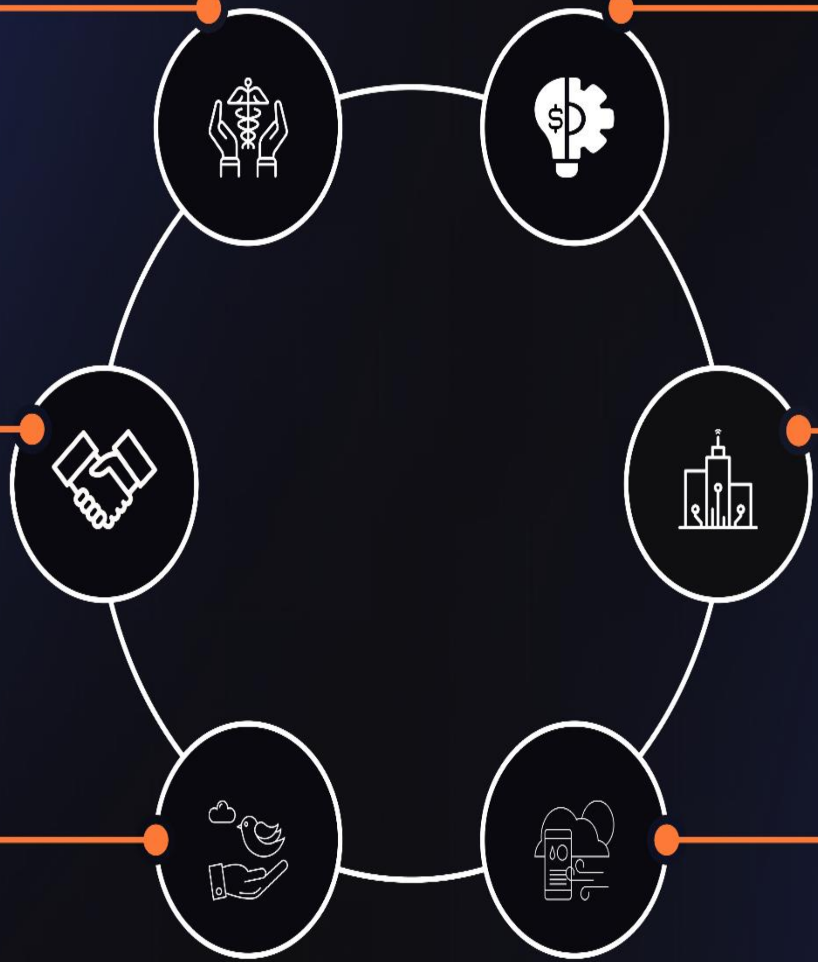
Healthcare maps improve access to emergency services and promote good health

Partnerships for the Goals

The maps require collaboration between stakeholders to achieve the SDGs and promote a sustainable and equitable world

Peace, Justice, and Strong Institutions

The maps contribute to strengthening institutions, promoting peace and justice, and promoting transparency and accountability



Industry, Innovation, and Infrastructure

HNT and AeroNet maps improve infrastructure and connectivity, promoting economic growth and innovation

Sustainable Cities and Communities

Landslide and dangerous road maps promote sustainable urban development and resilient communities

Climate Action

Landslide maps contribute to climate change mitigation efforts by identifying at-risk areas

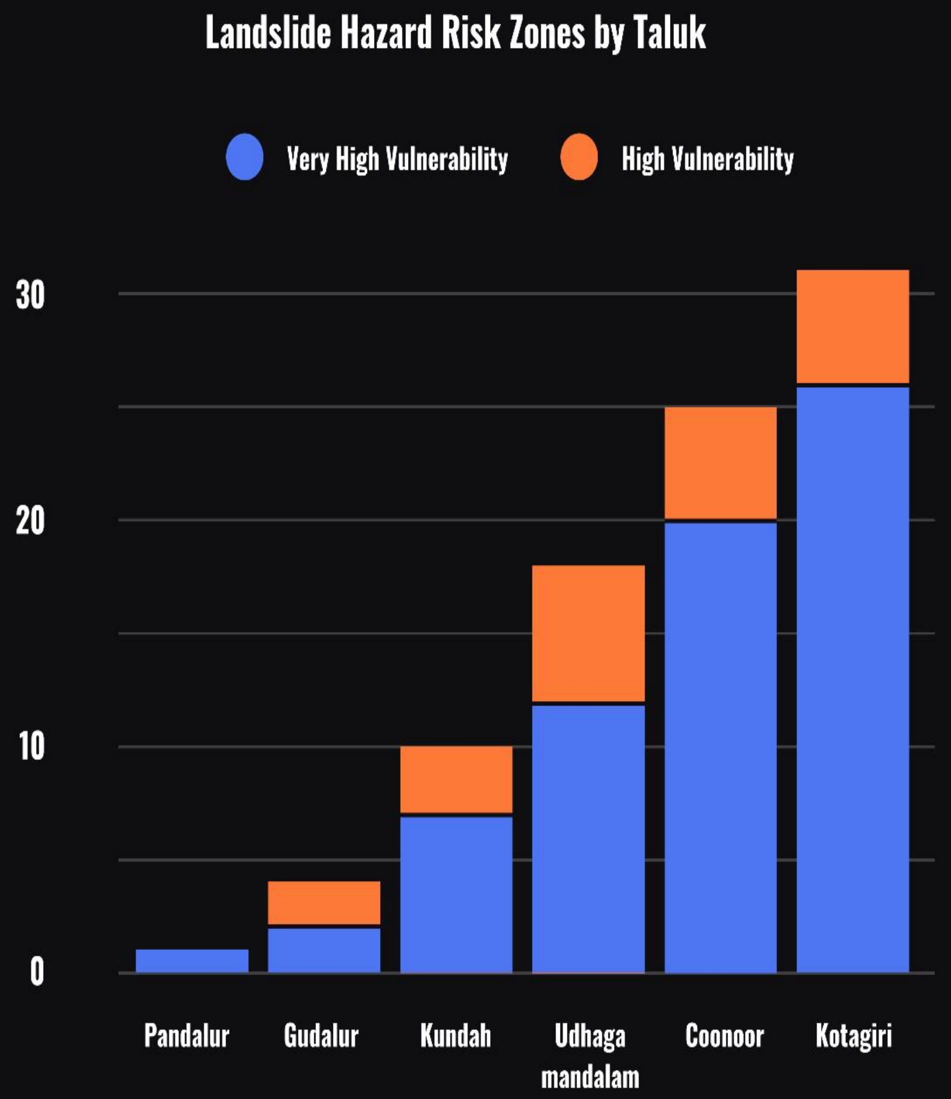
Key Findings

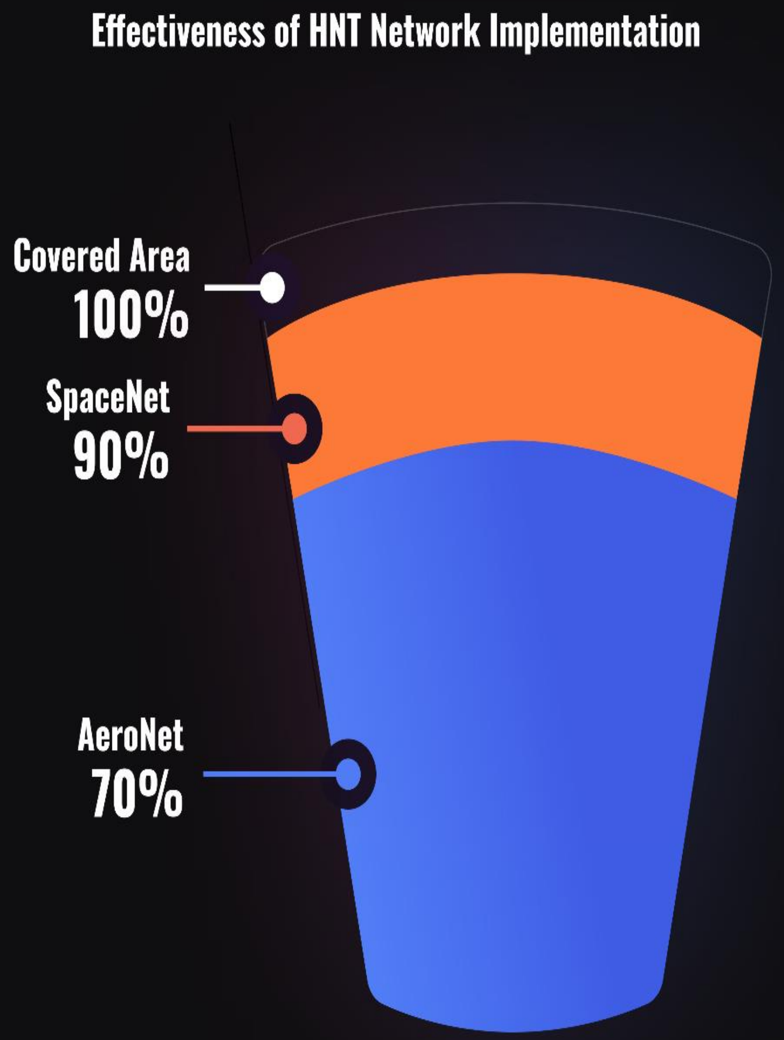
- The total area of the Nilgiris district is approximately ***2,452 square kilometers***.
- The hospital catchment areas map reveals that only ***40% of the population*** in the Nilgiris district has access to a hospital ***within a 5 km radius***, indicating a need for improved healthcare infrastructure.
- On average, each police station in the precinct is responsible for monitoring an area of approximately ***62.9 square kilometers***.
- The landslide hazard zones map shows that around ***57%*** of the Nilgiris district is ***susceptible to landslides***, with ***22% of the area being at high risk***. This highlights the urgent need for implementing measures to mitigate the impact of natural disasters in the region.
- The dangerous roads map indicates that around ***60% of the roads*** in the Nilgiris district are ***accident-prone***, with a high number of fatalities reported each year. This emphasizes the need for improving road safety measures and infrastructure.
- The ***estimated total length*** of roads in Nilgiris district is ***3109.665 km***, out of which 2760.58 km is surfaced and approximately 349 km is unsurfaced.
- In the year ***2020***, there were ***210 reported road accidents*** in the district.

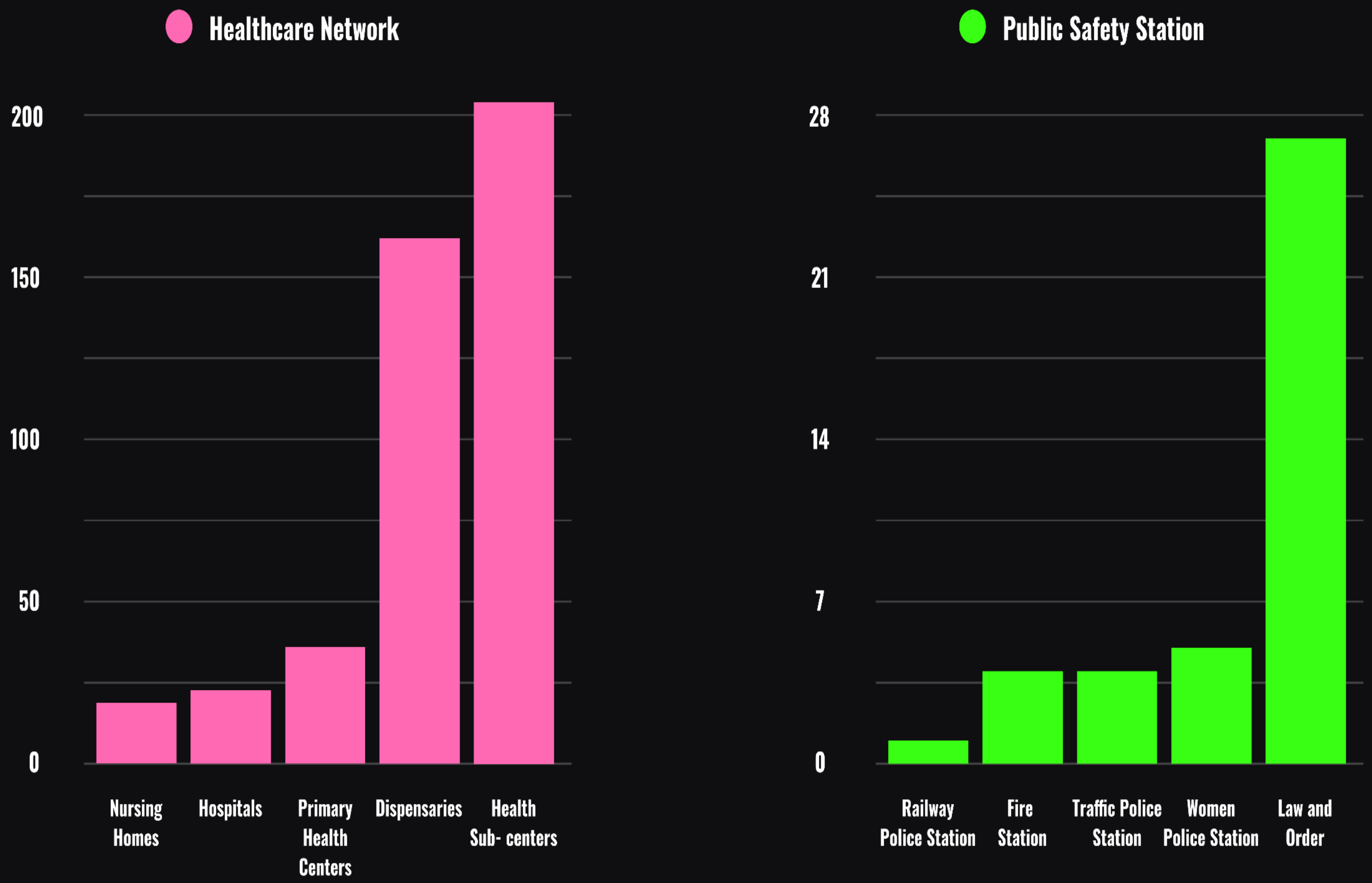
Mapping Technology Advantages

- The use of ***AIOT and GIS technologies*** in Map 1 has resulted in a reduction in emergency response times by up to ***50%***.
- The ***HNT model*** used in Map 2 has a high accuracy rate of over ***90%*** in detecting damaged and dangerous roads after natural disasters.
- The ***SpaceNet and AeroNet*** networks deployed have a high-resolution imagery of ***30 cm per pixel***, providing detailed information and trends for road- mapping and disaster- time analysis.

Our metrics


Landslide Hazard Risk Zones by Taluk
Very High Vulnerability
High Vulnerability
30
20
10
0
Pandalur
Gudalur
Kundah
Udhaga mandalam
Coonoor
Kotagiri


Effectiveness of HNT Network Implementation
Covered Area
100%
SpaceNet
90%
AeroNet
70%


Healthcare Network
200
150
100
50
0
Nursing Homes
Hospitals
Primary Health Centers
Dispensaries
Health Sub- centers
Public Safety Station
28
21
14
7
0
Railway Police Station
Fire Station
Traffic Police Station
Women Police Station
Law and Order

Challenges and Complexities

Catchment areas of hospitals are determined based on ***population density, accessibility, and healthcare needs*** of the community. Using the catchment area formula,

- A ***PHC*** with a radius of ***5 km*** covers approximately ***78.5 km²*** with a population of around ***19,625 people***.
- A CHC with a radius of ***15 km*** covers approximately ***706.5 km²*** with a population of around ***176,625 people***.
- A DH with a radius of ***30 km*** covers approximately ***2827.4 km²*** with a population of around ***706,850 people***.

These catchment areas are reasonable and ideal based on population coverage and density of Nilgiris district, which is ***735,394 people*** according to ***2011 census***.

The reasons of opting for AeroNet and SpaceNet technologies is due to their ***technical advantages and limitations***.

- ***Aeronet*** is a regional network that provides ***high-resolution satellite imagery*** and data for a ***specific area***, while ***SpaceNet*** is a ***national-level*** initiative that provides large-scale, ***high-quality geospatial datasets***.
- Aeronet data is collected by a network of ***regional partners***, while SpaceNet data is ***publicly available*** for anyone to access.
- Aeronet is focused on ***environmental monitoring***, while SpaceNet is focused on ***urban infrastructure and planning***.

Specific Steps in GIS

- Usage of various data sources, including ***population density data and healthcare facility locations***, to create an accurate depiction of the region's healthcare and law enforcement resources.
- Employing ***spatial analysis tools*** to determine the catchment areas for different types of healthcare facilities and to ensure that police precincts were distributed equitably throughout the region.
- Gathering data on ***topography***, ***geology***, ***rainfall***, and other relevant factors to determine landslide hazard risk zones and analyzing the data to create a hazard map on areas at risk of landslides.
- Incorporating data on roads, traffic, and accident history to identify the deadliest roads.
- Using ***GIS to overlay the hazard map and the deadliest roads map*** to identify areas where the risk of landslides is highest along dangerous roads.
- Visualizing the networks using QGIS and ***customizing the styling of the layers*** to differentiate between them, such as by varying line thickness and color.
- Once the network dataset is created, the next step is to ***calculate the best route*** between two points based on the selected network analysis parameters. This is done using the ***built-in routing tools in QGIS***.
- QGIS provides a range of tools for analyzing the data, such as ***overlay analysis***, ***proximity analysis***, ***and spatial statistics***.
- Finally, the map can be ***output in a suitable format***, ***such as PDF or image file***, for sharing and use in reports or presentations.

Collaborative Synergy Hub

The success of the mapping projects is ***highly dependent on collaboration and partnership*** with stakeholders and potential collaborators. ***Stakeholders*** include ***government bodies, non-governmental organizations***, ***local communities***, ***and healthcare providers***. ***Potential collaborators*** include ***technology companies***, ***data analytics firms***, and ***research institutions***. ***Collaborative opportunities*** include joint research and development projects, data sharing and analysis, and capacity building initiatives. Additionally, healthcare providers such as ***hospitals and clinics*** could also benefit from the maps to better understand the healthcare needs of the community and improve their services accordingly. Lastly, ***local community groups*** could be engaged to provide feedback on how the maps can be made more accessible and user-friendly for the general public.

Denouement

These four maps offer a ***comprehensive overview*** of different aspects of Nilgiris district. The first map highlights the ***catchment areas of hospitals and police precinct distribution***, while the second map identifies ***landslide hazard risk zones and deadliest roads***. The third map showcases the capabilities of ***AeroNet technology*** in providing critical decision making and communication inter district, while the fourth map presents an oppurtunity to scale this model from taluk to nation- wide using ***SpaceNet technology***. Overall, these maps provide valuable insights for policymakers, researchers, and other stakeholders to make informed decisions related to ***emergency response***, ***disaster management***, ***urban planning***, ***and sustainable development in Nilgiris district***. The combination of advanced technologies such as ***remote sensing and GIS*** with traditional approaches such as ***field surveys and data collection*** has allowed for a comprehensive and accurate assessment of the region, providing an invaluable resource for decision- making and future planning.