Geographic Information Data Supporting Development Platform for Smart City Management in Sam Phran, Nakhon Pathom Province, Thailand

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Abstract : *The United Nations predicts that by 2050, the world's population will increase by 2 billion. As a result, the number of mega urban cities will increase in the next 15 years. About 55% of people live in large cities, while 45% live outside urban areas. It is expected that the proportion of residents living in big cities will increase to 68% for Thailand. Currently, the occupancy rate in large cities is about 50%. Consequently, urban development has been undertaken to cope with such situations, including basic public utility management, environmental management, and housing management. Social services such as public health services or education, which cannot be addressed by conventional technology alone, require the application of geographic information technology. Geographic Information System (GIS) is an essential element in city management aimed at achieving smart city status. In this research, the area of Sam Phran Municipality in Nakhon Pathom Province was studied to prepare for the development of an intelligent city. The researcher aimed to analyze and design a geographic information layer based on data from high-resolution photos from drones, employing principles of photogrammetry survey. Additionally, the researcher proposed a smart city model based on analysis and design from geographic information in a three-dimensional system. This model serves as an input factor for the platform to display map data in 3D format, providing information to support policymakers' decisions in urban development.*

Keywords: Digital twin, Geographic information, Platform, Smart City

1.Introduction

Currently, approximately 50% of the global population resides in major cities. Beyond population growth, the evolving global situation has led to significant urban development efforts aimed at addressing various challenges. These include managing basic public infrastructure, environmental management, housing, social services, healthcare, and education (Suwannee, 2021). The concept of smart cities has gained worldwide popularity as a result. A smart city leverages modern technology and innovative solutions to enhance service efficiency and urban management, reduce costs, and minimize resource consumption. It emphasizes well-designed urban spaces and active participation from both the business sector and the community in city development. This approach is intended to create a livable, modern city that ensures a high quality of life and sustainable happiness for its residents (Digital Economy and Society Promotion Office, 2017).

Geographic Information Systems (GIS) are increasingly employed to advance the capabilities of cities towards becoming smart cities. GIS, a vital tool in urban management, integrates digital technology and innovation to improve the quality of life for citizens and promote sustainable urban management.

This research focuses on the Sam Phran Municipality in Nakhon Pathom Province, located in the central region of Thailand. The municipality recognizes the benefits of developing a smart city and is aligned with national development strategies, including the 20-Year National Strategy, the 13th National Economic and Social Development Plan, the Sustainable Development Goals (SDGs), provincial strategies, and local government development strategies. These frameworks are incorporated into the local development plan for 2023-2027, which includes initiatives for smart city development in the fiscal years 2024 and 2025, preparing the municipality for its transformation into a smart city.

The research aims to analyze and design Geographic Information System (GIS) data by utilizing high-resolution drone imagery (Mohammed, 1998), adhering to photogrammetry surveying principles. This data serves as input for the Geo Dashboard platform, which is used to analyze and visualize mapping data in a three-dimensional format. The study presents a virtual 3D smart city model to support decision-making for policymakers in the development of the municipality.

2. Study and Information Area

Sam Phran Municipality is a local government unit in Nakhon Pathom Province, central Thailand, located at latitude 13°43'59.53"N and longitude 100°13'07.09"E. Covering an area of 8 square kilometers, it transitioned from a sub-district municipality to a city municipality on February 1, 2008. The municipality borders neighboring local administrative units (Sam Phran Municipality, 2021). Land use in the municipality includes urban and commercial areas of approximately 3,371 rai, agricultural land covering about 1,175 rai, other areas such as industrial zones and farms totaling around 614 rai, and water bodies comprising about 5 rai, as illustrated in **Figure 1.**

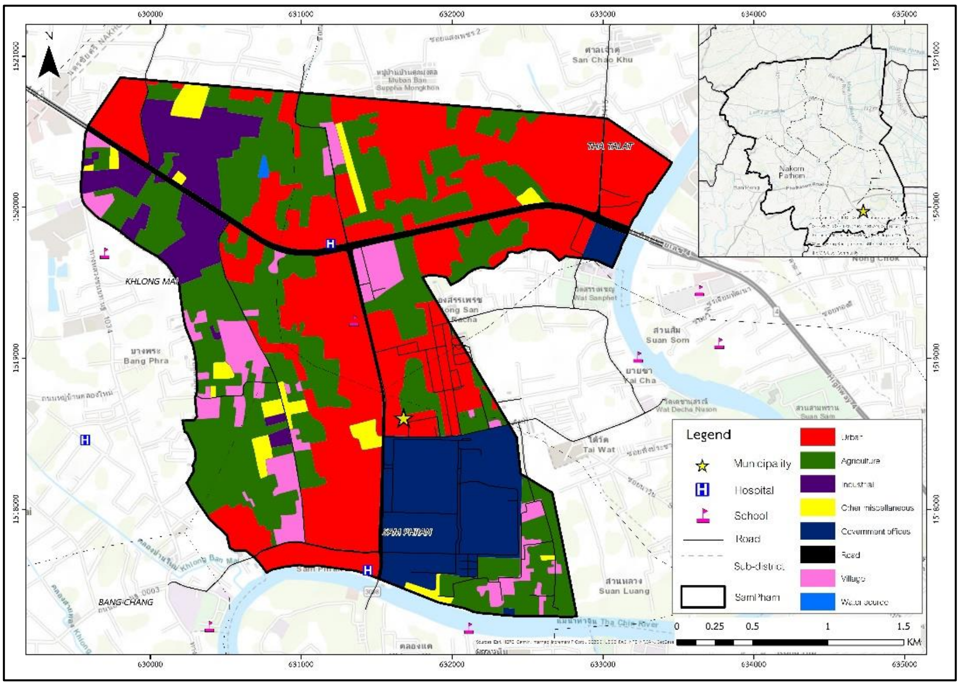

Figure 1: Boundaries of Sam Phran Municipality Covering an Area of 8 Square Kilometers

3. Tools and data used in the study

3.1 Tools Used

Table 1: Tools and software used in the research

Tools & Software	Meaning
1. Unmanned Aerial Vehicle (UAV) DJI Mavic 3 Enterprise	Drones are small, highly efficient tools that enhance operational efficiency and reduce flight time. They offer a maximum flight time of 45 minutes at a constant speed of 32.4 km/h. Equipped with a 20 MP wide-angle camera, a 4/3" CMOS sensor, these drones support RTK (Real-Time Kinematic) technology for precise mapping and surveying tasks.
2. GNSS Receiver Model Stonex S10	The GNSS receiver has 220 channels, offering high accuracy and support for all GNSS signals, including GPS, GLONASS, BEIDOU, and GALILEO.
3. Image processing software	Photogrammetry processing software. Is used to extract and interpret data from photographs that capture the physical characteristics of objects.
4. ArcGIS Platform	ArcGIS Platform is a mapping and spatial analysis system that enables the creation of geographic data and analysis through a Geo Dashboard platform. It provides tools for visualizing, analyzing, and managing geographic information in a user-friendly interface, making it easier to interpret complex spatial data.

3.2 Data

The development of the geospatial information platform for smart city management in Sam Phran Municipality utilizes the following data sources:

1. Aerial imagery captured via unmanned aerial vehicle (UAV) surveys, supplemented by ground control point (GCP) coordinate data for photogrammetric processing.
2. A spatial database system created from orthoimage data, containing features such as utility poles, building locations, and roads.
3. Photogrammetric outputs, including a Mesh Model derived from Point Cloud data, saved in formats such as .OBJ or .slpk for integration into the Geo Dashboard system.

4. Study methods

4.1 High-Resolution Aerial Survey Plan

The initial phase involves planning the flight path to ensure comprehensive aerial coverage, followed by conducting a Real-Time Kinematic (RTK) survey to establish ground control points (GCPs) and checkpoints. The survey should cover the entire Sam Phran Municipality, which spans approximately 8 square kilometers. A checkpoint density of one per 2 square kilometers is recommended, with a horizontal accuracy within 5 cm and vertical accuracy within 10 cm. Additionally, a minimum of four GCPs per square kilometer should be evenly distributed (Bureau of Urban Planning Engineering, 2020), ideally positioned in the overlap regions between flight paths (see **Figure 2**). This distribution is critical for ensuring the accuracy and reliability of the aerial survey data.

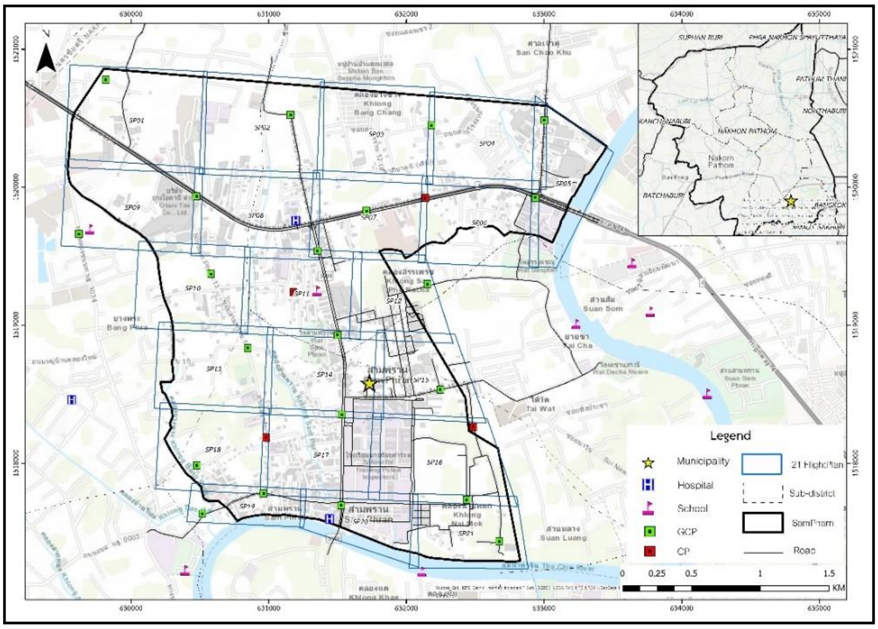

Figure 2: ground control points and the flight plan

Step Two: Conducting the Survey Flight. The survey captures vertical imagery with 80% overlap and 70% sidelap to ensure high-quality data. The images must be sharp, free from blurring, and exhibit consistent color representation. Conducted at an altitude of 90 meters, the flight produces a Ground Sampling Distance (GSD) of 3 centimeters per pixel, using the DJI Mavic 3 Enterprise drone. The process begins with an initial site safety assessment to address any preliminary safety concerns, followed by an on-site safety assessment to ensure that conditions are suitable for the survey. Risk management procedures are then implemented to identify and mitigate potential hazards associated with flight operations. Additionally, necessary permissions must be secured from landowners, relevant authorities, or related agencies before proceeding. Special permissions are required for operations in hazardous zones, such as VTD16 RATCHABURI from Kamphaeng Saen Flight School and the Air Traffic Control Division, as well as VTD47 SAMUT SAKHON (see **Figure 3**)

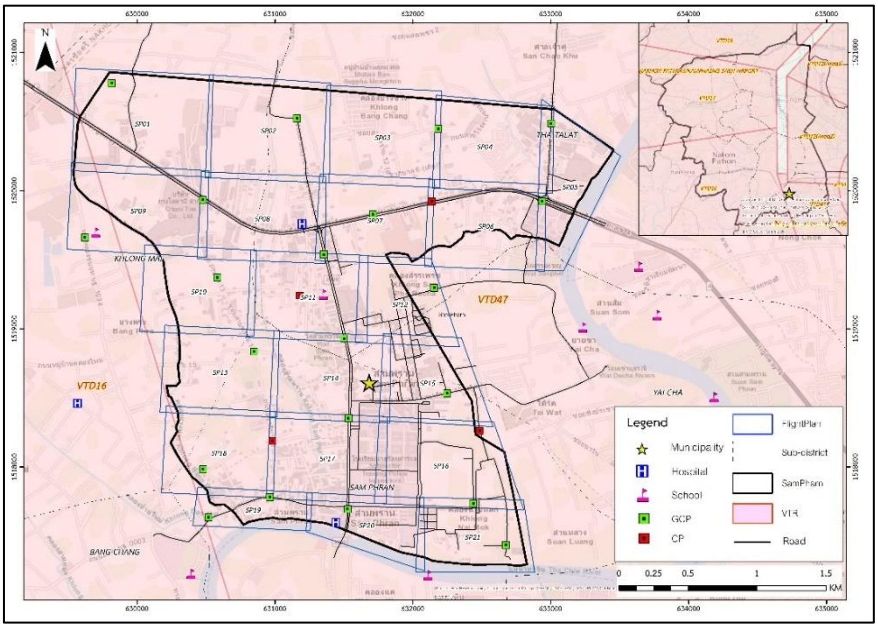

Figure 3: boundaries of restricted and hazardous areas, marked as VTD16 and VTD47, highlighted in pink.

Step Three: Data Processing and Compilation. This stage involves entering the aerial photographs into photogrammetry software for processing. The first step is to import the captured imagery into the software. Once uploaded, the images are aligned to create a coherent 3D model by matching overlapping features. From this alignment, a point cloud is generated to represent the three-dimensional structure of the surveyed area. The next step is to construct a detailed mesh model from the point cloud data. Following this, orthophotos are produced by correcting distortions and aligning the images with geographic coordinates. Quality checks are then performed to verify the accuracy and ensure the data meets required standards. Finally, the processed data is exported in suitable formats (e.g., .OBJ, .slpk) for integration into the Geo Dashboard system. As illustrated in Figure 4, these steps ensure the generation of accurate and reliable geospatial data.

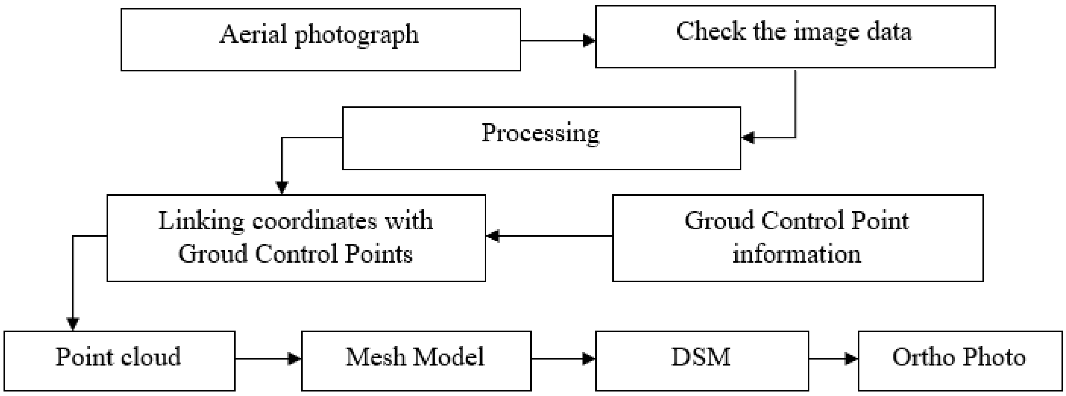

Figure 4: workflow for processing aerial photographs captured by unmanned aerial vehicles (UAVs).

Step Four: Data Integration and Verification. The process begins with importing all data layers and referencing them against the orthophoto to ensure accuracy. Each data layer is carefully reviewed to verify the information contained. In cases where data appears unclear, the point cloud is consulted for additional context and clarification. The next step involves integrating the vector spatial data with the Mesh Model generated from the aerial photogrammetry process. resulting in a combined dataset displayed as a Digital Twin (Grieves, 2016). A thorough verification of data accuracy is then conducted to ensure alignment with the orthophoto and point cloud references. This step guarantees that the data is accurately represented and properly integrated, providing a reliable Digital Twin for analysis and visualization.

Final Step: Geo Dashboard Platform Development. The process begins with developing the Geo Dashboard platform to display the spatial data, ensuring that it is projected in UTM WGS 1984 Zone 47N for accurate geographic representation. Next, all relevant spatial data, including the Digital Twin model and other datasets, are imported into the system. The data is then converted and organized into the appropriate spatial formats required by the Geo Dashboard, ensuring accurate reflection of the Digital Twin city model. Visualization settings are customized to enhance data presentation, including configuring layers, symbology, and interactive elements to effectively communicate the information. Finally, all data layers are linked to the dashboard's display components, enabling interactive and dynamic visualization. This step results in a fully functional and interactive Geo Dashboard platform that effectively integrates and visualizes the spatial data.

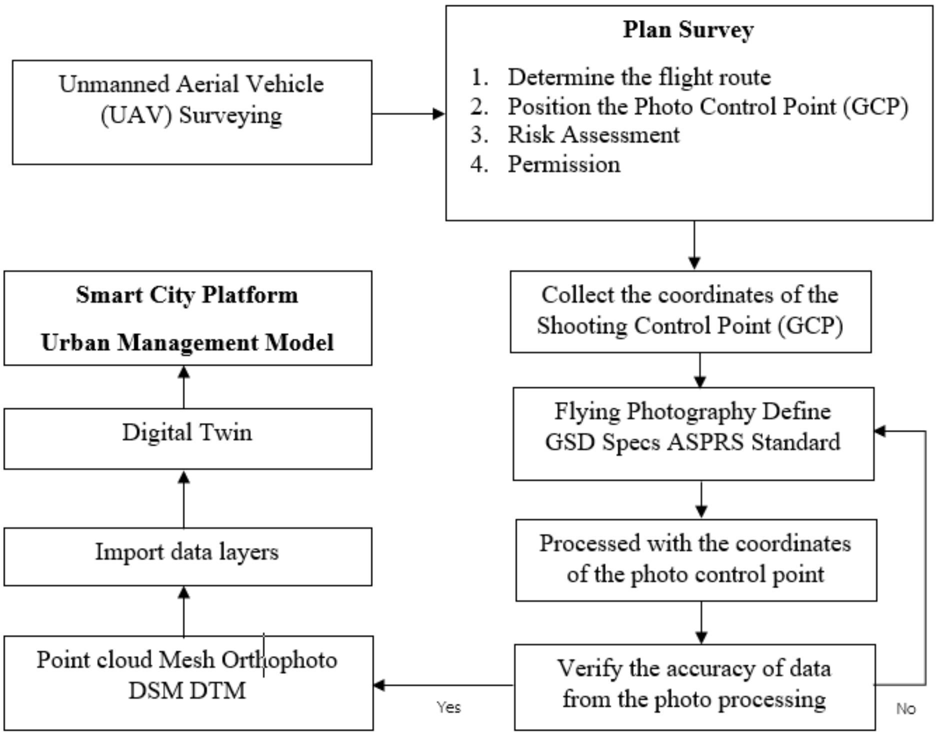

Figure 5: conceptual framework for the research project.

5. Results

5.1 Aerial image processing

The data for Sam Phran Municipality is available in both 2D and 3D formats, as shown in Table 2. This table provides an overview of the data types obtained through aerial image processing, along with descriptions and the corresponding coordinate systems used.

Table 2: Data from Aerial Image Processing

Data Type	Description	Coordinate System	Format
Dense 3D Point Cloud	Detailed 3D representation of the surveyed area with high point density	WGS 84	.las
Mesh	Textured 3D model of the surface features	WGS 84	.obj, .slpk
Ortho mosaic	Seamlessly stitched orthophotos providing a geometrically corrected image	WGS 84	.tiff
Digital Terrain Model (DTM)	3D representation of the ground surface excluding vegetation and buildings	WGS 84	.tiff
Digital Surface Model (DSM)	3D representation of the Earth's surface including all objects and structures	WGS 84	.tiff

Figure 6: The data for Sam Phran Municipality, (a) Dense 3D Point Cloud3D
(b) Mesh Model (c) Ortho mosaic (d) Digital Surface Model (DSM)
(e)Point Cloud Terrain (f) Digital Terrain Model (DTM)

5.2 Data Layer Import

The process of importing data from orthophotos in Sam Phran Municipality includes the following data layers: Streets, Street and Lights Buildings. This information is detailed in **Figure 7.**

Figure 7: Example of landuse types derived from orthophotos

5.3 Geo Dashboard System

The Digital Twin of Sam Phran Municipality, builds on a numcer of leyer of information in the city. Digital Twin uses this data to perform simulations and analyses, determine ideal building placements (White, 2021). Is visualized using ESRI's ArcGIS Pro software, as shown in **Figure 8.** This setup aids in urban management tasks such as:

- **Tax Mapping:** Verification of property and land tax information show in **Figure 9.**
- **Urban Planning:** Reviewing and updating land use and zoning plans.
- **Disaster Simulation:** Modeling and assessing flood events and other disaster scenarios.

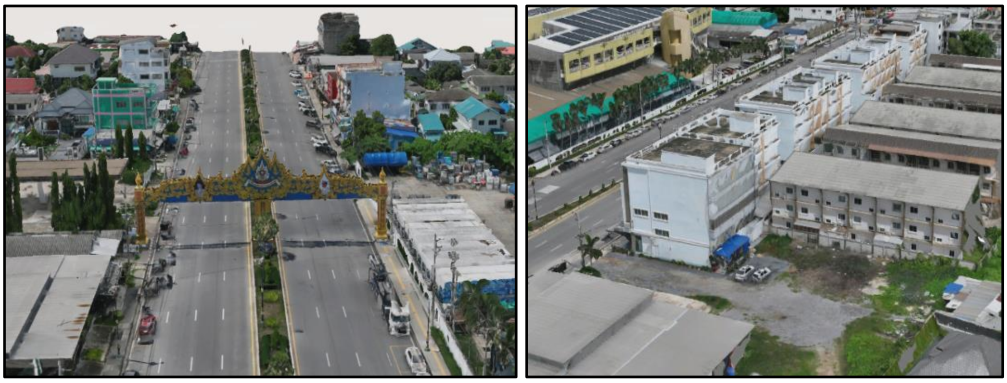

Figure 8: The Digital Twin of Sam Phran Municipality.

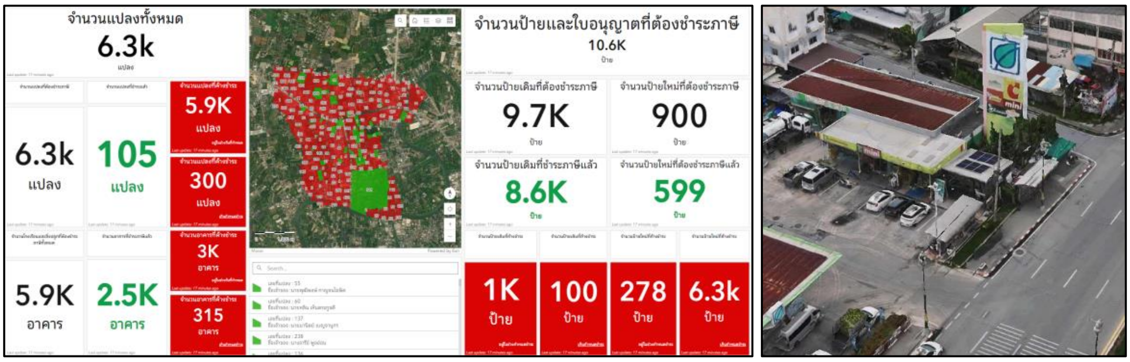

Figure 9: Tax Mapping of Sam Phran Municipality. This map displays the locations of signage within the municipality and enables direct measurement of sign sizes within the system. This functionality facilitates tax calculation without the need for field surveys. Additionally, the map provides an overview of tax payment statuses, allowing officials to track preliminary payment information efficiently.

Geo Dashboard system facilitates urban management through disaster event simulations and various other features:

- **Disaster Simulation:** Models scenarios such as flooding, allowing users to visualize and analyze potential impacts on the urban area.
- **Customizable Visualizations:** Users can adjust display settings, including light and shadow effects, to enhance decision-making for urban management.
- **Urban Planning:** Displays building locations and city layouts to assist in zoning and planning efforts.
- **Public Infrastructure:** Shows data on utilities such as streetlights and roads, integrating this information into the overall urban management framework.

These capabilities are illustrated in **Figure 10.**, demonstrating how the Geo Dashboard supports comprehensive urban planning and management.

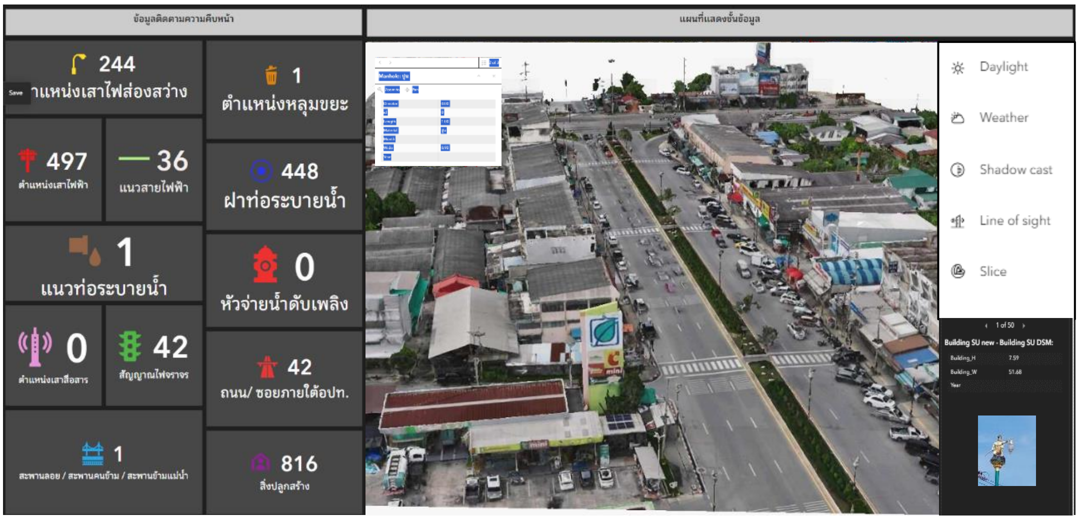

Figure 10: The urban management platform for Sam Phran Municipality, displayed on the Geo Dashboard.

6. Conclusion

This research focuses on developing a 3D platform to support the development of smart cities in central Thailand, specifically in Sam Phran Municipality, Nakhon Pathom Province. The researcher designed a geospatial database system using geographic survey principles, enabling the acquisition of high-resolution aerial imagery from drone photogrammetry. This allows for the creation of a geospatial information database to support smart city management with clear Digital Twin models. This includes integrating data on public utilities such as streetlights, roads, and buildings, which supports urban management in Sam Phran Municipality.

The development of a geospatial information platform for smart city management, combined with geospatial information technology, can enhance the efficiency of urban management in Sam Phran Municipality. Overall, a Geo Dashboard system helps organizations and decision-makers effectively manage and utilize geospatial data for various applications, including urban planning, environmental management, and emergency response.

Future research will involve testing the processing of Ortho, DTM, and DSM data at various resolutions and evaluating their realism for urban management. Additionally, it will explore the creation of tree models in urban areas by comparing DSM with Lidar-derived point clouds, aiming to contribute to green urban management within specific municipal areas.

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