# Constructing High-Level-of-Detail 3D Urban Models Using UAV Data and Ground Scanning, A Case Study in Ha Long City, Quang Ninh Province, Vietnam

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***ABSTRACT***

High-level-of-detail 3D (LOD3) data plays a crucial role in smart city development, aiding decision-making in disaster prevention and climate change response. In this study, we present the results of constructing a LOD3 3D dataset for the urban area of Ha Long city, Quang Ninh province, covering approximately 1 km². Our approach combines UAV data from a Phantom 4 Pro device, ground photography technology, and ground laser scanning to create a comprehensive 3D model. Analyzing the results, we confirm that the constructed dataset fully complies with the requirements for 3D LOD3 geospatial data outlined in Circular No. 68/2015/TT-BTNMT. These findings provide essential input for coastal smart city planning, construction, and management.

**Keywords:** LoD (Level of Detail), TLS (Terrestrial Laser Scanning ), UAV (Unmanned Aerial Vehicle).

## 1. INTRODUCTION

The process of urbanization and socio-economic development in Quang Ninh province is increasing the need for infrastructure management such as electricity, water, wastewater, communications and transportation. Therefore, a modern management and information system is needed to support infrastructure management and sustainable socio-economic development. Facing the pressure from urbanization and increasing population demand, cities need to improve current services through innovative measures and initiatives following the smart city model. Smart management of resources, environment and tourism is important, and being ready for smart city transformation is necessary. Research on building 3D spatial data for smart cities and responding to climate change is important and meets the development needs of society.

In the technology of building 3D geospatial data, the use of UAV technology to take photos with ordinary cameras is becoming the superior choice due to its low cost and high accuracy. UAV technology can take photos at different heights, ensuring the accuracy and detail of 3D digital geospatial data. Products from UAV are the basis for creating high-resolution topographic and thematic maps.

## 2. RESEARCH METHODS

### 2.1. Field investigation and survey methods

Collecting geospatial data and studying the impact of climate change in Ha Long city, Quang Ninh province. Selecting a research area of 1 km2, including typical coastal urban objects, to build 3D geospatial data with a resolution of 1:500. Using UAVs combined with RTK technology to capture images with a resolution of 2.5 cm and detail objects using GPS-RTK or electronic total stations. Measuring and capturing ground images to collect information about trees and road systems to serve the construction of 3D spatial data.

### 2.2. Method of interpreting remote sensing images and analyzing GIS data

Extracting information about 3D geospatial data of the surface and attribute information of artificial and natural land cover objects in the urban area from UAV images. Conduct 3D geospatial data construction based on collected geospatial data including the work of linking spatial data and attributes of all objects in the research area.

### 2.3. Expert consultation method

Consult experts on environment, urban, and climate change to compare, evaluate the results of the constructed 3D geospatial data and propose solutions for the smart city of Veb sea adapting to climate change.

## 3. RESULTS AND DISCUSSION

### 3.1 Construction of the experimental area's basic control network

#### *3.1.1 Establishment of the level 1 transmission line network*

In the survey area, 05 level 1 transmission lines are established, numbered GPS01; GPS02, GPS03; GPS04 and GPS05. The points are arranged in pairs of directional points, selected in places with stable and open terrain, the points are marked with the center point, and the markers are buried in the field according to the correct specifications. The points of the first pass are measured to connect to the original coordinate mark using the static GNSS positioning method; using 05 Comnav T300 dual-frequency GNSS measuring devices

#### *3.1.2 Establishing the technical leveling network*

The first pass mark is measured to connect the height with the TPHL08 mark. Using the NA2 leveling machine, the geometric height measurement method from the middle for measurement. The technical leveling network is measured in the form of a closed geometric leveling network.

## 3.2 Building 3D point clouds using geospatial technology

### *3.2.1 Building 3D point clouds using UAV photography*

The equipment is checked, tested and evaluated to ensure stable, safe and accurate operation for data collection.

* Establishing image control points (KCA) and test points (KT)

*a) <u>Designing the location of KCA and KT points</u>*

To ensure the accuracy of the digital surface model, it is necessary to arrange image control points on the survey area. The total number of KCA points is 16 and the number of KT points is 15. The points are arranged evenly on the survey area.

*b) <u>GNSS/RTK measurement of KCA points and KT points</u>*

KCA points and KT points are measured and determined by GNSS/RTK technology with an accuracy of ±3 cm. According to this method, the Base machine will be placed at the base control point of the survey area. The rovers are placed at the KCA and KT points with a signal reception frequency of 15"/point. The Rover has a straight and stable pole clamp throughout the measurement time.

### *3.2.2 UAV photography*

UAV image processing results: image processing to build 3D point clouds is performed on specialized image processing software Agisoft Metashape. The point cloud processing results are shown in Figure 1.

Figure 1. Point cloud constructed from UAV images in the experimental area

In addition, the products obtained from UAV image processing include digital surface models and orthographic images (Figures 2 and 3).

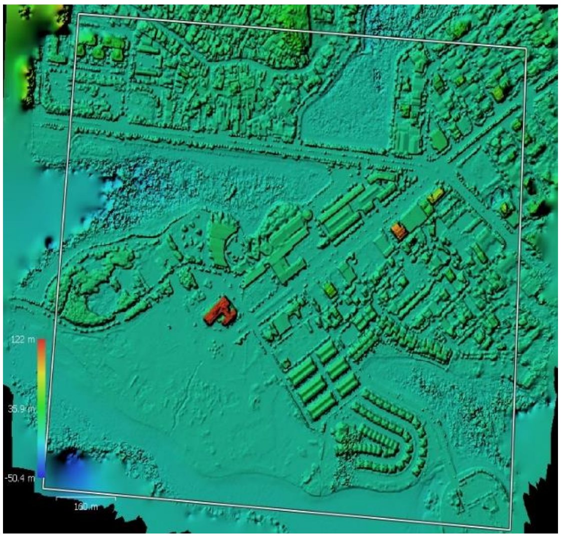

Figure 2. Surface digital model

Figure3. Orthogonal image of surveying area

*a) <u>Drone photography of independent houses to build 3D geospatial database in LOD3</u>*

Results of processing UAV aerial images for independent houses: image processing to build 3D point cloud is performed on specialized image processing software Agisoft Metashape. The product obtained from the UAV image processing process is a dense point cloud for independent buildings (Figure 4).

Figure 4: Point cloud of a detached house which is built from UAV images

*b) <u>Take photos of adjacent villas to build a 3D geographic database in LOD3</u>*

Results of processing UAV images of adjacent villas: image processing to create a 3D model is performed on specialized image processing software Agisoft Metashape. The product obtained from the UAV image processing process is a dense point cloud for the adjacent villas (Figure 5).

Figure 5. Results of photography in free-flight mode

***3.2.3. Ground laser scanning to acquire 3D point cloud***

* Ground laser scanning of independent buildings

*a) Design and layout of ground laser scanning (TLS) stations*

In this study, to evaluate the accuracy of the point cloud model of an independent building established by ground photogrammetry technology and UAV technology. The building was scanned by TLS on the outside. According to the design, there are 8 TLS stations.

Parameters selected for each scanning station:

- Scanning mode: Outdoor; Quality setting: 4X.

- Resolution setting: 1/4; Time for each scanning station is: 10'.

*b) Organization of TLS scanning of independent buildings*

The initial number of TLS scanning stations is 8. However, due to the fact that the area has many trees covering the building, 2 more scanning stations were added at the front of the building.

*c) TLS data processing results for detached houses*

The processing process includes the following steps: Create project, import scanning station data, Process scanning stations, merge scanning stations and evaluate accuracy, create point cloud and export point cloud. The result of the processing process is the point cloud as shown in Figure 6.

Figure 6. TLS point cloud for a detached house

*** Ground laser scanning of adjacent villas**

*a) Organizing ground laser scanning (TLS)*

With the aim of improving the accuracy and evaluating the accuracy of the point cloud model of the adjacent villas established by ground photogrammetry technology and UAV technology. The adjacent villas are scanned by TLS on the outside. According to the design, there are 10 TLS stations with a layout diagram of the machine stations.

*b) Results of TLS data processing for the adjacent villas*

The scanned data is loaded into the computer and processed on SCENE software. The stations are combined and evaluated for accuracy, before exporting to E75 format to serve the process of evaluating the accuracy of the UAV point cloud and ground photography.

The result of the processing process is the point cloud as shown in Figure 7.

Figure 7. TLS point cloud for row of adjacent villas

## 4. CONCLUSION

In this study, a 3D LOD3 dataset of the area of Ha Long city, Quang Ninh province was built by combining UAV technology, ground photography and ground laser scanning. The combination of technologies is demonstrated through the point cloud merging to create a complete point cloud using two methods: 1) from UAV and ground photography technology; and 2) from UAV and Lazer scanning technology. These two complete point clouds are the basis for providing an assessment of accuracy and technology options. Furthermore, in this content, the typical objects of the experimental area include: 1) Independent houses; 2) Rows of adjacent villas and 3) High-rise buildings are measured for LoD3 to clearly see the advantages and disadvantages of each technology for different objects in the field.

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