

# AUTOMATIC BUILDING DETECTION AND DELINEATION FROM HIGH RESOLUTION SPACE IMAGES USING MODEL-BASED APPROACH

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## ABSTRACT:

An approach was developed for updating the buildings of an existing vector database from high resolution space images by using spectral values, Digital Elevation Models (DEM) and model-based extraction techniques. First, the building areas are detected using image classification and normalized Digital Surface Model (nDSM). Those areas other than the buildings are excluded from further processing. Then, the buildings in the existing vector database are updated through evaluating the detected building areas and using the proposed model-based building extraction technique. The method was implemented in a selected urban area of Batikent, Ankara using IKONOS pan-sharpened and panchromatic images (2002). First, the building areas were detected by classifying the pan-sharpened image. The classified output provides the shapes and the approximate locations of the buildings. However, those buildings that have similar reflectance values with the other classes were not able to be detected. Therefore, nDSM was generated by subtracting the Digital Terrain Model (DTM) from Digital Surface Model (DSM). Next, the buildings were differentiated from the trees by using the Normalized Difference Vegetation Index (NDVI). Then, the buildings that exist in vector database and missing in the image were detected through analyzing the building areas coming from both the classification and nDSM for each building boundary and deleted from the vector database. Finally, the buildings constructed after the date of the compilation of existing vector database were extracted through the proposed model-based approach and the vector database was updated with the new building boundaries. The preliminary results show that the proposed approach is quite satisfactory for detecting and delineating the buildings from high resolution space images.

## 1. INTRODUCTION

Monitoring land use changes in settlement areas is important for urban planning. There is a great need for timely maps for urban and regional planning applications. Land use in urban areas changes continuously mainly due to the construction of new buildings, roads and other man made objects. The urban planners require up-to-date land use information to make and implement the city plans. Therefore, the maps should be regularly updated with the changes. Geographic data acquisition is usually very time consuming and costly. Thus, many Geographic Information System (GIS) applications suffer from the absence of current land use information. This problem however could be overcome by the Remote Sensing technology. Data acquisition by remote sensing for mapping and GIS has traditionally been characterized by the efficient and accurate manual extraction. However, manual information extraction is very time consuming and requires qualified people. Therefore, to speed up this process by automatic or semiautomatic feature extraction techniques has become a necessity.

Building extraction from remote sensing images has been an important research topic for the last decade. In most of the early studies, black and white aerial images have been used as a single data source (Huertas and Nevatia, 1988; Kim and Nevatia, 1999; Lin and Nevatia, 1998). These methods were mainly based on edge detection, line extraction, and building polygon generation. On the other hand, the height data appear

to be an important source for building extraction. DSMs generated from LASER/LIDAR data were used in several studies (Alharthy and Bethel, 2002; Priestnall et al, 2000). In the studies conducted by Niederost (2000) and Jaynes et al (2003), DSMs generated from high resolution aerial images were utilized. On the other hand, in several approaches, the building models were facilitated to automate building extraction procedure (Suveg and Vosselman, 2003; Tseng and Wang, 2003; Peng and Liu, 2005).

The increasing availability of high spatial resolution satellite images has provided a new data source for building extraction. When compared with the aerial photographs, the high resolution satellite images provide several advantages that include the cost and the accessibility. Several recent studies have used the spectral reflectance values to detect the buildings (Lee et al, 2003; Shan and Lee, 2002). The use of the combination of multiple data sources and the integration of images with the other data sources such as DSMs, existing GIS data, ground plans and apriori knowledge appears to be a new trend in building extraction.

This study presents a method for an automated map updating through developing a building detection and delineation technique by using spectral reflectance values of the images, DEM generated from high resolution stereo images, and the existing building vector database. The use of aerial/space images or a DEM alone may not be sufficient for an automated

extraction of the buildings. For this reason, this study utilizes both the high resolution satellite images and the DEM. First, the spectral information and the DEM generated from stereo images are used to discriminate the buildings from other objects. Then, the boundaries of the buildings are delineated through proposed model based building extraction technique.

## 2. METHODOLOGY

The main steps followed in the proposed methodology are given in figure 1. The approach consists mainly of three steps to extract the buildings from high resolution satellite images; (i) preprocessing, (ii) building detection and (iii) building delineation.

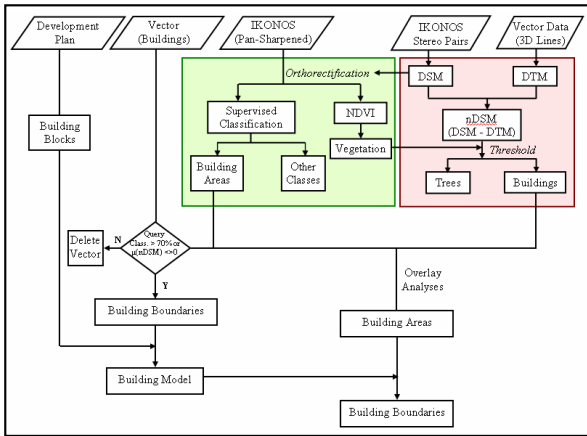


Figure 1. The main stages of the proposed building detection from high resolution satellite images

Initially, the orthorectification and the calculation of the Normalized Difference Vegetation Index (NDVI) are carried out as preprocessing. The images are orthorectified using the DSM generated from the stereo images so that they are accurately overlaid with the existing GIS database and be used as a base map for feature extraction. Then, NDVI is calculated to be used for masking the vegetated areas in the further processes.

In the second stage, the spectral reflectance values of the image and digital elevation models are used to detect the candidate building patches. To get the approximate locations of the buildings, the image is classified using the Maximum Likelihood Classifier (MLC). However, some of the buildings that have similar reflectance values with the other classes, such as roads and pavements, cannot be detected through image classification. In such cases, including the DEM in the processes could be useful. Therefore, nDSM is generated by subtracting DTM from DSM. The DTM and DSM are generated from the existing digital vector database and the stereo image pairs, respectively. A threshold is then applied to nDSM to separate man made features. In nDSM, the values above zero indicate the building areas. Next, the building areas in the classified image are overlaid with the thresholded nDSM to obtain the candidate building patches. The areas other than the buildings are excluded from further processing.

In the building delineation stage, the vector building database is analyzed together with the classified image and the nDSM to update the existing digital vector database with the new building boundaries. If both the percentage of the building class

pixels falling within the building boundary and the mean value of the elevation are higher than the preset threshold then, the building is considered to exist. If, on the other hand, the reverse is true then, the vector building polygon is deleted from the database. To delineate those buildings constructed after the compilation of the vector database, again the existing building vector database is used. A building polygon is selected as a building model from existing building vector database for each building block, because the shapes and the types of the buildings are usually same. Then, the selected building model is applied to detected candidate building areas.

## 3. STUDY AREA AND DATA DESCRIPTION

The proposed approach was implemented in the Batikent district of Ankara, the capital city of Turkey (figure 2). Batikent was a housing project of the 1980s in Ankara. After completing the expropriation process, the technical infrastructure projects and the feasibility research were done. The Batikent Housing Cooperation Union was founded and the initial constructions were started in 1980. The land cover of the area changed greatly by 1995. Batikent is a planned and regularly developed settlement which includes the buildings with different shapes and usage such as the residence, industrial, commercial, social and cultural facilities. Therefore, the area was suitable for implementing the proposed building extraction technique.

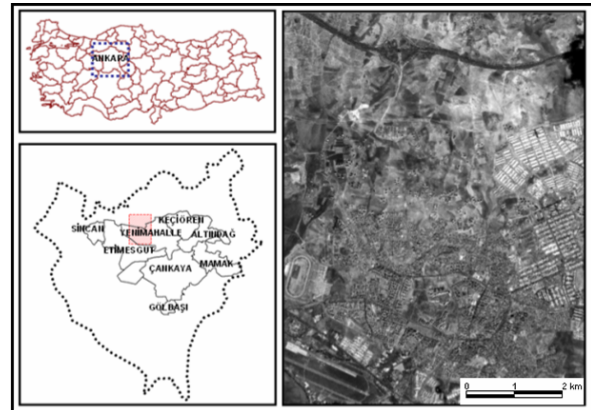


Figure 2. The study area, Batikent, ANKARA

The data sets used include the IKONOS stereo panchromatic and pan-sharpened images, the existing digital vector database and the development plans. The IKONOS images were acquired on August 4, 2002. They are along track stereo images and in “Geo” data format. The 1:1000 scale existing digital vector data covering the metropolitan area of Ankara was also available. The vector dataset was compiled by the Ankara Greater Municipality, General Directory of Water and Sewer System (ASKI) in 1999.

## 4. DATA ANALYSIS

The data processing and analysis operations were carried out using the PCI Geomatica 9.1 image processing and the Matlab 7.0 software.

### 4.1 Pre-Processing

The IKONOS images used were in “Geo” format with approximately 50m accuracy. Therefore, to remove the

geometric distortions including the relief displacement, the orthoimages were generated. This was necessary to overlay the images with the existing GIS database accurately and use them as the base map for performing the building extraction procedure.

In order to mask out the vegetated areas from nDSM and differentiate the trees and buildings from each other, the Normalized Difference Vegetation Index (NDVI) was calculated using the red and near-infrared bands of the orthorectified IKONOS pan-sharpened images. Then, the vegetated areas were separated from the non-vegetated areas using an empirically determined threshold value of 145.

#### 4.2 Building Detection

In the proposed approach, before delineating the building boundaries, the candidate building areas were determined. To detect the building areas, the spectral reflectance values of the pan-sharpened image and the nDSM were used.

**4.2.1 Image Classification:** The left image of the stereo pair was classified using the maximum likelihood classification (MLC) technique. Initially, five main classes and their subclasses were defined. Then, for each class, training samples were selected from representative areas. When collecting the training samples, the image was displayed on the screen as the infra-red band assigned to red channel, the red band assigned to green channel, and the green band assigned to blue channel (false color display). The main reason for using the false color display was that the classes were better discriminated in this band composition.

Next, for each class, the training statistics were generated that include the number of training pixels, the mean values, standard deviations and co-variances. During classification, each unknown pixel was categorized into the class it most closely resembles. After performing the classification operation, the sub-classes were aggregated into their main classes and a filter was applied to the classified output for removing the isolated single pixels and small patches. Figure 3 illustrates the false color composite and the classified output of the selected two building blocks.

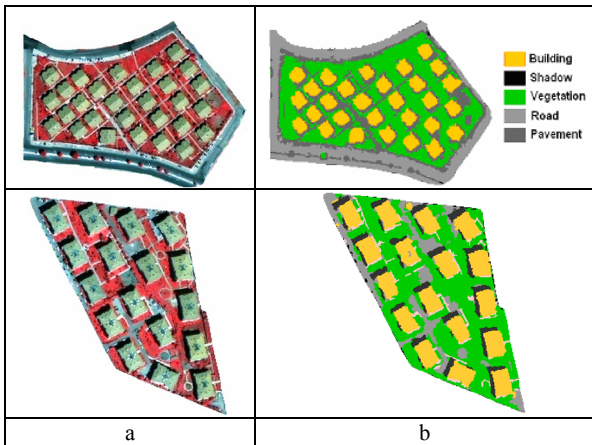


Figure 3. The (a) false color composite and (b) the classified output of two building blocks.

**4.2.2 The Generation of the Normalised Digital Surface Model:** A Digital Terrain Model (DTM) is the elevation model of the landscape which does not include above ground objects. On the other hand, a Digital Surface Model (DSM) includes the objects with their heights above the ground as well as the topography. The basic idea of using a DEM in a building extraction method is that the man made objects with different heights over the terrain can be detected by applying a threshold to normalised Digital Surface Model (nDSM). The nDSM was generated by subtracting the DTM from the DSM (figure 4). The difficulty in this process was the separation of the buildings from the trees as both features have heights above the ground. However, their separation can be achieved using a NDVI image.

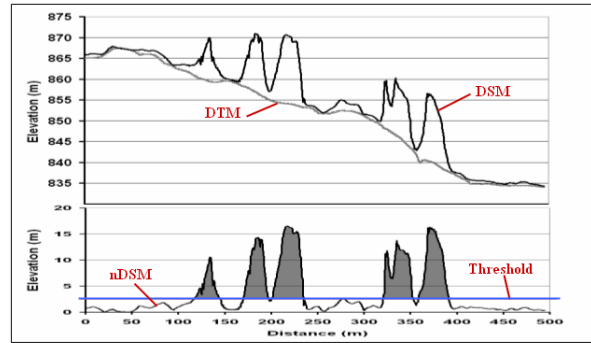


Figure 4: Generation of nDSM. The grey areas represent the 3D features after applying the threshold.

In the present case the DTM was generated from existing vector database that contains 3D lines and height points. The DSM was generated from the stereo pairs of the IKONOS satellite images using the OrthoEngine Module of PCI Geomatica image processing software. In order to generate the DSM, the coordinates of 48 ground control points (GCP) were measured through Differential Global Positioning System (DGPS) technique. Of these points, 24 were selected as GCPs and the remaining 24 were used as Independent Check Points (ICPs). While the accuracy of the generated DTM was computed to be 0.2 m, the accuracy of the DSM was found to be 0.7 m.

The nDSM was computed by subtracting the DTM from the DSM. The generated nDSM provides the above ground objects, such as the buildings and the trees. Next, the buildings were differentiated from the trees using the previously generated NDVI image by simply masking out the vegetated areas. Then, a threshold value of 5 m was applied to nDSM for separating the above ground features from the terrain surface (figure 5). The threshold value was determined as 5m so that even one storey building could be detected since it is unlikely that an object lower than 5m can be a building.

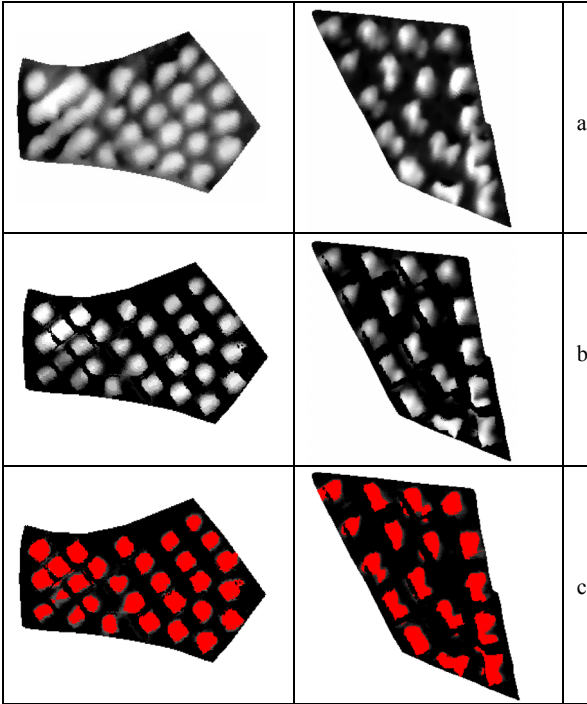


Figure 5. For the selected two building blocks (a) the nDSM, (b) nDSM after masking out the vegetation areas and (c) the pixels (red areas) that have higher elevation than the threshold.

The building areas detected through using the classified image and the nDSM were integrated. The result image includes the candidate building patches (figure 6).

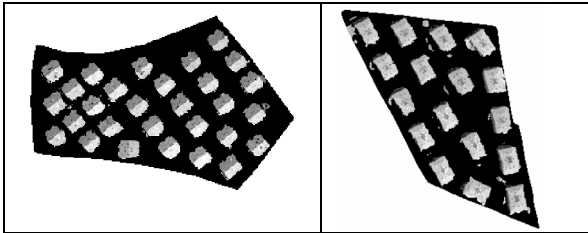


Figure 6: The candidate building patches for the selected two building blocks.

### 4.3 Building Delineation

After finding the candidate building areas, the next step was the delineation of the boundaries of the buildings. For this purpose, the panchromatic image that includes only the building areas, the existing building database, and the development plans were used.

As mentioned above, the vector building database compiled in 1999 was available. On the other hand, the space image used in this study was acquired in 2002. There is a three-year time lapse between the date of image acquisition and the date of existing vector building database. Three conditions can be defined for the status of a building:

- (i) The building exists both in vector database and in the image,

- (ii) The building exists in vector database and missing in the image, and
- (iii) The building exists in the image and missing in the vector database.

In the first condition, the building still exists both in vector building database and in the image. Therefore, the existing vector building boundaries must be preserved in the vector database and no update is necessary. In the second condition, the building does not appear in the image. Thus, the building should be deleted from the existing building database. The third condition corresponds to new buildings that were constructed after the compilation of the existing building database. Therefore, the boundaries of the new buildings should be extracted and the existing building database should be updated with the new buildings.

In the proposed approach, the existing building database was utilized for detecting the buildings defined in above given conditions. To detect the buildings in the first and the second conditions, the attribute tables of the vector database were updated through analyzing both the classified image and the elevation values of nDSM within the boundaries of each building (figure 7). The pixels falling within each building were counted and inserted to attribute database as the new field. Then, those pixels labelled as building in the classified image were counted and their percentage was computed. In addition, the mean height values within each building vector polygon were also computed from the nDSM. After updating the attribute table of the vector data, the buildings that still exist and the missing buildings were detected by invoking below query.

If the ratio of the pixels classified as building to all pixels is higher than 70% or the mean value of the thresholded nDSM is not equal to zero within a building polygon, then this building is preserved. Otherwise the vector polygon is deleted.

```
If %b_class > 70 or mean_nDSM <> 0
Vector = "building"
Else Vector <> "building"
```

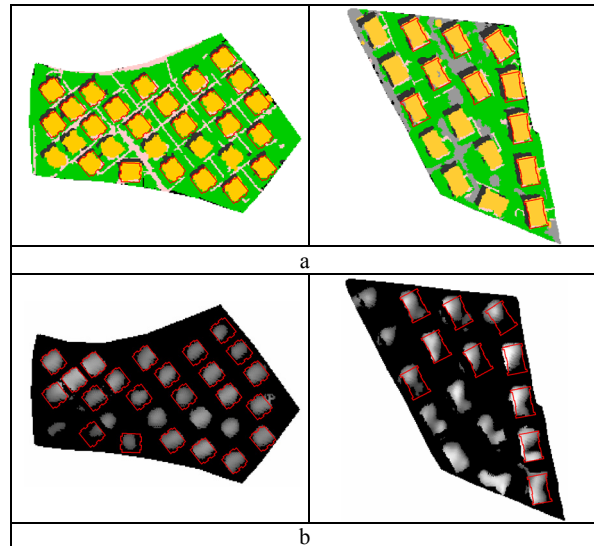


Figure 7. (a) The classification output with the building boundaries overlaid and (b) the nDSM with the vector building boundaries overlaid for the selected building blocks.

To extract the buildings in the third condition, the existing building database was used to determine the “building model”. In regularly developed urban areas, within a building block, the types and the shapes of the buildings are usually the same. Therefore, within a building block considered, a building polygon can be selected as a “building model” from the existing building vector database. In this study, the building block boundaries were obtained from development plans.

After selecting a building model, it was applied to the candidate building areas. This task consists of several steps: (i) removing speckles from the image that includes the building areas, (ii) finding the centroids of the building areas, (iii) finding the centroid of the building model, (iv) rotating the building model with the specified angles and (v) applying the building model to the candidate building areas.

The image that includes the candidate building areas only contains speckles caused by the misclassification or the interpolation conducted during DEM generation. To remove the speckles, the pixels were counted for each candidate building area. Then, those candidate building areas smaller than a threshold are considered speckles and eliminated from further processes. In this study, the threshold was determined as 50 pixels for the IKONOS panchromatic image (50m<sup>2</sup>), because objects smaller than the 50m<sup>2</sup> cannot be a building.

After removing the speckles, the next step was finding the centroids of the candidate building areas. The centroid of each separate building area was found and their x and y coordinates were kept. Then, the centroid of the building model was computed from the corner coordinates of the building model.

Although the shapes and the types of the buildings within the same building block are usually same, their orientation can be different. To apply the building model to the candidate building areas with right orientation, initially the building model was rotated with per 15 degrees angles from 0 to 360 degrees and applied to each building area. Next, for each building, the intersection areas of the rotated building model and the corresponding building area were calculated. To select the most appropriate rotation of building model, for each building area, the intersection areas of the rotated building models and the vectorized building areas were considered. Finally, the rotated building model, which has the highest intersection area, was selected and applied to the candidate building area. The developed algorithm was applied on two building blocks selected from the study area. The results are illustrated in figure 8.

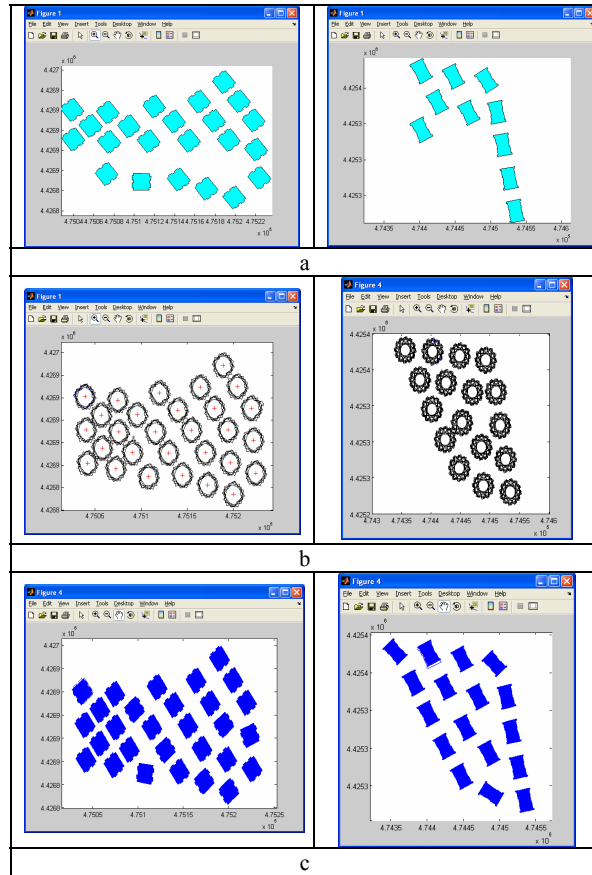


Figure 8. (a) The existing building vector database of the selected building blocks, (b) the rotated building models with 15 degrees and (c) the delineated building boundaries

## 5. SUMMARY AND RESULTS

High resolution satellite images provide a valuable new data source for geographic information acquisition. Building detection from high resolution satellite images has attracted great attention in recent years. To automate the process and produce reliable, precise, and complete datasets, multiple data sources and advanced techniques should be used. In this study, the IKONOS stereo panchromatic and pan-sharpened images, DSM generated from these stereo images and DTM calculated from the contour lines were used to detect the candidate building areas. Then, the boundaries of these buildings were delineated using the proposed building-model based approach.

The results of the classification provided the approximate locations and the shapes of the buildings. However, those buildings that have similar spectral reflectance values with the other classes were not able to be classified as buildings (figure 9). For this reason, both the classified image and the nDSM were used together to get the region of interest areas for the buildings.

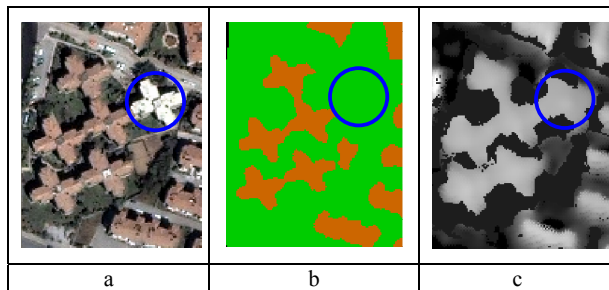


Figure 9. (a) The true color pan-sharpened IKONOS image, (b) the result of the Maximum Likelihood Classification and (c) the thresholded nDSM

The preliminary results show that the proposed building extraction method is quite promising for detecting those buildings constructed after the date of the compilation of the existing building database and those buildings destroyed and therefore do not exist in the image. In figure 10, the red coloured polygons indicate the buildings present in the existing vector building database but missing in the image.



Figure 10. The red coloured polygons indicate the buildings that do not exist in the image anymore.

The disadvantage of the building-model based approach is that determining and defining all possible building shapes are required. The shapes and the types of the buildings can be very different. Therefore, compilation of the building-model library is a difficult and formidable task. In the developed approach, the building-model is selected from existing building database. This procedure is more effective than determining and defining new building models such as parametric, prismatic and polyhedral building models. By using this method the buildings in different shapes can be detected.

## 6. CONCLUSIONS

In this study, an approach was developed to update the buildings of existing vector building database from high resolution satellite images with the use of image classification, DEM generation and model-based extraction techniques. The preliminary results show that the proposed approach is satisfactory for detecting and delineating the buildings from high resolution satellite images. Selecting vector building polygons from the building blocks of an existing vector database and use them as building-models appears to be more effective than determining all possible building models.

However, the restriction of this method is that it can be used for the regularly developed urban areas only.

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