

URBAN CHANGE DETECTION IN CITY CENTERS USING TEMPORAL SATELLITE IMAGERY

Dimitris KAIMARIS, Efstratios STYLIANIDIS, Athanasios LAMBROU, Konstantinos
PANOZACHOS, Nikolaos KANDIS

Aristotle University of Thessaloniki, Greece

School of Urban-Regional Planning and Development Engineering, kaimaris@auth.gr,
sstyl@auth.gr, alamprou@auth.gr, kpanozac@auth.gr, kandis@auth.gr

Keywords: Change detection, urban, satellite imagery, historical maps, GIS

Abstract:

The use of modern imaging techniques in urban areas allows the study of change detection of urban limits over time. The literature review facilitates the identification of the causes for the creation of specific spatial behaviour patterns. Additionally, such a study contributes to the assessment of territorial city expansion future trends. This work focuses on determining the temporal variation of the city of Veria (Central Greece) spatial limits through digital processing of temporal geographic data. More specifically, a variety of imagery data is used covering different scales; 1:10,000 to 1:30,000, from 1950 to date and historical maps of scale 1:2,000 to 1:50,000, from 1930 to 1990. For the geometric correction of both imagery and maps, ground control points with high spatial accuracy and well-known digital terrain model (grid size 20x20m) have been used. The introduction of the rectified images and geometrically corrected historical maps in a Geographic Information System (GIS) allows the identification of the city original core and determine the temporal boundaries. Combinational literature analysis facilitates the interpretation of spatial deviations and allows a concrete assessment for the future trends of city expansion.

1. Introduction

Veria is a city of Central Macedonia, built on the foothills of the mountain Vermio (fig. 1). It is well known for its traditional architecture and its rich history. It was famous from the classical era (Thoukididis wrote about the city) and flourished during the Hellenistic and the roman era.



Figure 1: Map of Greece and Veria location.

The aim of this study is the diachronic specification of the changes in the boundaries of the urban network through the digital processing of the diachronic remote sensing data, the historical maps and the urban designs. After the geometric correction of the geographical data and their incorporation within the GIS, the boundaries of the continuous urban city structure are mapped and the temporal changes are interpreted. Moreover, the future expansion of the city borders is predicted.

2. Data

The geographic data that have been collected in order to study the change detection of Veria's urban limits over time are presented below:

- Street plan of Veria (1936). Scale 1:2000. Received from the Department of Urban Planning, Veria Municipality
- Aerial photos presenting city of Veria for the year 1951. Scale 1:15.000. Received by Cadastre and Mapping Agency of Greece
- Aerial photos presenting city of Veria for the year 1975. Scale 1:15.000. Received by Cadastre and Mapping Agency of Greece
- Approved master plan (map) of Veria (1986). Scale 1:5000. Department of Urban Planning, Imathia Prefecture
- Master Plan modification Map of Veria(2005).). Scale 1:5000. Department of Urban Planning, Imathia Prefecture
- Latest Orthophotomaps of city of Veria for the year 2009. Greek National Cadastre
- Military Geographic Service map (1975). Scale 1:15000

3. Data digital processing

This stage includes the digital processing of imagery data using Erdas Imagine software. This process aims the optimal possible geographic coordinate system correction according to the Greek Geodetic Reference System (EGSA '87). Next is given a detailed description of the data geometric correction stages leading to the final imagery products used to detect the temporal changes of Veria's urban limits.

Street Plan of 1931

The Street Plan of Veria has been scanned in 600 dpi resolution. The process used for the geometric correction is the 1st Order Polynomial Geometric Model [1-6]. Specifically, the 28 GCPs (Ground Control Points) used between Street Plan and the Orthophotomaps of 2009. The final RMS Error of Geometric Correction is about 0,3metres.

Aerial Photos of 1975

The two aerial photos of Veria of the year 1975 have been scanned in 900 dpi resolution. Firstly, the Projective Transform Method was used in Erdas Imagine 9.0 Software for the geometric correction of the aerial photos [5, 6]. This process was based specifically on the use of the regional Digital Terrain Model (DTM). For the first aerial photo (124652) 21 GCPs were selected in relevance with the orthophotomap of 2009. The RMS Error estimated at 0,4 pixels.

Taking into account the 900 dpi resolution scanning and the scale of the aerial photo (1:15.000), the pixel size is corresponding to 0,4 meters GSD and the final accuracy is 0,17 meters. For the second aerial photo (124654), the use of 21 GCPs in geometric correction process gave an RMS Error of 0,4 pixels or 0,164 meters GSD. Finally, the two ortho-results were combined appropriate in order to produce one photo mosaic; reference for the year 1975.

Aerial Photos of 1951

The two aerial photos of 1951 have been scanned in 900 dpi resolution. The Projective Transform Method was also used during geometric correction with Erdas Imagine 9.0 Software. The regional DTM was used as well. In the next stage, the number of 21 and 20 Control Points used between the first aerial photo (11-21) and the mosaic of 1975 and similar between the second aerial photo (11-22) and the mosaic of 1975. The solution of geometric model resulted an RMS Error of 0,4 pixels or 0,16 meters GSD for both cases.

Approved Master Plan of 1986

The City Plan has been scanned in 600 dpi resolution. The geometric correction process was based on the 1st Order Polynomial Geometric Model. Furthermore, 51 GCPs selected between the Master Plan of Veria and the latest Orthophotmap (2009). The final RMS Error is 0,3 pixels which corresponds to 0,06 meters GSD.

Master Plan Modification Map of Veria (2005)

The Master Plan of Veria (Modification Map) has been scanned in 600 dpi resolution. For the geometric correction 45 GCPs were used and led to an accuracy of 0,3 pixels or 0,06 meters.

4. Spatial analysis using GIS

Spatial analysis and study of the temporal variation for Veria's urban limits was accomplished by using a Geographic Information System (GIS). The results from the digital processing fulfilled in the previous stage, have been incorporated in a GIS platform, where city limits for each time period were captured, analyzed and illustrated. A unique linear shapefile (shapefile-polyline) was assigned for each case, showing a single layer in the GIS.

Limits of the urban fabric in 1936

The City plan that was approved in 1936 has been used in order to study Veria's urban limits by that time. As shown in Figure 2, the urban fabric is mainly consisted by the historical core of the city which includes 4 historical places/neighborhoods (yellow circles, fig.2). These historical places reserved until nowadays. In that time the city fabric developed in close distance with the city's 3 main roads: Ellias Street (orange line, fig.2), Venizelou Street (green line, fig.2) and Mitropoleos Street (blue line, fig.2). Urban fabric of the historical core is consisted by large blocks of irregular shape, narrow streets and dead ends. West side area presents dilute and unregulated build, while the new urban tissue which has been formed to the north and south of the historic core bears linear road layouts and rectangular shaped blocks. This new urban tissue is sparsely structured but indicates the city's future trends of development.

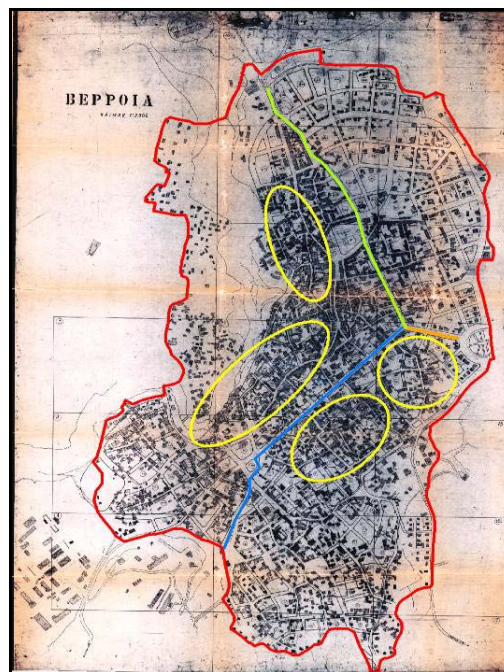


Figure 2: The boundary (red colour) of the urban tissue, City of Veria, Street Layout, 1931.

Limits of the urban fabric in 1951

The mosaic from the aerial photos of 1951 has been used in order to capture the limits of the urban fabric of the city in 1951, and record the developments during the period 1936-1951. As shown in Figure 3, during the period 1936-1951 urban tissue presents two small, northern and southern extensions of the existing tissue respectively (yellow arrows). These extensions are essentially a continuation of the new urban fabric that had been created in the previous period. In these parts, there is denser structure than in previous decades, which justifies partially the extensions' direction.

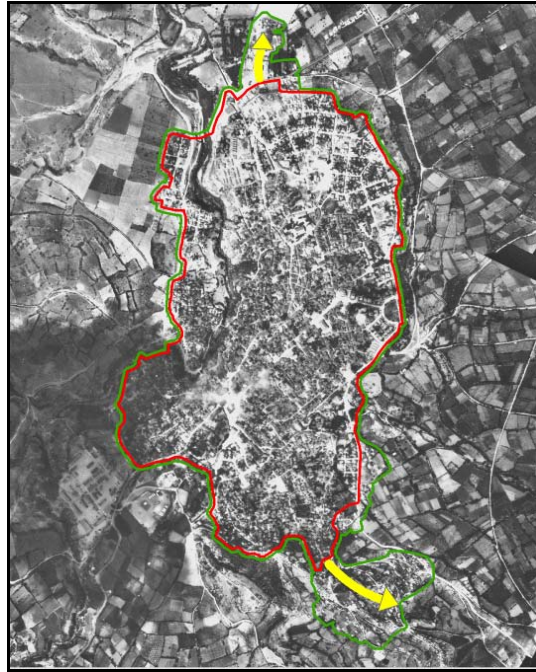


Figure 3: The limits (green color) of the urban fabric of the city in 1951 (aerial 1951).
The limits (red) of the urban fabric of the city in 1931.

Limits of the urban fabric in 1975

The mosaic of the aerial photos of 1975 has been used in order to capture the limits of the urban fabric of the city in 1975, and record the developments during the period 1936-1975. The extensions that are detected during this period, as shown in Figure 4, are all around the perimeter of the existing fabric. However, stronger directions are still North-Northwest (blue arrows) and Southwest (yellow arrow).

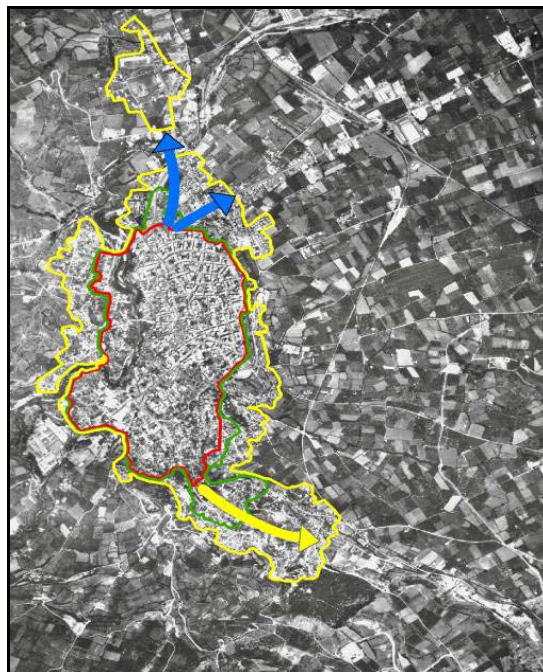


Figure 4: Limits (yellow) Of the urban fabric of 1975 (aerial photographs 1975).
Limits (green color) of the urban fabric of the city in 1951 (fig. 3).
The limits (red) of the urban fabric of the city in 1931 (fig. 2).

1st Approved Master Plan of 1986

The first Veria Master Plan was approved by the authorities on 14/05/1986. Alongside the visual recognition of the urban fabric limits through aerial photos of the city, the first Veria Master Plan of was further studied. The study of the Master Plan is particularly important for understanding the spatial characteristics of the city, such as urban organization and the establishment of the city. As shown in Figure 5, 20 urban sections were elaborated, including essentially 3 new extensions.

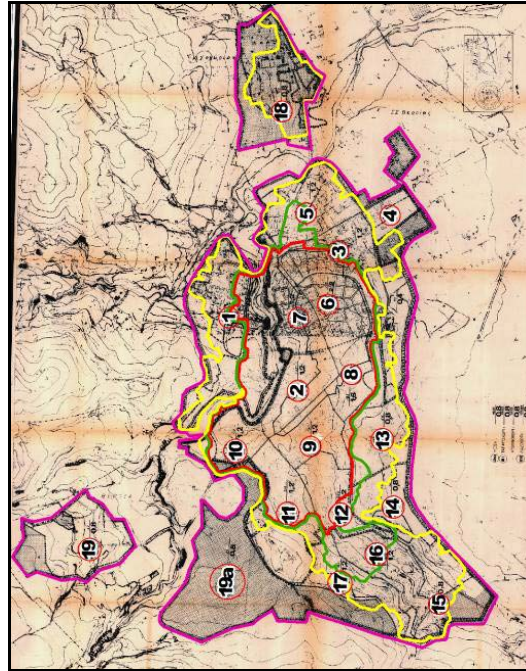


Figure 5: Limits(purple) of the 1st approved Veria's Master Plan of 1986. Limits (yellow) of the urban fabric of the city in 1975 (aerial photographs 1975). Limits (green color) of the urban fabric of the city in 1951 (fig. 3). The limits (red) of the urban fabric of the city in 1931 (fig. 2).

According to the Plan, land-use schemes in each urban section (building conditions, land uses) were also assigned, with the main objective to strengthen the local centers and the peri-urban zone, and to create new centers of development. The first area places in the city plan the settlement Ergochori to the North (urban section 18, fig.5). The second one places in the city as a separate urban unity the settlement Panorama to the west (urban section 19, fig.5), an extension that does not follow the trends of development in the basic roads. The third expansion refers to the area south-southwest of the city (urban section.19a, fig.5), which is in contact with the existing urban fabric.

Master Plan Modification of 2005

The institutional arrangements currently in force by the municipality of Veria were approved on 06/07/2005. As shown in Figure 6, three new urban sections (areas 23, 24 & 25, fig.6) are place in the city. The first section is in contact with the eastern part of the city, as a continuation of the urban fabric. The next two are located in the south-west without stain on any part of the urban net, but they follow the development trends towards the Egnatia Road (No.6, fig.8). According to the Master Plan, the smallest of these new urban sections is under development as an area of central city functions. It is clear that the southwest part of the city is being developed as an area of economic and administrative functions. At the same time, according to the Master Plan new building conditions and rules are set, in accordance with the new trends of development, while the city boundaries are fixed and new land-uses are established. High build is reduced in order to preserve the «sensitive natural areas». Finally, considerable improvements in infrastructure networks are scheduled.

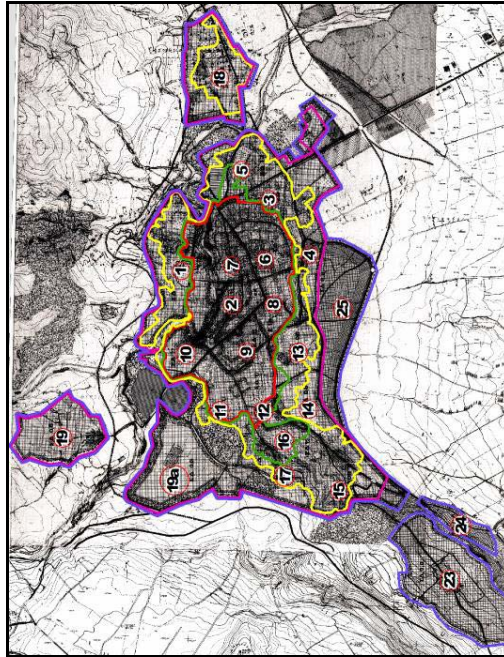


Figure 6: Limits(blue) of Veria's Master Plan Modification of 2005. Limits(purple) of the 1st approved Veria's Master Plan of 1986. Limits (yellow) Of the urban fabric of the city in 1975 (aerial photographs 1975). Limits (green color) of the urban fabric of the city in 1951 (fig. 3).
The limits (red) of the urban fabric of the city in 1931 (fig. 2).

Limits of the urban fabric in 2009

The modern orthophotomap of 2009 has been used in order to complete the capture and analysis of the latest spatial boundaries of the city's urban fabric. As shown in Figure 7, the urban fabric presents dense structure and consistency. It is clear that the city is attracted southwest, towards Egnatia Highway (No.6, fig. 8), where apart from housing, economic and trade activities are also developed. Northwest, structural trends are strong within the areas of the city. Nevertheless, the possibility of future expansion in that direction is limited by the establishment of industrial faculties. Finally, the western part of the city, at the left of River Tripotamos, (No.7, fig. 8) presents dense structure while the eastern part which is one of the latest city expansions presents relatively dilute structure.

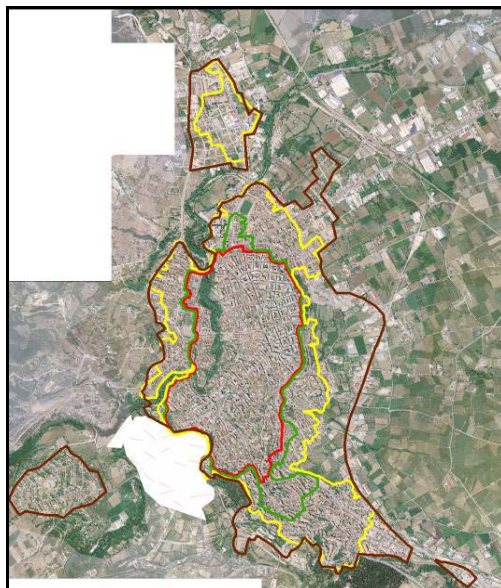


Figure 7: Limits (brown) of the urban fabric of the city in 2009. Limits (yellow) of the urban fabric of the city in 1975 (aerial photographs 1975). Limits (green colour) of the urban fabric of the city in 1951 (fig. 3). The limits (red) of the urban fabric of the city in 1931 (fig. 2).

5. Conclusions

Completing the process of spatial analysis in GIS, some general conclusions-research results are extracted. These results are basically the origin for the identification and study of city's spatial changes that occurred between 1930 until today.

The study of the temporal development at Veria's urban tissue shows two main trends-directions of the city expansion. The first and most intensive refers to the southwest part of the city (red arrow, fig. 8), which includes structuring and expansion along Pierion street (No.4, fig. 8) towards Egnatia Highway (No.6, fig. 8). The second (yellow arrows, fig. 8) is associated with the northern part of Veria, directed on both sides of the old national road Thessaloniki-Veroia (No.5, fig. 8), towards the settlement Ergochori (Area C, fig. 8) and the railway station (Area E, fig. 8) respectively. These trends that are maintained throughout the whole intended period (1931-2009) have essentially as main directions, the two main entrances of the city. On the other side, only weak trends detected to the east and west of the city, which may be caused by prolonged use of large areas for primary production activities (east), as well as the steep terrain of the land that is in contact with the foothills of Mount Vermio (west). An important element is the large spare space in the area close to the Military Barracks (Area D, fig. 8) and the fragmentary expansion to the settlement Panorama (Area B, fig. 8).

More specifically, there are several deviations of development in areas that even since the 1st Master Plan (1986) were proposed for residential development (1986) (Hatched areas, fig. 8). An important example is the vast area south of the military barracks, which was placed in the city limits by the 1st Master Plan in 1986, and until today has not been developed according to the schedule. It is possible that the close distance with the military barracks has made the area unattractive for residential development (Area J, fig. 8).

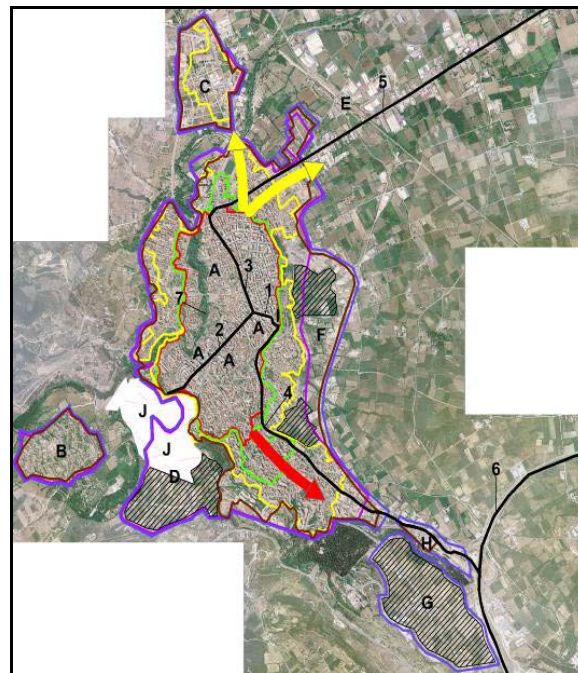


Figure 8: Limits(brown) of the urban fabric of the city in 2009 (fig 7). Limits (blue) of Veria's Master Plan Modification of 2005. Limits(purple) of the 1st approved Veria's Master Plan of 1986. Limits (yellow) Of the urban fabric of the city in 1975 (aerial photographs 1975). Limits (green color) of the urban fabric of the city in 1951 (fig. 3). The limits (red) of the urban fabric of the city in 1931 (fig. 2). A: Historical Places. B: Settlement Panorama. C: Settlement Ergochori. D: Area near the Military Barracks, E: Railway station area. F, G, H: Expansions by the Master Plan Modification (2005). I: Ellias Square. J: Military Barracks. 1: Elias Street. 2: Mitropoleos Street, 3: Venizelou Street, 4: Pierion Street. 5: Old national road between Veria & Thessaloniki. 6: Egnatia Highway. 7: River Tripotamos. North-northeast (yellow arrows) trend of development. Southeast (red arrow) trend of development.

According to the modification of the Master Plan in 2005, three areas are placed in the city limits (Areas F, G & H, fig.8), at the east of Ellias Square (Area I, fig. 8) and west of the city entrance close to Egnatia Highway (No.6, fig.8) interchange. These areas do not illustrate anything special in terms of urban development (unique exception is the establishment of the new courthouse (Area H, fig. 8)). As so they could be place under a future planning. In general, any new trends of urban development in Veria are not expected, but only trends of loading of the existing urban tissue.

6. References

- [1] Kaimaris, D., Georgoula O., Karadedos G.: *Historical maps and archaeological research*, Proceedings of 8th National Conference of Cartography *Cartography and good leaving*, Thessaloniki, Greece, November 2006, 51-62.
- [2] Balletti, C.: *Analytical and quantitative methods for the analysis of the geometrical content of Historical Cartography*, Proceedings of International Archives of Photogrammetry and Remote Sensing, Vol. XXXIII, Part B5, Amsterdam, 2000, 30-37.
- [3] Guerra, F., Miniutti, D., Auditore, G.: *Venice's Canal Grande Representation with Interactive Cartographic Software*, Proceedings of International Symposium CIPA, Surveying and documentation of historic buildings, monuments, sites, Traditional and modern methods, Potsdam, 2001.
- [4] Niederost, J.: *Image analysis for the history of cartography: Drawing conclusions from the evaluation of Pfyffer's Relief*, Proceedings of International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XXXV, Part B5, Commission V, Presented at XXth ISPRS Congress in Istanbul, Turkey, 2004, 389-394.
- [5] Georgoula, O., Kaimaris, D., Karadedos, G., Patias, P.: *Geoinformation and Archaeology: An integrated case study in the Archaeological Site of Philippos in N. Greece*, Proceedings CAA Congress Enter the Past. The E-way into four Dimensions of Cultural Heritage, City Hall Vienna, Austria, April 2003, 409 – 413.
- [6] Guerra, F., Miniutti, D., Monti, C.: *Bi-visual image coupling of cartographic and photographic images*, Proceedings of International Cartographic Conference, Mapping the 21st Century, Beijing, 2001.