Detection of Urban Alteration with the Use of CAD and Remote Sensing Data: The Case of Trikala, Center Greece

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Abstract

This research concerns visualization techniques of an urban area, exploiting spatial and descriptive data editing, connecting and creating also urban visualization processes. This methodology-process applies on the evolution of the urban planning network of Trikala town (Central Greece) since 1945 till today. Contemporary and historical aerial photos were used, scaled 1:8000 up to 1:42000. Satellite images were also used (QuickBird-2). These aerial photos were georeferenced exploiting the Digital Terrain Model (DTM) and contemporary ortho-rectified images through different periods of the study area. The results of the urban planning network evolution are presented with superimposed expansion maps and general indicators representing, in different periods, town limits evolution indicators, free or covering construction area evolution indicators, etc. The aim of this research is to combine visualization techniques and processes in order to produce and present visual or descriptive results ready to be exploited and used in urban planning network changes analysis.

Keywords: CAD; Remote Sensing Data; Geomatics tools; Urban visualization; Visualization techniques; Urban planning evolution.

1. Introduction

This research concerns a methodological exploitation and blending of contemporary techniques of spatial and descriptive data elaboration which aim the extraction of “end-products” permitting the study of urban space changes.

The proposed methodology-process of the urban network visualization is based on remote sensing techniques and processes of spatial identification (ortho-rectified aerial photos and satellite images, digital terrain model, etc) and on digitalization and calculation automatization processes on CAD system. The blending of different spatial visualization processes gives the opportunity for clearer identification, description and perception of space and it permits, simultaneously, the exploitation of important information to analyze the urban network.

The proposed methodology-process is applied to the city of Trikala (Thessaly region, Central Greece) (Fig. 1). It should be noted that the general piecemeal results of this study, such as the change of the town's urban network (indicative general indicators of the urban network's evolution from 1945 to today, etc.) do not intentionally constitute an urban analysis of the town's expansion; In contrast, this study offers necessary tools for further analysis of urban space (orthophoto maps, Digital Terrain Model (DTM), automatization of areas calculation, surfaces "vectorization", etc).

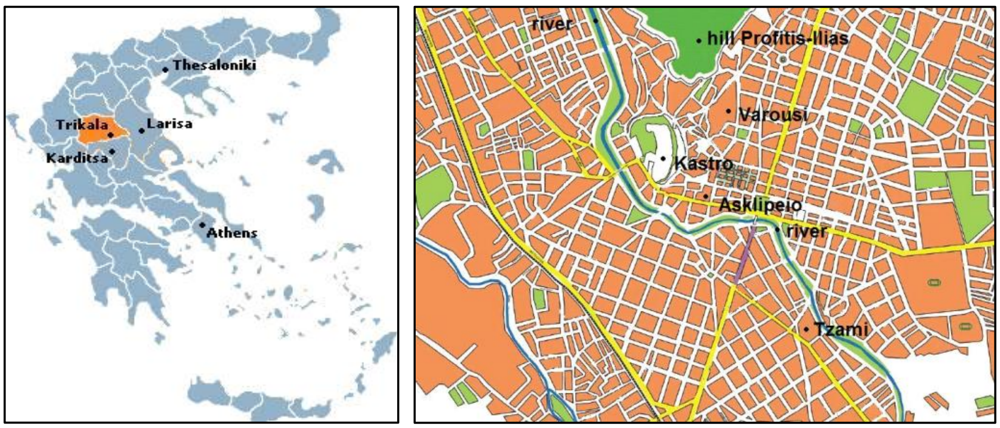

Figure 1. The region of the study. Left: Map of Greece, Right : Important places of Trikala city

The city of Trikala expands between two natural spots of the region, the Litheos river and the castle hill, where the ancient Acropolis must have existed. The initial name of the city was Trikki (from the nymph Trikki, who was born, as the myth says, on the river banks and gave her name to the city), and since the 12th century has been renamed and mentioned as Trikala. On the broader region, a habitation of the Middle Paleolithic Age is located and the city is connected with the Gods of health and medicine; in addition, the existence and functioning of the very Ancient Asclepiion of Trikki (hospital). The city is developing during the Christian period; the "Varousi" district is indicative, and constituted the Christian district of the city. However, nowadays, the 16th-century mosque of Osman Sach ("Coursoum mosque"), which constitutes the unique work of Sinan in the Greek territory (Thessaly region, 2009) is an inseparable piece of the city.

2. Methodological – procedural approach

The methodology-process of urban network visualization is based on remote sensing processes of spatial identification and on digitalization and calculation automatization processes on CAD system; aerial and satellite photos are used in parallel with 3D Ground Control Points for the extraction of the necessary Digital Terrain Model (DTM) and the orthophoto maps (Fig. 2). Maps including valuable information, such as the approved (or to be approved) town limit, are collected. With the "rehabilitation" of the maps' geometry, the exploitation of qualitative characteristics and measurements information is possible. At the same time, the collection of population elements of different periods is necessary for the extraction and construction of some indicators, such as the free area per person indicator, etc.

After the insertion of the ortho-rectified images in a CAD or GIS system, we can design and simulate all those spatial characteristics which serve the research objectives of a city's urban network. Some of the spatial characteristics which can be digitized are, among others, squares, construction covering or free areas, rivers, etc. Selecting adequate layers for the visualization of every 2D or 3D spatial information and exploiting polygons, calculation sheets and areas calculation automatization processes, different indicators can be extracted showing valuable information according to the research purposes.

Finally, the 3D simulation, exploiting the DTM and the telepiscopic images, permit the interpretation and the analysis of the study area (Fig. 2).

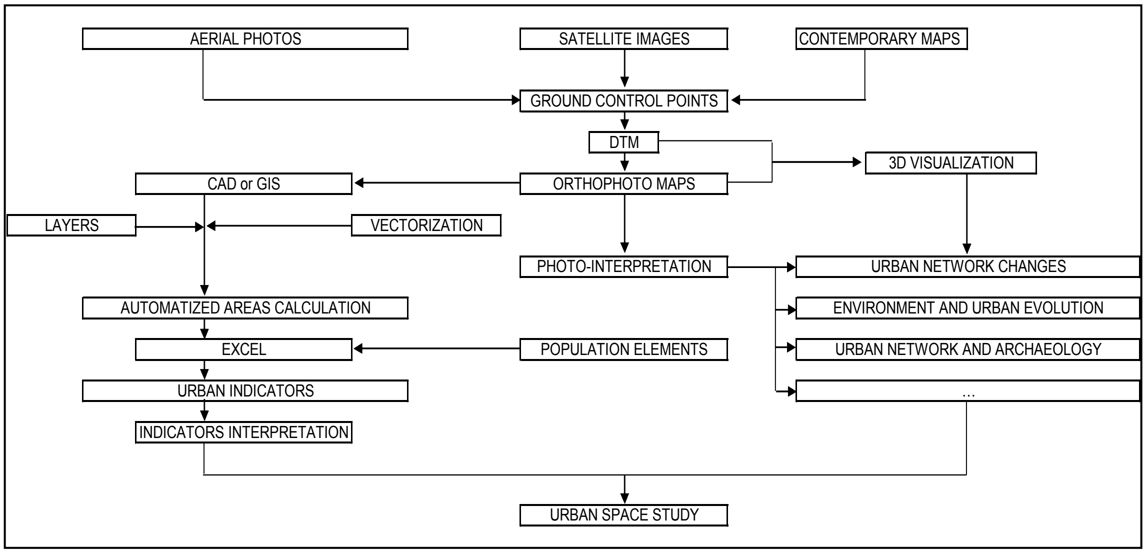

Figure 2. Flow diagram of the proposed methodology-procedural approach

3. Data, Elaboration and Results Visualization

The data which has been used for the city of Trikala and its elaboration is described in the following paragraphs. The methodology-process is essentially analyzed in this pilot application, focusing on the data nature, the elaboration techniques and the exploitation-visualization of some "end-products". It should be noted that these "end-products" constitute simply general "confirmation results" and they are extracted to be used for thorough study and analysis of the urban network change.

3.1 Aerial photos

The extended research which has been realized in the department of aerial photographs of Military Geographic Service (MGS) and in the Land and Map Registry Organization of Greece, (LMROG) has led to the collection of 24 vertical aerial photos of scale from 1:8000 to 1:42000, from 1945 to 1999 of the city of Trikala (Table 1).

Table 1. Characteristics of aerial photos of the study area

Origin	Date of taking	Number	Scale
MGS	1945	1	1:42000
LMROG	1960	2	1:33000
LMROG	1979	15	1:8000
LMROG	1999	6	1:15000

After the digitalization of the analogue photos in 1200 dpi, their mediocre quality (lightness and low contrast) imposed their further digital elaboration (Histogram Equalization, Brightness/contrast, Sharpen, Unsharp Mask, Convolution, Wallis Filter), which in turn improved their photometric characteristics. For the study area's DTM generation, aerial photos of 1999, of scale 1:15000 and Ground Control Points (GCP's) spatial accuracy, better than half of meter, have been used. After the "aerial-triangulation" and the DTM creation (Fig. 3-left), an ortho-rectified image of 1999 (it is conventionally used further on in the year 2000), of scale 1:5000 with corresponding spatial accuracy was produced (Fig. 3-right). The production of the ortho-rectified images of the rest of the years (Table 1), is based on the produced DTM and GCPs (solution of "back-section" and production of ortho-rectified images). Thus, the surveillance of the study area becomes better and the information extraction concerning covering construction and free areas measurements is ensured.

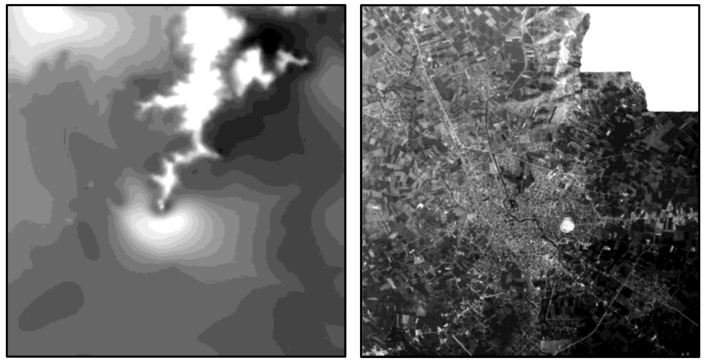

Figure 3. Left : DTM of the expanded region of Trikala (max height : white color, min height : grey color), Right : Ortho-rectified aerial photo of 1999 in the same DTM's area

3.2 Satellite image

For the acquisition of a contemporary background of the study area, thirty (30) color images have been selected (RGB, jpeg format) from the Google Earth Pro application. The dimensions of every image are almost 1000X700m on the ground, with resolution of 4800X3159 pixels and memory of 250 kB. The choice of these dimensions of images theoretically ensures the image's spatial resolution of year 2005 of the visual satellite system QuickBird-2 and greatest covering area during the saving of images in the computer. The digital elaboration (Brightness, Contrast, filter: Sharpen) for the visual improvement and the production of the images' mosaic was realized in the Adobe Photoshop CS2 software (tool : Automatic Photomerge). The production of the ortho-rectified satellite image is based on Ground Control Points (rectification in 2D).

3.3 3D visualization

The topography of the study area is an important factor for its interpretation and analysis. It is known that the 3D study of the Ground is easier than the 3D study of analogue or digital maps. The visualization can be realized in different ways (Sechidis *et all.*, 2005); one of the easy ways is the exploitation of the DTM and its produced ortho-rectified images (products of photogrammetry elaboration). Thus, in an adequate software, the DTM can be "superimposed" from an orthophoto map, creating a realistic image of the study area.

For the 3D visualization of Trikala, the DTM, the ortho-rectified aerial photo of 1945 and the satellite image of 2005 were used. All the 3D images of the study area were created in Erdas Imagine software, where the geometrical rectifications of the remote sensing data have taken place (Fig. 4).

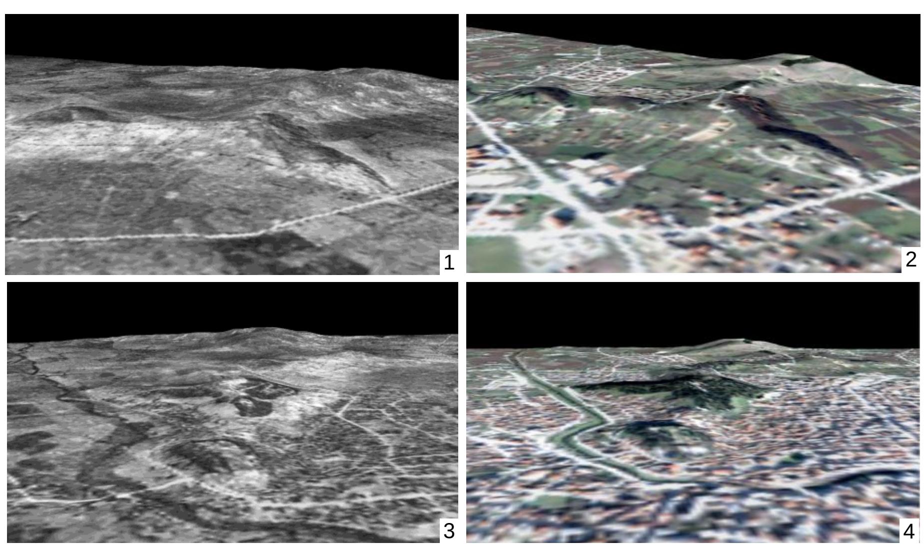

Figure 4. «Looking at» the north of the city hill, from southeast direction (up, 1-2) and «looking at» the south of the city hill, from south direction (down, 3-4), L: Aerial 1945, R: Satellite 2005.

3.4 Design data organization

The organization of the design data was realized in CAD environment with the aid of AutoCAD Architecture software. The philosophy of data classification in layers was based on each period of almost every 20 years for which aerial photos and satellite images of Trikala city were selected. The layer of each period (1945, 1960, 1980, 2000, 2005) was corresponded with the respective design data (aerial photo, free area, construction covering area, square, real town limit) and with correspondent properties (name of layer, color, linetype, line weight). The free area concerns an empty and free area of cultivated or uncultivated land. The construction covering area corresponds to the ground surface with human construction activities and the block is defined by the roads, the pedestrian zones or the river. The real city limit includes the densely populated area of Trikala city. This limit is every time connected with the spatial continuity of the construction area and it is defined by the influence of the visual discontinuity on spatial identification and cognition (Yanagisawa & Akahori, 2008) and the alternation of continuity and discontinuity (Fig. 5).

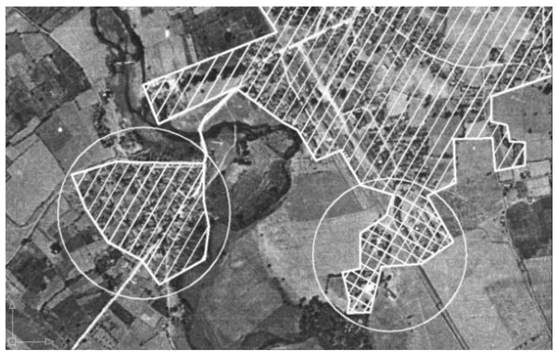

Figure 5. Definition of city limit, Left : Linear alternation of spatial continuity (construction area) and spatial discontinuity (free area). The selected area is not taken into account in the city limits. Right: Spatial continuity of construction area which is taken into account in the city limits.

The unique city limit, which was not defined in the sense of spatial continuity-discontinuity, is the limit of 2005 which was identified with the new, under approval, limit of 2008.

The design of the covering construction and free areas were realized with the method of "vectorization" (Kouzeleas, 2008a) of ortho-rectified aerial photos and satellite images. Afterwards, the vectorized surfaces were elaborated (closed surfaces control, addition and subtraction of vectors, modification in same level surfaces, automatic areas calculation), aiming the areas' calculation automatization of all the surfaces, as described further down.

3.5 Vectorized surfaces

As analyzed in the previous paragraph, every surface to be studied was vectorized per period. Thus, vectorized closed surfaces correspond to the city limits, the covering construction areas, the free areas and finally the blocks (Fig. 6).

Every closed vectorized surface is specially elaborated, as analyzed in the next paragraph, so that it is ready for exploitation and use. This exploitable "end-product" can be used as background for 3d models, GIS, extraction and exploitation for rendering and animation, elaboration of vectors properties and characteristics, superimposed layers creation of qualitative characteristics with geographical reference (e.g., sound, temperature, humidity, etc.) (Kouzeleas, 2008b) as well as for automatization of different mathematical or mechanical nature parameters, such as the calculation of densities, distances, areas, etc.

Figure 6. Closed vectorized surfaces, after special elaboration, simulating Trikala city (2005). Left: City limit and blocks. Right: Construction surfaces (yellow colour) and free areas surfaces (green colour). The unvectorized surface (without colour) correspond to pedestrian zones and the river edge.

3.6 Areas calculation

The calculation of the areas of the covering construction and free zones was realized with the aid of a specially developed routine in Visual LISP programming language. This routine is adapted to CAD environment (AutoCAD Architecture) and takes into account all the specially elaborated closed polygon surfaces which were vectorized onto the construction and free areas of the city. With the aid of 3D studio max software, all the polygon surfaces underwent a triangularization so that every surface to be measured becomes a flat surface. The algorithm which was developed is based on Heron's formula (1) concerning the area calculation of a triangle (a,b,c) (Buchholz *et al.*, 1998).

(1)

The current algorithm takes into account all the selected triangular surfaces which correspond to all the construction and free areas for every period of research adding, in an automatic way, their areas (Fig. 7). Thus, the totality of the covering construction and free areas were separately calculated for each year (1945, 1960, 1980, 2000 και 2005). Taking advantage of this routine, the areas of the city limits were automatically calculated in CAD environment as a closed simple polygon each time whereas the areas of the roads were calculated in calculation sheets as the result of the subtraction of limits' areas and construction and free zones' areas.

```
Triangle's area calculation
; (defun aire3d ( … / …)
)

Triangles massive selection and areas addition
(defun c:aire3d_total (/ …)                          Variables declaration
(setq ent1 (ssget '((0 . "3DFACE"))))                ; Triangles selection filter
(setq num (sslength …))                              ; Number of triangles
  (setq compteur 0)                                  ; Declaration before repeat looping
  (setq total-aire 0)
   (repeat num                                       ; Repeat loop
     (setq ent (…))                                  ; Id triangle definition
     (setq p1 p2 p3 p4 (…)                           ; Facets coordinates handling
     (setq total-aire (+ total-aire (aire3d p1 p2 p3)) ) ; Areas addition
     (setq compteur (1+ compteur))                   ; Repeat loop
   )  total-aire )                                   ; Final areas addition
```

Figure 7. Algorithm view (in Visual LISP) of automatic surfaces areas calculation in CAD environment

3.7 Population elements

The population elements of Trikala city were selected from the National Statistics Service of Greece (NSSG) (Table 2). These data were necessary due to specific indicators, such as the covering construction area per person, etc.

Table 2. Population elements (source: National Statistics Service of Greece).

Year	Population of Trikala city (habitants)
1945	20.638
1960	27.876
1980	40.857
2000	48.686
2005	50.643 (*estimation*)

3.8 Indicators

According to the bibliography, the urban space indicators are models that simplify complex issues into a few numbers which can be used to determine policy (Dueker & Jampoler, 2002). The main difference between indicators and other kinds of data is that the connection with policy is, or should be, explicit; indicators are about the interface between policy and data (Newton, 2001).

The aim of the urban indicators is, among others, to measure the quality of life and the nature of development of an urban area (Dueker & Jampoler, 2002), prioritize and define targets, measure performance of policies and programs, and guide strategic investment choices, etc., (Banerjee, 1996). The indicators must be capable of affecting citizen action and public policy making (Sawicki & Flynn, 1996) and hence must be formulated through a broad-based partnership approach involving all levels of decision-making and all stakeholders (Leitmann, 1999). For the choice of indicators, three main conceptual approaches are used and proposed which concern the "policy creation", the "thematic/index problems" and the "units and processes seeking best performance" (Newton, 2001).

In this research, the created indicators do not concern qualitative characteristics and, for this reason, they are not connected directly with decisions creation and policy application because the aim of this research is not the urban analysis of the city expansion but the definition of a process for data and results extraction capable to contribute in further analysis. Thus, the following basic indicators are partially placed in "thematic/index problems" which directly concern visualization matters and especially surfaces simulation, city limits changes and covering construction or free areas. These indicators, in relation with other qualitative indicators can constitute important information for results extraction or interpretation in order to proceed to urban analysis.

Taking into account the calculated areas and the collected population elements, some indicators were created (Fig. 8) in five different periods of 1945, 1960, 1980, 2000 and 2005:

a) Town limits evolution indicator (town area per period / town area of 1945) which concerns the covering construction and free area change from 1945 to 2005;
b) Free areas evolution indicators (free area per period / free area of 1945 or 2005) based on the years of 1945 and 2005 (taking also into account the new under approval town limit of 2008);
c) Covering construction area's evolution indicator (construction area per period / construction area of 1945);
d) Covering construction area's indicator per person (construction area per period / population per period) and free area's indicator per person (free area per period based on 1945 / population per period) concerning the changes of construction and free areas which correspond to every habitant of the city per period, from 1945 to 2005;
e) Free area's indicator per person based on 2008 (free area per period based on 2008 / population per period) concerning the changes of free areas (based on new town limits of 2008), which corresponds to every habitant of the city per period, from 1945 to 2005;
f) Increase of road network indicator (road network area per period / road network area of 1945).

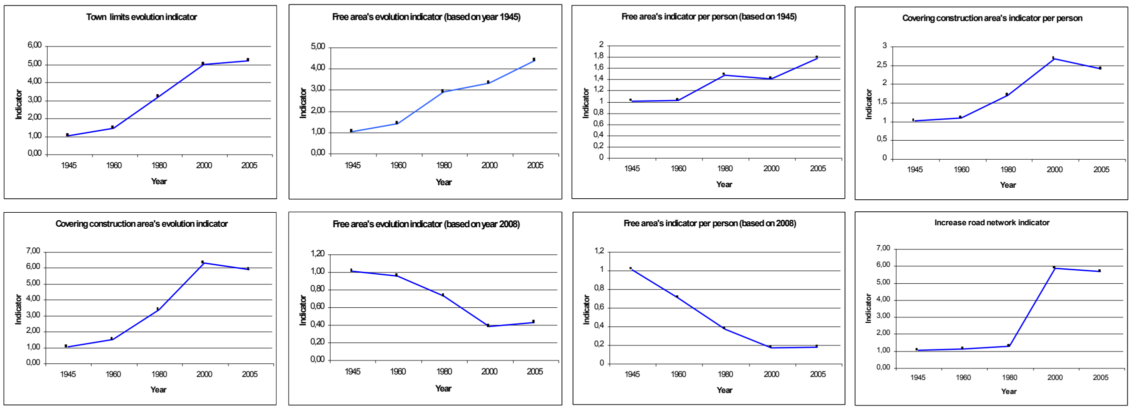

Figure 8. Town limits evolution indicator (1), Covering construction area's evolution indicator (2), Free areas evolution indicator (based on year 1945) (3), Free areas evolution indicator (based on year 2008) (4), Free area's indicator per person (based on 1945) (5), Free area's indicator per person (based on 2008) (6), Covering construction area's indicator per person (7), Increase road network indicator (8).

4. Results interpretation

4.1 Indicators

Through the digital elaboration and study of the remote sensing data and based on the real limits of Trikala city, it id concluded that in a period of sixty years (1945-2005) the city area increased almost five times (Fig. 8.1). In parallel, it is observed that in the first twenty years (~1945-1960) the city area was almost stable and after this period until today (1980-2005) there is an almost linear increase.

Based on the new under approval town limit of 2008, on the one hand, a small decrease of the free area in the first twenty years (~1945-1960), an important decrease from 1960 to 2000 and a stability from 2000 to 2005 are observed (Fig. 8.4). On the other hand, based on the town limit of 1945, a small increase of free area because of the small area of the town limits of 1945 is observed (Fig. 8.3). In particular, the free area of 1945 is decreasing more than half in a period of forty five years (1945-2000) (Fig. 8.4).

The total covering construction area is almost increased six times in a period of fifty five years (1945-2000) (Fig. 8.2), whereas the same area which corresponds to every habitant is unchangeable in the first twenty years (~1945-1960), increases almost three times in forty years (1960-2000) and is almost stable in the last five years (2000-2005) (Fig. 8.7).

Taking into account areas calculations, the new under approval town limits of 2008, a regular, almost linear decrease of the free area which corresponds to every habitant is observed (Fig. 8.6) because the indicator is decreasing in 9/10 in sixty years (1945-2005), whereas based on the town limits of 1945, the free area is almost stable in the first (~1945-1960) and the third twenty years (1980-2000), is increasing by half (1/2) in the second twenty years (1960-1980) and by ¼ in the last five years (2000-2005) (Fig. 8.5).

Some important observations concerning the changes of the roads network: from 1945 to 1980 stability and a rapid increase is observed from 1980 to 2000. In specific, in these twenty years (1980-2000) the covering area of the road network is almost increased six times (Fig. 8.8).

4.2 Urban network

According to the results of the proposed methodology it is observed that the initial core of the town of 1945 bases the architectural structure of its urban network on the Ippodamus system and not on the river direction. Small blocks with North-Northeast direction are developed in the south of the hill and the traditional area of the city (Fig. 9.1, 9.2).

The main observations concern the small expansion of the urban network up until 1960 preserving the initial core and developing new bigger blocks towards three directions, North, East and West (Fig. 9.1 to 9.4).

An essential increase of the urban network up until 1980 is following towards three directions (North, East and West), developing big blocks with direction and geometry which do not follow the logic of the initial core (Fig. 9.5, 9.6). The new town "is embracing" the hill and is exploiting the largest part of the river.

The town is significantly expanding after 1980 until 2005, mainly towards East and South (Fig. 9.7, 9.8). Very perceptible now is the connection of the two neighbouring towns of Larissa (East) and Karditsa (South) which has imposed the expansion of the city (Fig. 1); the organized urban network is developing south of the city with the incorporation of small settlements.

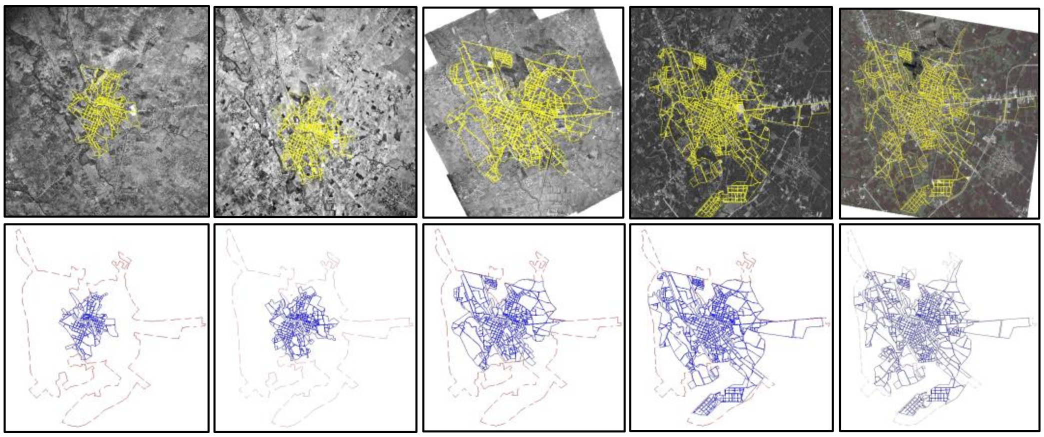

Figure 9. Ortho-rectified images of 1945 (1), 1960 (3), 1980 (5), 2000 (7), 2005 (9), and the simulations of existent blocks (blue color) and the new under approval town limits of 2008 (red intermittent line) of the years 1945 (2), 1960 (4), 1980 (6), 2000 (8), 2005 (10).

4.3 Further observations

4.3.1 Archaeological locations

The location of defensive ditches of the First and Second World Wars via aerial photos of 1945 are particularly interesting. Indicatively, a similar position was observed in the southeast of the city (Fig. 10). Similar constructions were located in the broader Greek land (Kaimaris *et al.*, 2008).

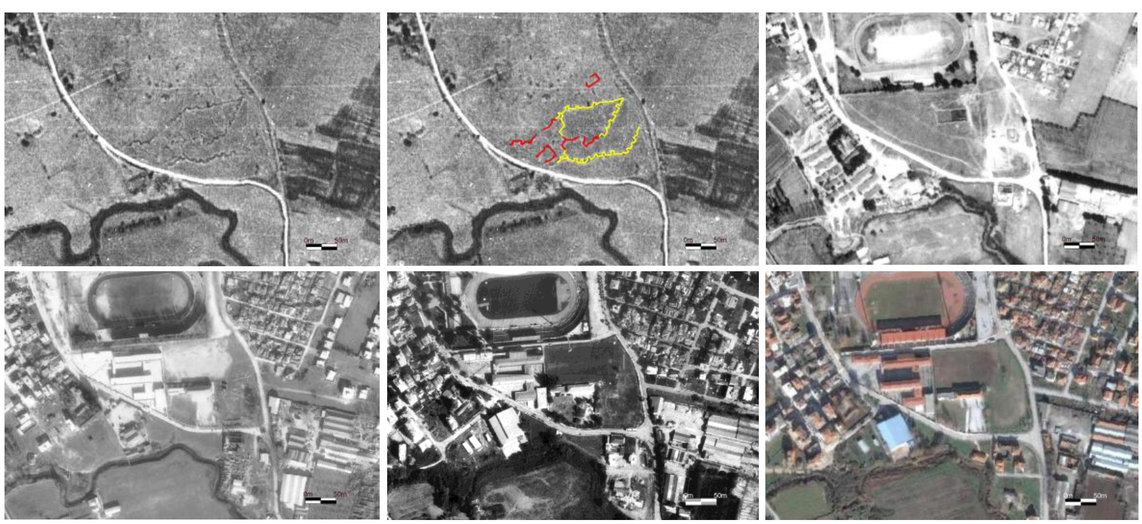

Figure 10. Traces of defensive ditches and aerial photos of the periods 1945-2005 in the southeast area of the city. Aerial photo of 1945 and traces of defensive ditches (up-left). Ditches simulation, covered parts in yellow color and destroyed parts due to the construction in red color (up-middle). The area of traces in 1960 (up-right) and 2000 (down-middle). Satellite image of the area of traces in 2005 (down-right)

4.3.2 Changes in relation to the environment

In the aerial photos of 1945 and 1960, the development of the construction area in the periphery of the river's (blue color) branches (cyan color) is located (Fig. 11.1 to 11.3). From 1960 to 1980, the river branch is covered (Fig. 11.3, 11.4) and the area is constructed following the town's planning characteristics of the initial core (Fig. 11.4 to 11.6).

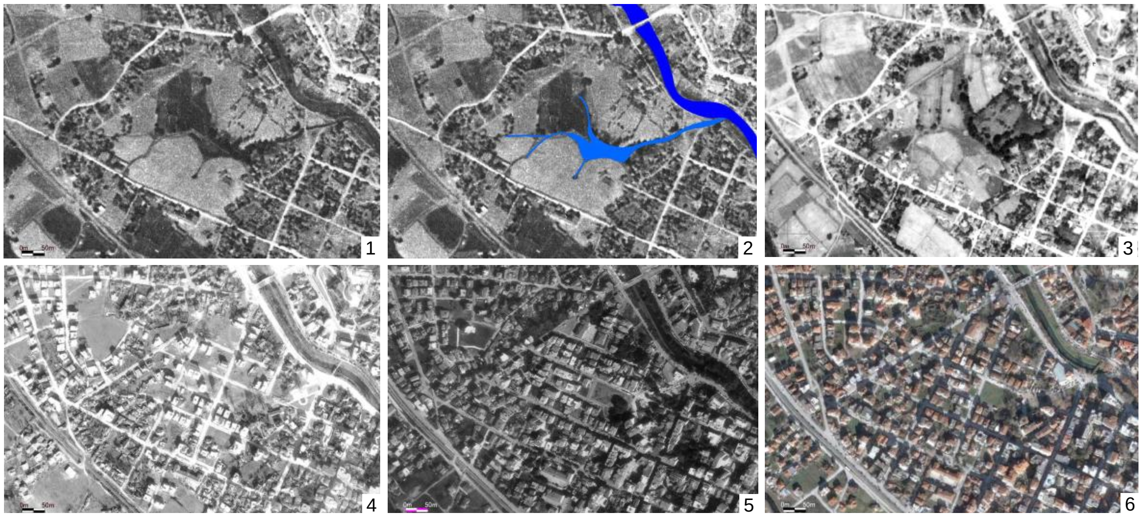

Figure 11. Aerial photos of the evolution of town areas near the river in different periods of year 1945 (1,2), 1960 (3), 1980 (4), 2000 (5) and satellite image of 2005 (6)

5. Conclusions - Perspectives

The methodological collection and elaboration of spatial and descriptive data of the city, through the proposed methodology, aim the extraction of different end-products of high qualitative value and measurements. The simulation-design of the researcher's desired characteristics of the urban space will permit the profound study of the urban changes of the city. The automatized process of areas calculation in local or country level is valuable because it ensures the brevity of the research and the measurements quality of the indicators.

Given that this research does not take into account the qualitative characteristics of the city and proceeding to a simple simulation-designing of the construction and free surfaces of the ortho-photo maps, basic conclusions, which interpret the sense of open-city that the visitor feels, are drawn. In particular, whereas the city multiplies by five its organized surface in a period of sixty years, with the simultaneous increase of covering construction surface that corresponds to each habitant, a smaller unexpected increase of the free area per habitant is observed. However, all interventions-changes are realized after 1960, virtually following a normal route in the course of time.

In many cases, the natural environment (hill, river, etc.) defined the architecture of the urban network. In addition, the tracing, inside of town, of unknown up to now covered monuments which can be made known, is a good thing.

The preservation of the dynamic tendency of the city expansion direction is expected in the future; this applies today and ensues from the study of remote sensing data. That is to say, a new expansion of the network to the east and south is predicted while the influence of the cities located towards those directions will keep on being great in the following years.

Finally, the study perspectives concern the definitions of zones in the urban area of Trikala city, taking into account qualitative characteristics such as protected natural areas, archaeological sites, architectural heritage conservation and protection areas, single sections of similar urban architecture, building according to height etc., in order to extract representative indicators per area that will facilitate an essential study and analysis of the urban changes of the city.

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