CHAPTER SIX

FRACTAL MAPPING:

PILOT STUDY AND FRACTAL ASSESSMENT OF THE SELECTED CASE STUDIES

Introduction

Chapter Six narrows down the research by formulating a specific target (see figure 1.3 in Chapter One). Therefore, the chapter will specify an urban morphological feature as its target to be examined. It will attempt to devise a fractal analysis tool to measure more accurately the degree of physical and spatial complexity that the selected case studies exhibit. To achieve this goal, the chapter is comprised of three main parts: a) the research refinement, b) the pilot study, and c) the case study examination.

In the first part, the main outcomes of the previous chapters will be reviewed to formulate the research target and to refine the research method for the empirical stage. The advantages and limitations of the suggested method will also be identified. In the third part, the steps of data processing, image processing, and the preparation the fractal analysis tool will be discussed. In the third part, the fractal dimensions of the selected case studies will be measured in order to produce a fractal map. This map would then be a base for comparing and analysing the morphological changes taking place over both place and time.

6.1 Part One: The Research Target and the Refinement of Method

One of the issues discussed in Chapter Three was that small changes occurring at a local level in a city could become significant changes at a global level (the butterfly effect). Thus, developing appropriate techniques to observe and measure small-scale changes will help to find better ways to analyse the sequence of changes that shape urban patterns at larger scales. At the end of Chapter Four, it was concluded that the views of city complexity in the area of planning and design should focus on bottom up approaches and therefore “architectural and neighbourhood scales” should be the major concern for decision makers. In that chapter, the literature was reviewed to identify the current approaches to urban complexity addressing directly the use of fractal analysis in measuring the complexity of urban elements at architectural and local urban scales.

However, there is little research on the potential of fractal dimension in measuring urban morphological “change” over time. Therefore, this research seeks to cover this less researched area, and to devise a fractal analysis technique addressing the above issues and measuring morphological change at neighbourhood scales. The objectives, therefore, can be elaborated as follows:

I) assessing the fractal dimension of different urban patterns within the case study and comparing the results with the degree of homogeneity or heterogeneity that they display. This will provide a fractal map leading to the fractal classification of urban patterns.

II) Selecting an area within the case study where historical records and data are available and then calculating its spatial fractal dimensions in order to observe and analyse the change in urban shapes and patterns caused by individuals, planning policies, or design proposals.

The latter objective addresses the concerns of complexity theorists related to the changes imposed by large-scale planning and urban design proposals (also known as urban interventions). Chapter Two discussed that Euclidian geometry is the tool in the hand of an architect, urban designer or a planner while planning and drawing proposals, and the imposition of this geometry – particularly on an old urban context – will inevitably create mistakes. It was also suggested that urban interventions are to be treated with extreme caution (Chapter 4), as they may reduce the level of complexity existing in urban system. Therefore, from a morphological point of view, there is a need to develop techniques to measure the degree of changes enforced by an urban intervention in order to evaluate which proposal or urban alternative is better adapted to its existing context. However, no research, so far, has developed such practical techniques; hence, the main goal of the present research is to devise a practical tool that responds to this need.

This chapter develops a fractal analysis tool to assess urban morphological change at a neighbourhood level. In Chapter Five, the case studies in the north of Tehran were selected for a detailed fractal examination. It was explained why these cases could be appropriate to the research aims. The next section will discuss which morphological features of the selected case studies best fulfil the above task and why aerial photos are used as the main source of data.

6.1.1 The source of data for measuring urban morphological evolution

A list of those morphological elements and their properties which can lend themselves to fractal measurement was suggested by Cooper (2000). Fractal dimension measurement can be either applied to each of the elements listed in Table 6.1 or a combination of them can be arranged to be analysed from a fractal point of view. For measuring changes, the important factor is that not only the contemporary data, but also data from the past must be available. For instance, it is possible to measure the degree of change in the fractal dimension of a street façade only if the historic images of the buildings' elevations of that street are available.

<table>
<tr><th colspan="2">Scale</th><th>Element type</th><th>Variable properties</th></tr>
<tr><td></td><td rowspan="7">Neighbourhood Scale</td><td>Street</td><td>Level of connectivity/integration, position in hierarchy, level of predictability/regularity, orientation, skylines irregularity.
Pattern: street pattern*.</td></tr>
<tr><td></td><td>Plot</td><td>Size: width, length, shape, proportion, orientation.
Pattern: ownership patterns and legal basis, level of connection to the street, plot pattern*.</td></tr>
<tr><td></td><td>Building</td><td>Size: width, depth, height, proportion, shape.
Texture of elevation: materials, color, ratio of walls to openings.
Other criteria: level of access, adaptability.</td></tr>
<tr><td rowspan="5">City Scale</td><td>Block</td><td>Size: width, length, shape, orientation, area*, perimeter*.
Pattern: block pattern.</td></tr>
<tr><td>Natural* Element</td><td>Topography (degree and variety of slope), sea and river edges, green spaces (parks, woodlands, and vegetation)</td></tr>
<tr><td>Land use</td><td>Scale of use: extent, intensify and degree of variety.
Pattern: Pattern of land use distribution.</td></tr>
<tr><td>Landmark*</td><td>Type, size, level of visibility, level of accessibility, distribution pattern.</td></tr>
<tr><td></td><td>Boundary*</td><td>City/district boundaries and edges.</td></tr>
</table>

Table 6.1: Measurable morphological elements at city scale and local neighbourhood scale. (Cooper, 2000, p.223; the elements and properties asterisked were added by the author)

As the objective of this research is to measure fractal dimensions of urban morphological patterns at a local urban scale (see Chapter One, section 1.2.1), it has led the research:

a) To focus on the local neighbourhood scale rather than large city scale elements with one exception. The exception is that the survey will require measuring both small-scale and large-scale urban patterns as part of necessary data for formulating a kind of fractal fingerprint for urban neighbourhoods in the next chapter (see section 7.2.1).

b) To use remote sensing city images taken through aerial cartography as the main source of the empirical survey. Aerial photos, in fact, consist of mixture of blocks, plots, and street patterns, which makes linkages with the research objectives. Greenery as part of the urban physical landscape that forms urban patterns was not excluded from the images at the empirical stage. This is also due to the outcome of chapter 5 where the role of greenery conservation as part of Shemiran's physical identity was emphasised.

Using aerial photos as a data source has three advantages: accessibility and reliability of data source, quality of data in the remote sensing survey, and availability of the records. Firstly, the aerial photos have been taken originally by the National Cartographic Centre of Iran (NCCI) and the copies are accessible from the Tehran Geographic Information Centre (TGIC). The advantage of working with this kind of data is that the research can be tested, experimented, and extended by other scholars or practitioners. Secondly, the quality of aerial photos is better than similar images taken by satellite and can pick up the elements as small as 50 centimetres. It would assist testing which resolution better suits the employed method. Finally, the other advantage of using aerial photos as compared to satellite photos is that their history is available. The aerial photos of Tehran – taken and recorded every 10 years since 1956 (see Appendix E) – provide the essential data required for measuring change over time.

6.1.2 Fractal mapping

The main goal of this chapter is to produce the fractal map of the selected case studies – as they are today – based on the fractal dimensions of their urban patterns. Since the research target is to devise a fractal analysis technique to assess changes occurring in urban patterns, the fractal map provides a benchmark by which changes over time to the urban patterns can be measured. The quantitative data that is obtained by assessing fractal dimensions of the patterns at different periods will be converted to pictorial data to identify the potential of the suggested fractal assessment technique in illustrating the evolution of urban patterns.

It is worth emphasising that this research aims to develop only a fractal analysis tool – not an evaluative tool – to assist decision makers to measure more accurately the degree of physical changes. This will assist urban specialists to assess quantitatively the physical impact that an urban intervention or even a new urban policy imposes on an existing urban fabric (see Chapter Seven, sections

7.3.2.1 and 7.3.2.2). As each individual case has its own unique properties and characteristics, it would be the responsibility of decision makers to judge, evaluate and approve any changes caused by the urban development proposals.

6.1.3 An introduction to the employed method and data processing steps

The research suggests a method by which fractal dimensions can be mapped. For this purpose, it has employed fractal analysis software (Benoit 1.3) linked with ArcGIS software (ArcMap 9.2). Benoit 1.3 is used for its ability to calculate fractal dimensions of urban patterns at different scales (producing quantitative data). Then, ArcMap 9.2 is employed to convert the quantitative data into pictorial data (producing a fractal map).

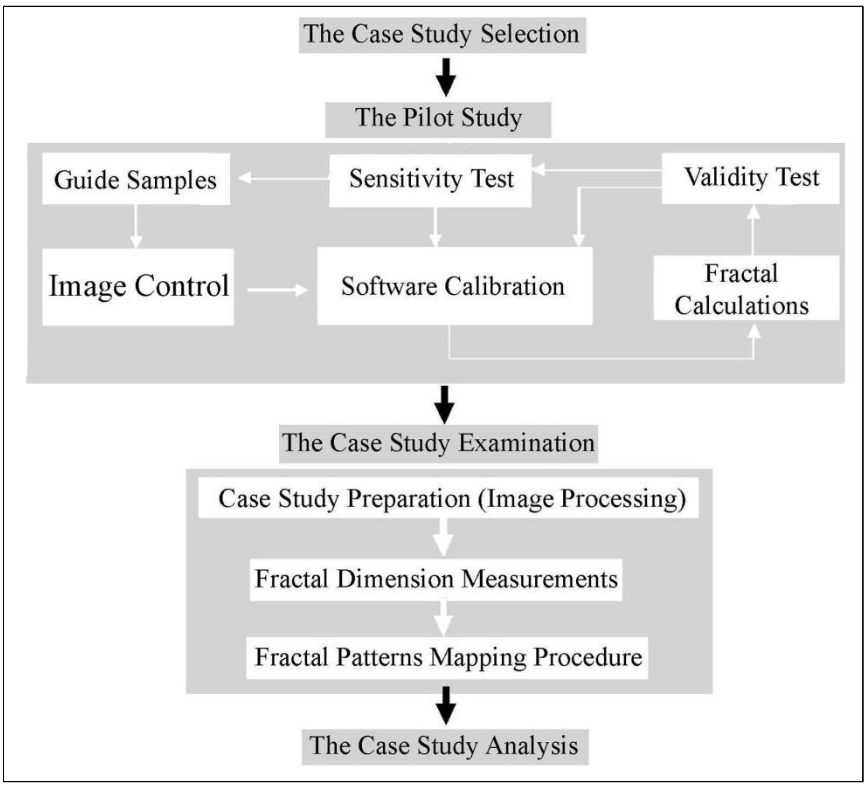


Figure 6.1: The main steps of the examination method, the pilot study and the case study examination.

As figure 6.1 shows, the method comprises two main stages: the pilot study and the case study examination. At the pilot stage, the fractal analysis software should be calibrated and the input images adjusted. At the examination stage, the fractal dimension of the selected cases will be calculated, and the result will be processed into ArcMap to be mapped (forming a fractal map). The fractal map will be produced based on the most recent aerial photos – taken in 2002 – to identify and typify fractally urban patterns within the case study. The fractal map will then provide a benchmark for data analysis in the next chapter, where the contemporary urban fractal pattern of the present will be compared to that of the past and future.

6.1.4 Advantages and limitations of using Benoit 1.3 and ArcMap 9.2

6.1.4.1 Fractal analysis software, Benoit 1.3:

Many fractal software programs have been developed to calculate fractal dimensions including, Benoit 1.3, FracLac 2.0, HarFa 4.9. This research has employed Benoit 1.3 due to its advantages. Firstly, the other software only uses one method for measuring the fractal dimension; while Benoit 1.3 provides multiple choices of using any of five different methods that were introduced earlier in Chapter Three (see section 3.3.5). The user can select an appropriate method depending on the particular type of data selected for analysis. For instance, the ruler method is appropriate for measuring fractal dimensions of a city boundary while box counting or mass dimension methods are more appropriate to deal with urban density or population.

Secondly, Benoit 1.3 has resolved one of the common problems that the other programs encounter when using the box counting method. The software provides an option to alter the minimum and maximum grid size depending on the subject scale. For instance, architectural scales (e.g. building elevations) and urban scales (e.g. street elevations) require different box size arrangements. The Benoit interface provides adjustable parameters, and the user should adjust them (by running a pilot test) in order to achieve an optimum result.

Thirdly, Benoit 1.3 not only measures fractal dimension but also the SD (Standard Deviation). As explained earlier in chapter three, the SD is a criterion by which a pattern composed of self-similar components can be distinguished from a pattern consisting of diverse elements. Finally, Benoit 1.3 also provides a logarithmic graph, illustrating both fractal dimensions and standard deviations.

Having explained the advantages of using Benoit 1.3, there are also some constraints as follows. Currently, none of the available software programs can measure fractal dimensions of 3D urban spatial patterns; therefore, the research is limited to two-dimensional examination and analysis of the case studies. The other constraint is that the software only performs a binary – black and white – image analysis. Therefore, some of the gray scale data information may be missed during examination. To overcome this limit, the contrast/brightness of the input images should be controlled according to the result of the pilot test to ensure that the main morphological elements – composing an urban pattern – are not missing.

The other limitation of using Benoit 1.3 is that it accepts only a bitmap image format, therefore the program cannot distinguish the difference between urban morphological and non-morphological elements in an image – for example the difference between a car and a statue. Therefore, the unnecessary data must be removed manually from an image before examination.

6.1.4.2 GIS software, ArcMap 9.2:

This research uses one of the latest versions of GIS software, ArcMap 9.2, due to its following advantages:

- It is capable of importing both numerical and pictorial data.
- Some data such as census, statistics and geographical data related to the selected case studies are in formats (e.g. ".shp", ".shx") which are readable by ArcGIS software.
- It has mapping capabilities by which quantitative data can be mapped.
- It has the capability of comparing different data layers according to their attributes and locations. This enables comparison of fractal data with other morphological data such as size, age, etc.

The process of importing data from Benoit software, adding attribute data, creating new shape-files, and projecting fractal maps require a number of sequential steps to be undertaken. This is a long process, difficult even for an expert operator. In this research, the process of producing a fractal map is applied to the selected cases in the north of Tehran. Application of the same method to produce a fractal map for the whole city of Tehran requires either an intermediate software program in order to process the data automatically, or a number of operators that the task can be divided between them.

6.2 Part Two: The Pilot Study

The pilot study aims to achieve two objectives: firstly, the employed fractal software, Benoit 1.3, needs to be calibrated according to the required "scales" at which the measurement will be carried out. Secondly, the aerial photos are to be tested in terms of "image resolution", "image contrast/brightness" and "image contents" in order to obtain optimum results (Figure 6.2). The latter test aims to pick appropriate morphological elements from the images and remove the elements, which may have a negative impact on the validity of the results.

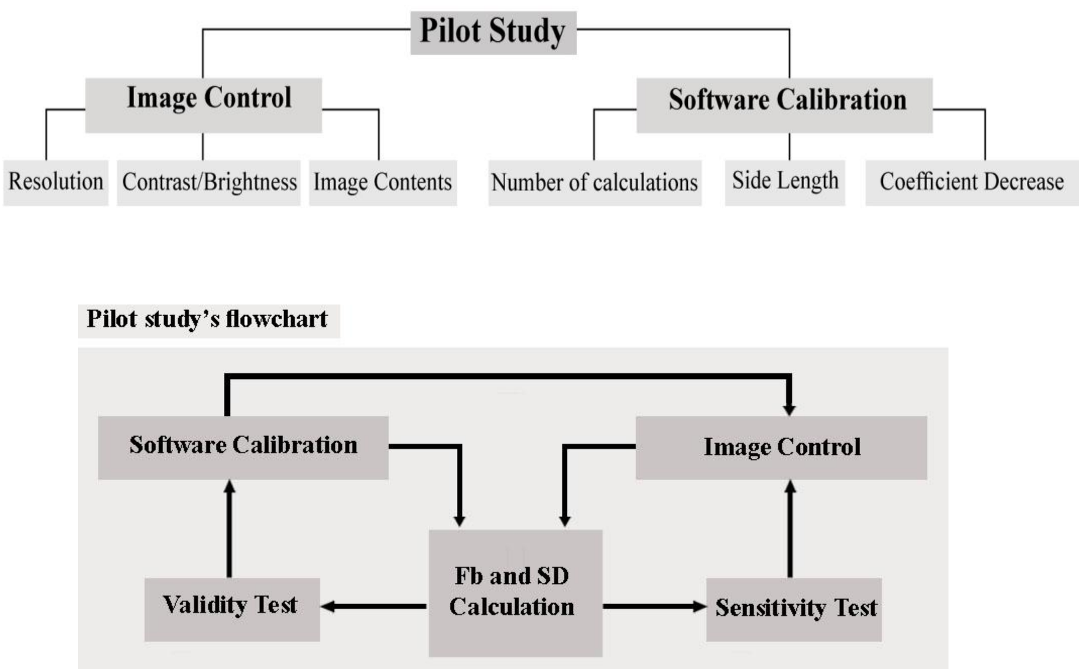


Figure 6.2: The pilot study; the steps of software and image configuration (above) and its flowchart (below).

6.2.1 Software Calibration – the validity test

A key issue for calculating fractal dimensions is the number of scale levels to be examined. As explained in chapter 3, in the case of regular fractals, calculation of fractal dimensions requires element counting of only two sequential scale levels. However, in the case of random fractals, where the fractal dimension varies at different scale levels, usually more than two scale levels are to be examined. Therefore, it is important to verify how many scale levels are required to obtain an optimum result, and which scales are more appropriate according to the research target.

As explained in Chapter Three (see section 3.3.5.1) , fractal dimensions can be calculated by the Box Counting method which requires a number of scale levels (N) of the targeted object. In the case of measuring fractal dimensions of urban patterns, this research targets neighbourhood scales. Increasing the number of scale levels (N) will focus on architectural elements (too detailed) and decreasing N will lead to the city scale levels (too large). Benoit 1.3 provides an adjustable interface to adjust the number of required scale levels required in this research. Figure 6.3 illustrates the interface of Benoit 1.3 and its adjustable parameters.

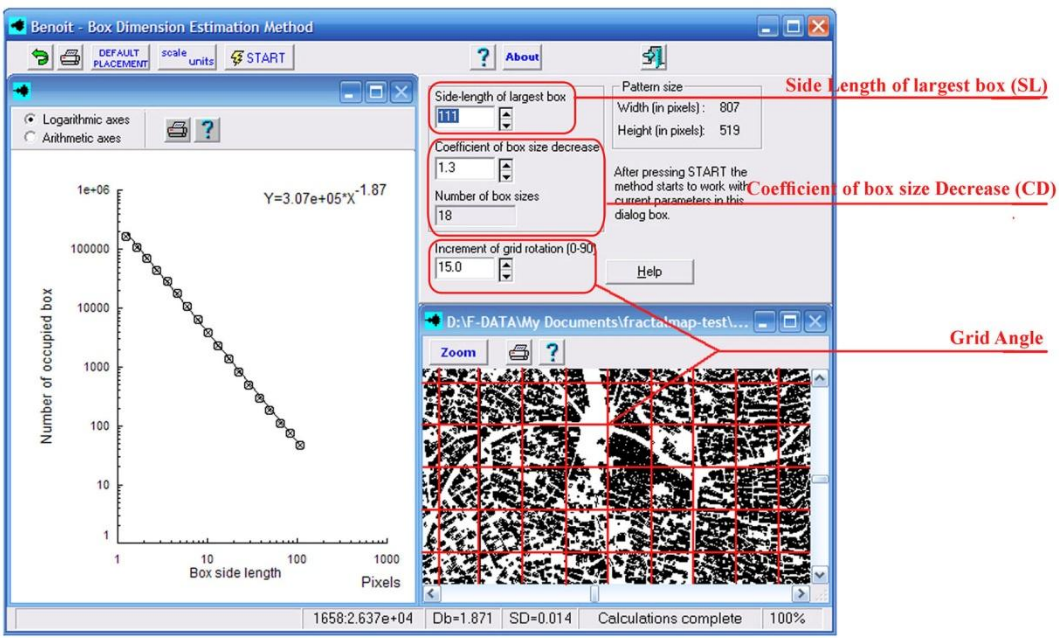


Figure 6.3: The adjustable parameters in Benoit 1.3's interface.

Benoit 1.3 provides two parameters (SL and CD) by which the number of desired scale levels of the examination (N) can be defined. The "Side Length" of the largest box (SL) can be adjusted based on the area of the examined pattern, and the smallest box is adjustable by controlling "Coefficient Decrease" of box size (CD). An appropriate combination of SL and CD will define the number of scale levels (N) to cover all desired scale levels. For instance, when SL is altered from 25 metres to 50 metres, either one more scale level will be added with a CD of 2.0; or two more scale levels will be added with a CD of 1.41.

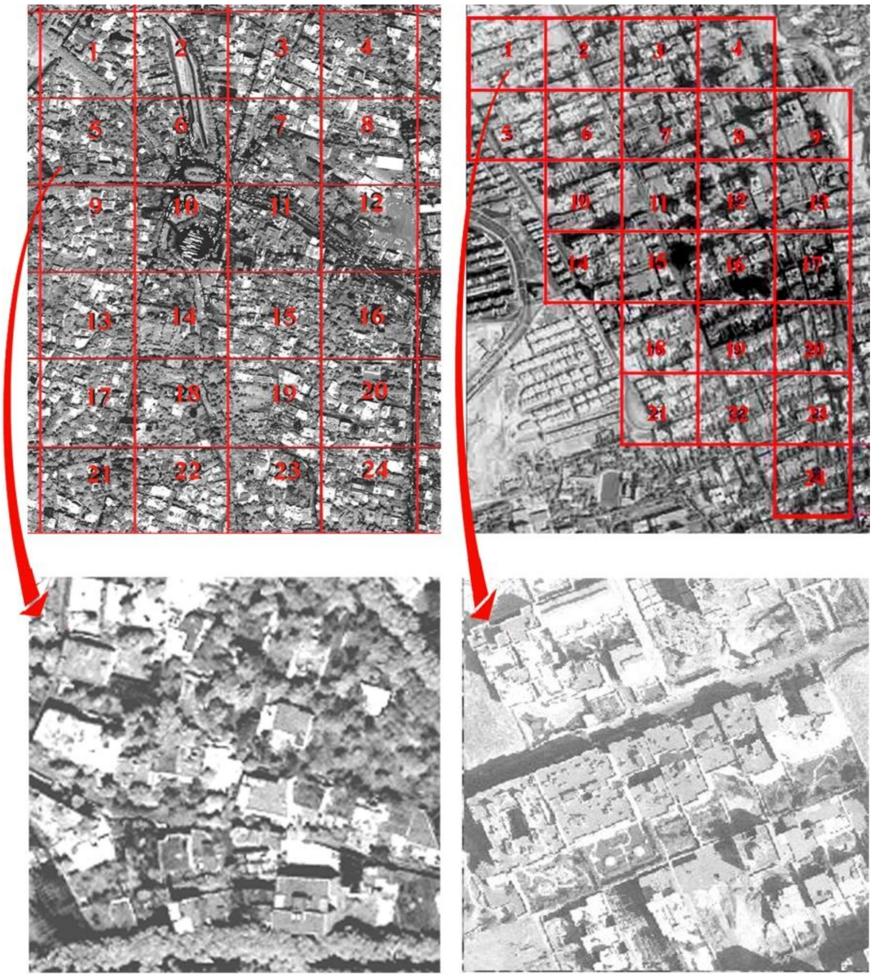


Figure 6.4: The pilot samples, neighbourhood no.5 in Tajrish (Left), and neighbourhood no.1 in Velenjak (Right). The neighbourhood area size of both cases is 200×200 metres.

Two pilot samples, one from Tajrish (the research main sample) and one from Velenjak (the research comparative sample) were selected in order to calibrate the above parameters (figure 6.4). At each step of the calibration, one of the parameters is tested by different values while the other parameter is kept constant. The pilot test was carried out on the guide samples with different possible values for SL and CD parameters. Tables 6.2 and 6.3 present the final test results.

Pilot Samples Sample 1: Tajrish N5 Sample 2: Velenjak N1	**Side-Length of largest box** per Pixel* (SL)	**Coefficient of box size Decrease** (CD)	**Number of scale levels** (N)	**Fractal Dimension** box method (Fb)	**Standard Deviation** (SD)	Check Mark
Sample 1 Sample 2	**200**	2.0	8	**1.7147** 1.3562	**0.0507812** 0.0421610	×× ×
Sample 1 Sample 2	**100**	2.0	7	**1.8710** 1.4898	**0.0017158** 0.0954492	× ××
Sample 1 Sample 2	**50**	2.0	6	**1.8879** 1.3777	**0.0005078** 0.0423040	√ √
Sample 1 Sample 2	**25**	2.0	5	**1.8900** 1.2505	**0.0004991** 0.0080866	√ √√
Sample 1 Sample 2	**10**	2.0	4	**1.8481** 1.1542	**0.0005692** 0.0000735	√ ×
Sample 1 Sample 2	**5**	2.0	3	**1.8079** 1.1627	**0.0000788** 0.0000518	√ ×
Sample 1 Sample 2	**3**	2.0	2	**1.78847** 1.1579	**0.0000000** 0.0000000	× ××
*** Each pixel in this test is equal to one metre.**			**×× Very poor, × Poor, √Acceptable, √√Good**			

Table 6.2: Calibration of Fractal analysis tool; the result of the pilot test when the side-length of the largest box (SL) varies, and coefficient of box size decrease (CD) is constant.

Pilot Samples Sample 1: Tajrish N5 Sample 2: Velenjak N1	**Side-Length of largest box** per Pixel* (SL)	**Coefficient of box size Decrease** (CD)	**Number of scale levels** (N)	**Fractal dimension** box method (Fb)	**Standard Deviation** (SD)	Check Mark
Sample 1 Sample 2	25	**3.5**	3	**1.8960** 1.2862	**0.0001781** 0.0031649	√ ×
Sample 1 Sample 2	25	**2.5**	4	**1.8871** 1.2653	**0.0005154** 0.0067514	√ ×
Sample 1 Sample 2	25	**2.0**	5	**1.8900** 1.2505	**0.0004991** 0.0080866	√ √
Sample 1 Sample 2	25	**1.7**	7	**1.8492** 1.2141	**0.0059931** 0.0130100	√ √
Sample 1 Sample 2	25	**1.5**	8	**1.8598** 1.2472	**0.0008817** 0.0083793	√√ √√
Sample 1 Sample 2	25	**1.4**	10	**1.8761** 1.2199	**0.0021314** 0.0136986	√ ×
Sample 1 Sample 2	25	**1.3**	13	**1.8555** 1.2083	**0.0059920** 0.0144382	√ ×
*** Each pixel in this test is equal to one metre.**			**×× Very poor, × Poor, √Acceptable, √√Good**			

Table 6.3: Calibration of Fractal analysis tool; The result of the pilot test when the side-length of the largest box (SL) is constant, but the coefficient of the box size decrease (CD) varies.

The following factors are to be considered about the results of the tool calibration test:

1- The preliminary test carried out in Chapter Five reveals that the two selected cases morphologically consist of similar urban patterns. Therefore, the selected parameters are valid where their output demonstrates low Standard Deviation (SD).

2- The test shows for each pilot sample that the fractal dimension output (Fb) fluctuates while different parameters were tested. It can be concluded that each fractal dimension output, which is far from the mean (the average), is not valid.

Based on the above factors, the acceptable parameters were marked by the green signs (√ and √√) in the above tables and the following comments can be made:

Comments on table 6.2: While SL can be adjusted between 3 to 200 pixels – according to the area and the resolution of sample cases – the pilot test shows that only an SL between 3 and 50 gives valid results; and when the largest SL is equal to 25, the optimum result can be achieved. The morphological interpretation of this is that the fractal analysis of a neighbourhood area of 200metre × 200metre squares will be covered with a range grid sizes beginning with 25 metres decreasing to 0.75 metre while the coefficient decrease parameter (CD) equals 2.

Comments on table 6.3: CD values ranging between 1.3 to 3.5 were tested while the largest SL is 25. The best result was obtained when CD is 1.5.

Morphologically, it means that the software is to be programmed to pick up elements sized between 0.75 metre and 25 metres in an urban context of 200metre × 200metre squares and to calculate the fractal dimension over 8 levels of scale with coefficient decrease scale values of 1.5.

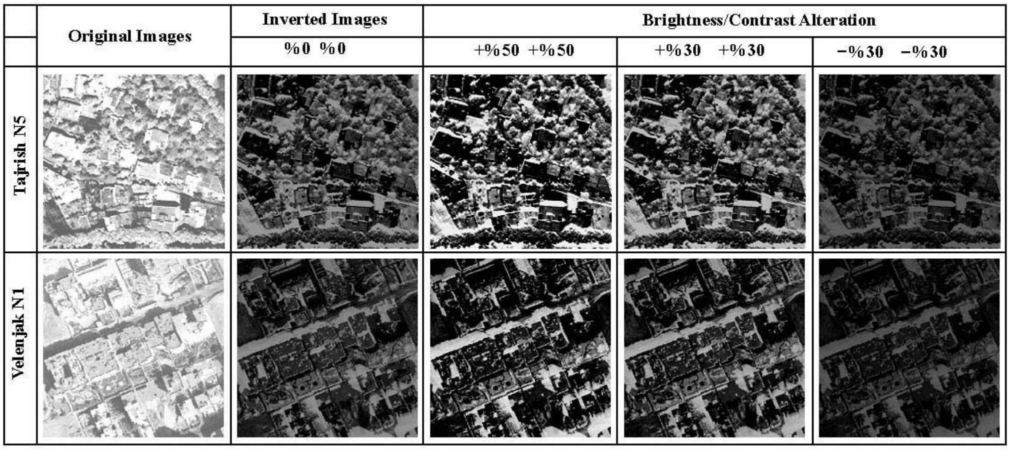
6.2.2 Image Control – the sensitivity test

The second part of the pilot study reveals that the quality and contents of input images do affect the results. Therefore, before running the main examination, all images are to be controlled in terms of the resolution, contrast, and brightness to ensure that all have the same quality and that the fractal analyser is sensitive enough to their contents. It should be noted that Benoit 1.3 recognises only white pixels as occupied boxes; therefore, all images should be inverted to negatives before being examined.

6.2.2.1 Contrast/Brightness test:

The other criteria that affect fractal calculations are the contrast and brightness of input images. The brightness/contrast of each pilot sample was adjusted by Photoshop software. As shown in table 6.4, the fractal dimensions of the samples are decreased significantly by decreasing the contrast or increasing the brightness; and inversely, their fractal dimensions are increased by increasing their contrast or decreasing their brightness.

Two factors are to be considered in order to obtain valid results; a) the maximum visibility of urban elements b) the equality of contrast/brightness for all images. The pilot test revealed that the original aerial photos have similar quality and there is no need to change their brightness/contrast. The only exceptions are the aerial photos of Tajrish for the years 1956 and 1970 in which the contrast were increased by 25% and 18% respectively to enhance their visibility to become of equal quality to the other photos.



Pilot Samples	SL	CD	N	F(b)	**Brightness** Percentage of change	**Contrast** Percentage of change	**Check Mark**
Tajrish N5	25	1.5	8	1.7867	-%30	-%30	×
				1.6027	%0	-%30	××
Velenjak N1	25	1.5	8	1.2106	-%30	-%30	×
				1.1674	%0	-%30	××
Tajrish N5	25	1.5	8	1.8598	%0	%0	√√
				1.9243	%0	+%50	××
				1.5805	+%50	%0	××
Velenjak N1	25	1.5	8	1.2472	%0	%0	√√
				1.4936	%0	+%50	××
				1.0966	+%50	%0	××
Tajrish N5	25	1.5	8	1.8879	+%30	+%30	√
				1.7185	+%30	%0	××
Velenjak N1	25	1.5	8	1.2889	+%30	+%30	√
				1.1571	+%30	%0	×

×× Very poor, × Poor, √Acceptable, √√Good

Table 6.4: The pilot test; the sensitivity to the changes in the contrast/brightness of the pilot images.

6.2.2.2 Resolution test:

The aerial photos used for the pilot test provide resolutions up to 400 pixels per the area of each neighbourhood (200metre × 200metre squares) equal to two pixels per metre. In other words, the fractal analysis tool can identify any elements with 50centimetre × 50 centimetre squares size or larger. This level of resolution may also be problematic because the elements which are not considered as morphological (e.g. people walking in the streets) will be processed by the software while counting the occupied boxes. Table 6.5 shows the impact of changing the resolution of pilot samples on the calculation of its fractal dimension.

Pilot Samples	SL	CD	N	F(b)			
				100 x 100 1pxl=2m	200 x 200 1pxl=1m	300 x 300 1pxl=0.75m	400 x 400 1pxl=0.5m
Tajrish N5	**25**	**1.5**	**8**	**1.7014**	**1.8598**	**1.8942**	**1.9142**
Velenjak N1	**25**	**1.5**	**8**	**1.1238**	**1.2472**	**1.3401**	**1.4101**

Table 6.5: the pilot test, the sensitivity to image resolutions. The acceptable resolution is in the grey box.

The resolution of one pixel per square metre will cover main morphological elements existing at neighbourhood scale (as presented earlier in table 6.1). At this level of resolution, the non-morphological elements, those of lengths lower than one metre, will not be visible; this reduces their negative impact. However, this level of resolution does not reduce the negative impact of the existing vehicles, and therefore, they are to be removed manually from the images.

6.2.2.3 Contents test:

Benoit 1.3 analyses binary black and white images and therefore cannot automatically pick up the targeted elements from a gray scale image. Therefore, the contents of all images must be controlled to ensure that built-up spaces are not mixed up with open spaces. The roads, outdoor parking spaces, and swimming pools in black and white image format are represented by black pixels similar to buildings. However, these elements are part of open space patterns not built-up urban patterns. Therefore, these elements are to be inverted to white pixels similar to other open spaces to avoid misinterpretation during the research analysis.

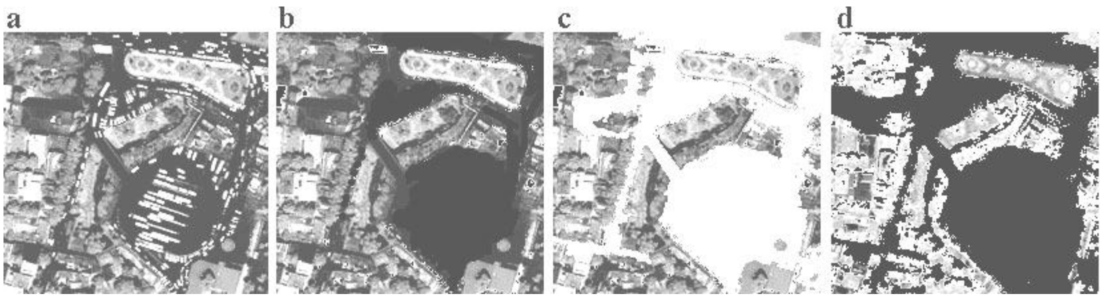


Figure 6.5: Image editing. Neighbourhood T-N10 in Tajrish and the steps of adjustments of its contents; a) original aerial photo, b) vehicles removal and element match, c) road inversion, d) image inversion.

Table 6.6 presents the result of tests before and after content adjustment for the pilot samples. Neighbourhood no.10 of Tajrish (figure 6.5) contains the main bus terminal in the north of Tehran and one of the major roads passes through it, and therefore, it was added to the pilot samples to be tested.

Pilot Samples and Tajrish N10	**SL**	**CD**	**N**	**F(b)**	**SD**	**Check Mark**
Tajrish N5 before contents adjustment	25	1.5	8	1.8598	0.0008817	×
Tajrish N5 after contents adjustment	25	1.5	8	1.8329	0.0008712	√
Velenjak N1 before contents adjustment	25	1.5	8	1.2472	0.0083793	×
Velenjak N1 after contents adjustment	25	1.5	8	1.2166	0.0076443	√
Tajrish N10 before contents adjustment	25	1.5	8	1.7296	0.0031395	××
Tajrish N10 after contents adjustment	25	1.5	8	1.5366	0.0026130	√√

Table 6.6: the pilot study – contents test. Road and parking spaces are inverted to white pixels indicating that they are part of the neighbourhoods' open spaces.

The pilot test reveals that roads and streets, as part of an urban pattern have great influence on the fractal dimensions; but should be adjusted to be accounted as part of urban open space in order to obtain more accurate results. The importance of the content adjustment is more obvious in neighbourhood no.10, which contains a main road and a large-scale bus terminal (figure 6.5).

6.3 Part Three: The Case Study Examination

This part comprises case studies' preparation, fractal dimension measurement, and mapping fractal dimensions. The main objective of this part is to create fractal maps for the research case studies including Tajrish as the main sample case and Velenjak as its comparator. Figure 6.6 illustrates the sequence of image/data processing in order to produce fractal maps.

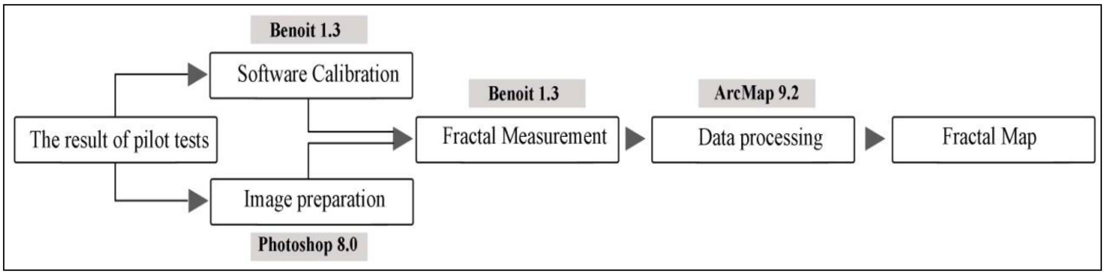


Figure 6.6: the case studies' examination; the flow chart shows the sequence of image/data processing at each steps and the employed software programs.

6.3.1 Case studies' preparation and image processing

The aerial photos related to the case studies are prepared for actual examination according to the suggestions made by the pilot study. The images are processed using the three following stages (figure 6.7). Firstly, all input images are to be controlled in terms of resolution and contrast\ brightness as discussed in sections 6.2.2.1 and 6.2.2.3. Secondly, the vehicles should be removed from the images and the open space elements (e.g. roads, streets) are to be merged into one layer in white as explained in section 6.2.2.3. At this stage, also, all images should be inverted to negatives, because Benoit 1.3 considers white pixels as occupied boxes and count them against the black pixels in the process of fractal dimension calculation (see also figure 6.5). Thirdly, aerial photos like any other kind of photos are usually out of scale. The ArcGIS-software has a geo-referencing tool by which the aerial photos of the selected case studies (Tajrish, and Velenjak) can be resized to fit into the scaled map of these areas (as a valid point of reference). This assists defining metrically the size of each neighbourhood unit, and to divide the aerial photos to 24 equal 200metre × 200metre square (see also figure 6.4). Figure 6.7 illustrates clearly the sequential steps undertaken at each stage.

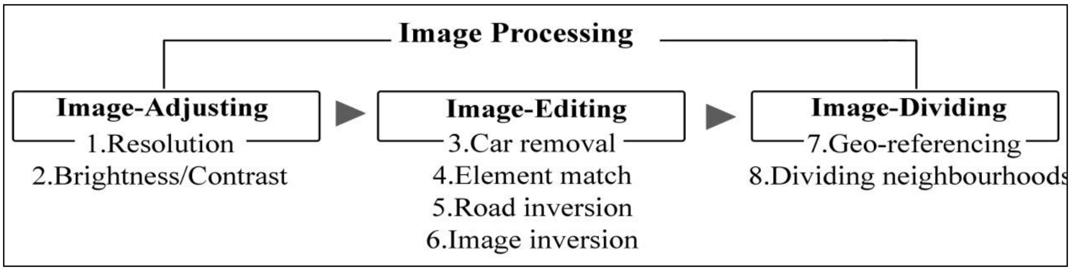


Figure 6.7: The required steps of image processing according to the results of the pilot study.

6.3.2 Fractal dimension measurement

6.3.2.1 Experiment one (fractal assessment at the neighbourhood scale):

Having calibrated the fractal analysis software – according to the result of the pilot tests – the fractal dimension (Fb) of each neighbourhood can be measured. Tables 6.7, and 6.8 show the result of fractal dimensions measured for 24 neighbourhoods of Tajrish and Velenjak respectively.

Neighbourhood ID	**T-N1**	**T-N2**	**T-N3**	**T-N4**	**T-N5**	**T-N6**	**T-N7**	**T-N8**
Fractal Dimension (Fb)	**1.8502**	**1.7239**	**1.7458**	**1.7898**	**1.7329**	**1.7016**	**1.7460**	**1.7554**
Standard Deviation (SD)	0.001997	0.000434	0.001787	0.000881	0.000871	0.000307	0.001886	0.000936
Neighbourhood ID	**T-N9**	**T-N10**	**T-N11**	**T-N12**	**T-N13**	**T-N14**	**T-N15**	**T-N16**
Fractal Dimension (Fb)	**1.7758**	**1.5366**	**1.7106**	**1.6346**	**1.7593**	**1.7808**	**1.7882**	**1.7846**
Standard Deviation (SD)	0.001656	0.002613	0.000151	0.003155	0.001956	0.001589	0.001871	0.004460
Neighbourhood ID	**T-N17**	**T-N18**	**T-N19**	**T-N20**	**T-N21**	**T-N22**	**T-N23**	**T-N24**
Fractal Dimension (Fb)	**1.7500**	**1.7849**	**1.7567**	**1.7751**	**1.7768**	**1.7141**	**1.7388**	**1.6996**
Standard Deviation (SD)	0.001678	0.001053	0.006038	0.002449	0.000408	0.005234	0.000418	0.000576
The average for ($\overline{F_b}$) ; ($\overline{SD}$)	$\overline{F_b} = \sum_{n=1}^{24} \frac{(Fb)_n}{N} = 1.7421$				$\overline{SD} = \sum_{n=1}^{24} \frac{SD_n}{N} = 0.001850$			

Table 6.7: Fractal calculation at neighbourhood scale of Tajrish, neighbourhood area size 200m×200m squares. The aerial photos of year 2002 were used for this examination.

Neighbourhood ID	V-N1	V-N2	V-N3	V-N4	V-N5	V-N6	V-N7	V-N8
Fractal Dimension (Fb)	**1.2166**	**1.2394**	**1.3345**	**1.3882**	**1.2583**	**1.1911**	**1.3338**	**1.3897**
Standard Deviation (SD)	0.007644	0.003876	0.003183	0.000548	0.000142	0.002920	0.003211	0.010245
Neighbourhood ID	**V-N9**	**V-N10**	**V-N11**	**V-N12**	**V-N13**	**V-N14**	**V-N15**	**V-N16**
Fractal Dimension (Fb)	**1.4275**	**1.3680**	**1.4048**	**1.4511**	**1.3547**	**1.4590**	**1.4225**	**1.5321**
Standard Deviation (SD)	0.004830	0.001143	0.000281	0.000677	0.002934	0.005923	0.010325	0.000297
Neighbourhood ID	**V-N17**	**V-N18**	**V-N19**	**V-N20**	**V-N21**	**V-N22**	**V-N23**	**V-N24**
Fractal Dimension (Fb)	**1.5261**	**1.2612**	**1.4277**	**1.3785**	**1.1516**	**1.1898**	**1.3065**	**1.3938**
Standard Deviation (SD)	0.005769	0.000841	0.003318	0.000252	0.000104	0.000405	0.000698	0.000884
The average for ($\overline{F_b}$); ($\overline{SD}$)	$\overline{F_b} = \sum_{n=1}^{24} \frac{(Fb)_n}{N} = 1.3245$				$\overline{SD} = \sum_{n=1}^{24} \frac{SD_n}{N} = 0.002935$			

Table 6.8: Fractal calculation at neighbourhood scale of Velenjak, neighbourhood area size 200metre×200metre squares. The aerial photos of year 2002 were used for this examination.

6.3.2.2 Experiment two (fractal assessment at the local scale):

In another experiment, if the fractal assessment is carried out at the local scale rather than neighbourhood scale, then the results will be as shown in table 6.9. In this experiment, the fractal dimensions and the standard deviations measured (Fb and SD in table 6.9) are higher than the average of these values measured in the first experiment ($\overline{F_b}$ and $\overline{SD}$ in tables 6.7 and 6.8)**.**

The research case studies	SL	CD	N	F(b)	SD
Tajrish	250	1.5	8	**1.8047**	0.030144
Velenjak	250	1.5	8	**1.4659**	0.007985

Table 6.9: Fractal dimensions measured at local scales (the area size of 1200metre×800metre squares) for Tajrish and Velenjak using the aerial photos of the year 2002.

The initial comments on tables 6.7, 6.8, and 6.9 are as follows. Firstly, in both experiments (both at local and neighbourhood scales), the measured fractal dimensions for Tajrish are higher compared to those for Velenjak. In other words, the gradual development or the organic urban pattern of Tajrish demonstrates a higher degree of physical complexity than the newly developed and planned pattern of Velenjak (see also figure 6.8). Secondly, the difference between Fb and $\overline{F_b}$ – measured in the above experiments – implies that macro scales have a higher degree of complexity than micro scales. In other words, the fractal dimensions – as the mathematical indicators of physical complexity – increase while zooming out from architectural scales to city scales.

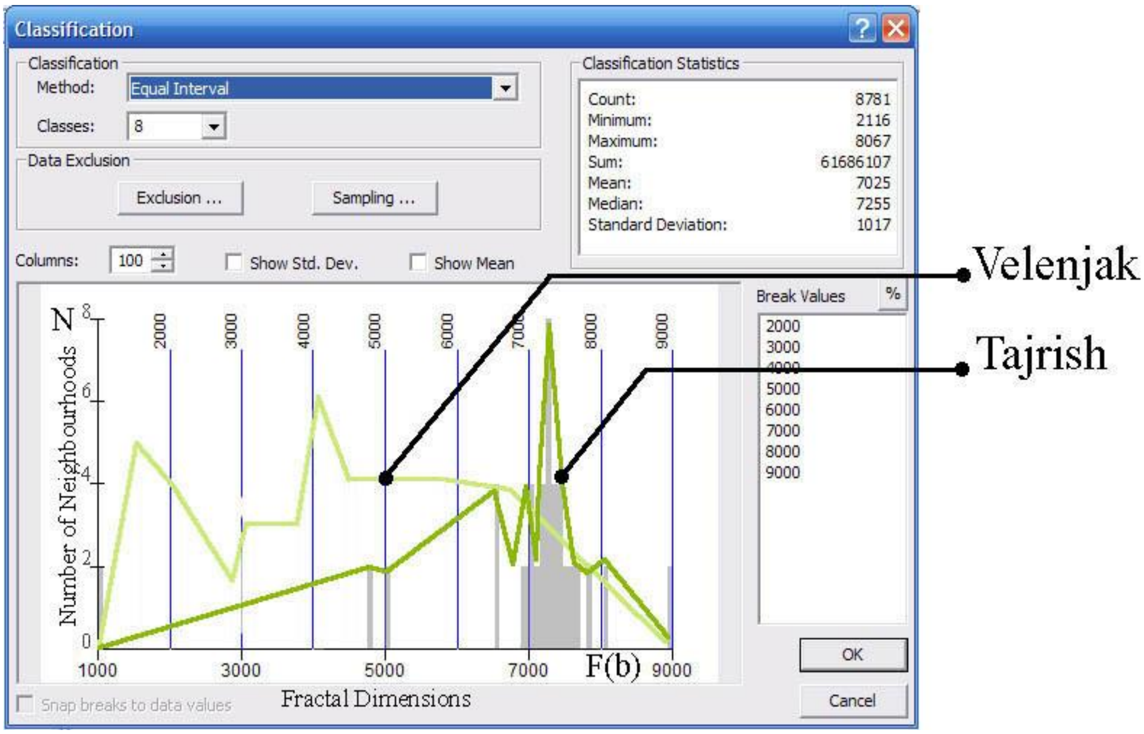


Figure 6.8: The histogram shows the dispersion pattern of the fractal dimensions assessed for the neighbourhoods in Tajrish as compared to Velenjak.

6.3.3 Mapping fractal dimensions, data processing to fractal maps

While the numbers in the previous tables might seem complicated or difficult to compare, converting them to a range of colour scales and creating fractal maps provides a much clearer basis for pattern analysis and comparison. The ArcGIS software has mapping capabilities enabling quantitative data to be converted to pictorial data.. The research carried out the following steps to create fractal maps:

1- <u>Creating a new shape file:</u> A new morphological layer in the format of new shape files (.shx) were created equal to the case study area sizes.

2- <u>Dividing the shape</u>: Each shape-file was divided into 24 equal 200metre × 200metre square subdivisions.

3- <u>Assigning fractal attributes to the shape file</u>: the fractal attribute, as a new feature, was assigned for each subdivision by transferring the fractal dimension data from Benoit 1.3 to the new created shape file in ArcMap 9.2 (figure 6.9).

4- <u>Mapping the fractal data:</u> the fractal attributes were added to the existing parcel data layer, which contains morphological data (figure 6.10).

Figure 6.9: Fractal shapes created for Velenjak (left) and Tajrish (right). They have been created by converting quantitative data to pictorial data by ArcGIS software. Tajrish neighbourhoods, as compared to Velenjak, demonstrate higher fractal dimensions except the areas that marked with red circles.

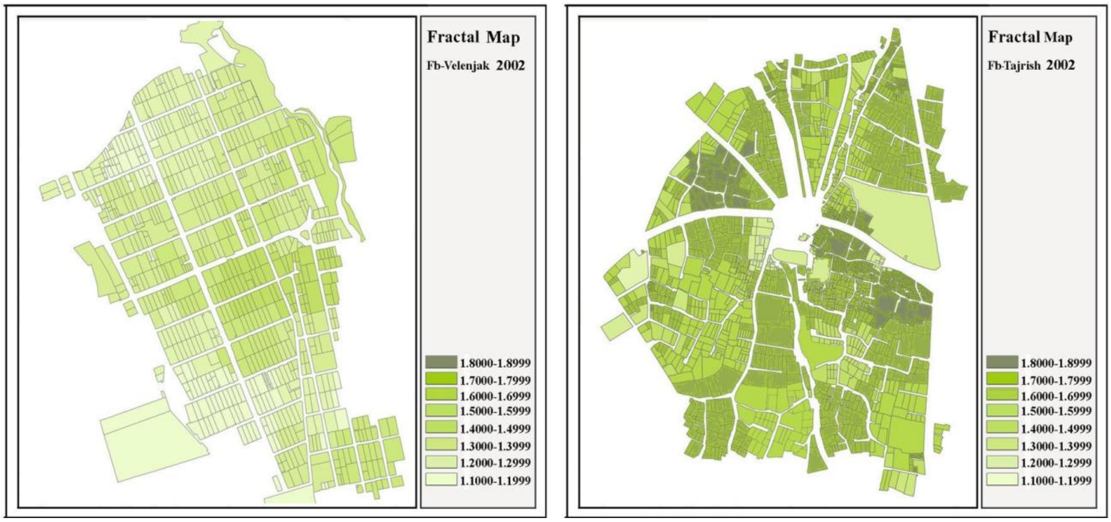


Figure 6.10: The fractal map of Velenjak (left) and the fractal map of Tajrish (right) for the year 2002.

Having carried out the above steps, the fractal maps were produced for the research sample cases (Tajrish and Velenjak). Steps one to three explain how ‘the fractal shapes’ were created (figure 6.9); and step four indicates how these shapes were converted to fractal maps (figure 6.10). It should be emphasised that the fractal dimensions have been calculated by neighbourhood, not by plot. Therefore, both figures 6.9 and 6.10 represent fractal dimensions at the neighbourhood level; however the latter is the map version of the first.

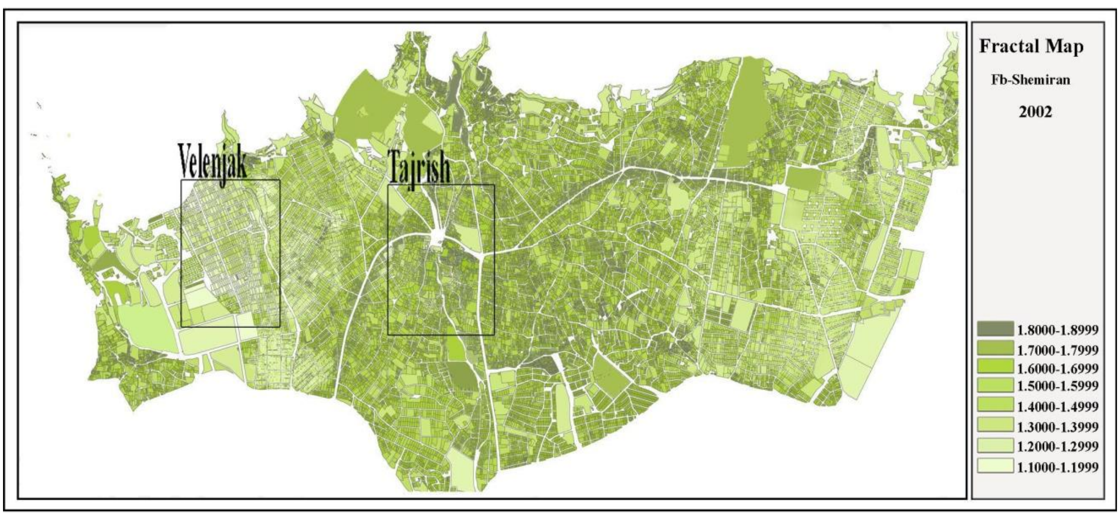


Figure 6.11: The fractal map of Shemiran for 2002 including the fractal urban patterns of the sample case studies, Tajrish and Velenjak, with their fuzzy boundaries.

The same method can be applied to produce a fractal map for the whole district of Shemiran and even for the entire city of Tehran. Figure 6.11 illustrates the first fractal map produced at the district scale based on the aerial photos of 2002. Having produced the fractal maps for the case studies, the following initial comments can be made. As figure 6.10 illustrates, the examined neighbourhoods in Tajrish generally have higher fractal dimensions than those in Velenjak. In other words, the urban patterns of Tajrish demonstrate significantly a higher complexity than those of Velenjak. This conforms to the research assumption that organic patterns are more complex than planned patterns. The observation also suggests that the areas around the centre of old neighbourhoods have generally high fractal dimensions. This implies that the older is more complex (see figure 7.9 in the next chapter). The observation also reveals that parks and gardens demonstrate higher fractal dimensions (see also section 7.3.3 in the next chapter).

The fractal shapes created for the neighbourhoods of Tajrish indicate generally high complexity with two exceptions. The fractal dimensions assessed for two neighbourhoods – marked with red circles in figure 6.9 – are low in comparison to the others. This might be due to recent large-scale urban interventions and developments around Tajrish Square such as the bus terminal, car parking (see figure D.2a, Appendix D), and the recent regeneration plan for the sites close to the shrine of Imamzadeh Saleh. As figure 6.11 shows, the fractal patterns of the neighbourhoods in Shemiran have fuzzy boundaries. It means that it is impossible to draw precise lines around the neighbourhoods with the same physical complexity (see Chapter Seven, section 7.2.1 and figures 7.5, 7.6 and 7.7). Further to the above initial comments, fractal maps reveal other valuable information for analysing urban morphological features including urban patterns. They can be used for pattern identification, comparison, and classification. The fractal map also provides the basis for measuring the changes occurring in urban patterns over time. These issues will be elaborated at the research analytical stage in the next chapter.

6.4 Chapter Summary

The chapter demonstrated both mathematically and graphically the degree of physical complexity of urban patterns in Tehran. Fractal examination of the selected case studies reveals that fractal dimension is a sensitive criterion showing mathematically the degree of urban physical complexity. This chapter also developed a fractal assessment technique to illustrate such a complexity in a map format (the fractal map). The fractal calculation software (Benoit 1.3) and the GIS software (ArcMap 9.2) were linked to produce the fractal maps of the case studies. The advantages and limitations of using each software were identified. The method of the fractal examination was tested and the steps of data processing, image processing, the preparation the fractal analysis tool (software calibration) and finally, the fractal examination of the case study was carried out in order to produce the fractal map (figure 6.12).

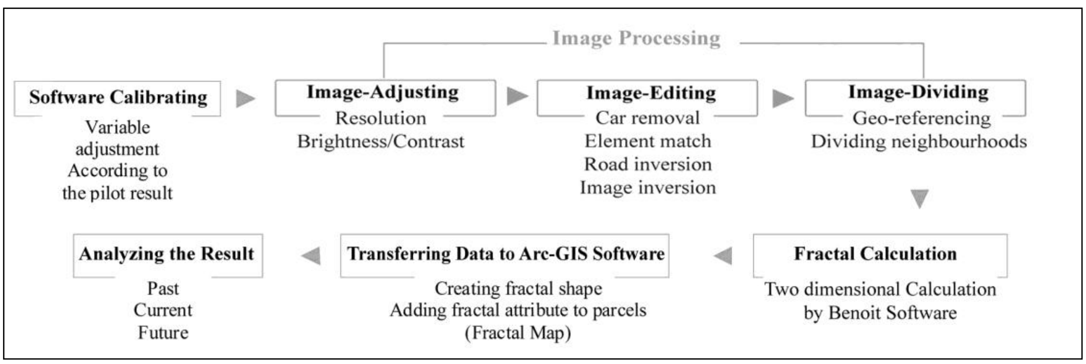


Figure 6.12: The summary of the sequential steps explained in this chapter to produce the fractal map.

Therefore, the chapter achieved its main goal of devising a fractal analysis technique to produce the fractal maps of the selected case studies. The maps explicitly show the differentiation in physical complexity that is exhibited by different patterns of growth. The organic pattern of Tajrish was found to have considerably higher fractal dimensions than the planned pattern of Velenjak. This supports the assumption that time plays an important role in increasing complexity (see the conclusion of Chapter Four). In other words, the older urban areas that gradually evolved are expected to be more complex than the areas that rapidly developed. In the next chapter, the result of the case study examination will be analysed in further detail.