J. King Saud Univ., Vol. 16, *Arch. & Plan.*, pp 1-22, Riyadh (1424/2004)

Analyzing Street Planting and Detecting Existing Patterns in Riyadh, Saudi Arabia

Omar S. BaHammam
College of Architecture & Planning, King Saud University, Riyadh, Saudi Arabia

(Received 16-05-1421H.; accepted for publication 17-03-1423H.)

Abstract. Trees have been associated with human settlements since the dawn of time. In modern time, trees play a major role in shaping healthy and beautiful cities. They scatter among the urban fabric mostly along public streets. Cities all over the world gave serious attention to street trees in order to overcome the decline of the natural environment as a result of the new industrialized urban growth. Riyadh City, as one of the fastest growing cities in the world, has adopted a new applied trends that led to increase the presence of greenery in the city, especially through the use of street trees. This study is trying to assess the existing situation of planting, detecting planting patterns and analyzing the existing patterns to identify appropriate planting ideas for existing and future applications. In order to address this research, different techniques were applied to answer the research concerns.

Keywords: Planning process, planting patterns, street trees, paved sides, middle islands, native trees, non-native trees, deciduous trees, maintenance, and pedestrian.

Introduction

People are by nature tree lovers. The evidence is all around us in the way we choose to live. We use trees for shade, food and energy. They cool and clean the air, break the wind, intercept the rain, beautify and increase property value. For these reasons, trees have been associated with the earliest human habitats. Early settlements appeared when man managed to cultivate plants. Among these plants were trees and shrubs that were cultivated for a number of uses, including food. Many early cities contained some residual vegetation and volunteer trees that were tolerated as long as they did not interfere with other activities [1, p. 49].

By reviewing history, we find a complete harmony between human settlements and the environment in its various forms. Many civilizations, starting with the Assyrians of Mesopotamia to the Egyptians, planned their urban settlements to include open urban

spaces. Greeks improved their urban areas with private groves and orchards. Romans who were an extension to Greek civilization produced elegant gardens in association with their villas and towns [2, pp. 117-119]. Arabs successfully introduced new plant materials and transferred irrigation techniques utilized for the urban forms and design into Western Europe through Spain [2, p. 120]. However, trees and associated vegetation were hardly used for public areas and were mostly limited to private use of the ruling classes and on the grounds of temples [3, p. 32].

The first intentional use of public trees in cities appeared in the circular city of Baghdad built by Caliph Abu Jaffar Al Mansur on the banks of Tigris river in the 8th century AD [4, p.70]. The center of the circle was the mosque and next to it the Caliph's residences; then a very large circular shaped open space, surrounding the mosque and the governor's residence which was laid out with features of various species of plants and flowing water. It became what we might call today a Central Park. Scattered in the gardens were the most important governmental buildings such as the police, the high court and other administrative public agencies. Surrounding all of this was the residential area and then the city walls [4, p. 70].

The use of trees in landscaped public open spaces continued in many cities during the booming civilization of the Middle East and was significant in the 15th-century AD in the Turkish City of Bursa where a group of public buildings were built in a green landscaped area. Because of the intensive use of trees, the facility was called the "green group" [4. p. 71].

In the West, the use of public (not private) trees in cities came much later in the 18th century, inspired by the Baroque gardens of France [5, p. 145]. These gardens were developed in hunting preserves and consisted of wide pathways radiating from clearing the forest for the purpose of shooting game during the hunt. This concept ultimately produced the radial street pattern of Washington, D.C. and Paris [5, p.150]. The new boulevards of these cities were lined up with trees on their sides.

But a real effort to introduce trees to streets started as a reaction to the negative impacts of industrialization in Europe and America in the early and mid 19th century because of the decline of the natural environment with the appearance of the new industrialized cities. Classic examples of such efforts were the work of Ebenezer Howard in 1898 who originated the "Garden City" concept [6, pp.262-263] and Olmsted's urban park projects in several American cities [6, pp.434-435].

In the last five decades of the 20th century, the City of Riyadh has been transformed from a small hidden town, in al-Arred Mountains of the Arabian Peninsula into a large modern capital of the Kingdom of Saudi Arabia. The city has adopted a new planning layout for its expansion. The urban pattern has changed from that of the compact, organic Mideastern City surrounded by groves of palm trees and gardens into one that hardly differs from any industrialized city in the world.

Authorities noticed the severe decline of green areas and trees in the rapidly expanding city, a fact which threatened to give an opposite image to the city's name (Riyadh), which in Arabic is the plural form of the word "rawdah", meaning a "garden". As a result of the environmental awareness, the municipality committed itself to increase the presence of greenery in the city, especially through the use of street trees [7, pp. 32-34].

Objective and Scope

Riyadh has gone through extensive planting stages in the last few decades to spread greenery in the city [7, pp. 35-37]. Priority has been given to trees because of the characteristics of their shapes in creating spaces and for their role in shaping the streets. However, after almost 40 years of planting and spreading greenery in the city's streets, the research reported here had three primary objectives: (a) assessing the existing situation of planting trees in the City's streets, (b) detecting the streets' planting patterns of the different stages of planting and determine the effect of those patterns on shaping streets, (c) and analyzing existing planting patterns to improve the planting situation and guiding future planting procedures.

To address these objectives two parallel techniques were utilized, archival search and fieldwork survey. Administrative search was applied consisting of archival search and interviews to obtain information about planting procedure, historical background, and concepts of planting trees in the City's streets.

The other technique utilized for this study was fieldwork survey. It was used to bridge the missing information from the archival search, especially when planting was done on different stages of the City's development and most was done before the establishment of the Beautification and Gardening Department. It also gave an accurate assessment to the existing situations of street planting and recorded the changes that happened to the process with time. For these reasons, fieldwork proved to be an important research technique in this study.

The paper begins with an overview of the planting background tied to the planning development of the City. An assessment of the planting situation is conducted. The existing planting patterns are identified by analyzing data gathered by using observation of checklist of (190) randomly selected streets (see Table 1). And, finally, some recommendations for improving and guiding existing and future street planting are provided.

Research Methodology

The city was divided into six zones to ease the classification of the data and to simplify the location of surveyed streets (see Fig. 1). The division was done according to the historical development of the urban fabric of the city of Riyadh and according to the common known neighborhood zoning divisions among the residents of the city.

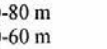
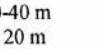
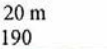
Streets were categorized into five zones according to the classification of the Municipality of Riyadh in its publication, "Mapping Guide the City of Riyadh." The selection of streets were randomly done in each classified zone (see Table 1). Attention was given to ensure coverage of all street categories in order to be able to generalize the study results. For the selection of a street the following criteria were used:

1. If a zone area has highways, at least one highway must be selected.
2. At least two main roads must be selected for every zone, if available. Every zone area was approached from its southwestern corner. The first two east west directed main roads were selected. If not available, the number must by completed by selecting north-south directed main roads approached from the north western corner of the surveyed zone.
3. At least four main streets must be selected for every zone if available. Approaching from the southwestern corner, the first six east-west directed main streets were selected. If not available, the number must be completed by selecting the first north south-directed main streets approached from the north western corner of the surveyed zone.
4. At least eight distributor streets must be selected in every zone. From every previously selected main street, the first two intersected distributor streets were selected.
5. At least twelve local streets must be selected in every zone. From every previously selected distributor streets the first two intersected local streets were selected until the number is completed.

Selecting surveyed segment comes after selecting surveyed streets. For streets' segments selection, the following criteria were used:

1. Streets shorter than three kilometers were surveyed for the whole length of the street.
2. Streets longer than four kilometers, the first kilometer is surveyed, then leave two kilometers and survey the fourth kilometers and so on.

Table 1. The randomly selected streets

Street categories	Street widths	Street shapes	No of cases
Highway	> 100 m		7
Main road	60-80 m		7
Main street	40-60 m		34
Distributor street	20-40 m		53
Local street	< 20 m		89
Total	190		

 Streets with side-walks and one or more middle islands.

 Streets with side-walks only.

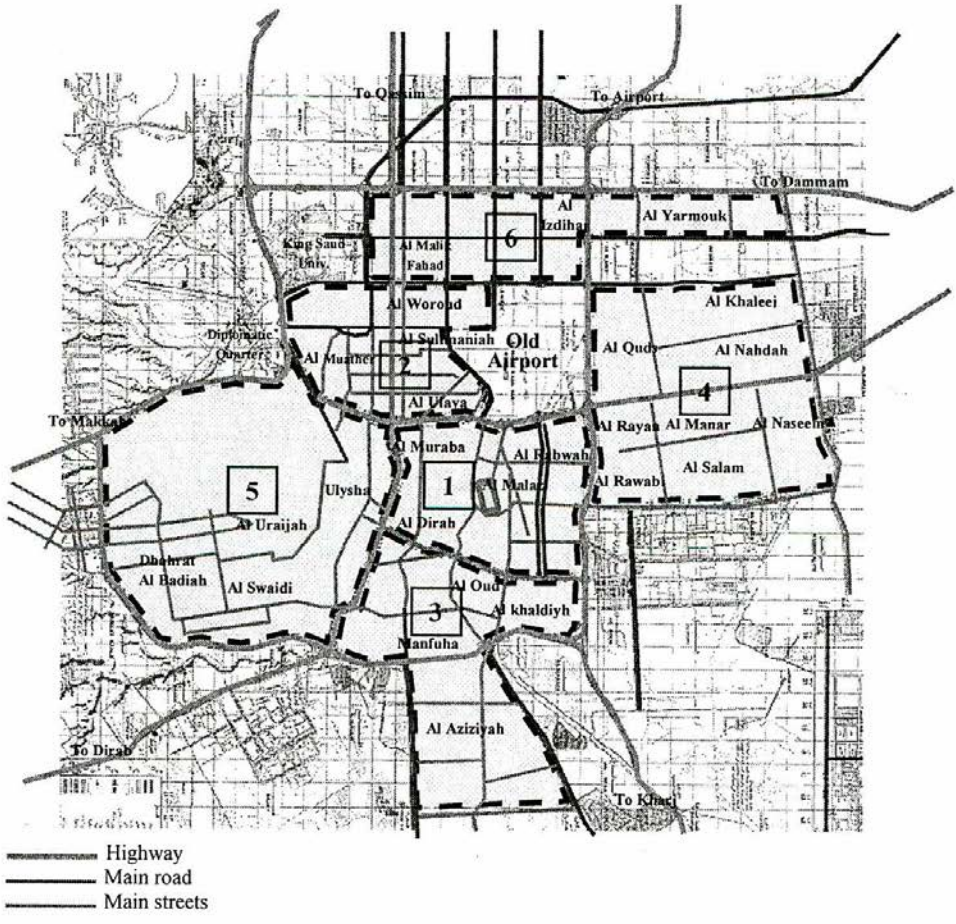


Fig. 1. A plan of the city of Riyadh showing the six divided zones for the fieldwork survey.

Background Information

The name Riyadh, as mentioned earlier, was derived from the extensive greenery of the area. William Palgrave, the British traveler who reached the city in 1863, tried to draw a picture of the urban landscape and surrounding areas:

> Before us stretched a wide open valley, and in its foreground, immediately below the pebbly slope on whose summit we stood, lay the capital, large and square, crowned by high towers and strong walls of defense.

> .... All around for three miles over the surrounding plain, but more especially to the west and south, waved a sea of palm-trees above green fields and well-watered gardens [8, pp. 228-229].

With modernity, the city spread over the traditional surrounding gardens. The new urban areas of the city represent a completely different land subdivision and street layout from the compact traditional one. This new pattern of streets was based on the grid pattern, which is usually comprised of equally spaced streets at right angles. Dwellings are lined up equally along these streets. To define the function between streets that were designed for automobiles and the dwellings on their sides, narrow side-walks were built on the edges of most streets.

In the period between the mid 1970's and the beginning of the 1980's, the city expanded dramatically as a result of the improved economy of the country because of the oil boom. The municipality of Riyadh was busy regulating and supervising the rapid and massive growth of the city [7, p. 34]. The municipality's planting work started with its establishment in the late 1950's. Although planting was limited at that time, and little attention was given to the matter, four full streets were planted with palm trees in their middle-islands. The first of these streets was the Airport Road (now King Abdul Aziz Road) [7, p. 35].

Planting at the time was very limited due to the lack of expertise within the municipality. The department that conducted planting the first four streets consisted of a local farmer as an observer and a number of workers [7, p. 35]. Planting was limited to native tree species, specifically phoenix dactylifera and Zizyphus spina [7, p.35]. The situation continues for many years with very limited changes.

In the early 1980s with the dramatic spread of the city's neighborhoods, the municipality realized that the city was nothing but concrete structures and wide asphalt paved streets and highways lacking the presence of greenery [7, p. 37]. In order to overcome this negative image, the municipality committed to increase the presence of trees in the city. The easiest and most logical way to do that, in a city like Riyadh, was to use the remaining public domains of streets (side-walks and middle-islands). From the beginning of the planting process, three technical problems can certainly be pointed out to have faced street planting. These problems were:

1. Most side-walks were (64.36 %) between 1.2 to < 2.00 meters in width (Table 2). This width, in general, is not enough for a tree pit, let alone to still function as a safe walking space for pedestrians [9, p.134]. Despite that, more than half the side-walks with width from 1.2 to 2.00 meters were planted with trees (Table 3).
2. The municipality lacked staff and expertise to conduct the planting process. The planting team at the beginning consisted of a local farmer as a municipality's observer with a number of workers.

3. To overcome the lack of staff and expertise during the 1980s, the municipality gave planting projects to private contractors with no certain specifications to regulate planting process construction.

Table 2. Side-walks widths

Width of side-walks	Percentage of width
< 1.2 meter	2.97 %
1.2 – 2.00 meters	64.3 %
2.40 – 2.80 meters	17.82 %
> 2.80 meters	14.85 %
Total	100 %

Table 3. Existence of plants on different sidewalk widths

Width of side-walks	Percentage of planted side-walks
< 1.2 meter 2.7 %	
1.2 – 2.00 meters	52 %
2.40 – 2.80 meters	13.3 %
> 2.80 meters	6.7 %
No defined side walks	25.3%

In the mid 1980s, more attention was given to increasing greenery in the city, which led to the establishment of the Beautification and Gardening Department in the Municipality of Riyadh. The new department took the responsibility from many administrations in the municipality to manage the planting process in the city. The department, unfortunately, had not kept detailed records of the planting projects conducted by the municipality crews nor by the field contractors. Little information is available regarding date of planting for each street, areas of the city covered in the planting process, exact number of planted streets, and selected planted species. All this related information and many more were not sufficiently available in the Beautification and Gardening Department in the municipality of Riyadh.

Stages of Street Planting

A review of planting from the early attempts to the present shows that planting street trees can be classified into three main stages. Each stage has its own characteristics and identity. These stages are:

The first stage consists of streets planted before the 1980s. This stage was characterized by the exclusive planting of native tree species. The two most used species in that stage were Phoenix dactylifera and Zizyphus spina christi. They were used mainly because they were well known species for the municipality's planting team at that time. Palm trees (Phoenix dactylifera) were mainly planted in the middle islands of important streets at that time, such as in the Airport Street and the University Street (see Fig. 2.A).

Zizyphus spina, on the other hand, was mainly planted in the paved-sides and in few cases in the middle islands such as in Salah Al Deen Street and some of Al Malaz

A B

Fig. 2. Examples of streets planted in the first stage with palm trees planted in the middle island (A) and Zizyphus spina trees in the side walks.

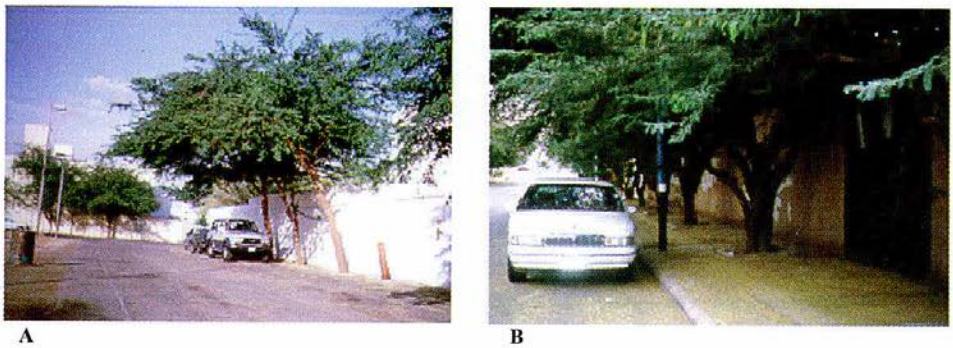
neighborhood streets (see Fig. 2-B). The reason for this distribution is unknown but field study proved that Zizyphus spina is unsuitable as a street tree. It has several disadvantages that will be discussed in the street pattern section.

The second stage consists of streets planted between the 1980s and 1990s. In this stage, planting gained momentum due to the expansion of the city and the awareness of the importance of trees for health and beautification [7, p. 36]. The main characteristics of this stage were:

(a) the dependence on the non-native (imported) tree species;
(b) planting reached about 58% of the city streets; and
(c) planting trees in paved side-walks as well as in middle islands of different sizes and categories of streets.

Planting in this stage was done mostly through contracting projects with private contractors. As it has been mentioned earlier, with the absence of specification guiding and controlling the planting process and the absence of knowledge regarding the suitability off native plant materials to urban life, contractors did their best in establishing their supply nurseries based on imported plant species. The study found that of the planted streets, about (12.5 %) were planted with native plant species only while about (51.8%) were planted with imported species, and about (35.7 %) were planted with both native and imported plant species.

Prosopis was the most popular tree planted on streets during the second stage (as in Fig. 3). It was used in almost 70% of the planted streets. Few other imported tree species were used also during this stage. Table 4 presents the most common tree species used in the city and the percentage of streets planted for each specie.



A B

Fig. 3. Two examples of a street planted with Prosopis trees in the paved side-walks during the second stage.

Table 4. Percentages of imported tree species among planted trees

Name of trees	% of streets where trees were planted among planted streets
Prosopis spp.	69.7%
Pithecellobium dulce	38.5%
Ficus religiosa	6.4%
Delonix regia	5.5%
Albizia lebbek	3.7%
Eucalyptus sergeant	3.6%

The third stage consists mainly of management and maintenance work. Since the beginning of 1990s, few new streets were planted with trees, and in general few changes have occurred to the existence of trees in the city's streets. Study found that the main reason for not continuing spreading greenery in the city was the lack of funds and the high expense of maintenance cost. Planting in this stage consisted of a steady process of replacing damaged and/or improper located trees. The Conocarpus Erectus tree has replaced many Prosopis and Eucalyptus trees. This tree specie has been successfully planted in the city in the last seven years. It proves to be suitable for street planting because of its upright oval head, extremely fast-growth and requirement for little maintenance and cleaning.

The dependence mainly on one plant species represents a very critical risk for the planting program. In many incidents when a disease attacked certain species and destroyed it or as it once happened when the temperature rose above normal, certain species died. Such incidents destroy the greenery of large areas of the city and result in big economic and environmental loss. Therefore, it has become a standard practice to equally diversify the plant selection used in cities. The existing situation put the planting program in the city at risk because of the dependence on two main species, Prosopis spp in the second stage and Conocarpus lately.

Street Planting Patterns

Despite the variety in street sizes and shapes and the differences in planting techniques and species from a planting stage to another and the uneven distribution of tree planting from one neighborhood to another, there have been some street planting patterns detected from the field study that can be highlighted. The following discussion will illustrate these patterns in relation to tree distribution, tree selection and street sizes, shapes and functions.

In contemporary streets, field observation showed that there are four main patterns of tree planting in streets. These street planting patterns are:

Pattern No. 1: **Local and Distributed Street Planting Pattern**

After plotting the results of the data collected from the different street categories, in Fig. 6, we noticed that there are two opposite curves of street tree-planting distribution. The first curve represents trees planted in the paved side-walks of streets (see Fig. 7). This distribution is found more in the smaller streets than in the larger ones. Table 5 shows also that about 47% of the local streets and 34% of the distributor streets in the city have trees in their side-walks while less than 17% of the combined three larger categories of the streets (highways, main road and main streets) have trees on their side-walks.

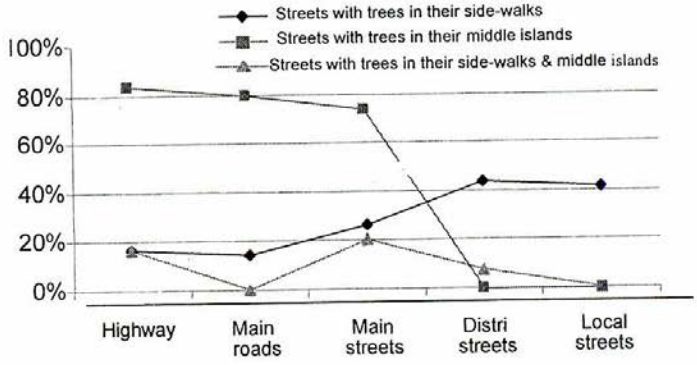


Fig. 6. Streets with trees in their side-walks, middle island(s) and in both side-walks and middle island(s).

From the above analysis it is logical to say that the first planting pattern is **the paved side-walks planting**. This pattern is the one most found in the street of Riyadh. More than 80% of the planted streets can be classified under this planted pattern. These streets are usually residential streets. In this pattern, trees were planted in the paved side-walks of streets adjacent to the private property's external walls. The outcome of full growth trees on the side-walks of streets define the space and give it a third dimensional limit (see Fig. 7).

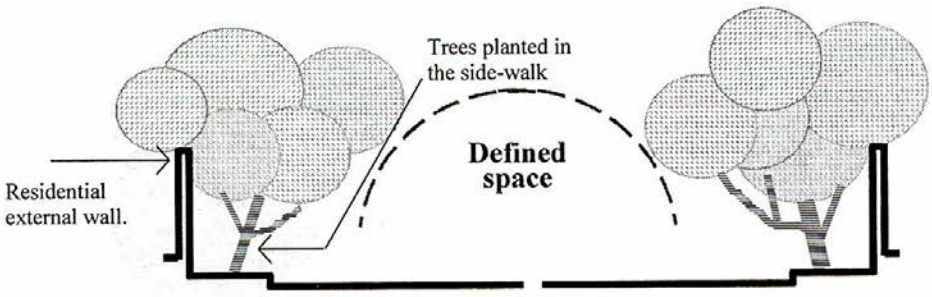


Fig. 7. Conceptual illustration of the detected planting patern of the local and distributed streets.

The majority of side-walks, in Local and Distributor streets, vary from 1.20 meter to 2.00 meters in width (see Tables 2 & 5). Most of them are 2.00 meters or 5 tiles in width, each tile is 40 X 40 centimeters (see Fig. 7A&B). Study found that 52% of these side-walks have trees in them (see Table 3). Tree pits are aliened in these side-walks every 6 meters apart. These pits are usually 1.2 X 1.2 square meters (see Fig. 8). The existing situation of side-walks, as it has been described, cased many problems. First, the remaining of the side-walk on both sides of planted pits is not enough for comfortable pedestrian movement which in turn force them to walk on the vehicular asphalt part of street (Fig. 9A). Second, the sizes of tree pits in these side-walks are much smaller than the minimum practical pit sizes which is about 1.5 meters [9, p. 134 and 10, p. 139]. Accordingly, root behavior of planted trees usually have their dramatic negative effects on the pavement structure (Fig. 9B).

Third, due to the narrow strips of the side-walks that is usually much smaller in width than the canopy size of an average grown tree and because of the tendency of a tree to lean toward the source of light away from the adjacent property walls, a tree usually leans over to the street causing a severe bending of the trunk over the years, a gradual damage of pavement structure, and finally blocking pedestrian movement and adjacent traffic lane (see Fig. 117A and B).

Table 5. Sidewalk width in relation to street categories

Street category	<1.20 meter	1.20-2.00 meters	2.4-2.80 meters	>2.80 meters
Highways	0%	16.7%	16.7%	66.7%
Main roads	0%	28.6%	14.3%	57.1%
Main streets	2.9%	26.5%	29.4%	11.8%
Distributor streets	1.1%	39.6%	7.5%	5.7%
Local streets	1.6%	35.6%	2.2%	0%

Prosopis spp., Pithecellobium dulce and Zizyphus spina are the most common trees planted in side-walks in Local and Distributor street patterns. Table 6 below shows more details regarding the distribution of the different tree species in side-walks. The characteristics of these trees are worth mentioning to know the immediate effects of the

outcome on this pattern.

Table 6. Occurence of different tree species planted in the middle island of Main Streets planting pattern

Name of trees	% of each tree specie within planted Main streets
Palm trees-Phoenix dactylifera	72.0%
Pithecellobium dulce	56.0%
Prosopis spp.	48.0%
Zizyphus spina	12.0%
Ficus religiosa	4.0%
Albizia lebbek	4.0%

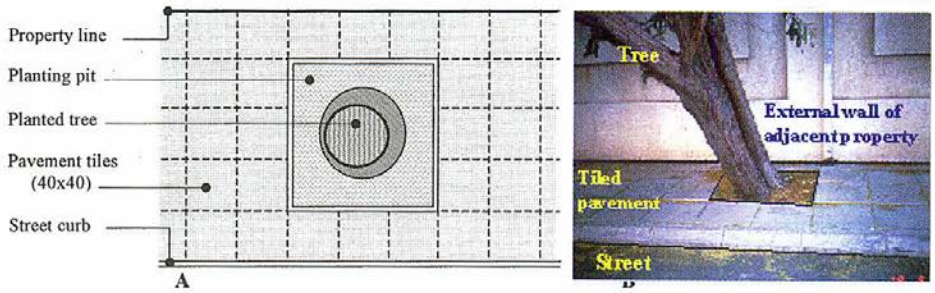


Fig. 8. Layout of the pavement and tree pits in the majority of side-walks in local and distributor streets.

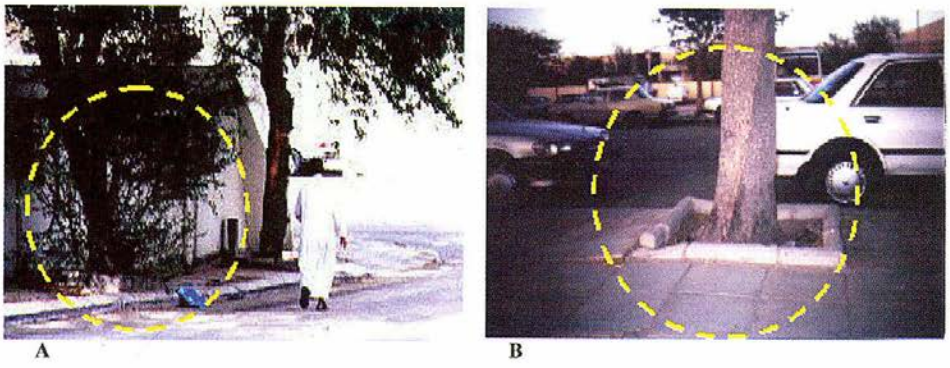
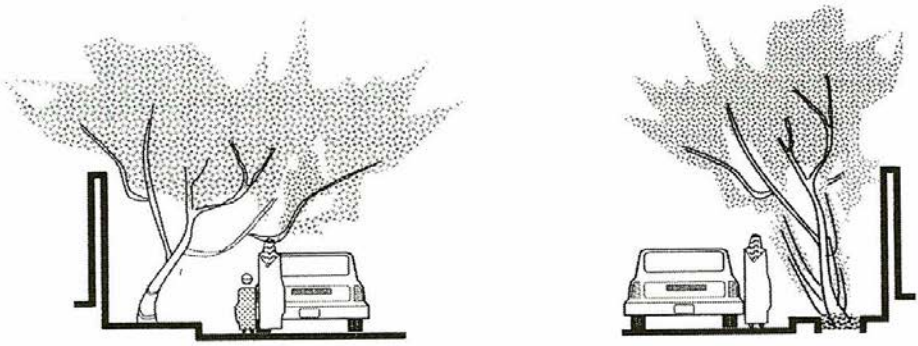


Fig. 9. Zizyphus spina usually fills up the space on the side-walks preventing pedestrians from using them (A), they also have their dramatic remark on pavement and structures (B).



A B

Fig. 10. Because of the narrow space available for trees in the side-walks and because of the pit size, average size trees usually lean towards the streets, which led to blocking pedestrian ways and sometimes adjacent traffic lanes.

Prosopis as a common tree specie has a large canopy that varies approximately from 6-8 meters [11, p. 315]. Lower branches must be removed, making for a tree with a wide-spreading umbrella-like top which is excellent for providing shade (see Fig. 3). On the other hand, Pithecellobium dulce and Zizyphus spina are medium scale trees from 7-10 meters [12, pp. 81, 94] with dark green foliage and unique branch habit. These two species need continuous shaping to take on a tree-like appearance [11, p. 314], otherwise they develop an awkward branch structure that grows straight in a shrub like form that fills the surrounding space and obstructs pedestrian movement (see Fig. 9A & 10B). Study found that Zizyphus spina in particular has an invasive root system that damages the pavement and nearby structures (see Fig. 9B).

A B

Fig. 11. Because of the narrowness of the side-walks and existence of property lines, a tree lean over toward street to claim more space for its canopy and to get required amount of light.

Pattern No. 2: **Main Street Planting Pattern**

Main streets were among the first to be planted in Riyadh. Planting of this category started in the first stage of planting. Examples of such streets are the Airport Street and the University Street. Main streets usually vary in width between 40-60 meters (see Fig. 1). A main street consists of side-walks and a middle island (see Fig. 12). The widths of the majority of side-walks in Main Streets are between 2.40-2.80 meters (about 29.4%) and between 1.20-2.00 meters (about 26.5%). Also, middle island's widths fell in the range of above 2.80 meters (about 41.2%) and between 2.40-2.80 meters (about 32.4) (see Table 7).

Because Main street planting started in the first stage of planting, their planting patterns were characterized by the characteristics of that stage. Field study found that 73.5% (see Fig. 6) of the planted streets have plants in their middle islands. Figure 6 shows that main streets were among the highest with trees planted in their middle islands. On the other hand, there are some trees planted on the side-walks of this pattern (see Figure 13). Survey showed that 26.5% of main streets have trees in there side-walks. The main reason for having low percentages of streets with trees in their side-walks is that because these streets are classified as commercial streets with commercial activities on their sides and trees are not planted to avoid blocking the view to those commercial activities.

Table 7. Main streets middle islands' width

Width of middle island	Existing percentage
< 1.2 meter	0.00 %
1.2 – 2.00 meters	11.8 %
2.40 – 2.80 meters	32.4 %
> 2.80 meters	41.2 %
Missing or Not applicable	14.6 %
Total	100 %

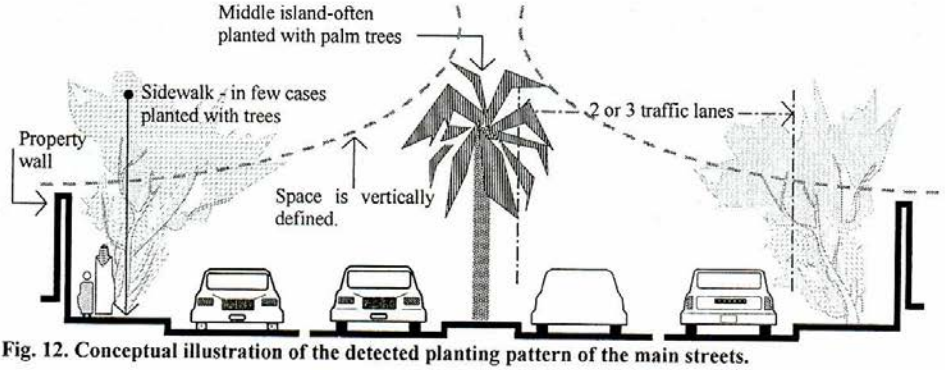


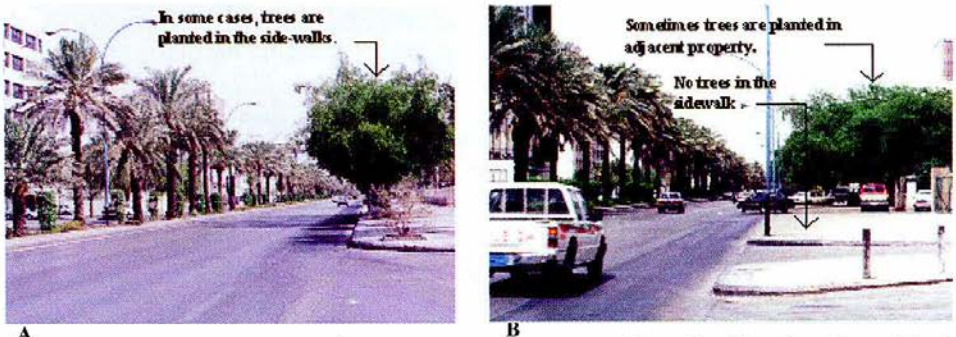
Fig. 12. Conceptual illustration of the detected planting pattern of the main streets.

Planting in middle islands is mostly done in continued ditches. Palm trees are planted aliened about 5 to 6 meters apart. Shrubs grasses are planted between palm trees in the planting ditches (see Fig. 2A). Planting in side-walks, when existed, is almost done in same planting pits sized 1.2 x 1.2 square meters.

Among the plant species, palm trees are the most popular in this pattern. This study found that 72% of the streets in this pattern have palm trees in their middle islands. As it has been mentioned earlier, it became a tradition in the city to plant palm trees in middle islands. Some other tree species were found to be planted in middle islands scattered besides palm trees. In very few cases, Prosopis and Zizyphus spina were found to be the main species in the middle islands such as in Salah Al Deen Street in Al Malaz neighborhood.

There are some advantages of planting palm trees in middle islands. Palm trees, because of their shapes, have ornamental landscape design values as large-scale vertical definers used repeatedly in courtyards, entry spaces and boulevards [11, p. 311]. Because the main function of middle islands is to separate the two opposite traffic directions in streets, palm trees are used as physical definers, creating vertical dimension to space and adding aesthetic values to streets (see Fig. 12).

Middle islands were found to be the best places for planting palm trees. The long thorny fronds of the palms and the large diameter of the crown (about 6 meters in width [11, p. 311]) require wider space in order not to block the traffic or the pedestrian (see Figs. 2A & 13A&B). As we have seen earlier, the majority of middle islands in this pattern (about 41%) fell in the range of above 2.80 meters (see Table 7).



A B

Fig. 13A. Two examples of main streets one with trees planted in side-walks (A) and another without trees in side-walks.

Among the most used tree species in side-walks is Zizyphus spina such as in Fig. 13A. Most streets that have Zizyphus spina in side-walks are among the first streets to be planted (during the first stage of planting). Most new Main Streets have no trees in side-walks because of the commercial activities on the sides as it has been explained. Study found that Zizyphus spina unsuitable as an urban tree specially in

pavements in streets. It has several disadvantages among which is the invasive root system structure that damages the pavement and nearby structures (see Fig. 9A). The tree also develops an awkward branch structure that grows straight from the main trunk which usually fill the surrounding space and obstruct pedestrian movement (Figs. 9A & 10B) and in cases of narrow side-walks obstruct also adjacent traffic lanes. Examples of streets with Zizyphus spina in side-walks are Al Washim Street and Omar Ibn Al Khattab Street.

Pattern No. 3: **Main Road Planting Pattern**

Main road planting forms a unique pattern that cannot be found in any other street category. Planting in this street pattern is concentrated in middle islands. About 80% of streets have trees in their middle islands while only about 14% have trees in their side-walks (see Fig. 6). Planting in this pattern is strongly related to the layout of main roads.

Simple anatomy of a main road can revel the main components which include one main middle island separating the two different traffic directions of the road, two secondary middle islands separating the main traffic lanes from service lanes of each direction, and two side-walks (see Fig. 13). The majority of main middle islands are wider than 3 meters (about 57%) while about (29%) fell in the range between 2-3 meters in width. Sub middle islands on the other hand fell in the range of 1-2 meters in width. Side-walks also vary in width with the majority fells in the range of over 3 meters (about 57%).

Trees in this pattern were mainly planted in the middle islands (as seen in Fig. 6). Because these roads were classified as major commercial and traffic arteries in the city, side-walks were purposely left unplanted to accommodate the commercial activities on the sides (see Fig. 13). In main middle islands, palm trees were the most common tree used. About 80% of the roads have palm trees in their main middle islands (see Table 8), in other words, almost all planted streets have this characteristic (see Fig. 6). Plantings in middle island were found to have been done in both planting pits (2.00 X 2.00 meters hole) and planting trenches (the same width as the pits) with no special emphasis on either one.

Table 8. Occurrence of different tree species planted in main roads

Name of trees	% of roads planted	Planting place
Palm trees-Phoenix dactylifera	80 %	Main middle island
Pithecellobium dulce	60 %	Secondary middle island
Prosopis spp.	40 %	Secondary middle island
Delonix regia	20 %	Secondary middle island
Albizia lebbek	20 %	Secondary middle island

Secondary middle islands, on the other hand, were found to be planted mainly with Pithecellobium dulce and Prosopis spp. (see Table 8). Few other tree species were also

found, but with low percentage of occurrence. Both of these two most used trees species develop an awkward branch structure that grows straight from the main trunk which easily exceeds the width of the secondary islands (1.20-2.00 meters) to the adjacent traffic lanes on both sides of the islands (see Fig. 14).

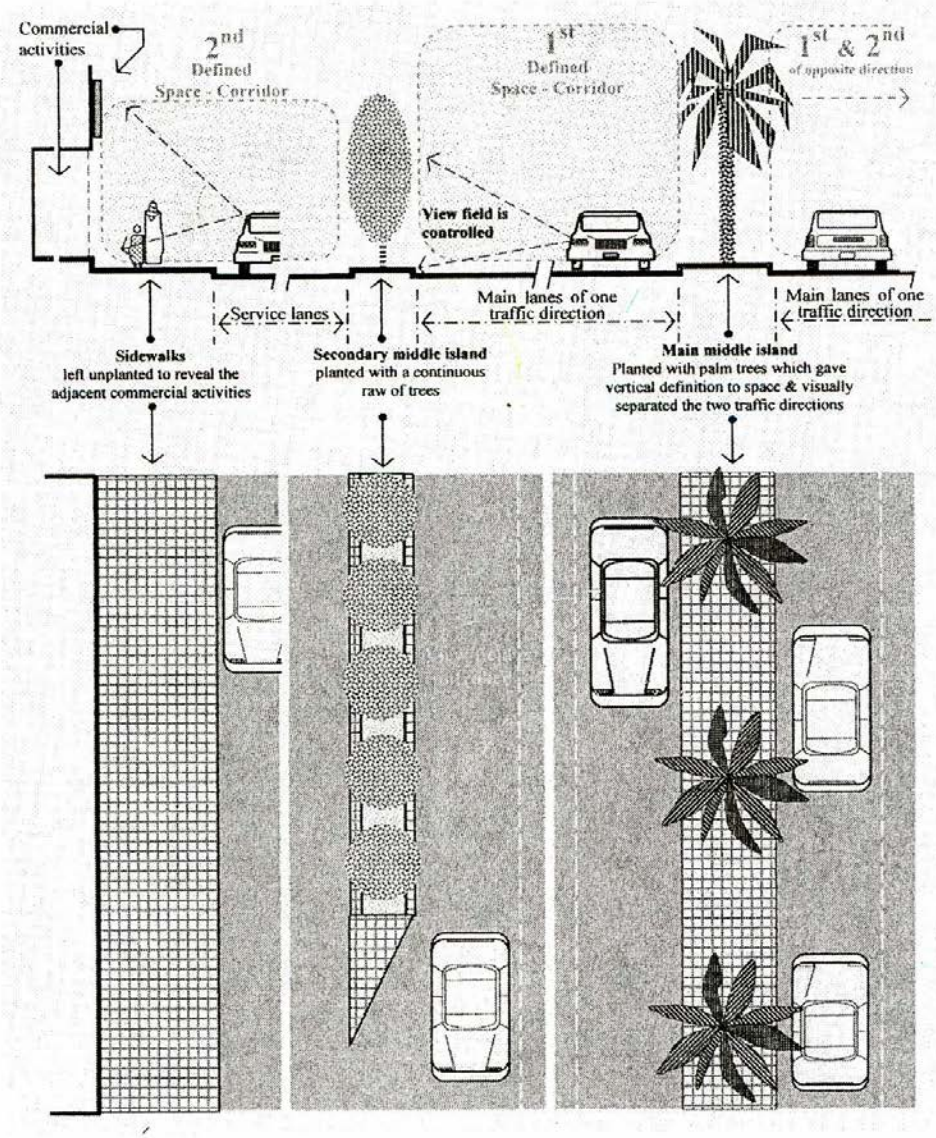


Fig. 13B. Conceptual illustration of the detected planting pattern of the main roads.

A B

Fig. 14. Views of Al Amir Abdullah Road showing the main middle island and its planting materials and planting pits (A) and secondary islands (A & B).

The planting pattern of this street category has several advantage and disadvantages. Among the advantages are: the use of palm trees in main islands that gave vertical definitions to the wide open road and provided visual separation between the two traffic directions. Trees in both main and secondary islands created a visually controlled corridor in each of the main lane traffic directions as seen in Fig. 13; and finally, trees of the secondary islands create physical separation between the busy main traffic lanes in the middle of the road and the active service lanes on the sides. In fact, the trees of the secondary middle islands provided spatial and functional separation of the different sections of the road (see Fig. 13).

Among the disadvantages of this pattern are: shapes and forms of selected trees for the secondary island are not appropriate. The narrow width of the secondary islands need trees with upright oval shape crown not a shrubby like wide canopy trees such as Prosopis spp.; and also, the continuous row of trees planted next to each other along the secondary middle islands, in either a continuous ditch or every 4-6 meters apart, block the drivers views between the main and service lanes of the road especially at intersections and at openings between main lanes and service lanes which in terns weaken the traffic safety on the road.

Pattern No. 4: **Highway Planting Pattern**

This pattern could definitely be classified as the most simple street planting pattern in the city. The survey found that trees only planted in the middle island of the Highway (see Fig. 15). In some cases, trees are planted in the secondary islands around and under over-passed bridges and exits (see Fig. 16B). There are no systematic patterns that can be detected. Planted middle island is a continuous concrete edge island higher than the road level with about 90 centimeters and filled with good planting soil (Figs. 15 & 16).

The most common tree species used in this pattern is palm trees-Phoenix dactylifera. Palm trees are planted in the middle of the island (as seen in Fig. 15). Sometimes, other tree species can be seen planted between the palms with no specific

pattern. Small shrubs were found to be planted on both sides of the palm trees (see Fig. 16A).

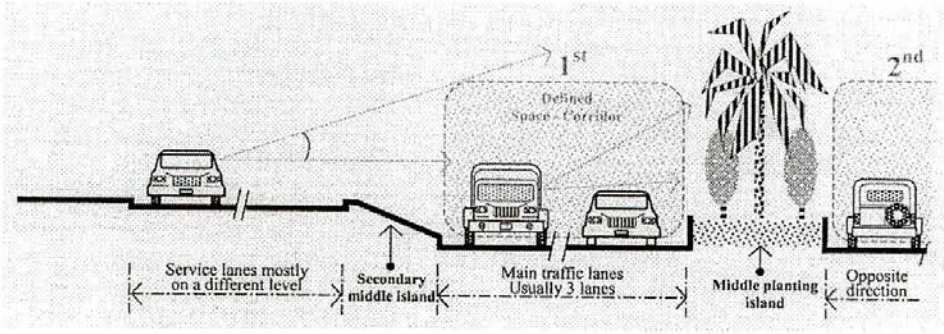
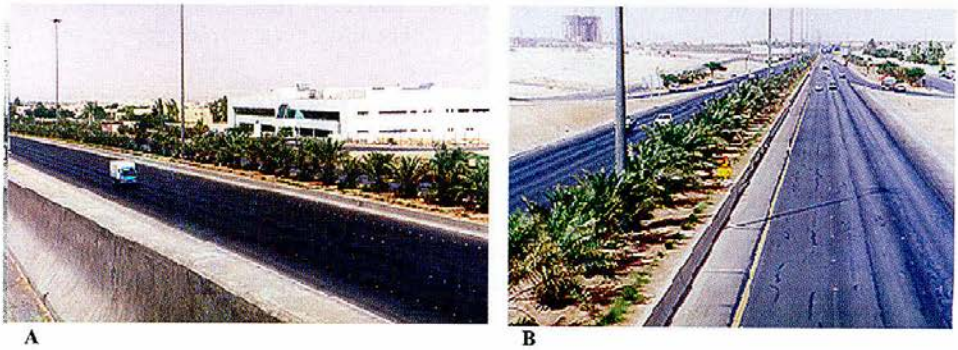


Fig. 15. Conceptual illustration of the detected planting pattern of the highway road category.

From analyzing the conceptual intersection of the highway in Fig. 15, it is logical to conclude that planting pattern is actually aimed to accomplish spatial and visual characteristics. Planting palm trees gave a vertical dimension to reduce the feeling of the width of the road. They also define the space and create a well marked corridor in each traffic dimension. On the other hand, palm trees with their tall and unique course texture play an aesthetic role that can be enjoyed by drivers on the highways.



A B

Fig. 16. Views of Northern Ring Road Highway (A) and Eastern Ring Road highway (B) showing the planting pattern in this street category.

Conclusion and Findings

Although there has been no specific formal planting program, Riyadh city has gone through extensive planting stages to spread greenery in the city. After almost four decades of planting, the paper tried to assess the existing situation of planting, detecting planting patterns and analyze the existing patterns to recommend appropriate ideas for now and the future.

Despite the variety in street sizes and shapes and the differences in planting techniques and species from one planting stage to another, field study detected four planting patterns that existed in the city streets. Planting patterns were strongly related to street sizes, shapes and functions. Tree species and their planting location play very important role in shaping streets and spatially define their spaces. Street planting also provided aesthetic value to streetscape and either enhance view field, creating corridors, or sometimes block views that are essential for the safety of drivers. The discussion will summarise the study of the findings and recommendations:

- Prosopis tree was found to be the most used tree in the streets of Riyadh.
- Planting trees in streets must consider variety of tree species to give different characters and provide for different uses and advantages. Planting must not rely on one specie even in planting one street because such policy could represent a very critical risk for the planting program when a disease attacks or when climatic changes occur.
- In placing trees for planting in streets, two technical aspects need to be considered:
  - First, in planting narrow side-walks or secondary islands, it is important to make sure that the width of the planting side-walks accommodate the minimum width of pit size of the planted trees.
  - Second, the distance between the planting spot and the adjacent vertical structure should consider the average canopy size of the planted trees so trees will not be forced to lean toward the source of light and block pedestrian circulation and adjacent traffic lanes. Therefore, such tree species are not recommended to be used as street trees.
- In selecting trees for street planting, it is very important to consider the root behavior of the selected species. Some trees species were found to have an invasive root system that damages the pavement and nearby structures.
- Tree shapes play important roles in street planting. Lower branches of large and medium size trees, such as Prosopis and Pithecellobium dulce, must be removed to allow for pedestrians circulation and to provide shade. In narrow strips, such as side-walks in local streets and secondary middle islands in main roads, it is recommended to plant trees with upright oval shape crown, and not a shrubby or wide umbrella like crown trees.
- In wide street categories such as main roads, several considerations were noted:
  - Planting trees in both main and secondary islands created a visually controlled corridor in each of the main lane traffic directions (see the section in Fig. 13).
  - Trees planted in secondary islands provide spatial and functional separation between the main speedy traffic lanes and the slow service lanes. On the other hand, planting ought to consider spacing them away from each other to allow for drivers views between main and service lanes of the road to enhance the traffic safety issues (see the plan in Fig. 13).
  - Planting palm trees in the wide streets give a vertical dimension to reduce the feeling of the large width of the street and create a well marked corridor in the

street (see Fig. 13). On the other hand, palm trees with their tall and unique course texture play an aesthetic role that can be enjoyed by drivers on multi-lanes fast driving streets.

The study has taken a step forward in assessing the planting situation and detecting and analyzing planting patterns in the city streets from a landscape point of view. There are also more influential factors that need to be considered here especially when dealing with a multi profession issue such as street planning. Further studies need to be done to cover other related issues that this study could not address in order to come out with a complete vision about future planning of city streets.

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تحليل أنماط توزيعات النباتات الحالية بمدينة الرياض–المملكة العربية السعودية

عمر بن سالم باهمام

كلية العمارة والتخطيط، جامعة الملك سعود، الرياض

(قدم للنشر في ١٤٢١/٥/١٦هـ؛ وقبل للنشر في ١٤٢٣/٣/١٧هـ)

ملخص البحث. لقد ارتبطت الأشجار منذ القدم بالمستوطنات البشرية. وفي العصر الحديث، لعبت الأشجار دوراً مهماً في التكوين البيئي والجمالي للمدن حيث انتشرت الأشجار في البنية العمرانية وبالأخص على طول الشوارع العامة. لقد ظهر الاهتمام العالمي بتشجير الشوارع للتغلب على مشاكل التدهور البيئي الناتج من النمو العمراني للمدن الحديثة. وحيث إن مدينة الرياض تعتبر من ضمن أسرع المدن نمواً في العالم، فقد تبنت اتجاه يهدف إلى زيادة الغطاء الأخضر في المدينة والذي تمثل في عدة إنجازات من ضمنها زراعة الأشجار في الشوارع العامة والذي نتجت عنه بيئة جديدة لها إيجابياتها كما أن لها سلبياتها الناتجة عن تبني هذا المنهاج الجديد على المدينة. من هنا جاءت هذه الدراسة محاولة تحليل البيئة الناتجة عن تشجير الشوارع ومستخلصة الأنماط التخطيطية الحالية الناتجة عن ذلك التشجير ومقدمة تحليل توضيحي لتلك الأنماط من وجهة النظر التصميمية والتخطيطية لشوارع المدينة. وللوصول لذلك الهدف تم طرح مجموعة من الأسئلة البحثية التي استعرضت في هذا البحث.

مصطلحات: خطوات التخطيط، أنماط زراعة الأشجار، أشجار الشوارع، الأرصفة الجانبية، الأرصفة الوسطية، النباتات المحلية، النباتات غير المحلية، الأشجار دائمة الخطرة، الصيانة، حركة المشاة.