

# Study of Bionic Architecture Strategies in Worn-Out Residential Textures in Order to Reduce the Heat Island Phenomenon Case Study: Region 11 of Tehran Municipality

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Received: July 24, 2015  
Accepted: September 31, 2015

## ABSTRACT

Heat Island consists of warming of the planet earth by surface radiation and reflection from sunlight collision. Studies show that increasing the temperature based on the expansion of heat islands in Tehran is more than that in other cities of the country and 11<sup>th</sup> region of Tehran municipality, as is the political, commercial and cultural heart of Tehran, is very important from this perspective. Of the 500 studied blocks in 11<sup>th</sup> district of Tehran municipality, 63/76% of blocks in best conditions, averagely take the least effect from the heat island dominating the environment and 21/26% of the blocks, on average, are in a state of severe impressibility and 10/03% are in a state of very extreme impressibility. On the other hand, as the old texture in 11<sup>th</sup> district of Tehran municipality constitutes over 75 percent of the district, but only 39/08% of the whole blocks are in the state of severe impressibility from this phenomenon, and this issue indicates that the architecture of new and semi-new tissues of the district are significantly much weaker and more impressible than old blocks in showing reaction to the heat island. According to the results of the authors' studies, it was revealed that the old blocks of 11<sup>th</sup> region of Tehran municipality are in average and semi-desirable level in control and reduction of heat island phenomenon and newly-built blocks are in weak and undesirable level and it is necessary and essential for the region to use appropriate strategies of Architecture and urban development to control and reduce the phenomenon of the heat island especially the newly-built buildings which will lead to the reduction of energy consumption.

**KEY WORDS:** Architecture, Bionic Architecture, Heat Island, District 11 of Tehran Municipality.

## 1. INTRODUCTION

The role of architecture is very strong in humans' lives. The shelter, the first human need, is shaped through art and science of architecture. That is why the science of architecture has always been in the spotlight, and it was tried to, by using the latest technologies related to building, the best and most ideal comfort conditions be provided for its contacts. Meanwhile, the topic of energy control, and reduction of its consumption is a subject that cannot be ignored. This study has necessity and importance since it directly refers to one of the most important issues of reduction and control of energy consumption, not only in buildings but also in the whole neighborhood, region and even the whole city.

Today the issue of the heat island phenomenon has turned to a major problem for populous cities around the world. While we can control it by taking advantage of simple ways, and even use it as an energy source. In this article we have tried to introduce the simple strategies to prevent this phenomenon by introducing basic problems of the studied area. There is hope that this article can be effective in the direction of architecture promotion and control culture and energy consumption optimization.

## 2. RESEARCH METHODOLOGY

The present study, in terms of goal, according to three categories of applied research, fundamental and developmental, is placed in the category of descriptive-applied researches. The purpose of this research type is to develop practical knowledge in a particular field (scientific application of knowledge) and to test theoretical concepts in real-life situations and to solve concrete problems. This research, using the background, context and knowledge provided through basic researches, is used to meet the human needs and optimize the tools, methods and models to promote the welfare, prosperity and enhance human life and the results of this research is objective and clear [1].

**2.1. Descriptive method:** The aim of this study is to describe a situation or a series of conditions in detail. The present research, as works with the description and interpretation of conditions and current relations and studies the current state of special subject, is based on the description method. This method is a qualitative method which is based on the interpretive philosophical view [2].

**2.2. Analytical method:** In this method, the explicit content and existing messages in a text are described systematically. In other words, in this method, the analysis of factors, elements and their relationships with each other, are done based on texts, maps and images and the specific characteristics of the documents are determined systematically and purposefully.

**2.3. Statistical sampling method:** For statistical sampling, systematic method has been used that in this method, instead of random selection, a pre-determined order is used. In the usual method, a list of all sampling units is needed which is not needed to be numbered. When the society units have a particular order within the sampling framework, the efficiency of this method increases. Systematic sampling method, especially when extraction of sample is about communities and the natural phenomena, is with substantial savings on time and costs associated with sampling [3]. The study sample of this research consisted of 500 residential blocks which were selected on a regular basis in different neighborhoods of the selected area that includes a variety of fine blocks.

#### **2.4. Single and multi-unit residential complexes:**

**2.4.1. Data collection method:** A-Documentary method: In this method, the needed information is collected through previous studies and the reports done in this area. Studies of these texts will provide basic information for analytical purposes of research.

**2.4.2. B- Field studies:** In this section, the information is collected through in-person referral and direct contact with the studied area. For this, methods such as scrolling, shooting, interviews, observations and drawing the sketch were used to record information.

**2.5. Method of information analysis:** Among the various methods available for analysis, this research follows the descriptive-analytical method and to analyze the data that makes up the main part of the article, uses the most commonly used method in the qualitative researches means content analysis. In the section of classifying of the studied area based on climate, the method of classifying the climate of Iran was used using the method "Oleg" and "Mahani". In the following, the classification of issues and subjects collected in the current situation are stated in terms of strengths and weaknesses and suggestions. This method, in analysis of topic, which includes both the external environment and internal environment of the system, provides the possibility to support architectural design by making decisions which match the studies.

### **3. REVIEW OF LITERATURE**

#### **3.1. History and study of the heat island effect**

Heat island is warming of the planet earth that has become a global problem today. Studies show that increasing the temperature based on the expansion of heat island in Tehran is more than other cities of the country [4]. The term, heat island was first suggested by Howard in 1833 [5]. Since then, many researches have been done and it was found that by cities growing fast, air temperature also has increased in different parts of the city. However, this increase in temperature varies in different parts of the city means the more condensed the facilities and the buildings, the further the temperature will go in these areas. This feature is more tangible in urban centers. Heat island forms due to the loss of natural surface cover (vegetation, soil, etc.), creation of urban artificial physical levels (buildings, asphalt surface and other facilities), and this causes that the solar energy be more absorbed by these surfaces during the day and during the night the heat energy (long wavelength) be trapped by these constructions and cooling process happens slowly, so the temperature of cities, especially in centers (due to a greater absorption by physical levels) will normally be higher than that in the suburbs [6].

Presence of artificial physical levels (asphalt, tile, etc.) instead of permeable surface (soil) and vegetation cause reduction of evaporation and transpiration and increase the sensible heat in the cities, and this makes the urban air be usually warmer than the surrounding air. Big cities can create special local climate, means to control the environment surrounding climate and the city weather is quite different with its surroundings. During the day, the dark building materials, absorb heat and keep it for hours after sunset. This process, in addition to the process of radiation to the body and dispatch of its longer wavelength, causes intensification of the warm air in megacities. NASA satellite studies show that all megacities on earth, due to the eliminating the plants and replacing them with construction materials, especially dark materials, are experiencing the same problem [7].

During the day, warming of urban buildings surfaces is faster than that in the villages around the city. From dawn, the walls of buildings prevent weak sun rays, although in this case the evaporation and transpiration are low, but the heat effects of radiations are intense [8].

### **4. DISCUSSION & REGIONAL STUDIES**

Tehran city, is located in the north of Iran and south of Alborz Mountains. Its population is 8,224,535 people and it is considered as the 25<sup>th</sup> populous city in the world. The area of this city is 730 square kilometers and is divided to 22 districts, 134 areas and 370 neighborhoods.

#### **4.1.1. Worn-out texture of Tehran**

Worn-out textures are considered as the city's vulnerable regions that require planning and coordinated intervention to organize and improve the quality of living. According to the information of Civil Company and Urban Development of

Tehran, deteriorated tissues area (approved) in Tehran, is equivalent to 3268 hectares and the proportion of worn-out texture compared to the total surface area of Tehran is around 5 percent, the identification criteria for worn-out textures are equal in value but the how of applying the criteria is defined and identifying distressed textures is based on the guidelines and a certain index which include fine, instability and impermeability. Proportion and degree of worn-out texture in districts of Tehran, are provided in the following table.

**Table 1.** Proportion and degree of worn-out texture in districts in Tehran city- Reference: Detailed plan information of Tehran districts and Renovation Organization of Tehran City (2014)

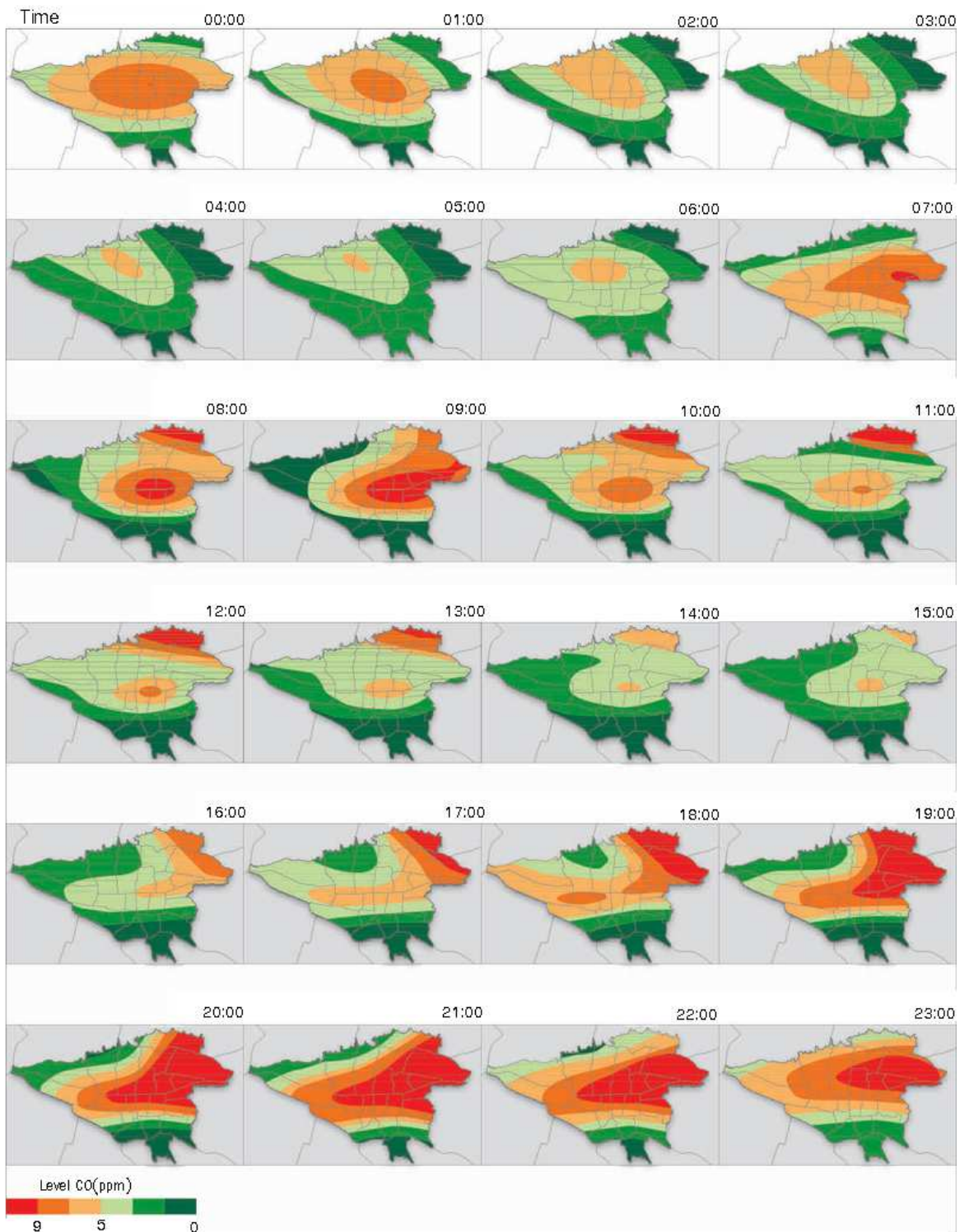
Proportion of worn-out texture (hectare)	Worn-out texture (hectare)	District area (hectare)	District	Proportion of worn-out texture (hectare)	Worn-out texture (hectare)	District area (hectare)	District
37/0	592.65	1600.81	12	1/4	64.28	4574.24	1
4/3	73.04	1700.01	13	0/4	18.65	4761.00	2
10/7	257.54	2412.43	14	0/8	24.54	2938.27	3
7/9	246.28	3130.31	15	0/1	7.72	6160.29	4
9/0	149.11	1652.14	16	0/2	11.58	5321.81	5
29/2	239.88	821.69	17	0/2	5.07	2141.26	6
3/7	102.82	3807.98	18	15/5	237.48	1536.54	7
1/1	22.36	2053.37	19	10/9	143.85	1322.12	8
6/1	137.23	3254.89	20	7/5	136.03	1951.43	9
0/1	6.92	5549.90	21	18/1	146.03	807.25	10
0/0	0.95	5851.09	22	29/2	352.35	1204.97	11

#### 4.1.2. Tehran Climate

Tehran's climate is influenced by the mountains in the north and the plains in the south. Apart from the north of Tehran, that under the influence of mountain, its climate is partly mild and wet, the climate of rest of the city is generally hot and dry and is slightly cold in winters. Finally, based on the climate division, Tehran is located in the relatively cool climate area.

#### Air pollution in Tehran

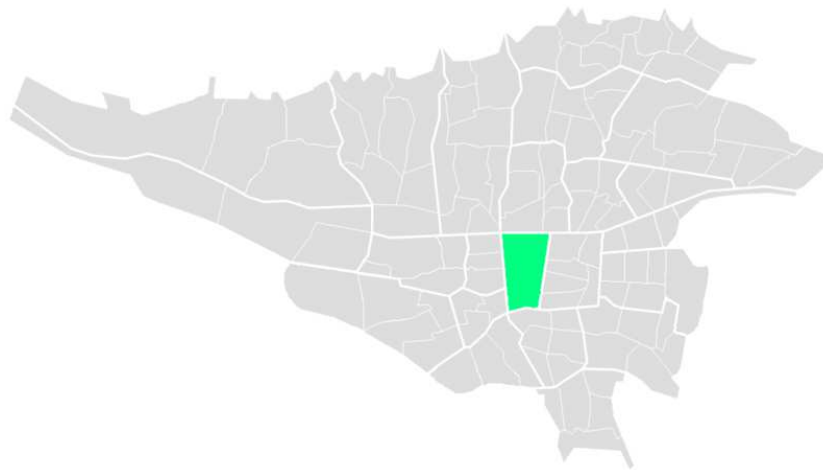
In Tehran, 16 million trips are made daily that for the movement of vehicles per kilometer, on average, 65 grams of pollution are made, and in total, 10 thousand and 88 tons pollutions are entered daily in Tehran by transportation vehicles. Also each day, 12 people lose their lives due to air pollution and this number is 4,500 per year. Investigation of pollutants SO<sub>2</sub>, NO<sub>2</sub>, CO and PM of stations Gholhak, Villa, Hesar, Pardisan, Azadi, Tajrish and Bahman shows that station Gholhak has highest CO and Hesar has the lowest pollution in CO, for NO<sub>2</sub>, Aghdasieh station the highest, and Hesar station the lowest pollution, for SO<sub>2</sub> pollutant, Aghdasieh and Fatemi stations the most, and Hesar station the least pollution, and for pollutant of PM particles, Golhak and Fatemi the most and Bazar station has the lowest pollution. In other words, in most of the pollutions, Hesar station has the lowest pollution and Aghdasieh and Golhak stations show the highest pollutions. Atlas of Tehran 2006 [9].



**Fig. 1.** Image of change of Tehran air pollution in 24 hours (annual average)

#### 4.2. Introduction and geographical status of district 11

District 11 of Tehran municipality is of the central parts of Tehran metropolis. History of the development of residential areas returns to the first regeneration of Tehran in 1901s, and coincided with those years and is related to the traditional figures of Tehran city. This district is of districts which are located in the center of Tehran and has an old texture and has an area of 6/12 square kilometers and is approximately equal to "1/8% of total area of Tehran and in this term, it is the seventeenth district of Tehran. The population of this district based on the 2011 census is 288, 884 people (98 556 households), including 142, 877 men and 146,007 women. [4]



**Fig. 2.** Area of 11<sup>th</sup> district of Tehran municipality

**Situation analysis:** strengths, weaknesses, opportunities and threats (SWOT)

**Table 2.** Table Swot. District 11 of Tehran Municipality

threats	opportunities	weaknesses	strengths
<ul style="list-style-type: none"> <li>• Lack of attention to the necessity to maintain and destruct places and buildings having historical value</li> <li>• Environmental pollution</li> <li>• Social Indicators and household income level</li> <li>• High density of residential space and increase of environmental phenomena such as heat island phenomenon</li> </ul>	<ul style="list-style-type: none"> <li>• Collective orientation and will for renovation of worn-out texture and reduction of earthquake damages</li> <li>• Orientation toward development of tourism activities in the field of cultural heritage</li> <li>• Existence of land with old buildings and suitable for the development of terminals</li> <li>• The operation of upstream projects in the development of arterial network</li> </ul>	<ul style="list-style-type: none"> <li>• Unorganized situation of worn-out and vulnerable textures</li> <li>• Failure and street network problems</li> <li>• Lack of allocation of land to service applications in proportion to the size of the population living in the neighborhood area</li> <li>• Residential tissue interferes with workshop centers</li> <li>• Poor neighborhood of applications</li> <li>• Lack of green spaces</li> <li>• Presence of environment pollutant centers in terms of pollutant jobs and workshops</li> </ul>	<ul style="list-style-type: none"> <li>• Performance of specialized markets and peoples' orientation toward using these markets</li> <li>• Historical history and identity</li> <li>• Establishment of the most important political-governmental centers</li> <li>• Strong neighborhood relationships</li> <li>• Important role of district in the development of subway lines</li> <li>• Operation of military lands in upstream projects and rules related to relocation of these centers</li> </ul>

#### 4.3. Organic architecture and reduction of the heat island phenomenon in Tehran

In organic architecture, it is tried to create the most compatibility with the climate and nature in designing the building and in fact, the architecture and the building get harmonized with the environment so that the lowest energy consumption be provided in order to reach the level of environmental comfort. Climatic design has an essential role in reducing heat island phenomenon, the use of all climate features, weather conditions, light and temperature and the environmental features ranging from city population, industrial facilities effective in climate conditions such as power plants and big industrial centers and ... can not only reduce energy consumption in buildings, but also reduce the heat island phenomenon [6]. To learn more about ways to reduce energy consumption, one first need to understand the human comfort conditions in the residential environment. Mahani bioclimatic table can provide complete information on the recognition of human comfort level in the artificial environment.

##### 4.3.1. Study of construction bioclimatic graph of Tehran city

Construction bioclimatic table revised by Gioni and Mylin in 1981, offers comprehensive information on the climate design in climate of Tehran city. According to psychometric table that is the basis of construction bioclimatic table and according to the parameters of dry temperature, wet temperature, relative humidity and steam pressure, the human comfort zone is specified. Human comfort zone is a set of conditions that is appropriate for at least 80% of people thermally. Study of construction bioclimatic graph shows that, in the climate condition of Tehran city, there is need for (mechanical) cooling in the warm months of the year. This implies that the heat island phenomenon is directly related to the increased use of cooling equipment as a result of an increase in city temperature in summer. Therefore, the use of temperature control to reduce energy consumption in buildings is very essential that by using methods of climatic design can help to reduce it.

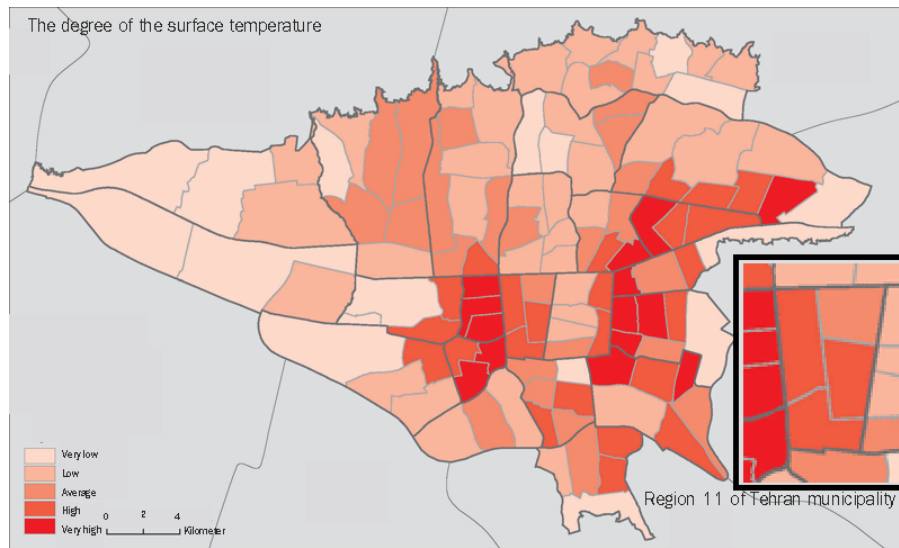


**Table 3.** Determination of the usage of the mechanical systems of the construction bioclimatic table in Case Study

Frequency	Type of mechanical system	No.
22-30 %	Heating by mechanical systems	1
10-12%	Heating by solar energy	2
10-25 %	Natural comfort condition	3
5-10 %	Natural cooling of heavy construction materials	4
15-19 %	Mechanical cooling of water cooler	5

#### 4.3.2. Strategies to reduce the heat island phenomenon in building tissues of District 11

In the following maps you can see that the district 11 of Tehran municipality is in a state of high surface temperatures. This means that the severe air pollution and also the lack of green space in this area have led to great increase of heat island phenomenon. In this section the main factors contributing to the reduction of heat island phenomenon in the district 11 (dead tissue) in Tehran city are investigated and the suggestions to improve the situation in the district will be proposed afterward.

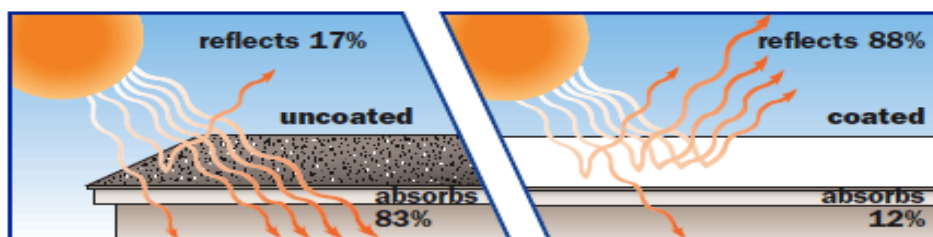
**Fig. 3.** The degree of the surface temperature in Tehran city

**4.3.2.1. Canopies:** Avoiding direct solar radiation into the room and thus reducing the indoor temperature has always been one of the most basic ways to deal with excessive temperature of the building. Therefore, the design of the open sections of exterior wall of the building is of great importance [10]. Therefore, the fundamental purpose of the canopies designs is to fit them with the need times for shadow and sun. In investigation the district 11 of Tehran and by the study of more than 500 housing units located in old textures in four areas, it was observed that more than 93% of buildings are without canopies and shadow is only provided by adjacent or opposite buildings and trees. Also 99.8% of the buildings were using curtains for shading, although the use of curtains is useful to block direct light into the building, but it cannot effectively reduce the heat island around the building.

**4.3.2.2. Landscaping:** Landscaping in addition to the beauty can play an important role in the thermal comfort of the buildings. For example, trees can have the role of shading for buildings in the summer and as a result adjust the buildings' interior spaces. Also researches show that the trees shading on the building can reduce the indoor temperature at 1 to 6 degrees. But we must be careful in the selection of trees and vegetation so that we do not prevent heat into indoors in winters [11]. While there are 23 gardens in the geographic area of district 11 of Tehran municipality, but in the context of residential area, the percentage of vegetarian is extremely low and in the investigation done, 17.6% of the area of residential texture has green space (planted trees). While the scope of the study has the capacity of 38% to increase green space by planting trees around the footpath within the texture.

**4.3.2.3. Cold surfaces:** The use of white roofs has an effective role in reducing the heat island phenomenon. The roof surface and the cold roof have both properties i.e. high reflectivity and high thermal emission to minimize the amount of light converted to heat and to maximize the amount of heat that is radiated to the surroundings. [12]. Any opaque surface reflects some of the incoming sunlight and absorbs and converts the others into heat. White ceilings reflect the sunlight more than dark roofs and convert less solar energy into heat. Increase in the reflection of the building, either through color of white surfaces or through the reflecting surfaces, can reduce the temperature of buildings, cities and even the entire planet. Most of the roofs are dark and do not reflect more than 20 percent of the incoming sunlight. (For example, these

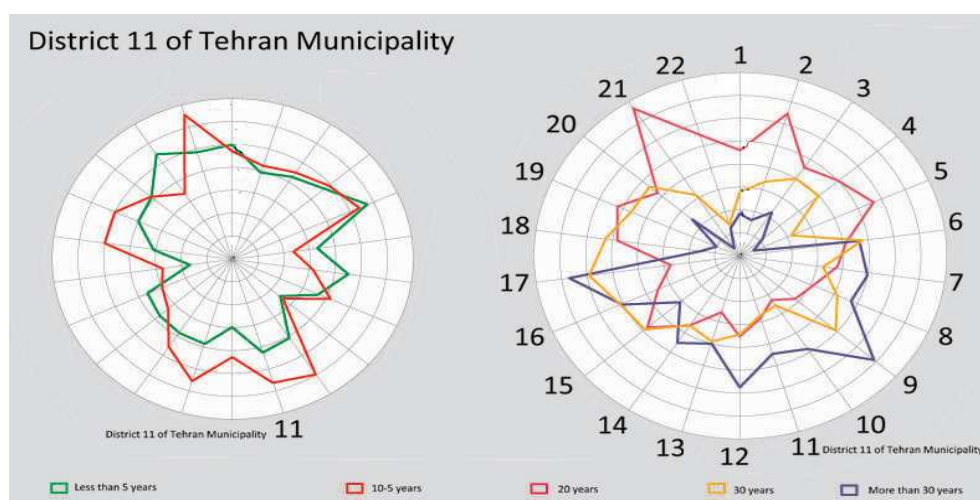
surfaces have a reflection of 0.2 or less). While the new white roof shows reflection of about 70 to 80 percent of sunlight (for example, reflection of these surfaces is between 0.7 to 0.8). The new white ceiling is typically 28 to 36 degrees centigrade (50 to 65 degrees Fahrenheit) cooler than the dark roof in the afternoon sun, while the old white ceiling is typically 20 to 28 degrees centigrade (35 to 50 degrees Fahrenheit) cooler.



**Fig. 4.** The effect of sunlight on light and dark surfaces -Source: Lawrence national Berkeley laboratory-2014

In the evaluation of 500 residential blocks located in 4 areas of district 11, 84.3% of the blocks had insulated roofs by using reflux fusing, and 3.7% were with insulated roofs with the method of white roofs (white insulations), and the 8.8% were with bitumen and packages and 3.2% of the roofs were covered with different materials including asphalt, mosaic and...

**4.3.2.4. Using coordinated materials by reducing the heat island phenomenon:** Improper construction methods in the society caused illness in the environment around us and has created an unhealthy biological systems. To create a true construction and maintenance of environment, materials used in buildings have very important role [13].



**Fig. 5.** The graph of the quality of residential units, according to districts in Tehran

In brick buildings, special heat is very close to the soil and in the cement and concrete buildings, special heat is close to the metal. Facing the changing temperature, the first one is more stable and second one is very unstable [14]. Taking advantage of the brick buildings, with review and consideration of all engineering factors, especially safety and earthquake, apart from preventing some psychological issues that arise due to living in a concrete structure, is very important to study and debate, due to the reduction of heat island effect, it will cause saving in the energy consumption. In investigation residential buildings in the four areas of district 11, materials of 430 blocks were distinctive from 500 blocks, among which 84% of the blocks have been built using bricks and clay blocks and 16% of the blocks with the use of materials such as panel sandwich - Gypsum blocks and etc.

**Table 4.** Comparison of the coefficient of conductivity of the materials used in the facade

Aluminum	Stone	Cement	Ceramic	Glass	Clay brick	Chile brick	Air	Building materials
237	2-7	1/73	1/06	1/4-0/9	0/7-0/5	1/3-0/8	0/02	Heat transfer coefficient (W/mK)

Of course the topic of the material of building façade has a role up to 38% in reduction of the heat island entry into the building; especially when building the façade has been done using the white stone, brick and light-colored materials. In the sample studied, the façades of 43.3% of the buildings have been built using white and cream colors and 18.6% using

bricks and 8.5% of the buildings with ceramic and designed composite laminates and 29.6% of buildings using other materials with dark colors.

**4.3.2.5. Double-glazed windows:** Using double glazed glasses in addition to preventing the entry of sound pollution, contribute largely to reducing the effect of the heat island phenomenon in Tehran city [15]. In the studied example, 154 residential blocks which were mainly newly-built had double glazed glasses and windows and the rest of the buildings located in the old tissue were devoid of any double glazed window

## 5. CONCLUSION

By the analysis done which were earlier stated, some results have been obtained that are presented as follows. Out of the 500 surveyed blocks, 63.76% blocks at best conditions have averagely the least impressibility from the heat island dominating the environment and 26.21% of the blocks, on average, are in a state of high impressibility and 10.03% in severe impressibility. The important point is that the worn-out texture which involves over  $\frac{3}{4}$  of the studied district, only involves 39.08% of the total blocks having the condition of high impressibility from the heat island. This indicates that the architecture of new and semi-new textures of the district are clearly much weaker and more vulnerable than blocks in the worn-out textures in showing reaction against this phenomenon which is 60.92%. Of course, urban design and green planted landscape design have significant influence on this sharp decline in newly-built units in comparison with worn-out texture.

Thus it is proved that the old residential blocks of district 11 of Tehran municipality in terms of controlling and reducing the heat island phenomenon are in the medium and semi-desirable level and new blocks area are in weak and unfavorable level. It means that architecture and urban design in harmony with the applicable residential climate of district 11 and also external surfaces and building spaces of residential area of district 11 are effective to reduce the heat island phenomenon in Tehran and the urgent need of the district to use appropriate strategies of architecture and urban planning to control and reduce the heat island phenomenon that lead to reduced energy consumption, seems very necessary.

## 6. SUGGESTIONS

**6.1.1.** Designing inactive solar system and using solar water heaters and the use of double-glazed windows to reduce heat waste. Designing windows near to the floor to bring cool air into the interior spaces and exit of additional hot air from the roof of the building to the outside and using the walls with high thermal mass (concrete) to store heat in the winter.

**6.1.2.** Using vegetation around the building to offset heat islands and using the canopies and skylights according to the depth of the shadow and intensity of incoming light to the building.

**6.1.3.** Using bright colors in the interior spaces allows more light reflection in the space, which in turn reduces the need for artificial light in the interiors.

**6.1.4.** Designing roof and green vertical surfaces: By benchmarking from the design of the hanging gardens of Babol which have been built about 2700 years ago by Iranian engineers and thinkers, we can, by executing the plan of green roofs, turn nearly one fifth of Tehran city into green spaces. As the name of this plan suggests, by the implementation of appropriate strategies and plans, we can make the houses roofs green spaces by rooting shrubs, apart from the heat island phenomenon and its pollution.

## 7. ACKNOWLEDGMENTS

The authors recognize to be grateful from great people such as Mr. doctor Abdullah Nazari, PhD in Statistics and university professor, who had a sincere cooperation in the selection of method and population sample as well as Mr. Dr. Morteza Seddig and Ms. Dr. Mahnaz Mahmoudi and Dr. Abolhasan Rezaei.

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