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Design Principles for Ventilation with Regenerative Results: Vernacular Diyarbakır Houses

Havalandırmaya Yönelik İlkeler ve Rejeneratif Sonuçları: Geleneksel Diyarbakır Evleri

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ABSTRACT

Many building assessment systems are criticized due to focusing on individual building performance. However, in order to be truly positive, the effects of different aspects of a built environment should be considered through correlative impacts across different scales. Ventilation and air related properties are among these important effects. With the aim of exemplifying architectural design solutions, a vernacular settlement in the southeast of Turkey: Diyarbakır and its houses are examined with a systematic evaluation approach through architectural design under three phases. In the first phase, outdoor environment components which induce or effect air movements are examined and evaluated along with user properties. Aspects of ventilation, building envelope and indoor environment of Diyarbakır houses are analyzed in the second phase. The last phase is the evaluation of houses in terms of ventilation efficiency by relating user requirements with acquired properties of air and ventilation. With this examination, many architectural features as passive systems are revealed in order to condition and move the air. Additionally, based on findings, it can be interpreted that presuming the built environment as a part of bigger and smaller systems may create net positive results for humans and other systems of the place.

Keywords: *Air quality; assessment; Diyarbakır houses; regenerative design; ventilation.*

ÖZ

Birçok güncel yapı değerlendirme sistemi, yalnızca tekil bina ölçeğinde yapı tasarımının belirli konulardaki etkinliğini sınama üzerine odaklandıkları gerekçesiyle eleştirilmektedir. Bununla birlikte, bir yapma çevrenin farklı özelliklerinin etkileri birbirini kapsayan çeşitli ölçeklerdeki etkileşimler bağlamında ele alınırsa gerçek anlamda olumlu bir nitelikten söz edilebilir. Havalandırma ve hava ile ilişkili özellikler bu önemli etkileşim türleri arasında yer almaktadır. Uygun nitelikte mimari tasarım ilkelerinin belirlenebilmesi amacıyla, Türkiye'nin güneydoğusunda yer alan eski Diyarbakır yerleşmesi ve evleri sistematik bir değerlendirme yöntemi kullanılarak birbiriyle bağlantılı üç aşamada incelenmiştir. İlk aşama hava devinimlerinin oluşmasını ya da mevcut devinimin özelliklerinin farklılaşmasını sağlayabilen dış çevre özelliklerinin ve yapma çevrenin kullanıcısının araştırılmasına odaklanmaktadır. Bunu izleyen ikinci aşamada Diyarbakır evlerinde havalandırmanın niteliği, yapı kabuğu ve iç çevre özellikleri ele alınmaktadır. Üçüncü ve son aşamada ise kullanıcının havayla ilişkili gereksinmeleri ile çevre araştırması sonucunda elde edilen verilerin karşılaştırılması yoluyla Diyarbakır evlerinin mimari tasarımla ilişkili özellikleri havalandırma etkinliği açısından değerlendirilmektedir. Bu değerlendirme çalışması ile edilgen sistemler olarak da tanımlanabilen, havanın devinmesi ve koşullandırılmasını sağlayacak birçok mimari düzenleme ortaya konulmakta ve yapma çevrenin kendisini kapsayan daha büyük ve içerdiği daha küçük çevre sistemlerinin bir parçası olarak kurgulanması doğrultusunda, hem insanlar hem de "yer"e ait diğer canlı sistemleri için olumlu sonuçlar doğurabileceği örneklenmektedir.

Anahtar sözcükler: *Hava kalitesi; değerlendirme; Diyarbakır evleri; rejeneratif tasarım; havalandırma.*

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Introduction

Under the effects of some dominant value frames or primer paradigms, humans can cause adverse effects during all stages of environment building. These effects depend strongly on decisions made in the design stage and mostly cause depletion of non-renewable resources and environmental degradation through harmful changes in the aspects of natural environment to which humans are connected to by means of an interactive relationship (Millenium Ecosystem Assessment [MEA], 2005) and are dependent to constraints and opportunities afforded by its systems (Cole, et al., 2012).

In order to prevent environmental problems, some strategies have been developed such as environmental management systems, life cycle assessment methods (World Business Council for Sustainable Development [WBCSD], 2006) which have been projected on built environment design as "environment friendly" or "green" building concept (du Plessis, 2012). This concept, armed with many building assessment methods, basically targets a decrease in consumption of resources, production of pollution and negative impacts on health (Tuna Taygun & Balanlı, 2013). However, Rees (2008) emphasized that negative impacts – more or less – will eventually cause degradation mainly because the aims of green building concept and natural boundaries create an evolutionary dead-end (du Plessis, 2012). The popularization of building assessment methods has been criticized due to many reasons such as mainly focusing on individual building performance by only inspecting some properties (Darçın, et al., 2016).

In the light of signified statements, a shift/transformation in thinking systems and design methods becomes a prior necessity. Regenerative design of built environment, appeared in this context, has been projected to form a new, co-equal partnership between humans and nature (Cole, 2012) under the aim of providing mutual benefit for both (Pedersen Zari, 2012). To manage these aims, essential alterations must be organized for the design of different aspects of built environment as strategic guidance, decision making process and support tool based on underlying patterns, relations and integration between issues and impacts across different spatial scales through a deep understanding of regional characteristics. One of the important aspects is ventilation in built environment and its air related properties.

However, it can be observed that many historical, anonymously built settlements and buildings around the world, some of which can still bein use, were created as living environments for humans in harmony with natural systems by dense and accurate public experience. These buildings can be seen as prospering examples in the light of regenerative design principles due to their successful environmental interdependence between various local system scales with many positive aspects (Tuna Taygun, et al., 2016) as well as ventilation and air quality. It is believed that, local builders, who had a comprehensive knowledge about the region, had idealized some architectural organizations by trial and error over centuries (Tuna Taygun, et al., 2015). In this context, although supplying clean and conditioned air was organized as wise architectural design solutions, it can be tracked in time that these design practices and local solutions have been overseen; difficult to transfer to contemporary architectural design processes or cannot find their counter examples in current assessment methods.

The aim of this research is to examine the architectural design characteristics related to ventilation and air of vernacular Diyarbakır Settlement in southeast Turkey and its houses which were proven to bear successful environmental relationships (Zorer Gedik, 2004; Şerefhanoğlu Sözen & Zorer Gedik, 2007) even in terms of regenerative design principles by using an integrated and interdependent, systematic evaluation approach which focuses on underlying patterns and relations between aspects and impacts of air, its quality and movement. It is estimated that, with the existence of this kind of guidance, tangible solutions, which originate from and supported by other systems of the place, can be revealed through architectural design of Diyarbakır houses with intentions to learn from regional design practices, to re-discover architectural diversity, to illustrate the design principles, methods and interrelations of existing collective knowledge and local solutions to be interpreted for net positive results in buildings of future.

This paper mainly focuses on the relations of built and natural environments in terms of ventilation; the subject and examination are limited with observations of an existing vernacular site through architectural collocations in the light of regenerative design principles. The proposed evaluation approach can be advantageous for organization of a quantification process of the ventilation/air quality performance in reasonable time-labor-money terms. The study basically has three main parts:

- presentation of evaluation approach for ventilation and air related properties of built environments,
- examination of Diyarbakır Settlement and houses with this approach,
- discussions of the findings in regard to architectural organizations and regenerative design.

A Systematic Evaluation Approach for Air and Ventilation in Built Environments

In regenerative design concept, it is essential for buildings to contribute positively to humans and natural systems through the way they relate to the place and engage flows (Cole, et al., 2012) by aligning human activities with natural processes in an interdependent relation based on deep understanding of regional characteristics (Plaut, et al. 2012). To achieve this, a built environment should meet its occupants' clean and comfortable air requirements by engaging entirely to and benefit from existing properties of the place through local architectural design solutions without creating pollution, consuming non-renewable energy or affecting health adversely. In order to manage this aim, it is essential that clear air with appropriate properties can reach settlements and buildings, and constantly polluted air should be removed. Therefore, air, its properties and movement should be examined in terms of its relation and coherence with various properties of outdoor, indoor, built and natural environments in different spatial scales (Figure 1).

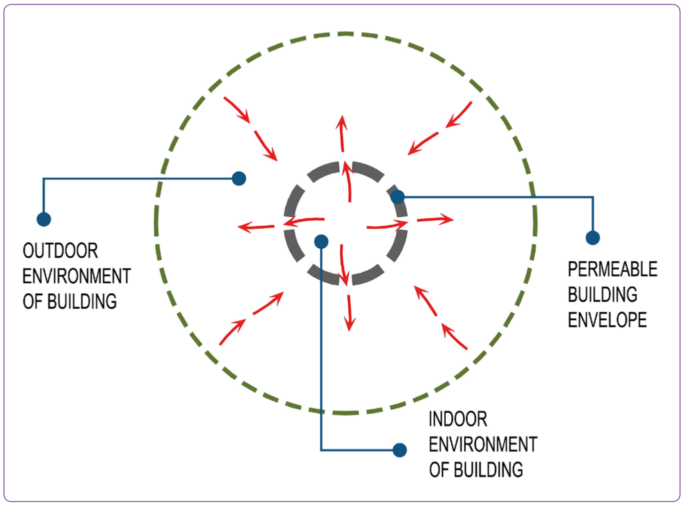

Figure 1. Outdoor and indoor environments of a building.

To evaluate a built environment's air related properties, a systematic approach, which is based on patterns, relations and impacts as understanding how entities influence one another within a whole and has been generated for both design and assessment (Darçın, 2020), can be used. As seen in the Figure 2, this approach has three main parts: pre-research, analysis and research.

Pre-research: Examination and Evaluation of Existing Environmental Factors

In the first phase of the approach, the existing environmental factors of the area of examination are examined and evaluated thoroughly.

First of all, information about climatic features of natural outdoor environment, the angles and properties of sun rays, prevailing wind, air temperature, and humidity should be collected along with properties of topography, green spaces and wetlands, buildings and urban gaps; properties of existing outdoor air pollution in and around the area of examination via meteorological surveys, site observations, aerial views, etc. Examiners should determine to what extend outdoor environment must be searched according to the components and relations the region affords. In the second step, users/user groups of the area can be exam-

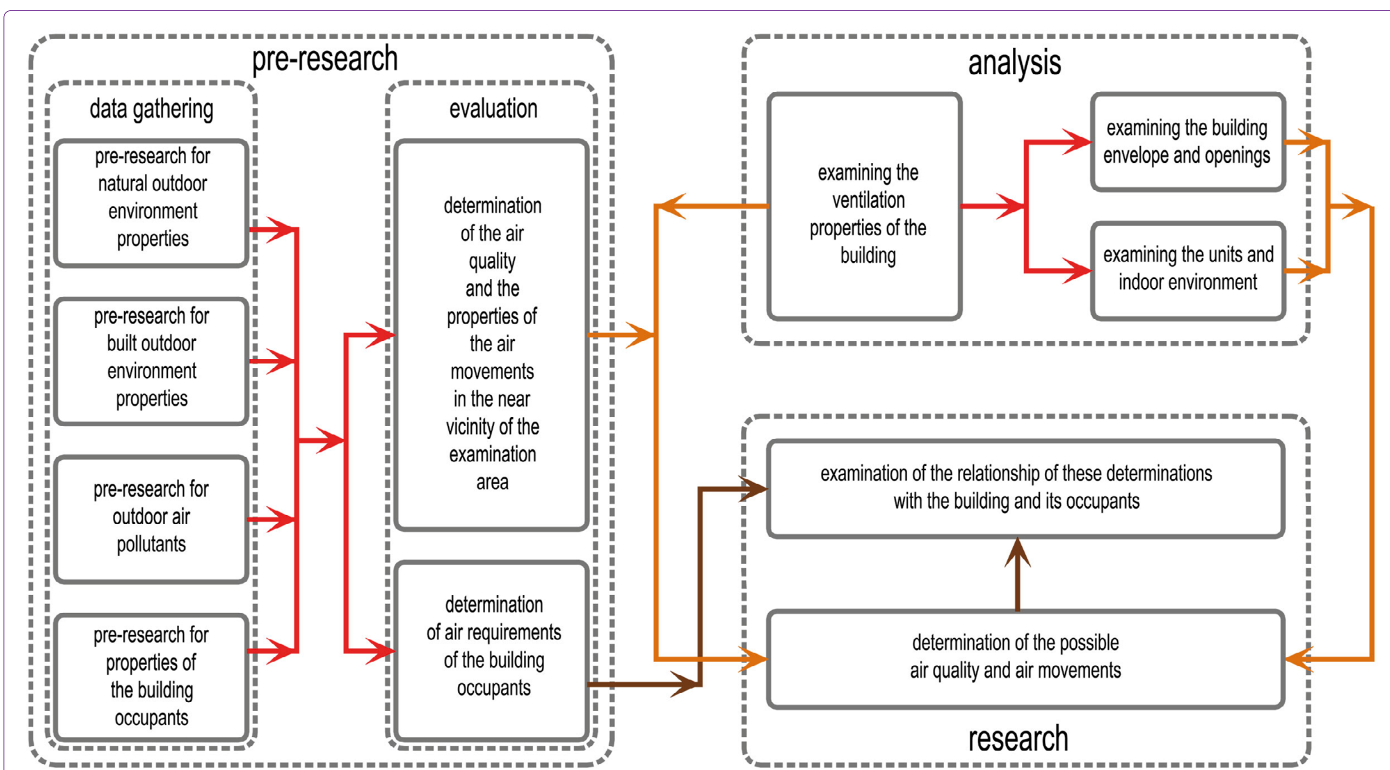

Figure 2. The main phases and relations of the proposed evaluation approach (Darçın, 2020).

ined according to their air related biological properties such as age, sex, existing or previous illnesses, etc.

These data collected about outdoor environment and users can be evaluated by relating them under various combinations as can be seen in Figure 3 (relations have been depicted in different colours for easy tracking). Firstly, approximate properties of outdoor air quality (temperature, humidity, pollutant types and concentrations) can be determined. By relating sun rays with natural and built environment properties, sun exposed areas and therefore formation of airflows in addition to prevailing wind; the properties of all air movements and pressure zones in the area surrounding the examination site can be revealed. Examiners can inscribe all data over site plans, sections or 3D models and generate air properties and airflow charts.

After evaluating the biological data of users/inhabitants and consulting scientific studies/standards, examiners can predict air related requirements of the users.

Analysis of Building in terms of Air Properties

In the second phase of the approach, examiners should investigate and analyse the buildings and their various properties (Figure 3).

Primarily, the type of ventilation, its approximate usage periods and the properties of ventilation such as the filtration and/or air conditioning techniques in the building of examination should be determined. Also, the proper-

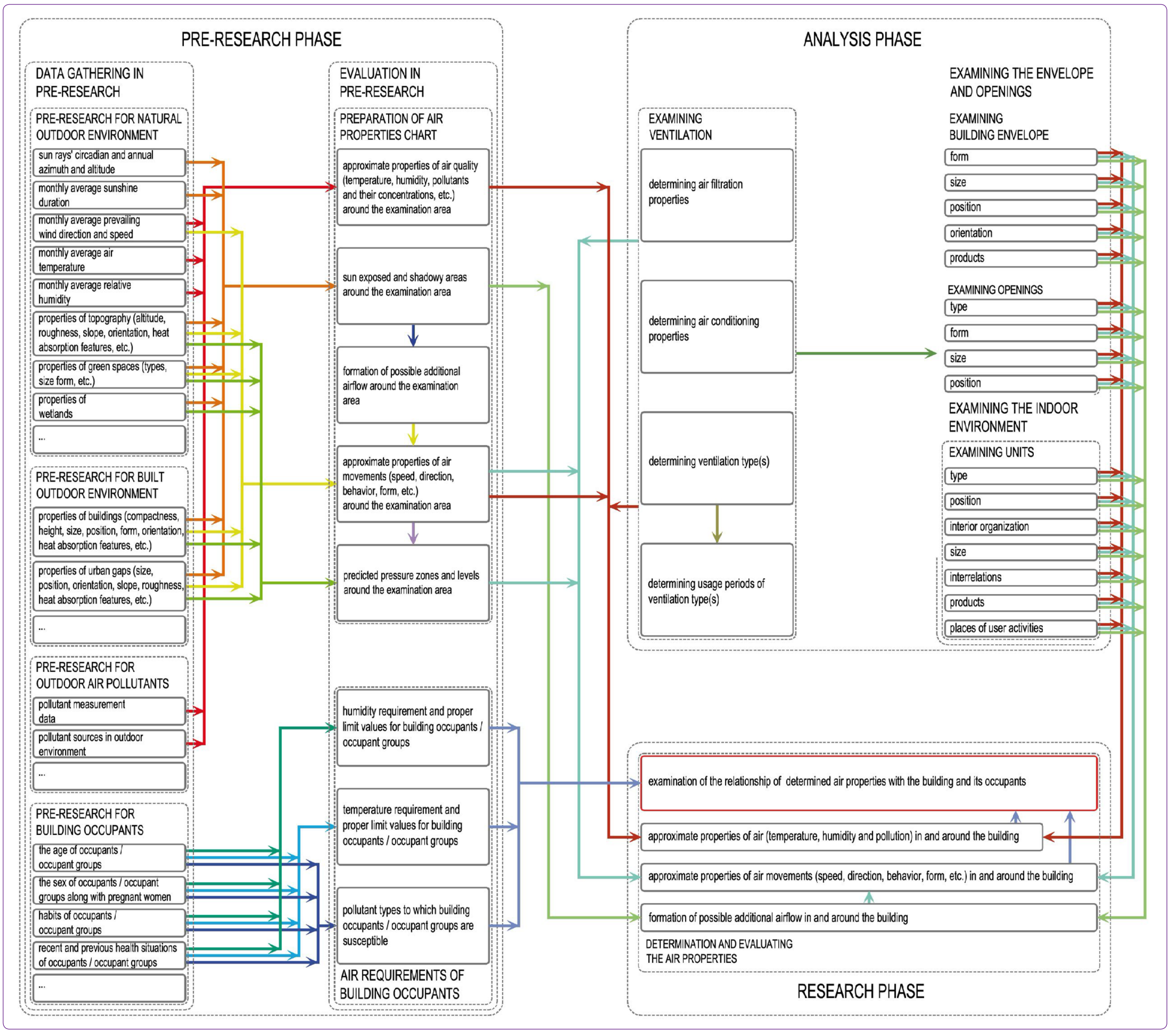

Figure 3. Architectural evaluation approach for air and ventilation properties in built environments (Darçın, 2020).

ties of the building envelope, openings and building units should be specified and information should be collected. Existing building products, users and their activities should be investigated in terms of possible air pollutants. These data can be inscribed over plans, sections, elevations or 3D models for further use.

Research: Evaluation of Building according to Its Air Quality and Ventilation Efficiency

Once all the required properties of the building are gathered, the estimated quality of air, the formation and properties of air movements in and out of the building should be analysed and evaluated in this last phase.

Firstly, the formation of additional airflows should be revealed by relating sun exposure situation of the area with envelope, openings and units. As all the air movements are determined, the properties of envelope, openings and units should be examined according to their effects on air movements via airflow charts made out of plans/sections or 3D models of previous phase.

In order to evaluate the building, examiners should investigate airflow charts whether pollutant free air at required temperature, humidity and speed can be circulated through breathing zones of users in every space. According to the findings of this investigation, an evaluation result can be generated under efficiency, energy consumption and effects over health.

Assessment of Ventilation and Air Properties in Vernacular Diyarbakir Houses through Architectural Design

Historical Diyarbakır Settlement is situated in the middle part of southeast Anatolia, on the east side of a basalt plateau, between Karacadağ Mountain and Tigris River (38° 51’ N, 40° 21’E). Although not certain, it is estimated that, the history of the city began with Hittites and Hurrians (BCE 3500) (Beysanoğlu, 2003). In CE 349, during the reign of Constantine the 2nd of Roman Empire, the city was encircled with walls (Tuncer, 1999). Diyarbakır was conquered by Arabs in 638, Seljuk Turks in 1085, then inherited by the Anatolian Seljuks in 1240 and finally, Ottoman Empire in 1515. Through centuries, the city, expressing a cosmopolitan social structure, hosted Turkish, Arabic, Iranian/Persian, Kurdish, Armenian and Jewish people living side by side in harmony. Most of the buildings, made of basalt stone masonry, are well preserved (approximately 160 houses are officially registered) and the oldest of houses can be traced back to 1500s (Özyılmaz, 2007).

Pre-Research: Examination and Evaluation of Outdoor Environment and User Properties of Diyarbakir Houses

In the first part of the evaluation, natural and built outdoor environment properties and users’ air related requirements of Diyarbakır Houses are examined and evaluated.

Situated in hot-dry climatic region of Turkey, a harsh continental and subtropical plateau climate is dominant around Diyarbakır Settlement. The summer season is very hot and dry and winter period is rather warm considering its neighbours (Diyarbakır Governorate, 2011).

Sun rays’ circadian and annual angles (calculated with Ecotech) can be seen in Figure 4. According to the values registered between years 1980 – 2011, 155 days in average have been sunny in a year (Diyarbakır Governorate, 2011) and average daily sunshine duration is 7,8 hours (Table 1).

In Diyarbakır, with its 2,4 m/s annual average wind speed, WNW(West-NorthWest) is the first and NNW(North-North-West) is the second prevailing wind directions (Figure 5 and Table 2) (Diyarbakır Governorate, 2006).

According to observations of 1970 – 2011 period, annual average air temperature is 15,8 °C (Table 3). Additionally,

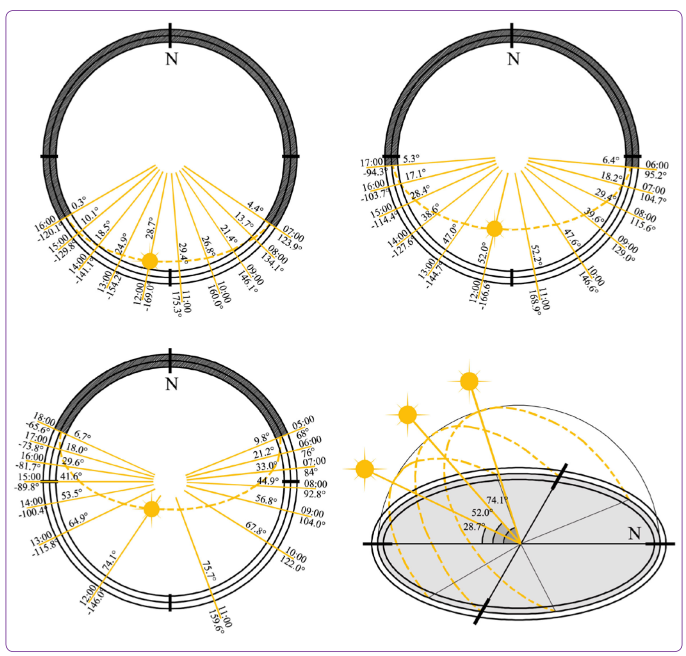

Figure 4. Sun path for Diyarbakır.

Table 1. Monthly average sunshine durations (h/day) in Diyarbakır (adapted from Diyarbakır Governorate, 2011)

Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
3,9	4,8	5,6	7,0	9,7	12,2	12,4	11,7	9,9	7,4	5,4	3,8

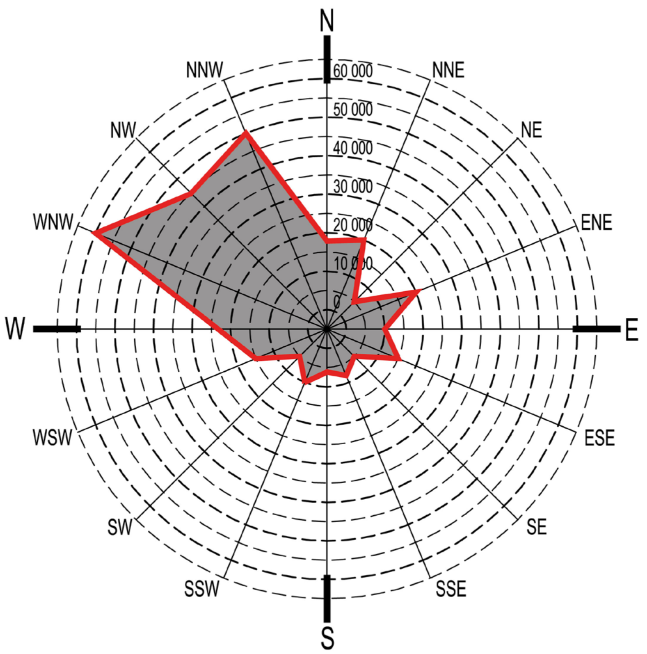

Figure 5. Wind rose for Diyarbakır (adapted from Diyarbakır Governorate, 2011).

owing to the climatic features, the temperature difference between night and day is high.

Based on monthly average relative humidity values in Table 4, precipitation mostly occurs in winter and spring.

The vernacular Diyarbakır Settlement spans an approximately 1,5 km² area (Özyılmaz, 2007), and it is approximately 650 m above sea level. On the west side of Tigris Valley, the settlement is on a terrain with a slope of 7% incline from north to south (Akın, et al., 2010) nearly 100 m above Tigris River (Yıldırım, 2002). The terrain changes into steep slopes between the border of the settlement and Tigris River in the east and south (Çetin, 1993).

Settlement is mostly surrounded by herbaceous plants; the region is poor in terms of forests (Diyarbakır Governorate, 2011). Nevertheless, the steep slopes between the settlement and Tigris River hold productive Hevsel Gardens which have been used to grow fruits and vegetables by the local community and is nourished by Tigris River and the sewer water of the settlement, which dates back to Roman era (Figure 6).

The vernacular city is encircled with an almost 5 km long, 8-12 m high, 3-5 m thick (Diyarbakır Governorate, 2011) wall which is reminiscent of a turbot seen from above. The wall was produced from black basalt stone which can be found nearby and its form has been mostly preserved since its date of construction (Tuncer, 1999) (Figure 7 and 8).

By the effects of climate and wall's restriction (Çetin, 1993; Cengiz, 1993), the settlement contains compact, attached buildings with two or three floors, flat roofs and a central courtyard. Access to buildings can be managed by four main streets, perpendicular to each other through NS and EW directions and by very narrow, sinuous alleys creating an organic pattern (Figure 7).

Because of its geographic location, dominant hot-dry climate and lack of green spaces (other than Hevsel Gardens), prevailing wind carries dust to the settlement (Diyarbakır Governorate, 2011). Other than dust, in the cold

Table 2. Monthly average wind speed (m/s) and directions in Diyarbakır (adapted from Diyarbakır Governorate, 2006)

Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1,9 NNW	2,4 NNW	2,6 NNW	2,3 NNW	2,3 NNW	3,0 NNW	3,3 NNW	3,0 NNW	2,5 NNW	2,0 NNW	1,6 NNW	1,6 NNW

Table 3. Monthly average air temperatures (°C) in Diyarbakır (adapted from Diyarbakır Governorate, 2011)

Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1,5	3,5	8,6	13,8	19,3	26,3	31,2	30,3	24,7	17,1	9,0	3,7

Table 4. Monthly average relative humidity (%) in Diyarbakır (adapted from Diyarbakır Governorate, 2011)

Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
75	72	66	65	56	38	29	28	34	51	66	75

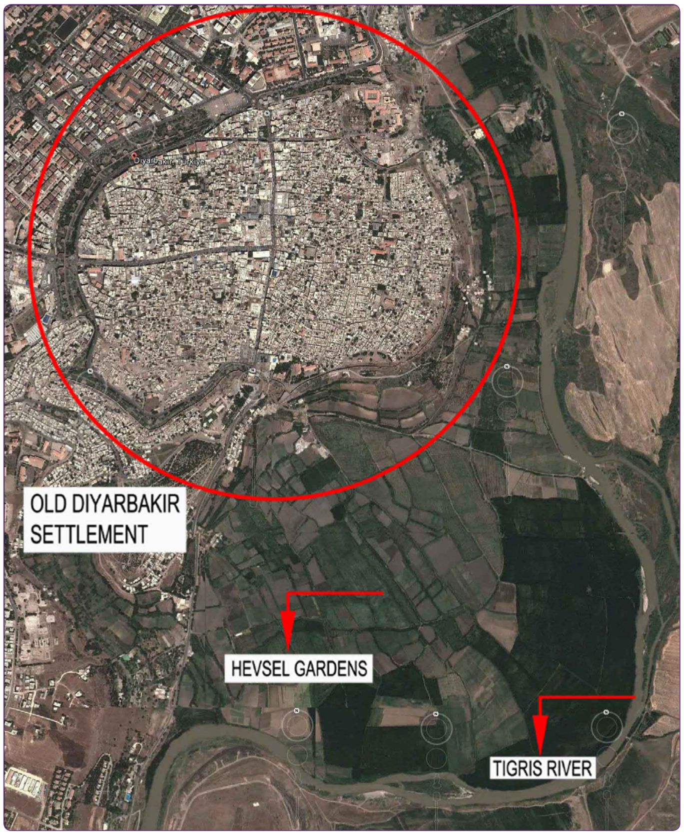

Figure 6. Vicinity of Diyarbakır Settlement (adapted from Google Earth in 2015).

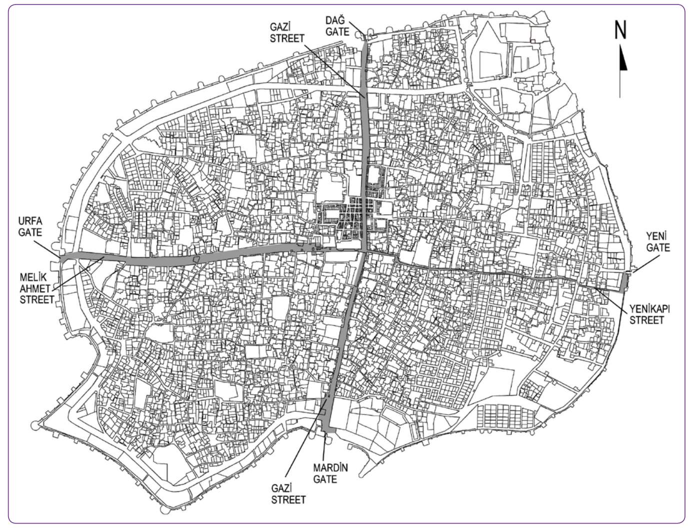

Figure 7. Vernacular Diyarbakır Settlement inside the city walls.

Figure 8. City walls, Hevsel Gardens and Tigris River (Yüksel, 2016).

period the combustion products due to heating,and in the spring time the pollens from green spaces in and around the settlement can be listed as the main air pollutants around the houses.

The vernacular houses host several generations at the same time. Usually, according to their wealth, a grandmother and grandfather, their several married children and some grandchildren live in one house, each family using a multi-functional room (Özyılmaz, 2007). Mostly men do the outside work, whereas women stay at home and manage house chores (Cengiz, 1993). Privacy has been the most important social requirement for families of all religions and ethnicities in Diyarbakır (Yıldırım, 2002).

As seen in Table 1, daily average sunshine durations are rather long and in Table 3, it can be seen that the hot period (between April and November, approximately 8 months) is longer than the cold period (between December and March, nearly 4 months). By examining Table 4, it is apparent the air around the settlement is rather dry, especially during the hot period. The dust, carried by the prevailing wind is considered to affect the users adversely for most of the dry period, whereas, chimney smokes may be problematic in the cold period along with other PM in the springtime.

Apart from the prevailing wind, the formation of additional air movement in the outdoor environment of houses can be investigated by examining the sun exposed and shadowy areas which can be revealed by relating the properties of sun rays with existing natural and built outdoor environment components. In this context, beside the NW prevailing winds, settlement can utilize airflow which occurs due to high number of sunny days through the year, sun exposed steep slopes and Tigris River surrounding the settlement in the east and south. This air movement may gain strength with the flow resulting from the air temperature difference caused by Hevsel Gardens and dark coloured built environment (such as city walls of basalt stone). This additional flow is shown schematically in Figure 9.

Position of buildings affect sun exposure properties of the built environment and cause temperature differentiations. Sun rays, due to circadian and annual rhythm, cast shadows in varying sizes in narrow alleys of the settlement, providing cool, shady spaces in the hot period as shown in Figure 10. Additionally, some upper floor rooms of dwellings were extended with oriels over an alley (Figure 11) or formed passage-like shady corridors (“kabaltı” in local language) by covering the alley (Figure 12). This temperature differentiations cause the air over sun exposed parts of the alleys to rise and cooler air of the shady spaces are transported and the result is micro-scale additional air movements.

As the air movements are formed in mainly NW and additional SE directions, the properties of outdoor environment may constitute obstacles and affect the properties of airflow. In this respect, it can be estimated that due to lack of high-rise free-standing structures, the mild slope of the plateau, the compactness of buildings and narrow alleys, the main speed and direction of the airflow will not be affected and apart from micro-scale turbulent forms, the straight form and behaviour will not be changed.

It can be observed that some alleys of the settlement are nearly parallel to air movements (NW and SE) whereas others are mostly located on NS or EW axis (Figure 7).

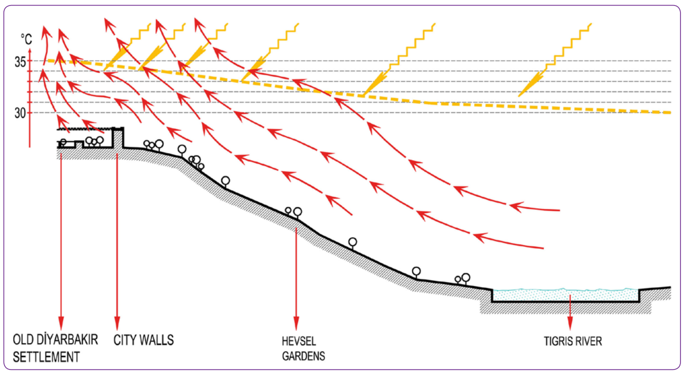

Figure 9. Additional air flow in the SE direction.

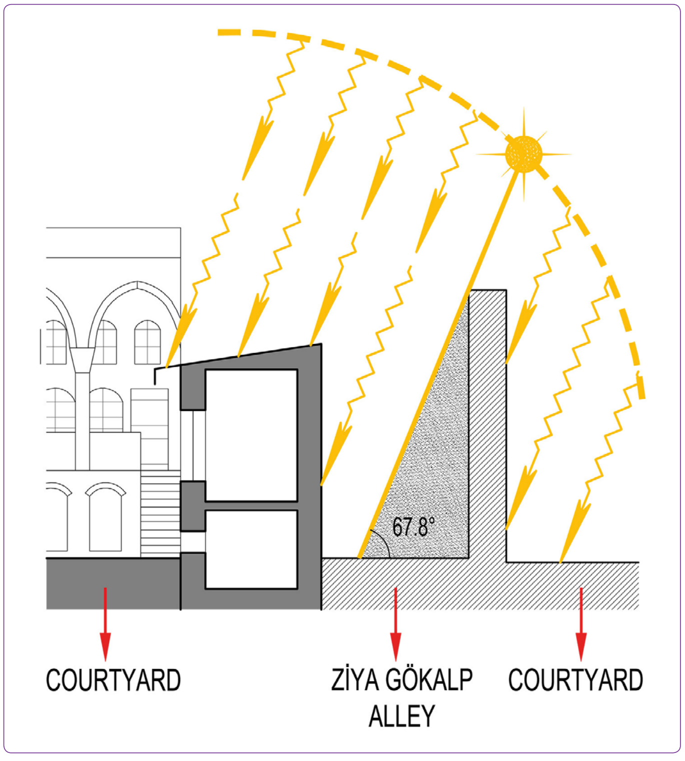

Figure 10. The shadow in an alley on 21st June at 10.00 a.m.

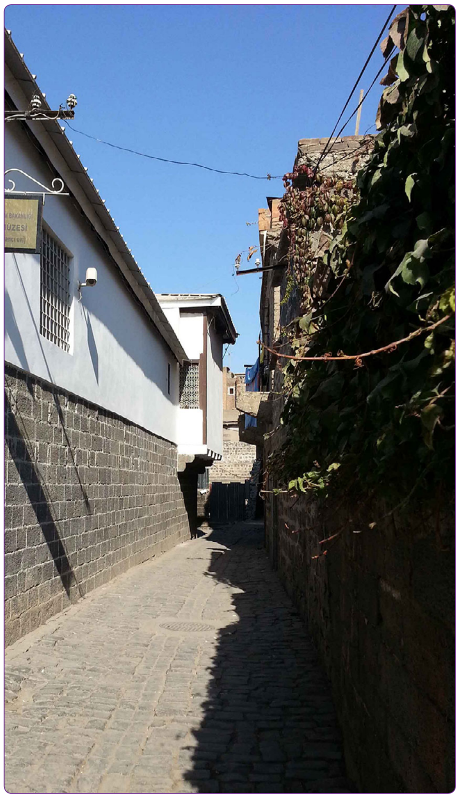

Figure 11. An oriel in a shady, narrow alley.

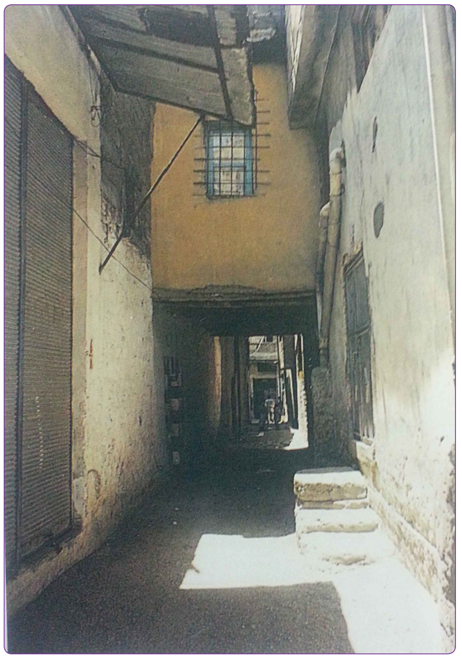

Figure 12. A “kabaltı” (Tuncer, 1999).

The narrow alleys, which are parallel or positioned with an acute angle to the air movements' direction, cause air to be compressed and hence to gain speed. As shown in Figure 13, due to high speed airflow, negative pressure in the alley affects the façades of the attached houses that border the alley.

If the direction of the gap is perpendicular to prevailing airflow direction, the properties of the flow is affected according to the size of the gap. The wider gap between the city walls and façades of the first line of the houses causes the airflow to rise after encountering the wall and create positive pressure zones on windward faces, whereas, negative pressure zones appear in the opposite face (Figure 14). In narrow alleys, the air is forced to encounter the building in the back before it can incline. Only negative pressure zone is formed due to turbulent micro air movements on the faces (Figure 15).

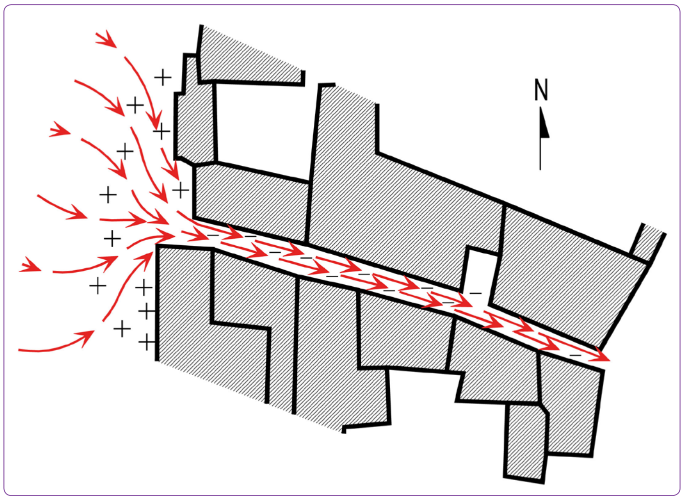

Figure 13. Airflow chart of a NW alley.

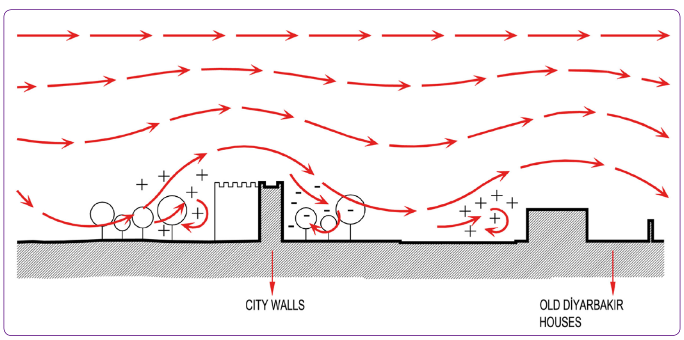

Figure 14. Airflow chart of the pressure zones of the gap between city walls and houses.

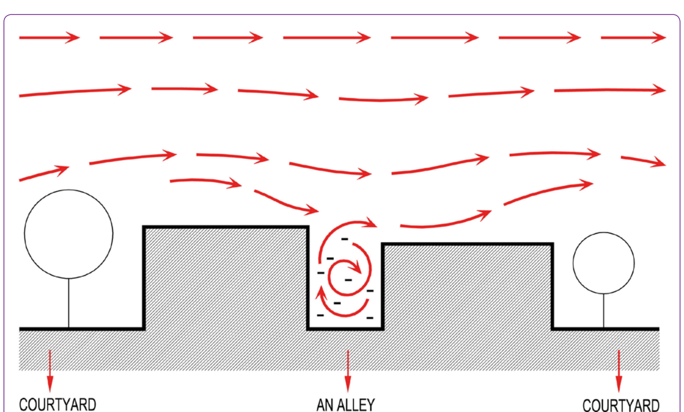

Figure 15. Airflow chart of the pressure zones of the alley perpendicular to air movements.

With this evaluation, it can be estimated that mainly hot, dust carrying prevailing NW wind sweeps the upper zone of the flat roofs, however, small scale additional air movements in SE direction in lower speeds and mostly turbulent forms cause mainly negative pressure zones on the façade levels. Also from this point, it can be predicted that the basic air related requirements of the users of these vernacular houses are to avoid excessive heat with proper air movements supplying cooling effects and retrieving the deficient humidity and in the meantime to avoid the dust transported from the vicinity of the settlement by the prevailing NW winds.

Architectural Design Analysis of Vernacular Diyarbakır Houses in terms of Air and Ventilation

The ventilation method in all vernacular Diyarbakır houses is natural ventilation all year long without any mechanical air filtration, distribution or conditioning organizations.

Due to the effects of climate (Çetin, 1993), topography (Baran, et al., 2011), the size of the plots (Tuncer, 1999), lifestyle and religious beliefs of the local community (Cengiz, 1993) nearly all vernacular houses of Diyarbakır were organized as inward looking, closely clustered and adjacent in a compact texture, arranged as blocks surrounding an open central courtyard, perpendicular to each other, with one or two floors over a basement and flat earthen roofs.

The most important living space of Diyarbakır houses is the open courtyard (Tuncer, 1999) which mostly has a square or rectangular plan and can be used in the hot period through the year (Şerefhanoğlu Sözen & Zorer Gedik, 2007). For purposes of privacy, courtyard is separated from streets or alleys by high, void-free walls (4-5 m) or with blocks of rectangular prisms made with black basalt stone masonry. All wall openings of blocks face the courtyard to a large extend in terms of privacy, furthermore if a block is facing neighbour's courtyard, this façade is designed windowless in order to protect neighbours from unfamiliar eyes (Cengiz, 1993). The façades and the openings of the blocks around the courtyard are mostly oriented to north or south (Zorer Gedik, 2004). Generally, the courtyard floor is covered with porous basalt stone (Çetin, 1993) and a pool with sizes changing between 1.00 x 1.80 m – 3.00 x 5.00 m, depth of app. 70 cm (Figure 16); water channels on the floor connected to this pool (Tuncer, 1999) (Figure 17) and one or two big fruit trees with wide leaves (Baran, et al., 2011) can be seen in courtyards.

The units of Diyarbakır Houses can be examined through classifications such as main spaces which involve courtyard, eyvan (recess - a vaulted room with one side open to courtyard), rooms and service spaces including kitchen niche, pantry, WC, bathroom (Çetin, 1993) or as open (courtyard), semi-open (eyvan) and closed (room, anteroom, WC, pantry, bathroom) (Tuncer, 1999). As seen in Figure 18, all units can be accessed through courtyard.

As seen in the plans and sections of three neighbour houses (the middle one is Cahit Sıtkı Tarancı House) in Figure 19, occupants use the mostly two storey block (Zorer Gedik, 2004) which is situated on the south side of the courtyard and oriented to north in summer. This block contains a pantry in the basement with high ceiling and windowless openings; an eyvan as a semi open space which can be used in hot period with a floor covered with porous basalt and a pool; rooms, each for a family to eat, live and sleep in with app. 4.00 x 7.00 m rectangular plans and app. 4.00 m high ceilings, many high windowless clerestories opening to courtyard and a special cool living room called "serdap" which has a floor at the same or a lower level, a pool and windows facing the courtyard. The one storey block on the north side of the courtyard is oriented to south to be used in winter and it contains rooms for families with smaller dimensions and windows than the south block; a kitchen which is a niche open to courtyard and is used only for cooking and an anteroom ("sofa" in local language) which is basically a closed eyvan. The blocks, which can be seen in some big houses on the west or east sides of the courtyard, are to be used in spring and autumn (Şerefhanoğlu Sözen & Zorer Gedik, 2007).

Figure 16. The courtyard of Cahit Sıtkı Tarancı House.

Figure 17. Water channels on the courtyard floor (Tuncer, 1999).

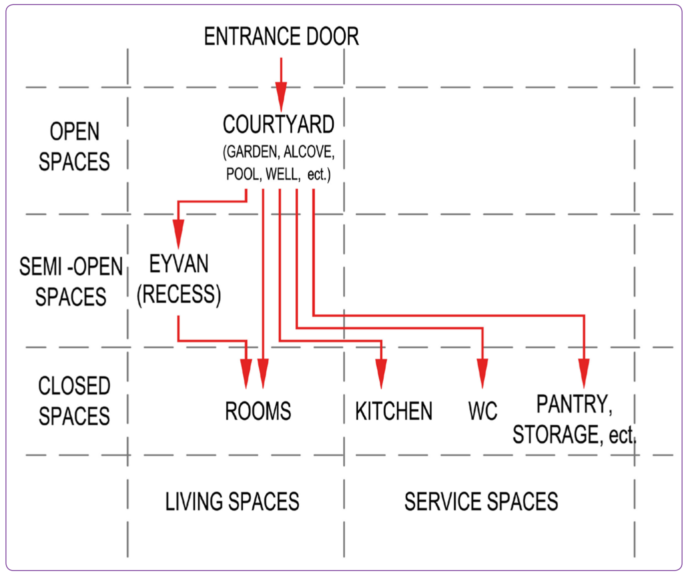

Figure 18. Function scheme of Diyarbakır houses.

Because of adjacent, clustered planning, two storey summer block of a house stands next to one storey winter block of the neighbour. According to the positions of courtyard and numbers of blocks, Diyarbakır houses differentiate as shown in Figure 20.

Air pollutants that can be encountered in a typical Diyarbakır house can be listed as smoke from cooking and heating activities, pollens from fruit trees and biological products of users. The heating is managed with braziers, after the charcoal is ignited, it is kept in courtyard till it becomes embers and smoke free and then it is carried to closed spaces.

Research: Evaluation of Diyarbakır Houses in terms of Air and Ventilation Efficiency

In order to reveal additional airflows in and around Di-

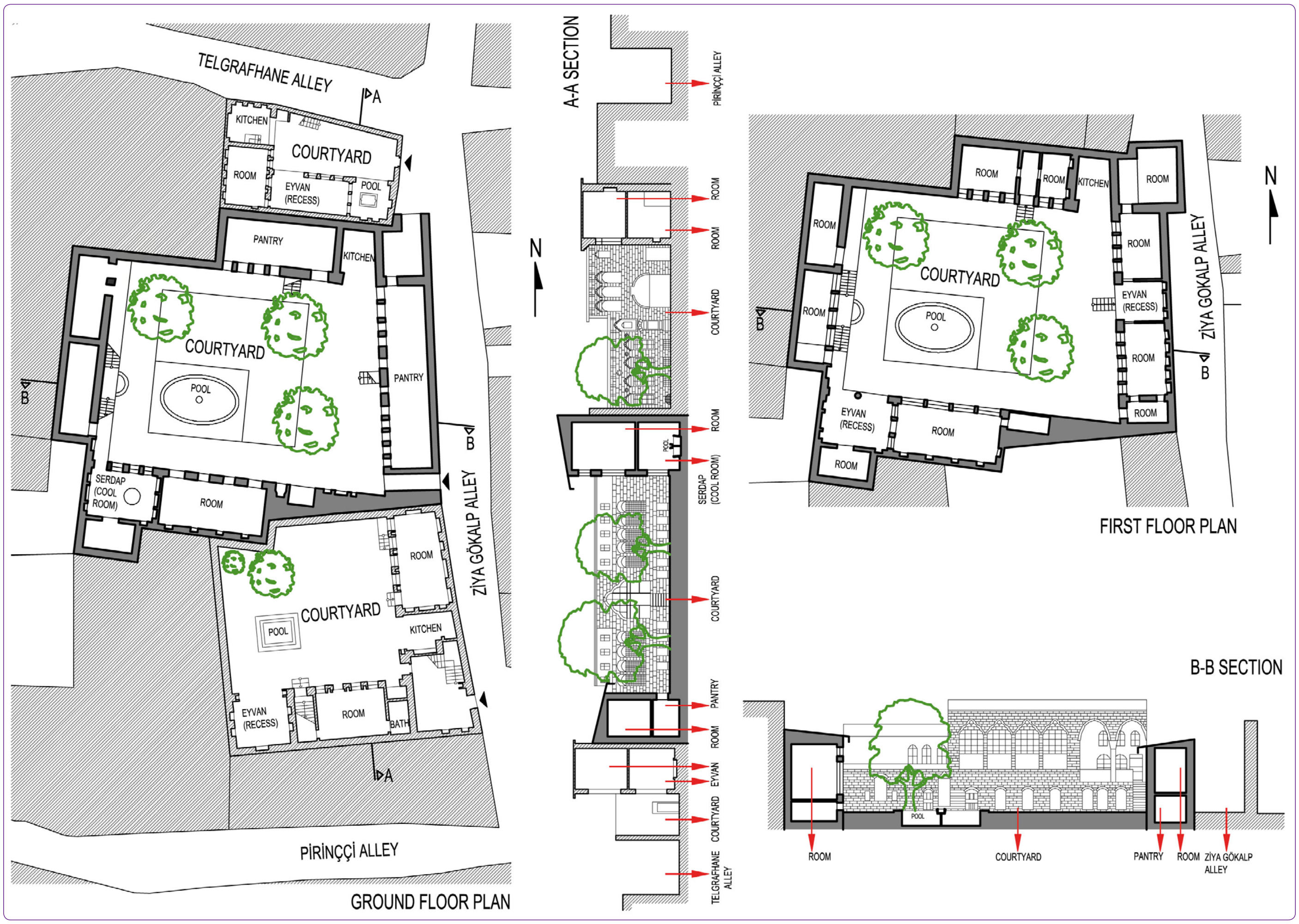

Figure 19. Plans and sections of three neighbour Diyarbakır Houses.

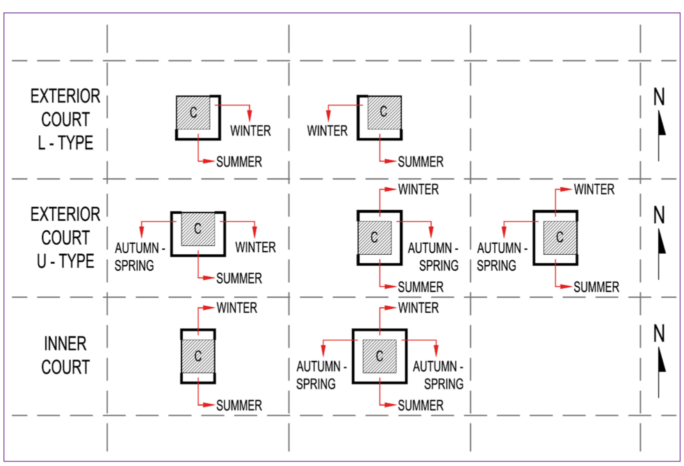

Figure 20. House types according to courtyards and positions of blocks.

yarbakır houses, the relation of buildings with sun rays can be examined to display thermal buoyancy induced air movements through the day and the year. The shadowy areas and sun exposed surfaces of the courtyard on 21st June, 21st September/March and 21st December at 10.00 a.m. are shown in Figure 21, respectively (the section of the sun exposure of 21st September is organized as an airflow chart) in Cahit Sıtkı Tarancı house.

According to this examination, it can be predicted that, the air in indoor and outdoor environments of north block which is exposed to sun in most of the year, rises as gaining heat to draw polluted air of its units away (Figure 22a). Similarly, due to sun exposed roof and back wall of south block, heated and polluted air rises to outdoor environment through high clerestories and cool air of shady courtyard and serdap room moves towards indoor environment (Figure 22b).

In the result of a serious experimental study about buildings with courtyards, Al-Bakri (1997) states that, if the air movement direction is perpendicular to courtyard, the air passes over without entering and if the direction of air movement is diagonal, only a small part of the flow may enter. In this manner, as shown in Figure 23, for Diyarbakır houses, most of which are oriented to north or south, a small part of prevailing NW and SE airflows may enter to the courtyard to form low speed turbulent flows and re-

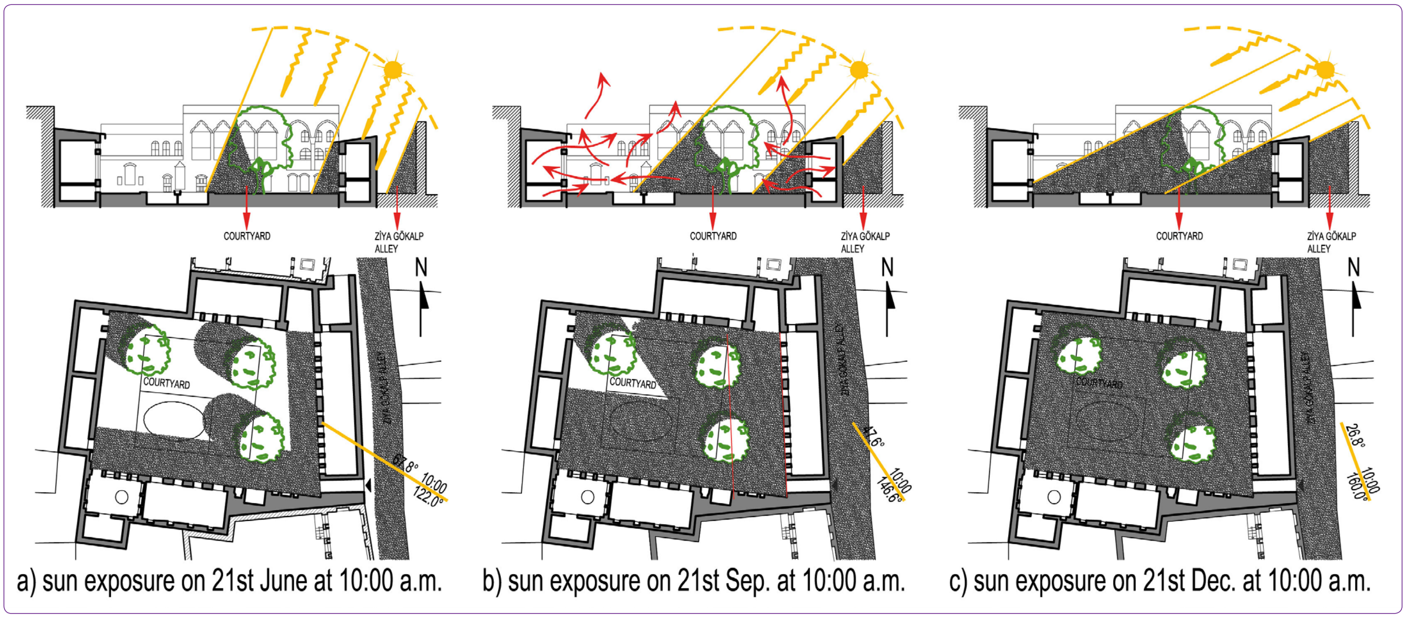

Figure 21. The additional airflows due to relation of sun rays and building.

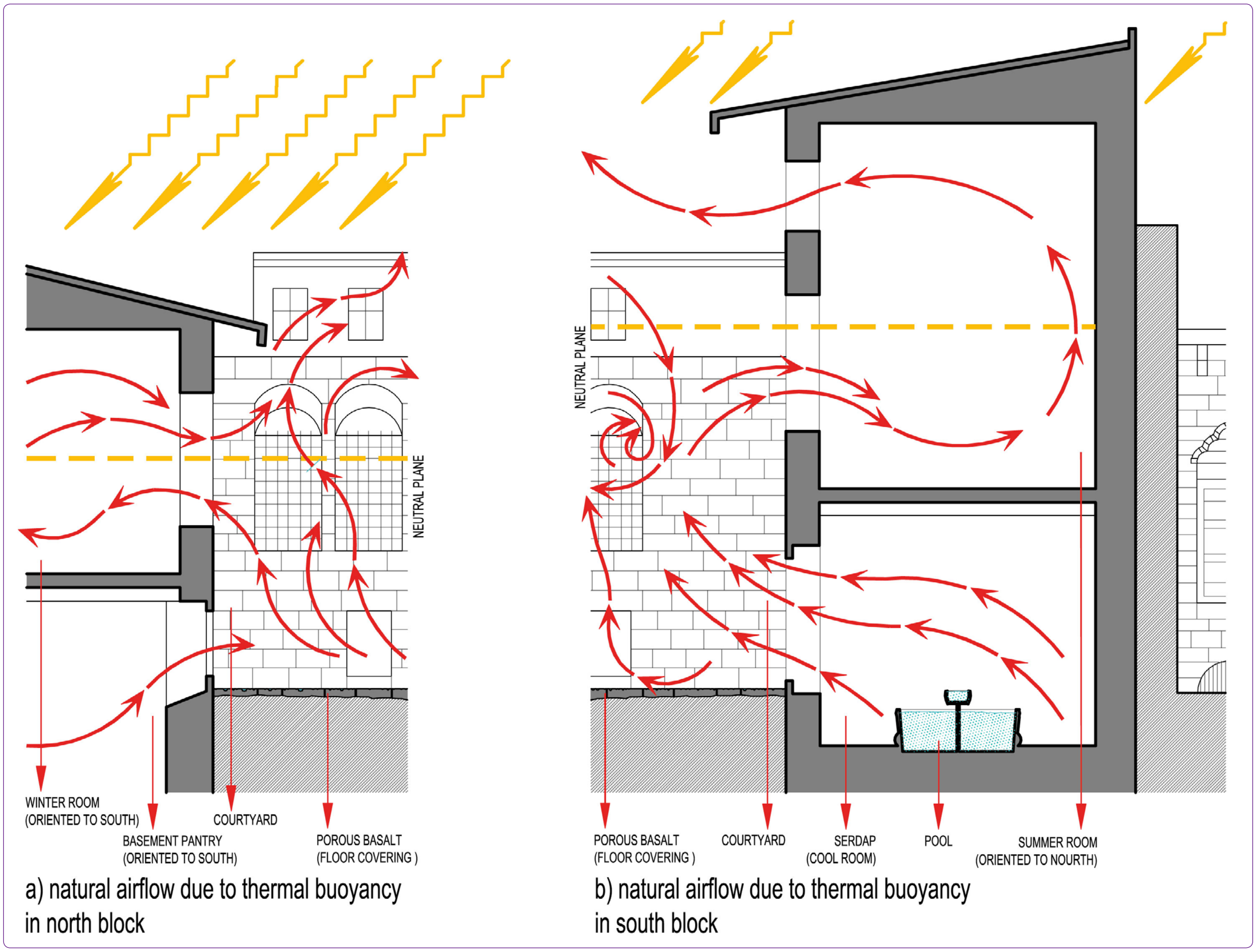

Figure 22. Natural ventilation in the north and south blocks.

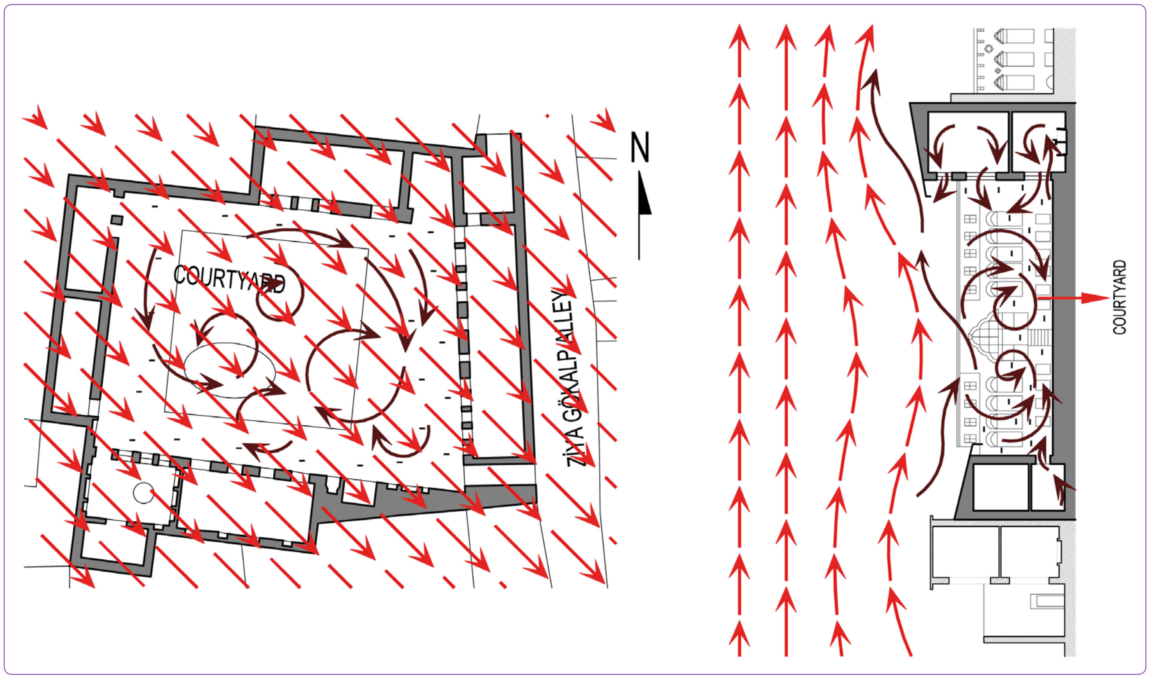

Figure 23. The relationship of Cahit Sıtkı Tarancı House with prevailing air movements.

veal a negative pressure on courtyard façades. Polluted air of the units can be sucked out and carried away by the prevailing air movements.

During night time, the courtyard and structure radiate stored heat; air in the courtyard rises and thus pulls the air of units out. As the result of high temperature differentiation between night and day, before sunrise, the cool air sinks with the effect of gravity on the courtyard floor to penetrate into units. The cool courtyard and building structure can store cool air for many hours after sunrise to assist the thermal comfort.

In many units of Diyarbakır houses, ventilation is single sided due to wall openings are placed only on the courtyard façades. In this type of ventilation, the depth of the unit is recommended to be less than two and a half times of unit's height (Liddament, 2000), which is under this limit in Diyarbakır houses.

Required humidity in hot arid climate is met by water in pools and channels of courtyard and serdap, along with the water left inside the pores of basalt stone covering the courtyard, eyvan and serdap floors after frequent water spreading. Especially, evaporation of this water in the pores supplies coolness due to heat transfer. It is stated that, the very same method is being used in middle region of Saudi Arabia (Al-Bakri, 1997) where the climate and mass forms of vernacular dwellings are very similar to Diyarbakır. Özer, et al. (2009) report that in Yezd (a desert city in Iran), which also has a very successful vernacular built environment in terms of natural ventilation, the open and closed spaces of the city can be used without discomfort during midday when the air temperature is 55°C. The wide leaves of the courtyard trees assist to provide shady areas and dust-free humid air.

Findings and Discussion

Vernacular Diyarbakır Settlement and houses are unique in the region, designed with deep understanding of environmental factors related to both outdoor and indoor environments and users' concerns such as dominant climate, social structure, properties of local building materials and systems, etc. (Tuna Taygun, et al., 2015) It can be observed that the design organizations of these built environments include proper solutions to meet users' requirements which occur in consequence of climatic and social interactions. In order to meet one of these needs, breathing clean, pollutant free air in appropriate temperature and humidity conditions, the outdoor and indoor environments and building envelope were designed and organized with proper indigenous and place specific architectural solutions.

Outdoor environment of houses is observed to be organized in a way that the prevailing air movements can sweep the settlement in a higher level and mostly create negative pressure/suction effect zones at the street level. It is estimated that this consequence is particularly useful for removal of polluted air out of the settlement and houses and it prevents the dust, carried by prevailing wind, to enter the living/breathing zone of inhabitants. It can be said that, site selection for the settlement, the relation of sun rays with topography, built environment, well organized green spaces (Hevsel Gardens) and water (Tigris River) and the position/orientation of the settlement can support the buildings with additional air movements. This is particularly important on days with no effective prevailing wind, so additional air movements can help to regulate the temperature and humidity of urban air due to evaporation through water and green spaces.

In the compact, adjacent houses containing an open central courtyard and inward looking, closed and semi open seasonal units, ventilation and air conditioning is supplied naturally with passive methods created by clever architectural organizations. This need is met without ignoring other requirements of users such as privacy, which may seem that it has to be met with reciprocal arrangements in terms of permeability of building envelope.

The predominant method for natural ventilation in Diyarbakır houses is to create airflow with thermal buoyancy that benefits from heat of sunrays. Courtyards of these buildings are the most efficient and important aspects for natural ventilation. It is seen that, either consciously or unaware, the location of units, their interrelations and organization of wall openings on the envelope were designed perceptively by considering the pressure zones that occur in the courtyard due to orientation and the form of building revealed in the air flow charts. Apart from the organization of design in building and units scale, the arrangements of the units, the clever usage of green spaces and water features in units (courtyard, eyvan and serdap), competent preference and usage of local building materials (porous and non-porous basalt stones), the temperature and humidity of air can be regulated. Dust-carrying prevailing air movements are utilized mostly for removal of polluted air.

In Pedersen Zari's (2012) research, appropriate ecosystem services, which can be undertaken by built environment in regard to existing design methods that already support the service, were determined. Two of these are regulation and supporting services. It is believed that analysing the findings of this research in terms of these services can be beneficial. Organizing and designing the built environment as sampled and presented in this research may have direct and indirect positive outcomes for humans and ecosystems of nature. Direct outcomes can be listed under regulation services as securing access to clean air with proper temperature and humidity, conserving non-renewable resources, assisting to decrease environmental pollution, mitigating urban heat island effect and under supporting services as habitat provision for plants. Indirect outcomes occur as the result of needed integration with components of natural environment: sun, wind, topography, water and green spaces for effective air movements. Especially Hevsel Gardens and courtyard vegetation forge successful examples, the positive outcomes can be examined under supporting services as habitat provision: enhanced biodiversity by creating and maintaining living spaces for animals and insects through vegetation, retaining soil and maintaining its quality and nutrient cycling: providing food for local community,and cycling of biodegradable wastes (sewer water).

Conclusion and Suggestions

The properties of a built environment in all its stages can be defined and determined according to their effects on indoor and outdoor, natural, built and social environments. In order to obtain positive outcomes, these effects should be taken into consideration in design stage. In addition to this, with proper assessment methods, such effects should be questioned via an integrated system which can be used to examine the relationship of building with its environments across different scales instead of individual building performances. Ventilation and indoor air properties are among important aspects that have to be related to environments of a building for accurate results.

In the world, public experience, purified into a pool of valuable accumulation throughout many centuries, had produced buildings which can still be used and can be identified as very compatible with modern environmental thinking, even regenerative concerns in terms of relations with physical and social environments. These buildings were designed considering all environmental factors as a whole: users, natural and built environments and production resources. They were formed based on logical, place specific and convenient design decisions. In this context, the air and ventilation properties of these examples were organized with wise architectural design solutions as well. However, in the modern age, it can be observed that these design practices and habits of creating place specific architectural solutions seem to be abandoned because of various difficulties.

In order to learn from different local design practices, to exemplify the principles used to create a proper air environment compatible with the requirements of the users and beneficial to other systems of the place, vernacular Diyarbakır Settlement and houses, their ventilation strategies and air related properties have been examined by using a systematic evaluation approach constituted over underlying patterns and relations between different aspects and impacts of air, its quality and movement. With the analysis and evaluation under three main phases of this approach, it can be seen that outdoor, indoor environments and building envelope of Diyarbakır houses were organized in a way that helps creating additional airflows apart from the prevailing wind, regulating the temperature and humidity of air and keeping pollutants away from the breathing zones of occupants without negative effects.

Based on findings of this architectural evaluation, it can be inferred and interpreted that with presuming the built environment as part of a bigger system and generating a new and organized system which contains smaller systems, each nested in and hierarchically linked to others through impacts and effects, many positive outcomes can be acquired. As sampled in Diyarbakır houses, a built environment, which conscientiously integrates humans and natural systems, will have net positive results, beneficial and supportive for both and contributing positively to their healthy co-existence.

Accurate ventilation in built environment with some positive outcomes can be managed and evaluated with the guidance of this kind of interdependent system which may also constitute a general framework with details available to change and improve. Using the system, examining the components through place specific patterns and relations in regards to effects of these components on each other and on the system's overall efficiency, can be beneficial for finding appropriate and procreative solutions originated from and convenient to possibilities the site has.

Employing the system to other existing vernacular or contemporary built environments may reveal its positive features and deficiencies. Additionally, more and different ventilation strategies, relationships and architectural organizations can be acquired to be used in development of regeneration-oriented design goals.

For the conclusion, it can be stated that a built environment, deliberately designed to have a ventilation pattern which does not create health problems, consume energy from non-renewable resources, increase environmental pollution can be considered as a system which has proper solutions for the air related requirements of building occupants in regard to built environment's share on environmental problems and potential positive outcomes for humans and natural systems as constituting an integral step between various linked systems.

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