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THE EFFECT OF RAPID URBANIZATION ON THE PHYSICAL MODIFICATION OF URBAN AREA

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Abstract

Today rapid urbanization is a major challenge for many cities. In 2007 urban population started to exceed the rural population. Increasingly, scholars and governments discuss the effects of this trend on future development of cities. It is obvious that any kind of urban development should be controlled and regulated, otherwise the outcome could lead to a chaotic and unsustainable development. Besides, it may result in environmental problems like air pollution, heat islands, urban climate and etc. Unfortunately, this kind of physical modification practically have not been considered by the planners and designers.

The current study is grounded on recent literature review and tries to concentrate on this problem mainly from the development and construction performance perspective. Moreover, the current study attempts to classify the effective variables under the urban form, urban geometry, and urban population.

Keywords

Urban Form; Urban Material; Urban Population; Sustainability; City Planning

1 Introduction

The world urban population for the first time in 2007 exceeds the rural population. The United Nations (2015) based on the current trend believe that by 2050 about two third of the world population will live in the urban area [1]. Besides anything else, the economic growth itself contributes to the increase of the urban population and associated with the urban development too. It is obvious that any kind of urban development should be controlled otherwise the outcome could lead towards a chaotic and also unsustainable development.

Unfortunately, especially in developing countries due to the rapid population growth, cities developed without a planned and regulated development policy. Obviously, this sort of developments has several severe negative effects, which somehow are solved by engineering,

medicine, agriculture and etc. However, the physical impacts like urban climate, air pollution, Urban Heat Island (UHI) etc. practically have not been considered by planners especially at microscale [2].

Fundamentally, dozens of variables include geographical location, regional meteorology, urban morphology, surface materials, vegetation/water bodies, human activity, and etc. are responsible for the physical implication in the urban area [3, 4]. The current study based on contemporary literature tries to figure out the effect of these variables on the physicals modification of the urban area. Apart from that, unlike any other study, in this study, the main concern is microclimate and neighborhood scale.

This study aims to explore the role of urban development with a focus on the microclimate and the neighborhood level to the physical modification of the urban area. Therefore, firstly recent transformation of the urban area considering the role of the modern built environment is discussed. Secondly, dimensions for the physical modification of the urban area are discussed. Afterward, the association of these dimensions are represented by the physical modification of the urban area.

2 The urban development and role of the built environment

In the current era, the increase of population and demand for housing etc. rapidly increase the construction of buildings inside the cities and spreading outwards the boundaries of cities. As a consequence, the *hard* surface of construction materials such as concrete, street pavement, roof material and etc. are expanding and replacing natural surfaces and green areas.

However, the transformation of the natural surface into construction platforms such as modern built environment has several negative impacts on the existing thermal balance. When vegetation and green surface is minimized and large surfaces are covered by rough and less permeable surfaces, it contributes to the decline of evaporation and increases the heat storage as the construction surfaces e.g. are not dense as the natural surfaces [5]. Moreover, the notable amount of solar radiation is stored by construction material with rough surface, dark color and less albedo [4, 6, 7, 5, 8].

This situation directly influences the overall air ambient temperature of the urban area. As a result, the urban area becomes warmer in comparison to the surrounding area. At the moment, this phenomenon is well-accepted and known as Urban Heat Island (UHI) effect (Figure 1). The UHI clearly defined as a temperature difference between the urban and rural (ΔT_{u-r}) areas [2, 6, 9].

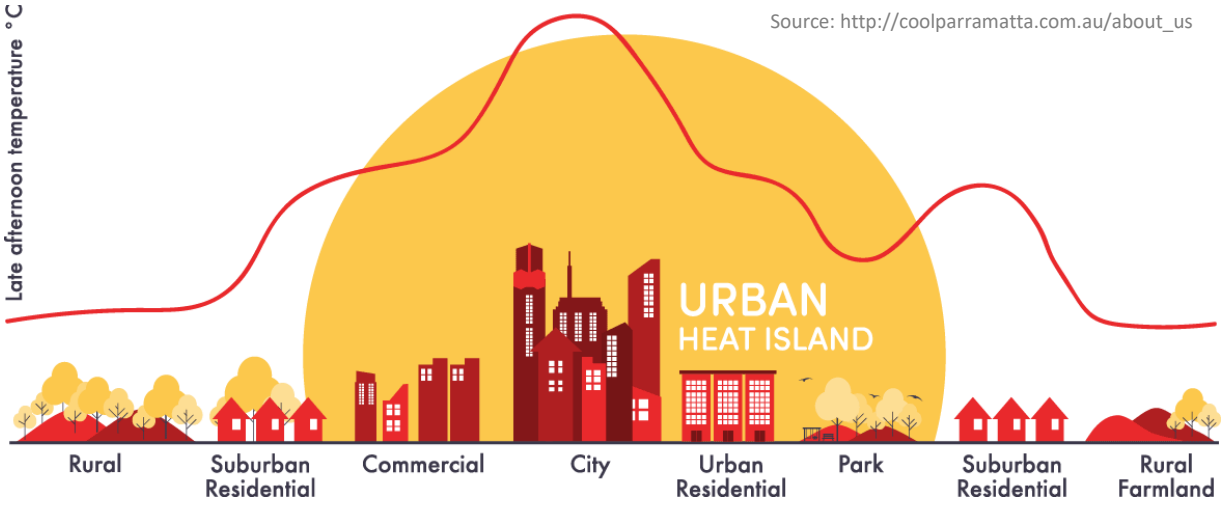

Figure 1. The effect of Urban Heat Island (UHI)

As stated before, the wide range of the natural and the man-made factors include seasons, cloud cover, wind speed, sunlight, urban canyon geometry, surface material, anthropogenic heat, and etc. are responsible for emerging of this phenomenon.

Up to now, countless studies consider this issue from different perspective, for instance Dimoudi & Nikolopoulou (2003) and Leuzinger, Vogt & Körner (2010) consider the vegetation impacts on urban environment, Taha (1997) consider the material, evapotranspiration and anthropogenic heat, Stone Jr. & Rodgers (2001) study on form of city and urban design and Jamei, Rajagopalan, Seyedmahmoudian, & Jamei (2016) review the impact of urban geometry on outdoor thermal. Unlike all of them, the current study firstly grounded on the primary physical properties – Evaporation, Heat Storage, Net Radiation, Convection and Anthropogenic Heat – which are represented by Gartland (2008). Secondly, the main concern for this study is the microclimate and the neighbourhood level.

According to the Gartland (2008), reduced evaporation and convection from one side, increased heat storage, net radiation, and anthropogenic heat from another side tremendously influences the physical modification of the urban area [10].

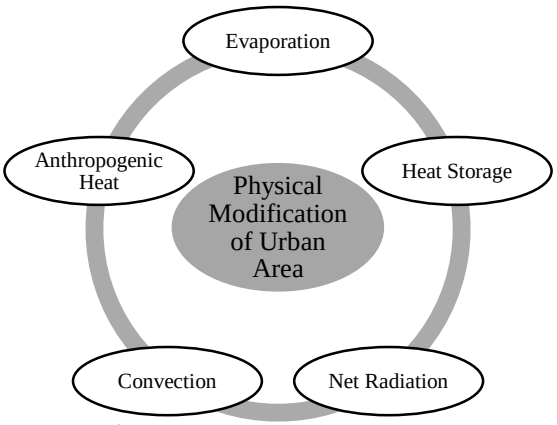

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Figure 2. The energy balance and the physical modification of the urban area

The above given dimensions (Figure 2) together represent the energy balance equation Eq. (1) too. The terms of energy balance in this topic represents the transformation of energy on the earth. In other words, based on the first law of thermodynamics, the energy never created

nor destroyed. While, it can be transferred from one location to another or it can be converted from one form to another form of energy.

Net Radiation + Anthropogenic Heat = Heat Storage + Convection + Evaporation (1)

To have a better insight into the energy balance and association of it with physical modification of the urban area, each of its dimensions are explained below.

2.1 Evaporation

The evaporation process is responsible for transforming a liquid into a gas form. In the atmosphere the available water on the wet surface, runoff, moist soil, and etc. by sun heat is converted into the vapor. Within this process, the sun's energy from the atmosphere transmitted to the earth surface. Whenever it collides to the wet surface, it turns into the vapor. The evaporation increases when the moisture and the fast wind available. The evaporation intensified in the warm-dry climate condition. Loss of evaporation results in increase in the heat storage capacity during the day, and then the stored heat is released at night. Therefore, the loss of evaporation can turn the construction platform into a place for the energy store [5, 10].

2.2 Heat Storage

The ability of the substance to absorb an amount of heat to increase its thermal temperature, known as the heat capacity. Therefore, a material with a high amount of heat capacity can store more amount of heat. Of course, the role of thermal conductivity is also important to measure the physical ability of the substance to transfer the heat by its molecular motion [11].

The heat storage with moisture has an inverse relationship too. In fact, the construction material which is minimized on the wet surface has negatively effect on physical modification of the urban area. In addition to that, most of the building material has good thermal conductivity and storage capacity. In simple word, the material with high thermal conductivity quickly transfers the heat inside itself, and if the material has the thermal capacity it can store more amount of heat in its body [10].

2.3 Net Radiation

The net radiation on the earth surface is shaped by following four distinct radiations: 1) The solar radiation is an amount of the energy radiated from the sun. The solar radiation can be affected by metrological properties such as season, cloud cover, air pollution, and etc. 2) The solar reflectance (albedo), the amount of solar energy reflected from the surface is the solar reflection. The amount of solar reflectance is highly dependent on the surface materials. 3) The atmospheric radiation is an amount of the heat emitted by particles in the atmosphere. A warm atmosphere with the dense particles contained more energy to emit. 4) The surface radiation is the heat radiated from a surface itself. The surface radiation highly depends on the temperature of the surface and its surrounding [10].

In the urban area, dark-colored materials include road, roof, pavement and etc. are minimized on albedo. Besides that, the urban geometry and level of air pollution as a catalyzer are contributing to increase of the amount of net radiation in the urban area. Based on the given

statement, it can be expected to see a high amount of net radiation in an urban area in comparison to the rural context.

2.4 Convection

The convection is a vertical interchange of the energy. It can occur in the liquid and gas forms. The convection can be intensified in the high wind speed and the turbulent air over the rougher surface. It can be intensify too when there is a temperature difference between the surface and the air [10, 11]. It is interesting to know, the physical modification of the urban area like emerge of the UHI phenomenon can be intensified in the calm and clear meteorological context. For instance, loss of air turbulence increases the heat capacity in the daytime. Apart from that, the urban geometry significantly contributes to the air turbulence and wind speeds. It can be stated that an urban area is responsible for decrease and increase of the convection [5, 10].

2.5 Anthropogenic Heat

It is mainly released as result of the human indoor/outdoor activities. The source of it can be found in many urban and rural contexts. The primary sources for the anthropogenic heat release are the heating system, the engine combustion, the creature's metabolism, and etc. [2, 10, 11, 12]. The human activities significantly contribute to the release of the anthropogenic heat [10]. Apart from that most of these activities are located in the urban area [13]. In this sense, Marsh & Grossa (1996) believed that population density from one side and the land-use from another side are important parameters for the amount of anthropogenic heat. Based on their own study in the urban area the amount of the particulate matter was five times higher than the rural and at least three times greater than the suburban area [12]. Furthermore, the traditional study concludes that the gains of anthropogenic heat in the winter is more than the summer. Unlike, the recent study found that the air conditioner dependency can intensify the gains of anthropogenic heat in the summertime [10].

3 Discussion

The current explanatory study in its own scope figures out that, the unmanaged rapid urban development is mainly responsible for the physical modification of the urban area. This modification can vary from urban climate, air pollution, UHI and etc. So far, several studies have focused on the buildings, materials and/or regional scale, while there is no agreed method and tools to examine the physical modification at the neighborhood and/or the microclimate scale.

For instance, most of the regional study scale done by the use of remote sensing data technologies. Likewise, different programs based on the study objective developed for the building scale. However, this situation is different for the neighbourhoods and/or the microclimate scale. Lack of a comprehensive method for measurement makes process complicate. Therefore, most of the study try to use specific dimension for their study and they offer their own model. Of course, recently some institutes and communities started to develop the program such as Envi-Met and Grasshopper plugin. However, these programs are at begging or trial stage. Apart from that, mostly able to study in specific dimensions, while

the physical modification of the urban area at local scale has several dimensions and this provides a great challenge to cover all of them [3].

Therefore, to solve this problem, based on the energy balance equation Eq. (1) the following criteria should be considered for assessing the modifications of urban areas: *The Urban Form*, *The Urban Material* and *The Urban Population*. The given dimensions are highly associated with the energy balance equation Eq. (1) and any modification on each contributes to the physical modification of the urban area.

Urban Form

In the urban form to define a space, the building used as a wall and the street used as a floor. The repetition of these elements together creates the urban form [2, 6, 11, 14]. The urban climatologist tries to classify the form of city based on the buildings height, street width, density and scale of the local neighborhood. The combination of these elements from one side contributes to the loss of longwave radiation at night time and from another side increase the solar absorbance at daytime. Apart from that, the urban form significantly contributes to modification of the airflow and wind speed [2, 3, 15, 16].

Furthermore, the height of building and width of street together define the aspect ratio and sky view factor (visibility of sky as a fraction from the middle of the street). This is an important factor to adjust the amount of solar radiant penetration. Moreover, the street orientation itself significantly associated with the solar radiation and air movement [3, 6, 15]. The following Figure 3 provides a better vision to the urban form.

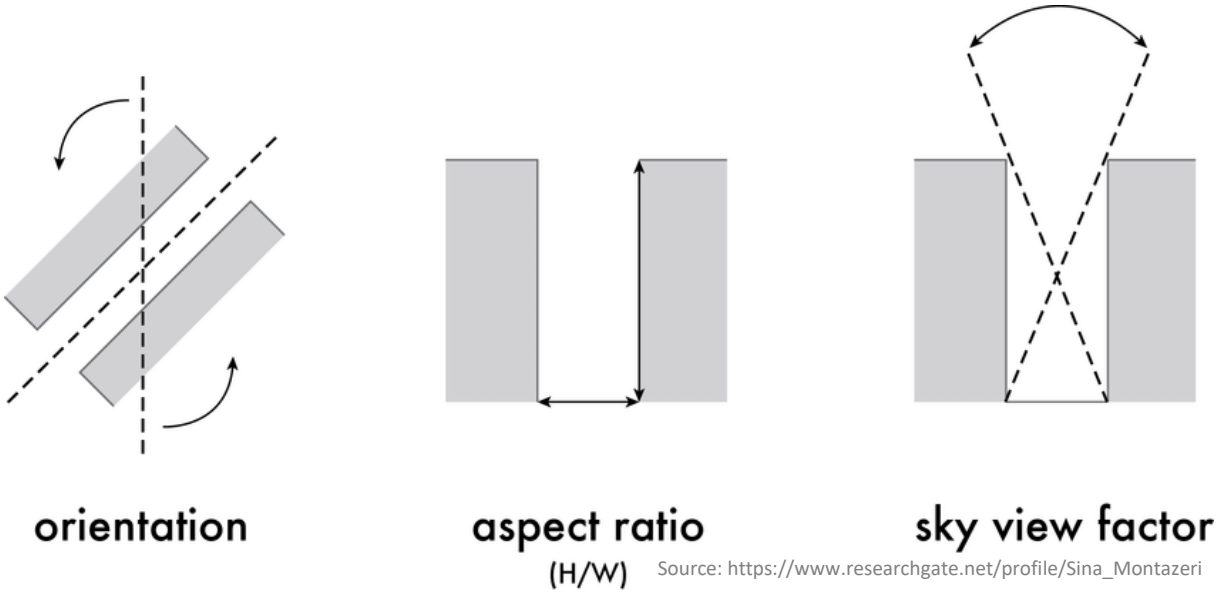

Figure 3. The Urban Form

Urban Material

The urban material includes the pavement, roof and wall are usually applied by the architecture due to various reasons like cost, durability, appearance, and etc. Certainly, each of these materials has a specific influence on the urban hydrological and the thermal balance. Furthermore, the physical modification of the urban area at microscale is dependent on the absorptivity and the thermal admittance of the surface [15].

According to the Akbari, Pomerantz, & Taha (2001), the thermal energy balance can be efficiently adjusted if the high albedo material and soft surface include the plant and the vegetation applied in the urban area [17]. From another point of view, the surface material changes are cost efficient since the new material can be easily applied to the current structure. Apart from that, with the new technology architecture is not limited to white color because the new material is modified high reflectivity and emissivity too [16].

The Urban population

As stated before head, the main source of the anthropogenic heat is human activity, the majority of this activity is located at the centre of the urban area too [12]. Therefore, population growth means increase of the number of the consumer which contributed to release the high amount of the anthropogenic heat. Apart from that, the population growth requires new towns. In this situation, if new construction irrespective of the urban form and materials developed, it can be negatively affected due to the physical modification of the urban area.

4 Conclusion

This study based on the contemporary literature tries to figure out the relation of the rapid urban development with the physical modification of the urban area. In this sense, the current study found that un-controlled urban development responsible for the physical modification of the urban area includes urban climate, air pollution, UHI and etc. Moreover, the current study believes that, majority of the study consider the physical modification of the urban area on regional and/or building scale. Therefore, a lack of microscale study is latent. On the other it is believed, that the microscale is an effective scale which contributes to the physical modification of the urban area. However, lack of appropriate methodology from one side different variables and aspect from another side made it impracticable. This study based on the energy balance equation tries to make an attempt to assess the physical modification of the urban area by considering the urban form, urban material and population.

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