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2ND INTERNATIONAL SCIENTIFIC CONFERENCE

REGIONAL DEVELOPMENT, SPATIAL PLANNING AND STRATEGIC GOVERNANCE

Conference Proceedings

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SUSTAINABLE SPATIAL DEVELOPMENT UNDER THE CONDITIONS OF DRY, HUMID AND MIXED CLIMATE ON THE EXAMPLES OF SOME TROPICAL COUNTRIES

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1. INTRODUCTION

The towns of tropical countries (dry, humid and mixed climate) are characterized by the framework of the everyday living which is more connected to other specific features of space – its bio-climatic factors which are being related throughout the world as a function of the Geographic Latitude and the difference between large regional spaces, depending on climate.

A common characteristic of these towns is, sometimes, an inventive system of adaptation which is directed by the essential and natural boundary conditions manifested through certain season's rhythms. Various types of rhythms have different effects on the man-made environment, be it in terms of a spatial organization of settlements or physiognomy of these settlements. Strabo, describing the environment of the North Africa of ancient times, wrote: "it resembles the leopard skin – her settled territories are spread over the yellowish waterless desert, as dark spots". (Strabo, as cited in Tošković, 1980)

Indeed, the space in these regions, in its synthetic form and throughout its spacious dimensions, heat, sand storms, and shortage of drinking water – represents, also today, a unique determinant directing the structure and form of these towns, architecture, and shaping of open spaces and so affects the behavior of their people, too. (Tošković, 1980)

In the already mentioned study on Libya, the author, with regard to these conditions, wrote:

"Arabic model of the closed, cellular or "patio" pattern of the urban anatomy, created against send storms, next to the provision of shade and coolness along the distance of the communications, was a direct answer on the difficulty of the housing in Libya" (ibid.).

Certain occurrences in the space can unwillingly challenge the changes in man's actions – and these to disturb the previously established rhythms, and so, establish a new system of physical relations. This is particularly occurring in those regions where a few rainless years bring food shortages and hunger, pushing population to migrate into new spaces, where some kind of equilibrium between man and nature existed until then. But, with the new demographic pressure, when this exceeds a certain quantitative threshold, previously established balance becomes disturbed. The final result is another eco-system, i.e. the system of "urban village" in Africa, for example, although all spontaneous settlements in developing countries fall into this category.

The consequences of this situation manifest themselves in an increasing accumulation of waste and germs, which, as such, bring the danger of creating new ecological conditions with negative effects on people. This is, at least, a gloomy image supporting the assessment of all things separating the living environment of "underdeveloped" from the environment of the "developed". (Žorž, 1979)
So, space in its general meaning, and expressed through the season's rhythms, gives a special emphasis to the everyday life of these people, related directly to the daily and periodic reality of the natural environment in all countries of agricultural civilization (ibid.).
There from, the social life is strongly coordinated with seasonal changes, but it is also characterized by the system of adaptation. In other words, in this situation there is an interaction between the individual and his surroundings, when the man's actions are formed into coherent wholes. This process of assimilation, i.e. the reaction of organism to surrounding things, and "accommodation" representing the opposite state, has been, from the psychological aspect, described by Piaget in the following way:
"The mental assimilation is, from there, certain incorporation of objects into the patterns of behavior" and, from there, the "adaptation" is a state of "the balance between assimilation and accommodation" (Piaget, 1950).
The system of adaptation implies essential empirical understanding of the environment as such and changeability of its elements, for a short and long time, as a balancing of the promoting, productive, actions to the imperatives of the environment, in accordance with the technical means the society developed. As it was demonstrated earlier, the Mediterranean civilization, even from the ancient era, shows excellent examples of adaptation of man to his natural surroundings, what was later further supplemented by Arabs through new forms.
But, this can't be said for tropical regions, what was the subject of a study made by UN experts who, with regard to the specific situation, in their report "Climate and Design of House", stated:
"It is considered that fatigue from climate is one of the main reasons for a slow progress of the technological and economic development among some of the nations in tropical zone…In comparison to the people of the north hemisphere, the inhabitants of the tropical zone have shown little initiative to improve the earth where they have been born in" (UN, op.cit.).
So, a rapid growth of towns, especially of "urban villages" in Africa, calls for another relationship towards this – a new ecological environment. A new urban thinking is called for, which should deal with the establishment of a new equilibrium between the way of living under new conditions of very high population density and climatic requirements.

2. SUSTAINABILITY OF SPATIAL DEVELOPMENT, MAN AND CLIMATE

How climate affects the man, his body, can be seen from the opinion of a well known French physiologist Claude Bernard who says:
"A happy and healthy man's life is possible only so long as the temperature in his body is held constant within narrow limits" (Bernard, 1965).
Taking into account this opinion, brought into a connection with the assumption that metabolism in the man's body tends to produce a surplus of heat, and that the body must be released from that surplus of heat, it is understandable how much more difficult it is to achieve this in zones characterized by hot climate, i.e. in tropical zones. That the physiological rhythm of work, fatigue and rest is under the influence of body temperature, was also considered by the UN experts, who stated:
"Fatigue is being accumulated, while the efficiency in performing the mental and physical tasks is falling…nor acclimatization, nor adaptation can completely overcome unsuitability of an unpleasant climate…however, it is possible to provide a release from the climatic stress by a well-designed building" (UN, op.cit.).
Thus, climate must be taken into account in making conceptualization of a design as a whole, through its elements: floor, orientation of buildings, shaping, character of structure, space to be encompassed and finally, but nothing less in its importance, the space between buildings (Olgyay, 1963), while, for example, the Mediterranean-desert climate calls for the so-called "group-project" characterized by a courtyard in the core of the house, and in tropical zones, the concept is reversed: more open space between houses providing breeze.
As an example supporting the abovementioned, Geoffrey Bawa, not well known in our environment, was the Sri Lanka's most influential architect and South Asia's leading guru of unique style, who named the tropical architecture. His work is distinctive by an outstanding aesthetic sensitivity to the site and context, especially to peculiar climatic conditions and demands. Although he started to engage in architecture late, in the age of 38, soon he became noted by his inventiveness in forming new canons and prototypes of modern architecture, based on the traditional knowledge and perfectly fitted in local surrounding. Bawa created sustainable architecture even before the term started to be used and his masterpieces broke down the barrier between inside and outside space, design of the interior and landscaping, reducing the building to a series of scenic spaces separated by courtyards and gardens (Danilović-Hristić, 2012).

2.1. The Four Case Studies

2.1.1. Libya

Libya, with her scattered settlements as points over a waterless desert, resembles a leopard skin. So, generally, Libya could be divided into the four climatic zones as follows: (Tošković, 1980, op.cit.) (Figure 1)

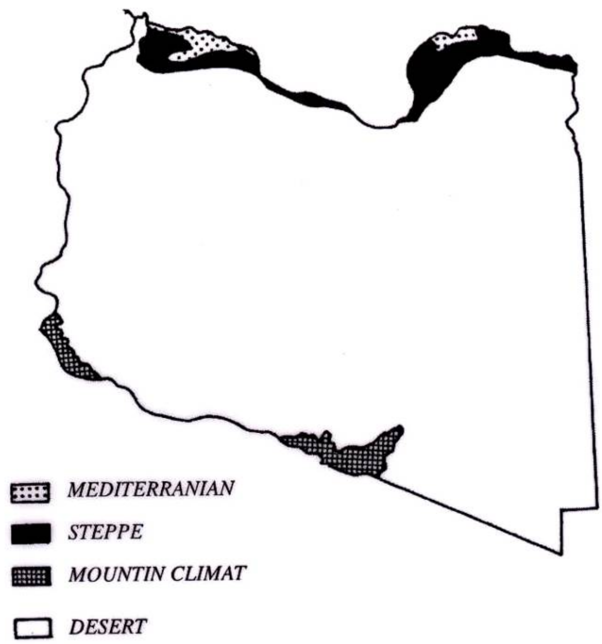
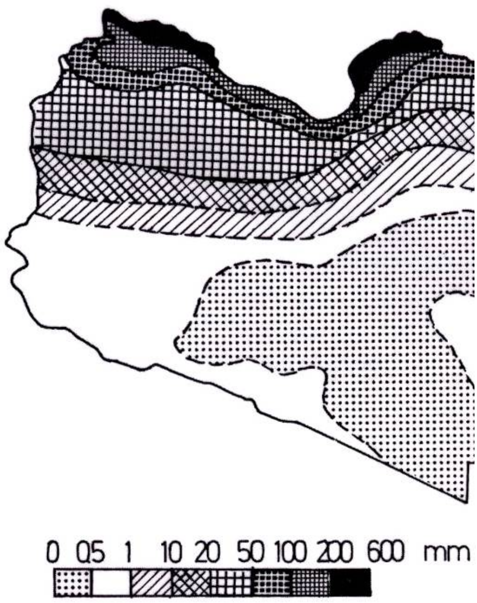


Figure 1. Climate of Libya

a) MEDITERANEAN-SUB-TROPICAL zone is characterized by a mean annual rainfall of 100-600mm with a mean annual relative humidity of 60-80% and a mean temperature in July of 22-28ºC, while a mean annual sunshine duration of 7-9 hours a day.
b) STEPPE zone having a mean annual rainfall of 50-100mm, a mean annual relative humidity of 50-60% and mean temperature in July of 24-28ºC.
c) NON-CLASSIFIED MOUNTAIN CLIMATE
d) DESERT whose climate is characterized by a mean annual rainfall of 0-20mm, while a mean relative humidity is 30-40%.

For farmers, the greatest inconvenience of the climate in Tripolitania is its non-predictability. In Tripolitania, there is no mountain of Atlas (in Algeria) to act as a barrier between desert and coast, so that the winter in the northern part is a special a cause for worry. A typical effect from this atmospheric instability is “ghibli”, the southern desert wind that could blow in every season, often causing great damages to agriculture, vineyards and oliveyards. The Fezzan and oases of the Libyan Desert are dependent mainly on the underground water deposits.

Territories having the highest rainfall in Tripolitania are the coastal belt between Sabrata and Misrata and the eastern-mountain part between Yefren and sea coast (Figure 2).
The coastal belt has another advantage –considerable underground water deposits which enable keeping quite a developed urban civilization, while the eastern-mountain belt enables a relatively large population through an engagement in the olive cultivation.
Towards the West, from the line connecting Sabrata and Yefren, the country lies in an arid zone. However, there are also large mountain villages as Kabaw, Wazen, Qasr Al-Haj and the town of Nalut, where the rainfall amount is 0-20mm, and the mean relative humidity reaches 30-40%, while the mean temperature in July ranges between 30ºC and 32ºC (Figure 3).



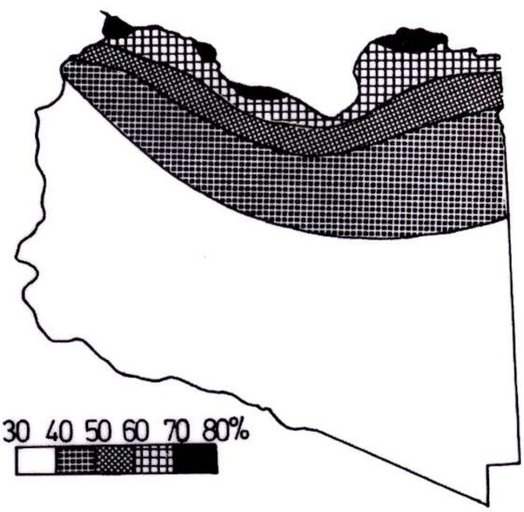


Figure 2. (left) Medium annual rainfall
Figure 3. (right) Medium annual relative humidity

The hinterland of Jefara is a real desert. To the East of Misrata, the coast of the Sirt Bay is partly exposed to winds accompanied by rain from the eastern mountain belt, but also to southern winds. Meanwhile, a narrow belt along the coast from the valley of Bei El Chebir to the border of Cyrenaica receives enough rain to maintain the small number of semi-nomadic population.
Such climatic conditions left their stamp on the model of the settlements as can be seen from the correlation between settlements and rainfall both in Cyrenaica and Tripolitania (Figure 4).

On the other hand, at micro level, a Libyan house as in other Arab countries was shaped by its internal yard. That yard provided not only roof, but, also, a piece of outer space that was brought in. From it, you can see the sky often contrasting the monotonous surroundings with its blue color. Thus, these people brought in their intimate house space a piece of the blue sky, as well as freshness (Figure 5).

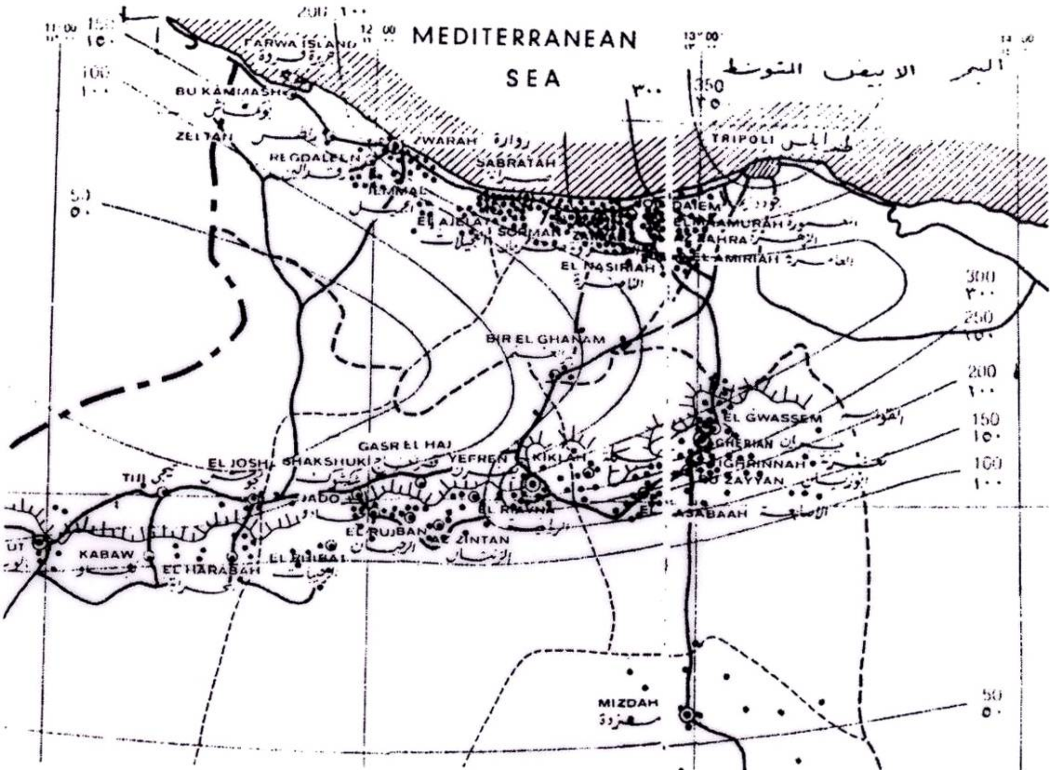


Figure 4. Tripolitania: Correlation between settlements and rainfall

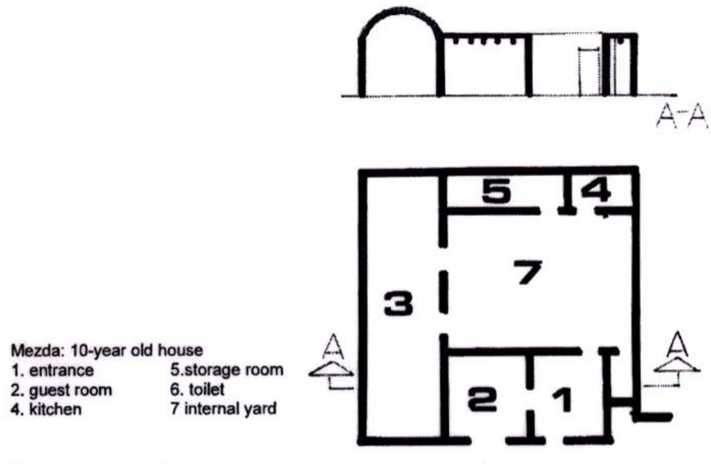


Figure 5. Mezda, example of a recent house

2.1.2. Abu Dhabi

The climate of the United Arab Emirates is relatively similar to the desert climate - hot and dry. It is characterized by hot summers and warm winters and an area with a high temperature difference between day and night. The average annual rainfall in the coastal area is less than 120 mm, but in some mountainous areas the annual rainfall often reaches 350 mm. During the late summer months, a humid south-eastern wind makes the coastal region especially unpleasant. The region is prone to occasional, violent dust storms, which can severely reduce visibility.[1]

Abu Dhabi is the capital city of seven member emirates of the United Arab Emirates. Abu Dhabi is on the north-eastern part of the Arabian Peninsula and it lies on a T-shaped island jutting into the Persian Gulf from the central western coast. Abu Dhabi has a hot arid climate. The months of June through September are generally hot and humid with maximum temperatures averaging above 35°C. During this time, sandstorms occur intermittently, reducing visibility. The weather is cooler from November to March with average temperatures minimum of 10 °C. This period also sees dense fog on some days. The dry desert air and cooler evenings make it a traditional retreat from the intense summer heat and year-round humidity.[2]

Elements of the traditional Arab architecture in the United Arab Emirates were designed and built to respond effectively to local climate conditions and dynamically to people's social, cultural and religious requirements at their time. (Sidawi, 2012)

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[1] http://en.wikipedia.org/wiki/Geography_of_the_United_Arab_Emirates (Accessed December, 2012)
[2] http://en.wikipedia.org/wiki/Abu_Dhabi (Accessed December, 2012)

Climate had a major effect on the performance of the Arab traditional building architecture and its energy consumption in hot dry area. Lack of water and harsh climate of these areas forced people to build their houses with some strategies based on efficient energy consumption. These strategies and architectural solutions are categorized in three levels: a) macro scale, b) medium scale and, c) micro scale. (Taleghani, et al., 2010)

2.1.2.1. Macro climate responsive design strategies

- **Distance between buildings.** In the design of traditional houses in the hot and dry area there are several precautions taking against the hot climate. Distance between buildings develops a system of paths so that during the day, external high walls of houses provide usually shady areas in narrow streets and isolated corridors from sun radiation. Small-scale spaces provide vast access to shade.

- Enclosed urban environment. As a whole, the city structure resembles a fully enclosed form and from all directions prevents high velocity winds and sand storms to penetrate into the town. Meanwhile, the compacted nature of the buildings prevents the very high temperature of sun radiation to penetrate into the town.

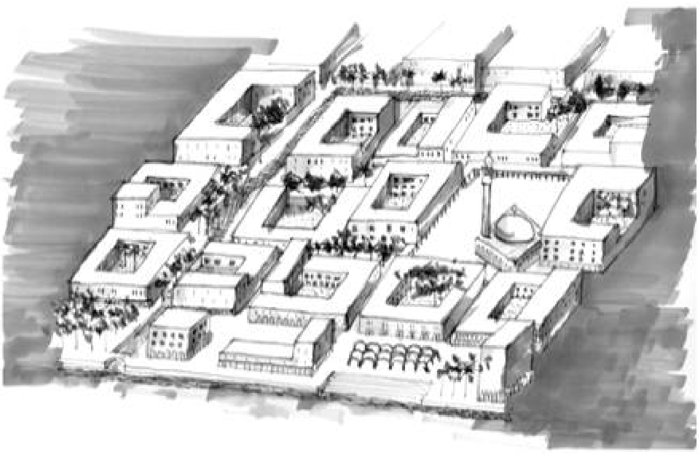


Figure 6. The new model of traditional Arab communities

The „patch“ model (Figure 6) was planned for Mussafah District with large plots (1x1km) and very much resembles the traditional structure of Arab communities, the ’fareej’ and ’kasbah’ city (Quassabah). A ‘fareej’ is a traditional neighbourhood scheme. The courtyard-style homes are built on the edge of the plot in order to maximize the use of land and separate private space from public realm. Small paths, known as ‘sikkak’, strategically connect homes to each other within the neighbourhood, forming intimate public spaces known as ‘barahaat’, as well as larger gathering spaces known as ‘meyadeen’. Together, these elements constitute and form the „fareej“. (Bajić-Brković and Milaković, 2011)

- Narrow and irregular streets. The streets in towns are facing the direction of the wind. Surely, if streets were not narrow, more wind would have flown into streets and the moving sand of the desert and ferocious winds would have penetrated into the city districts.

2.1.2.2. Medium climate responsive design strategies

- Building form. In hot and dry climate, a courtyard house is the most preferred type of house. In order to minimize the area affected by the solar radiation, compact forms with courtyards are chosen. In courtyards, with the help of water and plants for evaporative cooling, the floor temperature can be minimized by high walls surrounding the courtyard making shaded areas, while open areas can be used during the day. Channels for water poured out from the pool are important elements for cooling.

- Self-efficiency in materials. The use of local materials to reduce energy expenditure will reduce the initial embodied energy, as well as the costs, especially transportation cost. In desert regions all the earth excavated during housing construction is used as a building material in the form of unbaked bricks and mud which strongly resist the incessant sun rays in the very warm summer months. Due to very hot temperatures, the building materials absorb heat from the sun and make it available later when the sun goes down.

- Optical and thermophysical properties of the building envelope. In hot and dry climate, by means of the high heat capacity of the traditional building envelope, the effect of the outside temperature is minimized and precautions against the solar radiation are: minimization of the area and number of windows, construction of windows at a high level to block the floor radiation, minimization of facade absorption by white or light colours, providing natural ventilation especially at night, constructing a part of the house into ground, which is to be always cooler than the outer ambient temperature in summer.

2.1.2.3. Micro climate responsive design strategies

- Atrium and Courtyard. A common natural ventilation and thus cooling technique in traditional houses of Arab countries is the use of courtyards. The courtyard was developed mainly in response to climatic requirements. For many centuries and to the present day the courtyard has been one of the most characteristic forms of residential architecture in warm climates. Courtyards are the heart of the dwelling spatially, socially, and environmentally. They also serve as temperature regulators, as a collector of cool air at night and a source of shade in the daytime. Thermal comfort is affected by several factors like building orientation, ventilation, and shadowing. (Noor, 1991) As central position in buildings, the courtyard can provide a relatively enclosed space and bring the airflow as convective natural ventilation in and around a building. The necessary light for different parts of houses would be provided through the central courtyard.

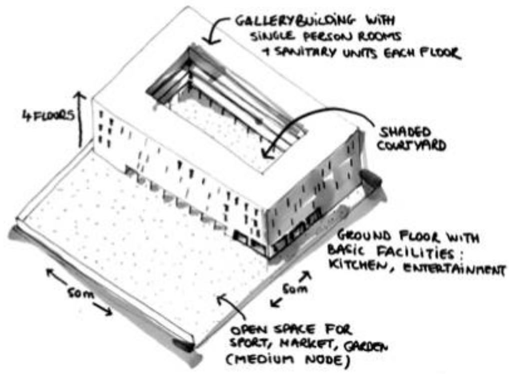
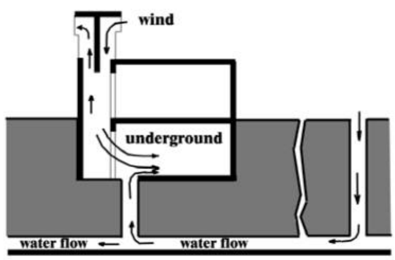


Figure 7. Suggested new model of house with regard to traditional Emirate courtyard house

- Eyvan and Revak. South and east oriented *Eyvan*s (three side closed passageway in front of the rooms) are very cool and shady places for summer afternoons. The *Revak* semi open colonnade arranged in the courtyard always provides shady areas.

- Wind catcher (Air trap). Air trap was the specific feature of traditional Persian architecture in the majority of warm regions. In ancient times, the air trap functioned like the present modern air conditioning system. Air trap is like a chimney whose end is in the underground and the top is set over the roof. At the upper outlet many small openers or ducts are set. At the end of the air trap at the bottom, a pool is set whose water was provided by aqueducts. They are built to catch any hint of a passing breeze to channel all the way down to the rooms built in the basement where the family would mostly live in the hot summers. A wind catcher functions also as a stack effect aggregator of hot air. It creates a pressure gradient which allows less dense hot air to travel upwards and escape out the top, so temperature in such an environment can't drop below the nightly low temperature. (Figures 8 and 9)



Figures 8 and 9. Wind catcher

- **Al Mashrabiyah.** The architecture of Al Mashrabiyah has responded effectively to the Saudi Arabia`s harsh, dry desert climate with great temperature extremes. A wooden screen provides shade and protection from the hot summer sun while allowing the cool air from the street to flow through. The wood itself absorbs the humidity from the air. The mashrabiya has four environmental functions (Sidawi, 2012): controlling the passage of light, controlling the air flow, reducing the temperature of the air current and increasing the humidity of the air.

2.1.2.4. Specificity of Abu Dhabi - combination of traditional and modern

Hyper dynamic development of cities like Abu Dhabi reflects two types of aspiration: to be ahead of global trends and at the same time to emphasize the respect for tradition. As the building industry in the UAE, particularly in Abu Dhabi Emirate, the issue of sustainability has not been taken into consideration despite representing a rich resource for architecture that is based on the use of certain features that are climate responsible in the traditional heritage. At present, architects of the UEA used to incorporate various elements of the Islamic historical buildings in their design work. They usually take into account only the form of elements that strips the meaning and function from its historical context and values. Modern buildings of Abu Dhabi use traditional elements that are detached from their historical, social, psychological, cultural context.
Modern building practices ignored the specific climate conditions and began to use excessive technology to shape the built environment. (Czastka, 1997) The traditional pattern has been forgotten with hyper-growing development. The structure of cities is being shaped by rectangular network of multilane roads. The modern multi-level buildings of rapid urbanization have not much to do with intimacy of the courtyard. The contemporary Emirates cities have large distances between residential zones connected with wide streets unfriendly for pedestrians. Other paradoxal example of neglecting the climate are shopping malls with aquariums and sharks, as well as the Mall of the Emirates with largest indoor ski slope in the world.
By comparing the total energy use, artificial lighting and cooling energy use per square meter per year for contemporary and traditional buildings, the study indicates that contemporary buildings in the UAE use almost six times more energy than traditional buildings. (AboulNaga et al., 1997)

2.1.3. India

As in the Northern India, during the winter period, there is a warm weather, and in the remaining part of a year, a mainly hot weather, hence India is usually treated as a tropical country. (Sing, 1979)
As a result of the influence of space, relief, and very hot temperature in the summer period, as well as a corresponding surface heating, an area of the low-air pressure is formed in the North-West India. In the winter period, that area is characteristic by coldness with weaker

anticyclones influencing the outward flow of air towards the Indian Ocean, while, in the summer, due to the low atmospheric pressure, the situation is reversed: winds come from the Indian Ocean.

With seasonal exchange of the atmospheric pressure regime in this country, monsoon winds change their direction. That seasonal exchange is also predetermined by other factors: the formation of high cyclones during the last week of May and beginning of June, over the Northern Part of Pakistan, which bring with them summer monsoons.

Mountain mass coverage along the direction of North-South forces backward one part of the atmospheric masses and so carry out the south-west monsoon straight towards the west. Also, Himalayas, lying along the east-west direction, prevent the penetration of summer monsoons towards the north and in that way limit its extension over the territory of India, thus directing the summer monsoons to the north-west, where the atmospheric pressure is very low in the summer period.

The Indian Peninsula, having a pointed form going towards the South, surrounded by the Bengal Bay on the East and the Arabic Bay on the West, is exposed to pleasant sea breeze blowing from the Indian Ocean (Figure 10).

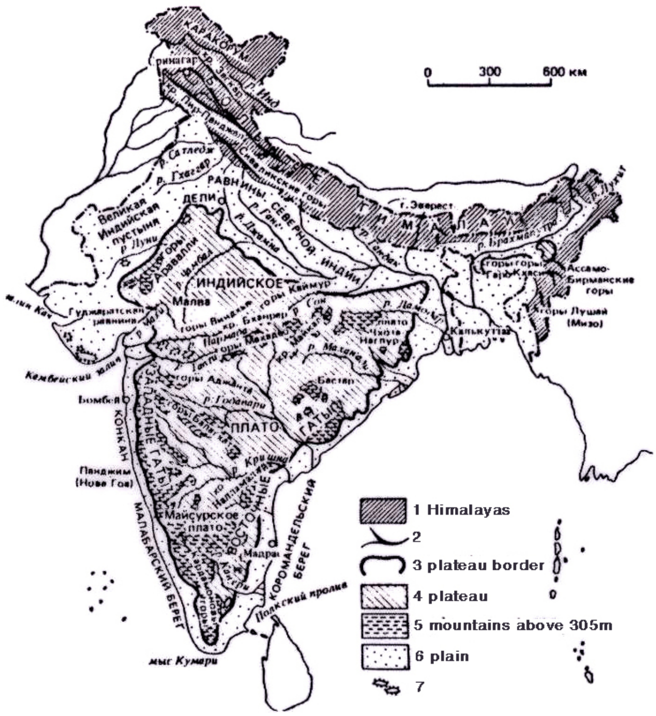
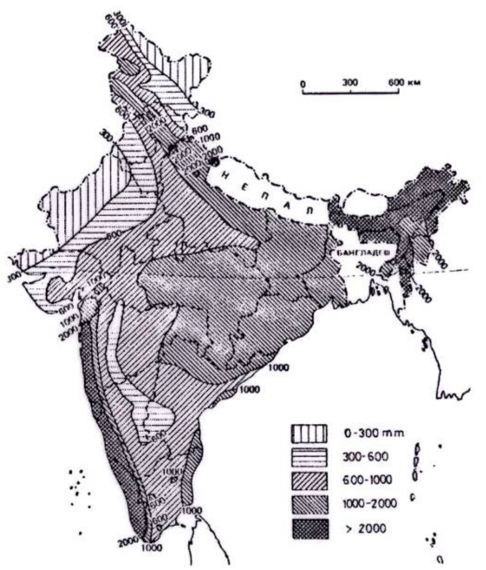


Figure 10. Relief of India

The summer season is a dominant one in this country, lasting from the middle of March to the middle of September. In this period, under the conditions of the anticyclone conveniences, the sky is without clouds, so that solar heat is very intensive. The first half of summer (up to the middle of June) is dry and warm. The second half of summer (up to the middle of September) is warm and humid. According to these characteristics, the summer in India is divided into two seasons: hot and dry, or pre-monsoon season, and warm and humid, or monsoon season.

The temperature during the hot and dry season in May is approximately the same throughout India (excluding the mountain areas) and reaches 32ºC. In June, when monsoon season begins, the heat is somewhat lower in the Southern and Eastern India, so that in June, the North-Western India remains the only hot area where the mean June temperature reaches 35ºC, while maximum temperature , exceeds 46ºC in many places.

During the dry season when the ground surface is worm and the air is very humid, the, destructive thunderstorms occur over the most part of India. In Asam, Bengal and Orisa – these storms cause a lot of damage to cultivated areas, as well as to people. The rainfall is not evenly distributed all over India throughout the year . So, in the western part of Rajastan, annual rainfall is only 90mm, which makes it one of the driest regions of the world, while in Charapunji, the amount of rainfall reaches up to 10800mm. Annual amounts of rainfall increase with increasing altitude, going from the western to the eastern parts of the country. (Figure 11)



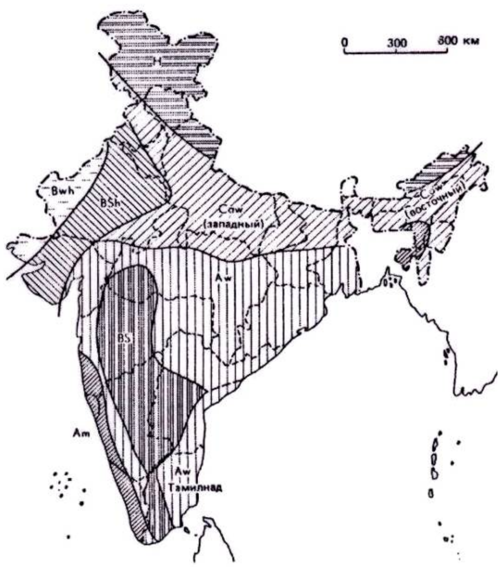


Figure 11. (left) Annual Rainfall
Figure 12. (right) Climate regions

Climate regions of India consist of the four basic climate groups (A, B, C and H) which then could be subdivided into seven climate subgroups (Figure 12) as follows: (ibid)

GROUP A –HUMID TROPICAL CLIMATE

- Am – Tropical monsoon climate, characterized by strong seasonal winds and a very short dry period
- Aw –Tropical humid and dry climate, or savanna climate characterized by a dry winter.

GROUP B – DRY TROPICAL CLIMATE

- Bs – Tropical semi-arid (steppe) climate
- Bsh –Tropical and subtropical steppe climate where mean annual temperature exceeds 18ºC
- BWh –Tropical and subtropical desert climate where mean annual temperature exceeds 18ºC

GROUP C –HUMID SUBTROPICAL CLIMATE

- Caw – The humid subtropical climate with dry winter and hot summer reaching in a hot month a temperature higher than 22ºC

GROUP D –MOUNTAINCLIMATE

In the Himalayan mass and in Karacorum, a drop in temperature of 0,6ºC for every 100 meters of altitude, leads to a variety of climates.
In the context of sustainable development, attention is drawn only to those aspects of the biosphere creating suitable conditions for the development of favorable characteristics of soil and vegetation of settlements.
The characteristics of vegetation, on the spot, depend on temperature, amount of rainfall, land and activity of man.
As the climate in its essence is a tropical one, hence, throughout India in the territories of the 900 meters above sea level and less, the vegetation is also of tropical monsoon type. The variety of species and richness of vegetation mainly depend on the distribution of rainfall. The existing use of underground resources, as well as an uncontrolled cutting of forests, has led to degradation of vegetation cover. An example is the transformation of humid green forests into a dry savannah, and dry green forests into a semi-desert area.
The changes in soil cover have caused different negative phenomena (erosion, etc). These changes, under the influence of the specific rainfall distribution over different parts of the country, as well as, under the influence of different biological factors, have created a variety of vegetation: from grassy plains to evergreen forests. In magnificent Himalayas, extending directly from the warm tropical valleys to the highest areas of the world – the vegetation represents a set of various green belts, from a purely tropical to an Alps one (Figure 13).

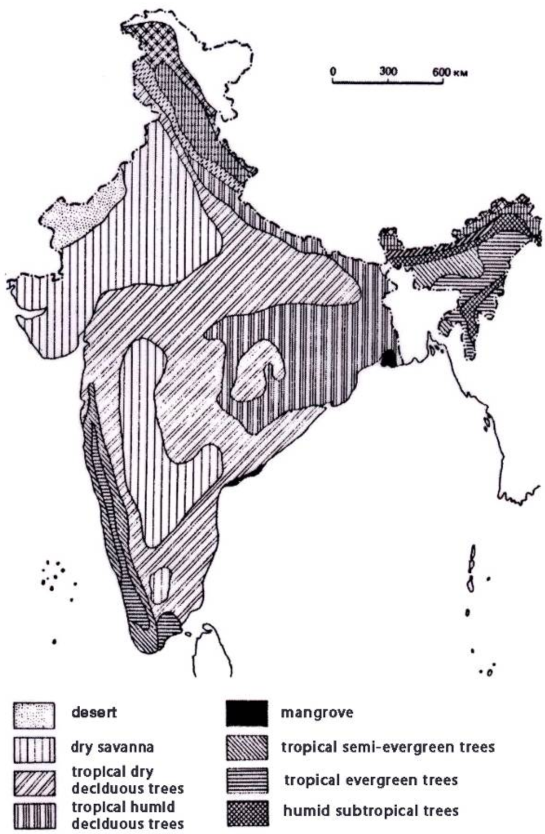
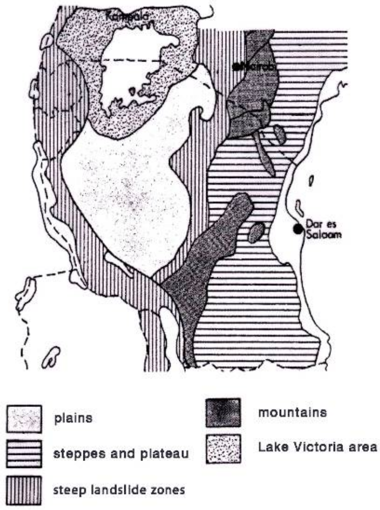


Figure 13. Vegetation cover

2.1.3. Tanzania

The climate in Tanzania is tightly related to its position. Its northern border is formed by Lake Victoria, western border by Lake Tanganyika and 800km of eastern border is formed by the Indian Ocean,. Along the eastern border, the coast is flat and ranges in width from 16 to 60km, across which the land rises to big central plateau of 1200 meters above sea level. Kilimanjaro, 5850m high, the highest African mountain is on the north-east side of the central plateau. To the north, the plateau descends towards the Lake Victoria, and to the west, the plateau descends towards Lake Tanganyika and Malawi, forming the west valley with steep slopes. (Figure 14)



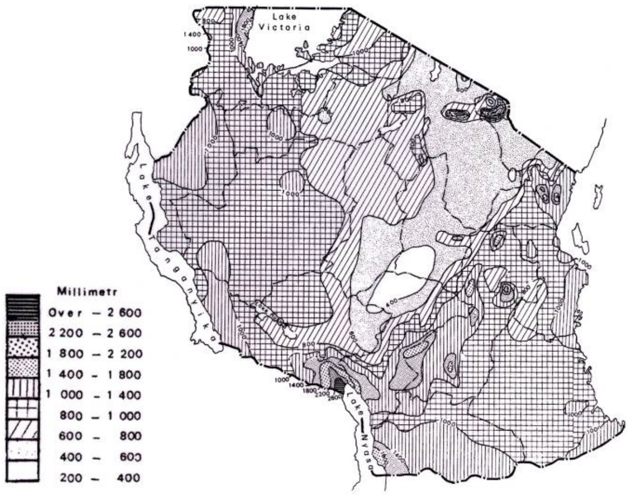
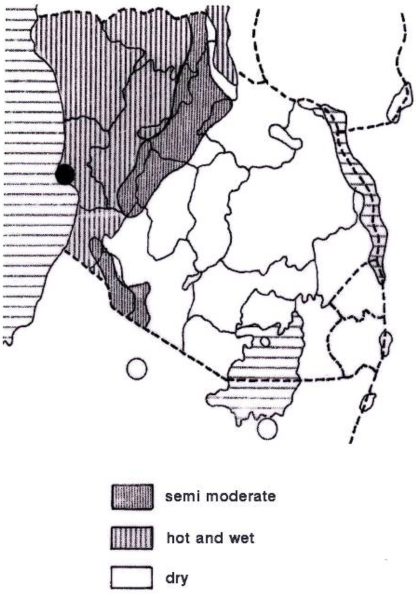


Figure 14. (left) Relief
Figure 15. (right) Average annual rainfalls

The amount of rainfall is the greatest in mountain area at the altitude from 1400 to 2600mm, with very narrow part with more than 2600mm. Then, there are the coastal areas and territories around Lakes Victoria and Tanganyika with rainfall of 800-1400mm, and finally, the central plateau with 400-800mm, along with one smaller zone with even smaller amounts of rainfall of only 200-400mm (Figure 15).
This natural surroundings and rainfall with adequate temperature characteristics have created three main climates in Tanzania (Figure 16):

1. WARM AND HUMID TROPICAL CLIMATE
   that comprises coastal plains is characterized by annual average temperature of 24ºC, maximal temperature of 33ºC in March and minimal in July and August of 17ºC. The rain season lasts from October to May. The dry season is more fresh and agreeable (Figure 17).
2. DRY CLIMATE comprises the central plateau characterized by warm and dry climate with average annual temperature of 22ºC and rainfalls of 400-800mm. The nights are cooler and daily temperature demonstrates great variations.
3. SEMI-MODERATE CLIMATE comprises zones with hills and mountains where there are no extreme temperature variations, neither hot nor cold, and with the greatest rainfall of 1400-2600mm.



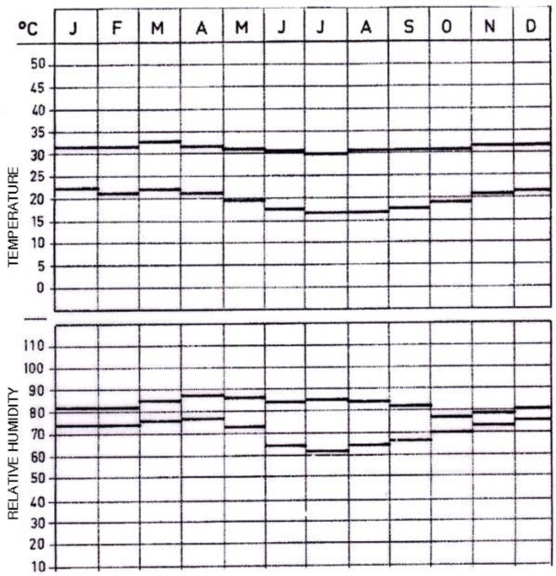


Figure 16. (left) Climates
Figure 17. (right) Temperature and humidity in warm-humid climate

3. INSTEAD OF CONCLUSION: PLANNING AND DESIGN CONSIDERING CLIMATE

3.1. How to Start

Adjusting the climate data to the specifications of buildings is relatively easy if the weather is stable and dry. Unfortunately, this is not often the case. The greatest number of settlements has mixed climate conditions, where the annual cycles can include hot, moderate, fresh dry or humid seasons which differ in duration and intensity.

In making decision on the type of construction that is required, the relative length of season has to be considered under such conditions. Even if this is made according to the monthly averages, it will increase the intensity of project data that will be taken into consideration. Architects who conscientiously collect climate information are faced with the confusion over the great number of data that can, it seems, lead to contradictory or incompatible decisions.

Due to this difficulty, many designers rely on intuition, i.e. they rely on the “feeling of climate conditions”. Since the possible answers are numerous, the possibility for wrong decision is high. A wrong decision is an expensive one. Responsible designer tests his intuition by longer calculations of heat flows, or even ask an expert to do so. He pays the price of the wrong decision during the working hours, or the consultant’s invoice. An

irresponsible designer builds his decisions on the grounds of his intuition and hence transfers the risk to the client who will be the one to pay, or suffer, if intuitions were wrong.
In order to eliminate these difficulties, Carl Mahoney developed a simple series of tables for the presentation and analysis of climate information. His method does not require the knowledge in mathematics. A designer who follows this method is led step by step from climate information to the type of specification for the layout, orientation, shape and structure of the building that is needed as a sketch of the project stage (Mahoney, 1973).

3.2. Example of the City of New Delhi

This example for the application of the Mahoney's method is chosen as specific since this city, situated in the plain of North India, has three climate seasons: (ibid, workshop task)

a) Hot and dry from March or April until June
b) Warm and humid from July until October
c) Fresh and dry from November until February

Unlike Kolkata (India) and Dar el Salam (Tanzania) that are placed in hot, humid climate, the designer's task here is more complex considering the comfort.
The daily span in temperature is wide in this city, during the two dry seasons. It declines with the growth of humid air at the end of June and remains small during the monsoon season. In general, the characteristics of comfort are following. From May until October it is too hot for the comfort during the day and night. During the warm and humid season the airflow is necessary to encourage evaporation. During the hot and dry season the tick walls should be used to keep the inside freshness of daily temperature. The fresh season is pleasant over the day, but nights can be cold.
The authors derived the following recommendations from the existing conditions:
Buildings in this city should reflect the compromise between the conflict demands of the different climate. They should be well distributed to use the breeze from the East and South-East during the humid season. Basis of the project can be compact and rooms placed in two rows, but the inside openings have to enable airflow during the three months of humid season. The heavy walls and roofs have to be used in order to obtain protection against the extreme temperatures. These tick walls will accumulate the heat for the nights.
During the fresh season this is a valuable quality, but during the hot-dry season the accumulated heat will make sleeping outside significant. The windows should be of the middle size in order to secure good inside airflow, with well made tick blinds that should reduce the flow of cold air during the fresh season and the flow of hot and dusty air during the hot and dry season. All this is the result of the following information and analysis completed by the authors. In order to better understand the attached tables, especially tables 5 and 6, attention should be drawn to the following indicators:

a) HUMIDITY INDICATORS

B1 indicates that the airflow is basic. This is applied if high temperature (daily thermal stress = B) is combined with high humidity (B1 = 4) or if high temperature is (daily thermal stress = B) in daily range (dr less than 10° C).
B2 indicates that the airflow is desirable. This is applied if the temperature inside the comfort limits are combined with the high humidity (B1= 4)
B3 indicates that precaution against the intrusion of rain is necessary. Problems can be caused by even small amounts of precipitation, but will be inevitable if the rainfall is over 2000 mm per month.

b) INDICATORS OF DRY CLIMATE

C1 indicates the need for thermal accumulation. It is applied if the wide daily range (10°C or more) matches the moderate or small humidity (B1=1,2-3)
C2 indicates the desirability of external space for sleeping. This is necessary if night temperature is high (night thermal stress = 1 (hot) and humidity is small (B = 1 or 2). That will also be necessary when the nights are comfortable outside, but warm inside as a result of the heavy thermal accumulation, humidity group = 1 or 2 and when the daily range is above 10°C.
C3 indicates winter problems or fresh seasons. This happens if daily temperature is below the limit of comfort (daily thermal stress = X).
On the basis of these indicators, the authors recommend the following construction standards:

1. <u>LAYOUT OF BUILDINGS FOR WARM-HUMID CLIMATES</u>
   1.1 ORIENTATION NORTH-SOUTH for the living rooms
   1.2 EXTERNAL LAYOUT: airflow through and around buildings
   1.3 INTERNAL BASE: unilaterally leaned rooms
   1.4 EXTERNAL OPENINGS: big, protected
   1.5 EXTERNAL WALLS: thin, protected
   1.6 EXTERNAL SURFACES: reflexive
   1.7 INTERNAL WALLS: thin, transparent for the breeze
   1.8 PORCHES: covered
   1.9 EXTERNAL COMMUNICATIONS: shaded
   NOTE: A special care should be taken to protection against heavy rains, insects

2. <u>LAYOUT OF BUILDINGS FOR HOT-DRY CLIMATES</u>
   2.1 ORIENTATION NORTH-SOUTH for the living rooms
   2.2 EXTERNAL LAYOUT: compact planning
   2.3 INTERNAL BASE: rooms concentrated around the yard

2.4 EXTERNAL OPENINGS: small, near the ceiling
2.5 EXTERNAL WALLS, ROOF: heavy
2.6 EXTERNAL SURFACES: reflexive
2.7 INTERNAL WALLS: massive
2.8 YARD SURFACES: shaded ground
2.9 EXTERNAL COMMUNICATIONS: shaded
NOTE: A special care to be paid to the protection of sand storms and insects

Therefore, for example, warm and humid climate imposes wide streets as an imperative. Kolkata is in the warm, humid zone and has desirable wind direction from the South. Due to high humidity, the living rooms are oriented towards the prevailing breeze and houses are laid parallel to each other, perpendicular to the wind direction. The houses are sometimes laid in a way that forms the wind corridor, increasing the wind velocity towards the end blocks.

However, the houses in Kolkata do not require protection from sun and air humidity only, but also the protection from excessive rain. Hence, wide porches, various architectural elements that protect from intrusion of rain and sun, then tree-lined streets, terraces, open terrains, etc., contribute to the desirable, i.e. sustainable living in New Kolkata (Salt Lake City) and influence the overall picture of this city by giving it a specific expression.

In the evening when fresh breeze blows in Kolkata, all streets become common spaces, giving the specific atmosphere to the shape of the city. That is the expression of the population's wish to gather into groups, and the first author of this paper had that in mind when, as the author, prepared the conceptualization of the Salt Lake City.

Therefore, while the social and economic promptness was the leading power on the West, the biological unity was the skeleton between the members of one group on the East. The mutual connection between a man and the environment is abstract on the West, while it is specific and direct on the East. It could also be stated that while a man on the West is in the struggle with nature, insomuch is a man on the East adapted to the nature also adapting the nature to his needs.

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Figure 4. ibid., p. 281
Figure 5. ibid., p. 298
Figure 10-12. ibid., p. 118
Figure 13. ibid., p. 119
Figure 14. ibid., p. 235
Figure 15. ibid., p. 236
Figure 16-17. ibid., p. 237.

Figure 6. Bajić-Brković, M. and Milaković, M. (2011) Planning and designing urban places in response to climate and local culture: A case study of Mussafah District in Abu Dhabi, *Spatium no. 25*, pp. 14-22.
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SUMMARY

In this paper, we have covered both the conditions of living in tropical climate and the consequences on the construction of towns in such environment, demonstrated on the examples of the four countries. The objective of the paper is to instruct professionals – planners and designers, to plan and design with climate in order to achieve sustainability of spatial development taking into account the man and climate. In this context, attention is drawn only to those aspects of the BIOSPHERE that create adequate conditions for the development of settlements: characteristics of vegetation, on the spot, depend on temperatures, amount of rainfall, land and activity of MAN. Methodologically, it is explained HOW TO START in such process of planning and design. Finally, on the example of New Delhi, we tasted many influences on the building of houses by Carl Mahoney tables.